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including special issue: Adding Value

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comprenant un numéro spécial: Ajouter de la valeur

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una revista internacional
incluido un número especial: Añadiendo valor

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Editorial

Dear reader,

Activities that add value to locally adapted breeds also support biodiversity and promote local heritage and tradition. But how to add such value? This 53rd volume of *Animal Genetic Resources* includes a special issue on adding value to livestock breeds. The idea for this special issue was born during the session "Strategies to add value to local breeds" of the 61st Annual Meeting of the European Federation of Animal Science (EAAP), held in August, 2010, in Crete, Greece. This session was jointly organized by the working group of the European Federation of Animal Science for Animal Genetic Resources, the European Regional Focal Point for Animal Genetic Resources (ERFP) and the Food and Agriculture Organization of the United Nations (FAO). Nine papers are presented here, including an introductory paper, which summarizes the different approaches illustrated by the contributing authors. The articles describe various strategies that have been used to add value to local breeds, in various countries and regions, with the aim of increasing the competitiveness of these breeds and promoting their sustainable use in the long term.

The 10 contributions not falling under the topic of the special issue reveal the continuing importance of the characterization of local breeds. It is the first step towards sustainable use and development of genetic resources and also the basis for strategies that seek to add value. Actions related to characterization, inventory and monitoring of trends and associated risks for animal genetic resources represent the first strategic priority area of the *Global Plan of Action for Animal Genetic Resources*[1].

The Global Plan of Action for Animal Genetic Resources was the response to the findings of the *The State of the World's Animal Genetic Resources for Food and Agriculture,*[2] which identified significant gaps in capacity to manage animal genetic resources, particularly in developing countries. At its 14th Regular Session, the Commission on Genetic Resources for Food and Agriculture requested FAO to prepare an update of *The State of the World's Animal Genetic Resources for Food and Agriculture.* This might eventually lead to a revision of the Global Plan of Action. FAO's Animal Genetic Resources Branch is guiding countries through the reporting process. The web site "Implementing the Global Plan of Action for Animal Genetic Resources"[3] has been newly structured and enriched. There is now a specific page with information about this journal,[4] which includes links to all previous volumes. Another page is dedicated to the preparation of *The Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture.*[5]

The editors would like to encourage the readership of *Animal Genetic Resources* to contribute with their valuable knowledge to the process of updating *The State of the World's Animal Genetic Resources for Food and Agriculture,* in collaboration with their respective National Coordinators for the Management of Animal Genetic Resources.[6]

Ms Beate Scherf, Editor in Chief of the journal for several years, will coordinate the update of *The State of the World's Animal Genetic Resources*. With a heavy heart she had therefore to reduce some of her other activities, including her activities for the journal. The editors would like to take this opportunity to thank her for her constant efforts to improve the quality of the journal. I now have the pleasure of replacing her as Editor in Chief, and hope to continue what Ms Scherf started, together with the members of the Editorial Board and the contributing authors from all over the world.

Yours sincerely,

Roswitha Baumung

[1] http://www.fao.org/docrep/010/a1404e/a1404e00.htm
[2] http://www.fao.org/docrep/010/a1250e/a1250e00.htm
[3] http://www.fao.org/Ag/AGAInfo/programmes/en/A5.html
[4] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/journal.html
[5] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/Second_state.html
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=-1,contacts

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Éditorial

Cher lecteur,

Les activités qui ajoutent de la valeur aux races localement adaptées soutiennent aussi la biodiversité et promeuvent le patrimoine local et les traditions. Mais, comment est-ce qu'on ajoute cette valeur? Ce 53ème volume de *Ressources Génétiques Animales* inclut un numéro spécial sur l'addition de valeur aux races des animaux d'élevage. L'idée de ce numéro spécial est venue au cours de la séance «Stratégies pour ajouter de la valeur aux races locales» de la 61ème Réunion Annuelle de la Fédération Européenne de Zootechnie tenue en Août 2010 en Crète, Grèce. Cette séance a été organisée conjointement par le groupe de travail de la Fédération Européenne de Zootechnie sur les Ressources Zoogénétiques, le Centre de Coordination Européen pour les Ressources Zoogénétiques et l'Organisation des Nations Unies pour l'Alimentation et l'Agriculture (FAO). Neuf articles sont présentés ici, y compris un article d'introduction qui résume les différentes approches illustrées par les auteurs collaborateurs. Les articles décrivent différentes stratégies ayant été utilisées pour ajouter de la valeur aux races locales, dans différents pays et régions, dans le but d'accroître la compétitivité de ces races et de promouvoir leur utilisation durable à long terme.

Les 10 contributions ne relevant pas du sujet du numéro spécial mettent en évidence combien il est encore important de caractériser les races locales. Ceci s'avère le premier pas vers l'utilisation durable et la mise en valeur des ressources génétiques et fournit de même la base pour les stratégies qui cherchent à ajouter de la valeur. Les actions en rapport avec la caractérisation, l'inventaire et la surveillance des tendances et des risques associés des ressources zoogénétiques représentent le premier domaine prioritaire du *Plan d'Action Mondial pour les Ressources Zoogénétiques*[1].

Le Plan d'Action Mondial pour les Ressources Zoogénétiques a été la réponse aux conclusions de *L'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*,[2] quia identifié d'importantes lacunes dans la capacité à gérer les ressources zoogénétiques, en particulier dans les pays en voie de développement. Lors de sa 14ème Session Ordinaire, la Commission des Ressources Génétiques pour l'Alimentation et l'Agriculture a demandé à la FAO à ce que soit préparée une mise à jour de *L'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*. Ceci pourrait finalement mener à une révision du Plan d'Action Mondial. La Sous-division des Ressources Zoogénétiques de la FAO est en train de guider les pays dans le processus de présentation des rapports. Le site web «Mise en œuvre du Plan d'Action Mondial pour les Ressources Zoogénétiques»[3] a été récemment restructuré et enrichi. Il existe maintenant une page spécifique informant sur ce journal,[4] qui inclut des liens aux volumes précédents. Une autre page est consacrée à la préparation du *Deuxième Rapport sur l'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*.[5]

Les rédacteurs voudraient encourager les lecteurs de *Ressources Génétiques Animales* à contribuer avec leurs précieuses connaissances au processus de mise à jour de *L'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*, en partenariat avec leurs respectifs Coordonnateurs Nationaux pour la Gestion des Ressources Zoogénétiques.[6]

Mme Beate Scherf, Rédactrice en Chef du journal pendant plusieurs années, coordonnera la mise à jour de *L'État des Ressources Zoogénétiques pour l'Alimentation et l'Agriculture dans le Monde*. À son grand regret elle devra donc réduire certaines de ses activités, y compris ses activités dans le journal. Les rédacteurs voudraient profiter de cette occasion pour la remercier de ses constants efforts pour améliorer la qualité du journal. J'ai maintenant le plaisir de la remplacer en tant que Rédactrice en Chef et j'espère continuer ce que Mme. Scherf a amorcé, avec les membres du Comité de Rédaction et les auteurs collaborateurs de partout dans le monde.

Cordialement,

Roswitha Baumung

[1] http://www.fao.org/docrep/010/a1404f/a1404f00.htm
[2] http://www.fao.org/docrep/011/a1250f/a1250f00.htm
[3] http://www.fao.org/Ag/AGAInfo/programmes/en/A5.html
[4] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/journal.html
[5] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/Second_state.html
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=53f75c3638497d5dc-d3e07bc80762ca8,contacts

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Editorial

Estimado lector,

Las actividades que dan valor a las razas adaptadas localmente también mantienen la biodiversidad y promocionan el patrimonio y las tradiciones locales. Pero, ¿cómo se aporta dicho valor? Este 53° volumen de *Recursos Genéticos Animales* incluye un número especial sobre la adición de valor a las razas ganaderas. La idea de este número especial surgió durante la sesión "Estrategias para añadir valor a las razas locales" de la 61ª Reunión Anual de la Federación Europea de Zootecnia que se celebró en Agosto de 2010 en Creta, Grecia. Esta sesión fue organizada conjuntamente por el grupo de trabajo de la Federación Europea de Zootecnia para los Recursos Zoogenéticos, el Centro de Coordinación Regional Europeo para los Recursos Zoogenéticos y la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). Se presentan aquí nueve artículos, incluido un artículo introductorio que resume los diferentes enfoques ilustrados por los autores participantes. Los artículos describen varias estrategias que han sido utilizadas para añadir valor a las razas locales, en distintos países y regiones, con el propósito de incrementar la competitividad de estas razas y promocionar su uso sostenible a largo plazo.

Las 10 contribuciones que no se enmarcan en la temática del número especial ponen de manifiesto lo importante que sigue siendo la caracterización de las razas locales. Éste es el primer paso hacia la utilización sostenible y el desarrollo de los recursos genéticos y constituye también la base para las estrategias que buscan la adición de valor. Las acciones relacionadas con la caracterización, el inventario y el seguimiento de los riesgos asociados y las tendencias para los recursos zoogenéticos representan la primera área estratégica prioritaria del *Plan de Acción Mundial sobre los Recursos Zoogenéticos*[1].

El Plan de Acción Mundial sobre los Recursos Zoogenéticos fue la respuesta a las conclusiones de *La Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura*,[2] que identificó lagunas importantes en la capacidad para gestionar los recursos zoogenéticos, en particular en países en vías de desarrollo. En su 14ª Reunión Ordinaria, la Comisión de Recursos Genéticos para la Alimentación y la Agricultura solicitó a la FAO que preparase una actualización de *La Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura*. Esto podría llevar finalmente a una revisión del Plan de Acción Mundial. La Subdivisión de Recursos Zoogenéticos de la FAO está guiando a los países en el proceso de presentación de informes. La página web "Aplicación del Plan de Acción Mundial sobre los Recursos Zoogenéticos"[3] ha sido recientemente reestructurada y enriquecida. Existe ahora una página específica con información sobre esta revista,[4] que incluye los enlaces a todos los volúmenes anteriores. Otra página está dedicada a la preparación del *Segundo Informe sobre la Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura.*[5]

Los redactores querrían animar a los lectores de *Recursos Genéticos Animales* a contribuir con sus valiosos conocimientos al proceso de actualización de *La Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura*, en colaboración con sus respectivos Coordinadores Nacionales para la Gestión de los Recursos Zoogenéticos.[6]

Dña. Beate Scherf, Redactora Jefe de la revista durante varios años, coordinará la actualización de *La Situación de los Recursos Zoogenéticos Mundiales para la Alimentación y la Agricultura*. Muy a su pesar, ha tenido en consecuencia que reducir algunas de sus otras actividades, incluido su cometido en la revista. Los redactores querrían aprovechar esta oportunidad para agradecerle sus constantes esfuerzos por mejorar la calidad de la revista. Tengo ahora el placer de sustituirla como Redactora Jefe y espero continuar lo que la Sra. Scherf comenzó, junto con los miembros de la Junta Editorial y los autores colaboradores de todo el mundo.

Atentamente,

Roswitha Baumung

[1] http://www.fao.org/docrep/010/a1404s/a1404s00.htm
[2] http://www.fao.org/docrep/012/a1250s/a1250s00.htm
[3] http://www.fao.org/Ag/AGAInfo/programmes/en/A5.html
[4] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/journal.html
[5] http://www.fao.org/Ag/AGAInfo/programmes/en/genetics/Second_state.html
[6] http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=a5b4ae83520ba08d-de6c2e2247259524,contacts

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Phenotypic cluster and diversity analysis of native chickens in Western Visayas, Philippines

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Summary
Western Visayas has largest population of native chickens in the Philippines; however, data on the phenotypic and genetic diversity is limited. Eight hundred and ten chickens from 270 different flocks, from six provinces within the region were chosen for characterization. Data collected includes farmer selection practices, means of identifying genetic groups and information on phenotypic traits of native chickens. This information was analysed using statistical tools suggested by FAO. Phenotypic diversity and equitability of distribution were analysed using Simpson's diversity index and equality of distribution. Results showed that native chicken genetic resources are comprised of two types, the Jolo and Bisaya; the latter was further divided into Bisaya–Cluster I and Bisaya–Cluster II. Jolo chickens were the heaviest ($P < 0.01$) but comparable with Bisaya–Cluster II in terms of egg weight, head shape and phenotypic distance. They all had higher diversity and equitability of distribution in their plumage colour and pattern, though the iris and shank colour had higher diversity but had limited distributions. Bisaya–Cluster II and Jolo chickens had higher diversity and above average distribution in liveweight. They were also homogenous in feather morphology and distribution; head and breast shape, and skeletal variants. Thus, the observed diversities and distributions can be used in identifying genetic materials for any breeding undertakings.

Keywords: *Philippine native chicken, Simpson's diversity index, Simpson's equitability of distribution, phenotypic diversity*

Résumé
Western Visayas possède la plus grande population de poulet indigène dans les Philippines. Toutefois, les données sur la diversité génétique et phénotypique est limité. Huit cent dix (810) poulets à partir de 270 troupeaux différents provenant également de six provinces de la région ont été caractérisés. Les données recueillies comprennent les pratiques de sélection des agriculteurs et des moyens d'identifier les groupes génétiques. Informations sur les traits phénotypiques des poulets indigènes ont été recueillies, aussi. Ceux-ci ont été analysées à l'aide d'outils statistiques proposés par la FAO. La diversité phénotypique et de l'équité de la distribution ont été analysés en utilisant l'indice de diversité de Simpson et l'égalité de la distribution. Les résultats ont montré que les ressources génétiques indigènes de poulet sont constitués de Jolo et Bisaye mais celle-ci a été encore divergé en Bisaye – Groupe I et Bisaye – Groupe II. Poulets Jolo étaient les plus lourds ($P < 0.01$), mais comparable à Bisaye – Groupe II en termes de poids de l'œuf, forme de la tête et de la distance phénotypique. Ils avaient tous une plus grande diversité et de l'équité de la distribution dans leur plumage couleur et le motif. La couleur de l'iris et de la tige a une plus grande diversité, mais avait distributions limitées. Bisaye – Groupe II et des poulets Jolo eu une plus grande diversité et surtout la distribution moyenne en poids vif. Ils étaient homogènes dans la morphologie des plumes et des variantes de distribution, la tête et la forme du sein, et du squelette. Ainsi, les diversités observées et les distributions peuvent être utilisés pour identifier le matériel génétique pour toutes les entreprises d'élevage.

Mots-clés: *Philippine poulet indigène, l'indice de diversité de Simpson, Simpson équité de la distribution, de la diversité phénotypique*

Resumen
Visayas Occidental tiene la mayor población de pollos nativos en las Filipinas. Sin embargo, los datos sobre la diversidad fenotípica y genética es limitada. Se caracterizaron 810 ocho trescientos diez pollos de 270 diferentes rebaños que estaban divididos igualmente en seis provincias de la región. Los datos recogidos incluyen prácticas de los agricultores de selección y los medios de identificación de los grupos genéticos. La información sobre los rasgos fenotípicos de pollos nativos se reunieron, también. Estos fueron analizados utilizando herramientas estadísticas sugeridas por la FAO. Diversidad fenotípica y la equidad de la distribución fueron analizados mediante el índice de Simpson diversidad y la igualdad de la distribución. Los resultados mostraron que los recursos genéticos nativos de pollo se componen de Jolo y Bisaya pero este último se separaron aún más en Bisaya – Grupo I y Bisaya – Grupo II. Jolo pollos fueron las más pesadas ($P < 0.01$), pero comparable a Bisaya – Grupo II en términos de peso del huevo, forma de la cabeza y la distancia fenotípica. Todos ellos tenían una mayor diversidad y equidad de la distribución en el color de su plumaje y el patrón. El color del iris y la caña tuvieron mayor diversidad, pero tenían distribuciones limitadas. Bisaya – II Cluster y pollos Jolo presentaron mayor diversidad y distribución por encima del promedio en peso vivo. Ellos fueron homogéneos en la morfología de las plumas y las variantes de

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distribución, la cabeza y la forma del pecho y esquelético. Por lo tanto, las diversidades observadas y las distribuciones se puede utilizar en la identificación de los materiales genéticos de las empresas de cría.

Palabras clave: *pollo nativo de Filipinas, el índice de diversidad de Simpson, equidad de Simpson de distribución, diversidad fenotípica*

Introduction

The diversity of poultry genetic resources in the world is decreasing. This is manifested by 38 percent of the reported breeds being classified as at-risk status (Hoffmann, 2010). Diversity is important as it serves as a reservoir of genes needed for changing environmental conditions and production enhancement. It is also the main source of genes to meet the changing preferences of consumers, adaptation to different production practices, and tolerance or resistance to emerging diseases. However, conservation of 1 273 reported poultry breeds is financially infeasible (FAO, 2007; Boettcher *et al.*, 2010).

Six out of 243 recorded local poultry breeds in Asia can be found in the Philippines (FAO, 2007; DAD-IS, 2011). Farmers prefer native chickens as they can survive better in local conditions with available feed resources. They need minimal management to produce meat and eggs which are both used for household consumptions and local markets (Magpantay *et al.*, 2006). The population ratio of native chickens to commercial varieties shows a declining trend during the last decade (BAS, 2011). These can be due to the changes in production systems (Rege and Gibson, 2003), socio-economic preference (FAO, 2007), occurrences of catastrophe (FAO, 2007; Lamont, 2009; Hamer, 2010) and indiscriminate crossing of breeds (Hiemstra *et al.*, 2006). However, prioritization of the breeds for conservation must be done to justify financial feasibility (Boettcher *et al.*, 2010). This needs comprehensive information and knowledge on the level of diversity within and between breeds, which can be done through molecular and phenotypic techniques. Molecular characterization provides reliable information but is highly complicated and expensive (Al-Atiyat, 2009). It should also be supplemented with phenotypic information in order to be useful for any decision making regarding conservation and utilization (Davila *et al.*, 2009; Zanetti *et al.*, 2010). In the absence of molecular data, the discriminate and cluster analysis of phenotypic characteristics can be used as alternative techniques in determining genetic groups (FAO, 2012; Boettcher *et al.*, 2010). This can provide information on phenotypic distances between breeds or genetic groups of animals which can be used towards prioritization of breeds or groups for conservation, and studies have proven its effectiveness as an alternative method (Barbosa *et al.*, 2005; Abdelqader, Wollny and Gauly, 2008; Al-Atiyat, 2009; FAO, 2009a; Dana *et al.*, 2010).

Among the regions in the country, Western Visayas has the largest population of native chickens in the Philippines (BAS, 2011). There have been studies dealing with native chickens for the standardization of Darag[1] chickens (Cocjin *et al.*, 1999, 2001, 2004, 2007; Lopez, 2008; Tomambo *et al.*, 2010). Additional data on diversity of other genetic groups of native chickens is important for future breeding programs. The uniqueness of native chickens from Antique, Iloilo, Guimaras and Negros Occidental based on protein polymorphisms should be supplemented with phenotypic data to confirm their distinctiveness (Roxas, Villanueva and Lambio, 1996; Davila *et al.*, 2009; Groeneveld *et al.*, 2010; Zanetti *et al.*, 2010). Thus, this study was conducted to determine the phenotypic clusters or groups and analyse the diversity of native chickens in Western Visayas, Philippines.

Materials and methods

Sampling sites, selection of farmers and number of chicken characterized

This study employed purposive sampling in selected provinces of Aklan, Antique, Capiz, Guimaras, Iloilo and Negros Occidental in Western Visayas. Forty-five farmers from three different municipalities of each province were identified, through the help of the personnel from the office of municipal agriculturist and the farmer technicians of Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG) and with allied people organizations (POs) in some areas. This was to limit collecting data from closely related flocks (Mwacharo *et al.*, 2007). The flock size considered for characterization had to have at least one rooster and five hens.

One rooster and two hens at their active reproductive age, with dominant plumage colour and pattern were taken from each farmer for characterization, with a total of 810 chickens selected for characterization in this study.

Data collection

The data, which included selection practices and means of identifying native chicken genetic groups, were collected through personal interviews with the farmer respondents using a structured questionnaire. Phenotypic traits like plumage colour and pattern; feather distribution and morphology; colours of the earlobe, skin and shank; shapes

[1] Traditional or native chickens standardized as based on plumage colour and pattern, shank colour, comb, and some productive performance under the leadership of Dr. Bernabe C. Cocjin of West Visayas State University, Lapaz, Iloilo City, Philippines.

of the head, breast, and body; comb type, skeletal variants, live weight, egg weight, age at first laying and annual egg production were also collected based on the guidelines set by the FAO (2012), Cuesta (2008) and FAO & UNEP (1986). This information was gathered following the procedures explicitly described by Cabarles *et al.* (2012) in their study "Distinct morphological features of traditional chickens (*Gallus gallus domesticus* L) in Western Visayas, Philippines".

Statistical analysis

Cluster analysis

Cluster analyses are a set of algorithms used to analyse data and group data according to similarities, and is used to assign individual chickens into groups according to the set of traits considered. The qualitative traits, morphometric traits, reproductive performance, survival rate and growth performances were subjected to two-step cluster analyses to determine the combination of traits with higher discriminating values and number of possible groups. Only the live weight, egg weight, age at first egg laying, annual egg production and head shape were found to have good discriminating values. These data were further subjected to discriminate analysis to determine canonical discriminating function, group membership and cluster size. The hierarchal cluster analysis was used to determine phenotypic distances using the squared Euclidean distances which were illustrated using a dendrogram.

Comparison of native chicken groups

Native chicken groups were identified based on the data for live weight, egg weight, age at first laying and annual egg production. This data was subjected to one-way analysis of variance (ANOVA). Significant differences were further analysed using the Duncan's Multiple Range Test. The Kruskall-Wallis test was used to analyse the differences in occurrences of head shapes; whereas the least significant difference (LSD) for rank was used to determine significant differences between the groups.

Phenotypic diversity indices

The phenotypic diversity indices for plumage colour and pattern, feather morphology and distribution, earlobe colour, skin colour, shank colour, head shape, breast shape, body shape, comb type, skeletal variants and live weight of different groups were determined using the Simpson's diversity index (SID). The SID was computed using the equation (Hunter and Gaston, 1988; Magurran, 2004; Price, 2004):

$$\mathrm{SID} = 1 - \left[\frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}\right]$$

where: SID = Simpson's index of diversity; N = total number of observations of representative population; n_i = number of observations belonging to i^{th} category; S = total number of categories for characterized traits.

The index value ranges from 0–1; where 0 means perfectly homogenous and 1 as perfectly heterogeneous or the highest diversity. On the other hand, the equality of distribution for the above phenotypic traits was determined using the Simpson's equality of distribution (ED) equation (Beals, Gross and Harrel, 1999):

$$\mathrm{ED} = \left[\frac{1}{\sum_{i=1}^{S} pi^2}\right] \times \frac{1}{S}$$

where: ED = Simpson's equality of distribution; pi = proportion of the ith category in relation to total number of categories for the trait; S = total number of categories for the trait.

The ED index ranges from 0 to 1; with 0 as uneven distribution and 1 as equally distributed.

Results and discussion

Selection practices and groups of native chickens

Tables 1 and 2 shows the distribution of farmers who practiced selection and the traits they considered when selecting their native chicken breeding stocks.

Selection practices and means of identifying local names

The data showed that of the farmers questioned, 44.81 percent selected their breeding stocks, with the majority (60

Table 1. Distribution of farmers who practice selection in raising their native chickens.

Applying selection to replace breeding stocks	Farmers	
	n	%
Yes	121	44.81
No	149	55.19
Total	270	100.00

Table 2. Distribution of farmers who practice selection as to their preferred traits for their native chickens breeding stocks (multiple response; $n = 121$).

Traits	*n*	%
Body weight	73	60.00
Reproductive performance	61	50.00
Body conformation	39	32.00
Plumage colour	33	27.00
Good mothering ability	25	21.00
Survival rate	22	18.00
Behaviour	5	4.00
Breed or strain	1	1.00

Table 3. Phenotypic differences between groups of native chickens in Western Visayas, Philippines.

Local name	Bisaya–Cluster 1		Bisaya–Cluster 2		Jolo	
Sex	Male	Female	Male	Female	Male	Female
Live weight (kg)	1.52 ± 0.06^{c}	1.17 ± 0.02^{d}	1.74 ± 0.05^{b}	1.32 ± 0.02^{c}	2.07 ± 0.06^{a}	1.40 ± 0.03^{bc}
Egg weight (g)	39.42 ± 0.28^{b}		41.63 ± 0.30^{a}		42.67 ± 0.41^{a}	
Age at first laying (months)	6.84 ± 0.09		7.00 ± 0.09		6.74 ± 0.09	
Annual egg production (pcs)	50.89 ± 1.03		48.67 ± 0.88		48.84 ± 1.01	
Group size (%)	35.00		40.60		24.40	

	Flat		Snake-like		Flat		Snake-like		Flat		Snake-like	
Head shape[1]	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
	283	99.65	1	0.35	0	0	329	100	3	1.52	194	98.48

[a,b,c,d]Different superscripts within row indicate significant differences ($P < 0.01$).

Figure 1. The hen (left) and rooster (right) of Bisaya–Cluster I which were smaller in body size and possessing flat head shape.

percent) preferring body weight, while the rest considered reproductive performance (50 percent), body conformation (32 percent), plumage colour (27 percent), good maternal behaviour (21 percent) and survival rate (18 percent) as bases for selecting their breeding stocks. Some farmers also preferred chickens that regularly roosted in hen houses and hens which laid eggs in nest boxes. Only one of the farmers considered the breed or strain during selection. These findings indicate that nearly half of the farmers were aware of the importance of breeding stock selection; in addition, they were also concerned with the improvement of body size and reproductive performance of native chickens. These findings were similar to the report on famers in Southern Tagalog (Magpantay *et al.*, 2006).

Groups of native chickens

Table 3 shows the phenotypic differences among the groups of native chicken in Western Visayas, Philippines. Cluster analysis was done using the head shapes, live weight, egg weight, age at first laying, and annual egg production of native chickens as discriminating variables. The results revealed that Bisaya chickens can be further divided into two groups, leading to three major groups. These are the Bisaya–Cluster I (Figure 1), Bisaya–Cluster II (Figure 2) and Jolo (Figure 3) chickens.

The Jolo rooster was the heaviest ($P < 0.01$) having 2.07 ± 0.06 kg live weight, this was followed by Bisaya–Cluster II with 1.74 ± 0.05 kg and Bisaya–Cluster I with 1.52 ± 0.06 kg. The live weight of hens ranged from 1.17 ± 0.02 to 1.40 ± 0.03 kg with Jolo hens the heaviest and the Bisaya–Cluster I as the lightest. Hens of Bisaya–Cluster II (1.32 ± 0.02) had an intermediate live weight. The observed variations in live weight may be due to the genotypes of each group. Jolo chickens were introduced by Muslim sailors from Jolo through the "pauwak"[2]. They

[2] An endurance/stamina cock fight that uses Jolo rooster.

Figure 2. The hen (left) and rooster (right) of Bisaya–Cluster II which were bigger than those of Bisaya–Cluster I but smaller than Jolo and possessing snake like head shape.

Figure 3. The hen (left) and rooster (right) of Jolo which were the largest and had snake like head.

are bigger, noted for their stamina and leaner than the Bisaya chickens. The improvement in live weight of Bisaya–Cluster II was probably due to the crossbreeding of Jolo with Bisaya–Cluster I. Farmers in the region may have opted to improve this trait and therefore found it necessary to acquire Jolo chickens for this purpose.

There was no significant ($P > 0.05$) difference among the native chickens in terms of age at first laying and annual egg production. The delayed onset of egg laying can be a natural response of hens to fluctuating availability of feeds in a scavenging production system (Zaman, Sorensen and Howlider, 2004; Mapiye *et al.*, 2008). Ershad (2005) reported that hens raised under intensive management lay their first egg at four to five months rather than at seven months of age as observed in this study. The egg weight of Jolo (42.67 ± 0.41 g) and Bisaya–Cluster II (41.63 ± 0.30 g) were comparable but significantly higher ($P < 0.01$) than those of Bisaya–Cluster I (39.42 ± 0.28 g). These variations were shown to be directly related to the hens' live weight. Heavier hens laid larger eggs as explained by Wolanski *et al.* (2007).

All the Bisaya–Cluster II and Jolo chickens had snake-like heads whereas Bisaya–Cluster I had a flat head shape. According to Dana *et al.* (2010) head shape is one of the important morphological characteristics that can be used to discriminate differences between populations. The findings of this study corroborated this observation, with the occurrence of snake-like heads among Bisaya chickens possibly due to its crossing with Jolo chickens. The outstanding growth performance of the Bisaya–Cluster II may have encouraged more farmers to breed them. This was confirmed by 40.60 percent of the characterized chickens belonging to Bisaya–Cluster II.

Table 4 presents the squared Euclidean distances of different groups of native chickens in Western Visayas, Philippines while Figure 4 shows the dendrogram obtained through the squared Euclidean distances of the hierarchal cluster analysis for the three major groups of native chickens in Western Visayas, Philippines. The result showed a closer squared Euclidean distance unit of 1.20 between Jolo and Bisaya–Cluster II. The distances between Bisaya–Cluster I to Bisaya–Cluster II and Jolo were

Table 4. Squared Euclidean distances between different groups of native chickens in Western Visayas, Philippines.

	Bisaya–Cluster I	Bisaya–Cluster II	Jolo
Bisaya–Cluster I	0		
Bisaya–Cluster II	10.91	0	
Jolo	15.94	1.20	0

This is in terms of similarity of live weight, egg weight, age at first laying, annual egg production and head shape.

10.91 units and 15.94 units, respectively. The close distance between Jolo and Bisaya–Cluster II was due to their similarity in head shape. This conforms to the observation of Dana *et al.* (2010) when using head shape as a discriminating variable. The closer distance of these two groups was further strengthened by the comparable live weight of hens and egg weight.

The multivariate cluster analysis employed in this study also revealed the discrete differences of native chicken groups in this region. Similar studies conducted in other countries using this technique showed analogous results. Using this technique, Abdelqader, Wollny and Gauly (2008) and Al-Atiyat (2009) were able to identify groups within local and specialized chickens in Jordan. This result was similar to those conducted among the local chickens in Cambodia (FAO, 2009).

Phenotypic diversity of different groups of native chickens

Table 5 shows the Simpson's diversity indices for selected phenotypic parameters of different groups of native chickens in Western Visayas, Philippines. The frequency and percentage distributions of these phenotypic traits are shown in Supplementary Table S1.

Table 5. Simpson's diversity index (SID) and equitability of distribution (ED) for selected phenotypic traits of different groups of native chickens in Western Visayas, Philippines.

Parameters	Bisaya–Cluster I		Bisaya–Cluster II		Jolo	
	SID	ED	SID	ED	SID	ED
Plumage colour	0.825	0.510	0.873	0.694	0.835	0.538
Plumage pattern	0.690	0.533	0.699	0.550	0.677	0.510
Feather morphology	0.014	0.507	0.006	0.503	0.000	0.500
Feather distribution	0.076	0.155	0.111	0.161	0.050	0.150
Iris colour	0.803	0.278	0.802	0.277	0.759	0.227
Earlobe colour	0.431	0.251	0.558	0.322	0.517	0.294
Skin colour	0.343	0.506	0.442	0.596	0.497	0.660
Shank colour	0.737	0.470	0.763	0.522	0.663	0.367
Head shape	0.007	0.504	0.000	0.500	0.030	0.515
Breast shape	0.007	0.504	0.048	0.525	0.059	0.531
Body shape	0.366	0.786	0.471	0.943	0.488	0.973
Comb type	0.484	0.276	0.556	0.321	0.456	0.261
Skeletal variants	0.028	0.206	0.066	0.214	0.079	0.217
Liveweight	0.568	0.385	0.666	0.503	0.690	0.530

Plumage colour and pattern

The results showed that the Simpson's diversity index for plumage colour of Bisaya–Cluster I, Bisaya–Cluster II and Jolo were 0.825, 0.873 and 0.835, respectively. These indicate relatively heterogeneity of groups in this trait; however, Bisaya–Cluster II (0.694) had higher equitability of distribution (ED) than the Bisaya–Cluster I (0.510) and Jolo (0.538) chickens. These findings imply that chickens

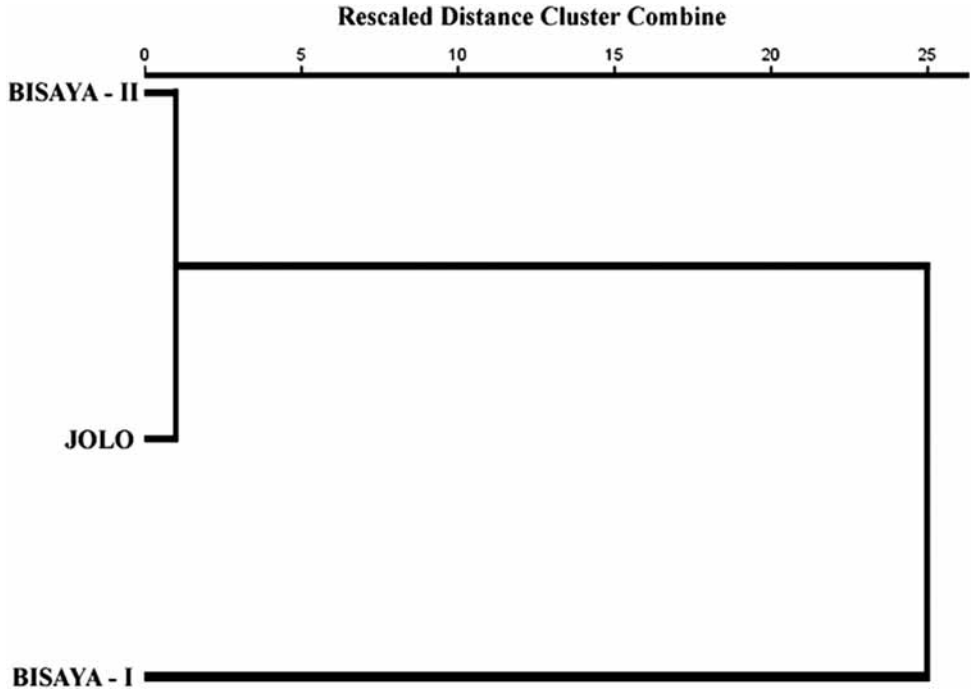

Figure 4. Dendrogram obtained through the squared Euclidean distances of hierarchal cluster analysis for the three major groups of native chickens in Western Visayas, Philippines.

from Bisaya–Cluster II had more variations in plumage colour than those belonging to the other groups. The reason for this variation was probably due to the dominance of a particular colour within the group and selection preferences of farmers.

Diversity index for plumage colour pattern was somewhat lower than that in the plumage colour. The Bisaya–Cluster II had a higher diversity (0.699) than Bisaya–Cluster I (0.690) and Jolo (0.677) chickens. The equitability of distribution ranged from 0.510 to 0.550. Observed differences between plumage colour and colour pattern may be due to limited types of the latter than the former. The prevailing colour patterns may possibly have been more adapted to the present environment of the chickens. The number of occurrences was close across groups indicating a few types of plumage colour patterns dominating the groups of native chickens in the region. Other colour patterns were noted with the number of chickens with these additional colour patterns being fewer.

Feather morphology and distribution

It was found that the feather morphology (0.000–0.014) and distribution (0.050–0.111) of native chickens in the region were homogenous to normal (Table 5). The results indicate that mutations in these traits were very minimal; however, ED in feather morphology was average (0.500–0.507) while that in feather distribution was unevenly distributed (0.150–0.161). The higher ED in feather morphology can be attributed to their limited types; probably due to the limitation of the equation in determining equitability of distribution. The presence of several categories enables the ED to detect the evenness of distribution as observed in feather distributions.

Colours of the iris, earlobe, skin and shank

Results showed moderately greater diversity in iris colours of Bisaya–Cluster I (0.803) and II (0.802) than that of Jolo (0.759) chickens (Table 5). However, the ED was closer to uneven distribution (0.227–0.278). This implies that the occurrence of various iris colours increase the diversity level but the greater number of chickens having amber, golden brown, sunburst and flame than those observed with other colours reduced the ED. The absence of additional colours in chickens from other groups further lowers the equitability distribution. The diversity of iris colours can be attributed to the amount of carotenoid ingested and utilized, gene action and effects of other colour modifying genes. Its distribution may be due to its prominence among the native chickens in Western Visayas.

In terms of earlobe colour, it was found that the diversity level among Bisaya–Cluster II (0.558) and Jolo (0.517) was slightly above the average; whereas that of Bisaya–Cluster I (0.431) was below average. Furthermore, the distribution was not equal given the ED which ranged from 0.251 to 0.322. This indicates that there were some earlobe colours which were not observed in other groups. The lower ED was due to a greater number of chickens having red and reddish with white earlobes than those having other colours. The observed differences may be due to chickens that inherited the most dominant earlobe colours from their parental lineages, the *Gallus gallus*. The mutation of other colours was not prominent; probably because of some associated traits that limits their adaptation to the local conditions and available feed resources.

The diversity in skin colour was below the average which ranged from 0.343 to 0.497; whereas the ED was above average (0.506–0.660). Lower diversity index was due to limited skin colour and the greater magnitude of chickens having only one colour. The above average ED was due to fewer numbers of chickens having the other colours. The Jolo chickens had a relatively higher ED due to the near equal distribution of chickens of two major skin colours compared with the other groups. The observed diversities and distributions of skin colour may be attributed to its dominance over the specific group.

It was also found that the diversity in shank colour ranged from 0.663 to 0.763 with those from Bisaya–Cluster II being relatively higher than the Jolo chickens. On the other hand, the ED for Bisaya–Cluster I, Bisaya–Cluster II and Jolo chickens were 0.470, 0.522 and 0.367, respectively. These results indicated that diversity in shank colour is greater but the non-existence of other colours in some groups decreases its equitability of distribution. This lower ED signifies the minimal number of chickens having colours other than the dominant one.

Shapes of head, breast and body

Results showed that the head shapes were homogenous (0.000–0.030; Table 5). The Bisaya–Cluster II and Jolo chickens were homogeneous for having a snake-like head while the Bisaya–Cluster I was homogeneous for having a flat head. Its ED was in the average of 0.500–0.515. Dana *et al.* (2010) commented that this trait can be used as a discriminating variable considering its specificity of occurrence among the groups of Ethiopian local chickens. This proposition agrees with the findings of this study. The average ED can be attributed to the distribution which was concentrated only in one of two categories.

Native chickens in Western Visayas had wedge-shaped breast (0.007–0.059) while the ED ranged from 0.504 to 0.531. The detected prominence of a wedge-shaped breast was due to the interaction of multiple genes as pointed out by Moiseyeva *et al.* (2003). This may be of great importance considering the flighty nature of these chickens, as the wedge-shape reduces friction between the breast and wind when flying. Average ED indicates an unequal distribution within the group of chickens possessing convex and wedge-shaped breast. Wedge-shaped breast can be one of the indicators for differentiating Bisaya and Jolo chickens from commercial lines/breeds.

The diversity index for body shapes was closer to average among the Bisaya–Cluster II (0.471) and Jolo (0.488) than

that of Bisaya–Cluster I (0.366). It was also found that the ED of Bisaya–Cluster II (0.943) and Jolo (0.973) were nearly equal. These results indicate that occurrences and distributions of blocky and wedge body shapes were nearly equal. Body conformation can be attributed to accumulated types of genes in different body parts (Somes, 1990). It is possible that the majority with wedge-shaped breasts, which were found in the uplands came about by natural selection. Combinations of wedge-shaped breast and body may also have enhanced the flying ability of native chickens when threatened by danger.

Comb type, skeletal variants and liveweight

The findings on comb type showed that Bisaya–Cluster II (0.556) had slightly above average diversity than the Bisaya–Cluster I (0.484) and Jolo (0.456) chickens (Table 5). The observed ED was closer to unequally distributed which ranged from 0.206 to 0.217. These results indicate that single and pea combs were dominant among the native chickens in the region.

Results revealed that native chickens were homogenous for normal skeletal variants as revealed by its diversity indices (0.028–0.079) and ED (0.206–0.217).

As to live weight, results showed that the Bisaya–Cluster II and Jolo chickens had a wider range of live weight which reached more than three kilograms. Diversity analysis also revealed that these groups had a relatively higher diversity (0.666–0.690) than the Bisaya–Cluster I (0.568). However, a greater distribution of chickens was detected within the weight levels of 1.00–2.00 kg as supported by ED of 0.385–0.530. Those in Bisaya–Cluster I was within 1.00–1.50 kg. Somewhat higher numbers of Jolo chickens were in the weight level of 2.51–3.00 kg than of Bisaya–Cluster II but 1.53 percent of the latter had a live weight of more than 3.00 kg. The findings indicate that there is greater variation in Jolo chickens which can be exploited if a farmer aims to improve adult body weight. Jolo chickens are bigger than Bisaya chickens and some farmers may possibly have applied crossbreeding of these groups to produce the Bisaya–Cluster II with an improved body weight (Table 1).

Conclusions

Findings of this study revealed higher phenotypic diversity of native chicken genetic resources in Western Visayas, Philippines. This indicates the potential source of genetic materials for breeding purposes. The Bisaya–Cluster II and Jolo chickens can possibly be considered for breeding stock, if farmers and/or other interested parties opted to develop native chicken breeds with heavier slaughter weight. The native chickens belonging to the Bisaya–Cluster I also showed their capability in egg production. Since, native chickens in rural areas are free-range; appropriate conservation techniques must be studied to preserve some of the traits prominent to each genetic group for future use. Further studies of molecular analysis are encouraged to determine if there is gene flow between groups and as a basis in decision-making toward conservation and utilization of these genetic resources.

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Statement of Interest

The author hereby declares that there is no conflict of interest involved in this study.

Supplementary material

Supplementary materials of this paper is available at http://journals.cambridge.org/agr

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Pedigree analysis of the Nilagiri sheep of South India

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Summary
The Nilagiri sheep is a dual utility (fine wool and meat), native to the Nilagiri hills of Tamil Nadu. It is known for its adaptability to high altitude and low input system of rearing. At present, this breed is endangered with less than a thousand numbers existing, of which about 50 percent is maintained at Sheep Breeding Research Station, Sandynallah. Efforts are on to conserve the breed *in-situ.* Generation interval (GI), pedigree completeness level, inbreeding coefficient (F), average relatedness (AR*)*, effective population size (N_e), and effective number of founders (f_e) and ancestors (f_a) were studied for the breed. Pedigree analysis was carried out using data available at the research station on 5 051 animals from 1965 onwards using ENDOG ver. 4.8. Higher values of pedigree completeness (more than 80 percent for 5th generation), balance in percent of ancestors between sire and dam pathways and higher equivalent complete generations (7.12) for the reference population were indicative of the depth in pedigree. The GI, F, and AR were 3.36 years, 2.17 and 3.45 percent, respectively. N_e based on maximum number of generations and individual increase in inbreeding was 298.83 and 97.25, respectively. f_e and f_a were 59 and 41, respectively, for the reference population. F was far from critical values of inbreeding and f_e/f_a ratio indicated absence of stringent bottlenecks. The effective population size was on the higher end of the range reported for endangered sheep breeds. The knowledge on genetic diversity and effective population size coefficients would support the cause of conservation.

Keywords: *pedigree analysis, Nilagiri sheep, effective population size, inbreeding, relatedness*

Résumé
Les moutons Nilagiri, bétail à double aptitude (laine fine et viande), sont originaires des montagnes Nilagiri du Tamil Nadu. Ces animaux sont réputés pour leur capacité d'adaptation aux altitudes élevées et aux systèmes d'élevage à faible intensité d'intrants. Avec moins d'un millier de têtes recensées, dont environ la moitié est maintenue à la Station de Recherche en Sélection d'Ovins de Sandynallah, la race est à présent menacée. Des efforts se réalisent pour la conservation in vivo de la race. L'intervalle générationnel (GI), le niveau de complétude de la généalogie, le coefficient de consanguinité (F), la parenté moyenne (AR), la taille effective de la population (Ne) et le nombre effectif de fondateurs (fe) et d'ancêtres (fa) ont été étudiés pour la race. L'analyse de généalogie a été menée avec des données, de 1965 en avant, disponibles à la station de recherche pour un total de 5 051 animaux, en utilisant ENDOG ver. 4.8. Des valeurs de complétude de la généalogie élevées (plus de 80 pour cent sur la cinquième génération), l'équilibre dans les pourcentages d'ancêtres entre lignes paternelles et maternelles et un nombre élevé de générations complètes équivalentes (7,12) pour la population de référence sont signe de la profondeur de la généalogie. GI, F et AR ont été de 3,36 ans, 2,17 pour cent et 3,45 pour cent, respectivement. La Ne basée sur le nombre maximal de générations et l'augmentation individuelle de la consanguinité a été de 298,83 et 97,25, respectivement. Pour ce qui est de fe et fa, les résultats ont été, respectivement, de 59 et 41 pour la population de référence. La valeur de F a été loin d'être critique et le rapport fe/fa a indiqué une absence de goulots d'étranglement sévères. La taille effective de la population s'est située sur l'extrême supérieur de la plage de valeurs rapportées pour les races ovines menacées. Les connaissances en diversité génétique et l'appréciation des coefficients de la taille effective de la population serviraient à soutenir la cause de la conservation.

Mots-clés: *analyse généalogique, moutons Nilagiri, taille effective de la population, consanguinité, parenté*

Resumen
El ganado ovino Nilagiri, de aptitud doble (lana fina y carne), es oriundo de los montes Nilagiri de Tamil Nadu. Estos animales son conocidos por su capacidad de adaptación a altitudes elevadas y a sistemas de cría con bajos insumos. En la actualidad, esta raza está amenazada, quedando menos de un millar de ejemplares censados, de los cuales cerca de la mitad se mantienen en la Estación de Investigación en Mejora de Ganado Ovino de Sandynallah. Se están realizando esfuerzos para la conservación in situ de la raza. Se han estudiado, para la raza, el intervalo generacional (GI), el nivel de compleción del pedigrí, el coeficiente de endogamia (F), el parentesco medio (AR), el tamaño efectivo de población (Ne) y el número efectivo de fundadores (fe) y ancestros (fa). El análisis de genealogía fue llevado a cabo con datos, de 1965 en adelante, disponibles en la estación de investigación para un total de 5 051 animales, usando ENDOG ver. 4.8. Valores altos de completitud del pedigrí (más del 80 por ciento para la quinta generación), el equilibrio

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en el porcentaje de ancestros entre vías paternas y maternas y un elevado número de generaciones completas equivalentes (7,12) para la población de referencia son indicativos de la profundidad de la genealogía. El GI, F y AR fueron, respectivamente, de 3,36 a|ños, 2,17 por ciento y 3,45 por ciento. El Ne basado en el número máximo de generaciones y el incremento individual en consanguinidad fue de 298,83 y 97,25, respectivamente. Los resultados de fe y fa fueron de 59 y 41, respectivamente, para la población de referencia. El valor de consanguinidad F estuvo lejos de ser crítico y el ratio fe/fa indicó ausencia de cuellos de botella severos. El tamaño efectivo de la población se situó en el extremo superior del intervalo referido para razas ovinas amenazadas. El conocimiento de la diversidad genética y de los coeficientes del tamaño efectivo de población sería de ayuda para la causa de la conservación.

Palabras clave: *análisis de genealogía, ovejas Nilagiri, tamaño efectivo de la población, consanguinidad, parentesco*

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Introduction

The Nilagiri sheep, native to the Nilagiri hills of Tamil Nadu is known for its adaptability to high altitude. They are usually maintained in a low-input system for dual utility (fine wool and meat). These Sheep have been maintained over centuries in the Nilagiri hills. Shortt (1869) has given an account of sheep being offered for sacrifice by the Toda tribes of the Nilgiris. Littlewood (1936) was perhaps the first to describe the sheep of Nilgiris with good-quality wool. The breed has been used along with Merino, in the development of another synthetic wool breed named Sandyno, which has better wool quality. The Nilagiri sheep are able to withstand wide climatic variations (frost during winter and high wind velocity and humidity during monsoons) prevalent in the region. The population was reported as 8 000 by Ganesakale and Rathnasabapathy (1973). At present, the breed is endangered, with numbers less than one thousand (Report, 2008; personal survey), warranting immediate action towards conservation (Bhatia and Arora, 2005). The Sheep Breeding Research Station (SBRS), Sandynallah, which has been maintaining the breed for over 40 years has about 50 percent of the current population of Nilagiri sheep. A Government of India scheme on "Conservation of Threatened Breeds" for enumeration, *in situ* conservation, health care and provision of feed supplements, is functioning at SBRS.

Pedigree analysis is an important tool to describe genetic variability and its evolution across generation. Computation of effective population size (Falconer and Mackay, 1996) is a key not only to understand the genetic diversity, but also for further prognosis in terms of conservation. Another important goal in conservation of endangered breeds is to restrain the rate of inbreeding. Several studies in sheep report a reduction in reproduction, growth and wool production due to inbreeding depression (Lamberson, Thomas and Rowe, 1982; Ercanbrack and Knight, 1991; Mandal *et al.*, 2005). An increase in inbreeding is directly related to decrease in heterozygosity for a given locus in a closed, panmictic population of finite size (Wright, 1931). Additionally, in the case of domestic livestock population, founder equivalents (Lacy, 1989) and f_a (Boichard, Maignel and Verrier, 1997) provide complementary information to inbreeding parameters (Gutiérrez *et al.*, 2003).

While efforts are being made to conserve the Nilagiri sheep, it is appropriate to understand the genetic structure of the population through pedigree analysis. Management methods based on pedigree analysis (Goyache *et al.*, 2003; Gutiérrez and Goyache, 2005; Gutiérrez *et al.*, 2008; Gutiérrez, Cervantes and Goyache, 2009) can act as a tool for preventing the breeds from extinction. In this study, the generation interval (GI), pedigree completeness level, inbreeding coefficient (F), average relatedness (AR), effective population size (N_e), Genetic Conservation Index (GCI), and effective number of founders (f_e) and ancestors (f_a) were calculated from pedigree information to evaluate the current status of the breed with respect to genetic variability.

Materials and methods

With the total population of Nilagiri sheep being less than one thousand, a major proportion of the population is being maintained at SBRS. The flock has been closed with no introduction of animal from outside, after 1990 for more than 20 years and selection was practiced for 6 months body weight. Selected rams were usually removed after three seasons of breeding. Data on 5051 Nilagiri sheep maintained at SBRS were utilized for the study. Pedigree information collected included unique identification of animal, sire and dam, date of birth, and sex. Records available for 48 years (from 1965 up to 2012) were utilized for the study.

GI was studied as the average age of parents when their progeny used for breeding were born. It was calculated along the four gametic pathways; father to son, father to daughter, daughter to son, and daughter to daughter. The evolution of this parameter was studied as per Gutiérrez *et al.* (2003). The reference population for GI was taken as those animals who were parents during the four years (from 2008 to 2011) previous to the last year of analysis. A period of 4 years was preferred keeping in mind the average GI for sheep. To study evolution, GIs for another

sample of animals born in a block of four consecutive years from 1988 to 1991 were computed.

The reference population for all other parameters included animals with known parents and born during 2009–2011. Data on animals born during 2012 were not complete at the time of study. Pedigree completeness level was studied as the proportion of parents, grandparents and great-grand parents known and complete equivalent number of generations (Boichard, Maignel and Verrier, 1997). The equivalent number of generations was assessed for each animal (i) in the reference population as follows:

$$\left(\mathrm{EqG}_i\right) = \left(1/2\right)^n$$

where "n" is the number of generations separating each known ancestor from the individual.

F values of all the individuals were calculated as in Wright (1923). N_e, i.e. the number of breeding individuals that would give rise to the same rate of inbreeding if they contribute equally to the next generation, was calculated as per Wright (1931) as below:

$$N_e = 1/2\Delta F$$

Where, ΔF is the rate of inbreeding per generation. The rate of inbreeding was estimated as per as per Gutiérrez *et al.* (2003) and Gutiérrez *et al.* (2008) modified by Gutiérrez, Cervantes and Goyache (2009). The later method corrects for variations in depth of pedigree and also allows overlapping generations.

The average relatedness (AR) could be defined as twice the probability that two random alleles, one from the animal and the other from the population in the pedigree (including the animal), are identical by descent and can then be interpreted as the representation of the animal in the whole pedigree regardless of the knowledge of its own pedigree. This was computed as described in Dunner *et al.* (1998). It is the average of the coefficients in the row corresponding to the individual in the numerator relationship matrix.

The f_e, is the number of equally contributing founders that would be expected to produce the same genetic diversity as in the population under study (James *et al.*, 1972; Lacy, 1989). The effective number of founders was calculated as

$$f_e = \frac{1}{\sum_{k=1}^{f} q_k^2}$$

where q_k is the probability of gene origin of kth ancestor.

f_a (Boichard, Maignel and Verrier, 1997) was studied for the reference population. f_a is the minimum number of ancestors, founders or not, necessary to explain the complete genetic diversity of the population under study. f_a is less than f_e and the comparison of both numbers can be used to find the bottlenecks that have occurred from the founders to the present population (Boichard, Maignel and Verrier, 1997): the greater the f_e/f_a ratio, the more stringent the bottlenecks.

GCI (Alderson, 1992) was calculated for all the individuals in the population under study as the reciprocal of proportion of contribution of all the founders in the pedigree of the animal.

All the analyses were done using the software ENDOG version 4.8 (Gutiérrez and Goyache, 2005).

Table 1. Number of Nilagiri sheep enumerated*.

	Ram	Ewe	Ram lamb	Ewe lamb	Total
Farms	54	292	56	41	443
Research Station, Sandynallah	36	265	70	62	433

Nilagiri sheep are exclusive to the Nilagiri hills of Tamil Nadu, India.

Results and discussion

The census for Nilagiri sheep (Table 1) indicate that half the population of the existing animals are maintained in the farm. The population for the breed was 8 000 in 1973 (Ganesakale and Rathnasabapathy, 1973) and has drastically reduced to less than a thousand. Pedigree analysis was done from data available in the station.

Generation interval

The overall GI and the evolution over periods are presented in Table 2. The mean GI for the whole population was 3.36 years. GI calculated from sire and dam pathways were 2.55 and 4.15 years, respectively. GI decreased from 3.29 years in the earlier reference period to 3.18 year in the last four consecutive years of the study. This could be due to better reproductive management and use of genetic evaluation for decision-making in breeding. A similar trend was noticed by Gutiérrez *et al.* (2003) for beef cattle in Spain. However, in the present study, the trend was different in the father pathway, where the GI increased in the recent years. The larger GI could be due to retaining of sires for longer periods. Lower and higher GIs have already been reported for sheep in the literature. Goyache *et al.* (2003) reported GIs ranging from 2.67 to 2.87 year on the father side and from 3.11 to 3.23 year

Table 2. Evolution of generation interval.

Pathway	Overall	2008–2011	1988–1991
Father–son	2.49	2.58	2.24
Father–daughter	2.64	2.54	2.24
Mother–son	4.16	3.71	4.34
Mother–daughter	4.12	3.70	4.28
Average	3.36	3.18	3.29

on the mother side for Xalda sheep (genealogical data of 805 individuals). Li Strandén and Kantanen (2009) reported GIs for Finnsheep in terms of all possible pathways: father–son 2.96 years, father–daughter 3.15 years, mother–son 2.65 years, mother–daughter 2.49 years. Danchin-Burge *et al.* (2010) reported a mean GI between 2.9 and 4.1 years for analysed sheep breeds in France. GIs ranging from 2.2 to 4.1 years on the father side and from 3.9 to 5.6 years on the mother side for a closed Merino Rambouillet flock over 50 generations of inbreeding was reported by Prod'homme and Lauvergne (1993). Oravcova and Krupa (2011) reported higher values of 4.07 ± 0.157 years for the whole population.

Pedigree completeness

Knowledge on pedigree completeness is important as the inferences drawn on inbreeding and N_e depends on it. The decrease in proportion of ancestral knowledge from first to fifth generation was 98.81 to 84.47 and 85.58 to 35.47 percent in the reference and whole pedigree population, respectively (Figure 1).

The percent of ancestor knowledge was balanced, with almost equal proportions for sire and dam pathways, even in the fifth generation. Several other studies have shown pedigrees more shallow and imbalanced than this population. Oravcova and Margetin (2011) observed a decrease from 100 to 34 percent in the first to fifth generation of the reference population and from 63 to 16 percent in the first to fourth generation of the whole pedigree population for the Former Valachian sheep.

The equivalent complete generation for the reference population was 7.12 compared with 3.75 for the whole population. This was indicative of good depth in pedigree. Values reported in literature for other breeds were 1.09 for whole population of Xalda breed of sheep (Goyache *et al.*, 2003), 1.40 and 0.43 for reference population and whole population, respectively, for Mallorquina sheep (Goyache *et al.*, 2010) and 4.70 and 1.16 for reference population and whole population, respectively, for Former Valachian sheep (Oravcova and Margetin, 2011). Danchin-Burge *et al.* (2009) reported higher number of equivalent generations (ranging from 4.6 to 10.5) for younger individuals in reference population in sheep breeds of small populations in France. The inbreeding coefficient and equivalent number of generations reported for various sheep breeds has been compared with that obtained for Nilagiri sheep (Figure 4). A balanced ancestral knowledge with higher equivalent complete generation in the present study is indicative of good pedigree depth.

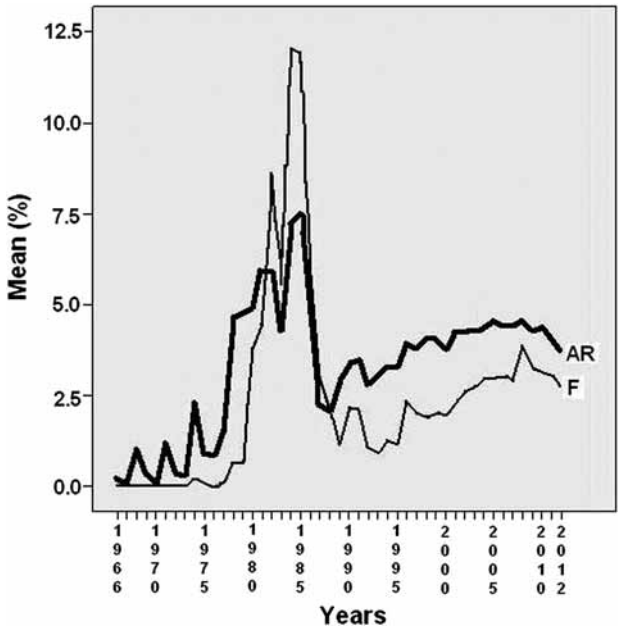

Figure 2. Trends of mean inbreeding (F) and average relatedness (AR) of Nilagiri sheep over years.

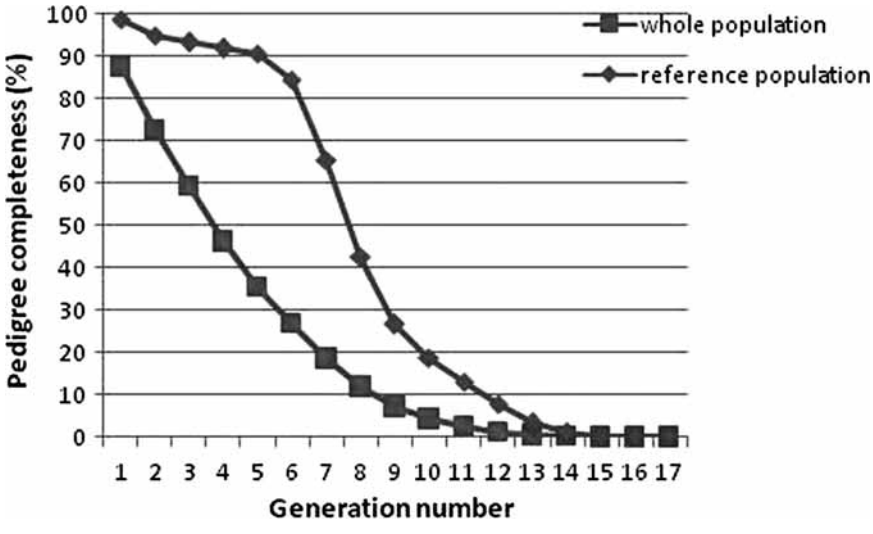

Figure 1. Percentage of ancestral knowledge for whole and reference populations in Nilagiri sheep.

Table 3. Inbreeding coefficient (*F*), average relatedness (AR), individual increase in inbreeding (AF) and effective population size (N_e) in whole and reference populations.

	Parameter	Whole population	Reference population (2009–2011)
F (%)	Mean	2.17	3.16
	Minimum	0.00	0.00
	Maximum	33.59	26.54
AR (%)	Mean	3.45	4.23
	Minimum	0.00	0.03
	Maximum	10.71	5.73
AF (%)	Mean	0.65	0.50
	Minimum	0.00	0.00
	Maximum	43.75	4.89
N_e	Regression over birth date	544.54	
	Maximum generations	298.83	
	Complete generations	53.21	
	Equivalent generations	90.34	
	Individual increase in inbreeding	97.25	

Inbreeding coefficient and average relatedness

F and AR values for the whole and reference population are presented in Table 3. Previous studies have demonstrated that the completeness of pedigree information has an effect on the estimates for *F* within a breed (Lutaaya *et al.*, 1999; Cassell, Adamec and Pearson, 2003). The pedigree completeness and equivalent number of generations for the Nilagiri breed was optimal. The average inbreeding values for the whole and reference population were 2.17 and 3.16 percent, respectively. The inbreeding values were thus well below critical levels. In the whole population, 45 percent were inbred, while 78 percent had inbreeding less than 3.125 percent. The highly inbred matings in the whole population were 159 (3.15 percent) between half sibs and 22 (0.44 percent) between parent-offspring. Similar finding of high mean value of heterozygotes (0.72), which was also indicative of low level of inbreeding, has been reported based on molecular characterization of the Nilagiri breed (Haris Girish *et al.*, 2007).

The AR (2.45 percent) was higher than the mean inbreeding and this may be due to the closed nature of the flock and good pedigree depth. Goyache *et al.* (2003) also observed an AR of 1.8 percent, which was higher than the inbreeding value (1.5 percent) in a small population of Xalda sheep. Very high values of AR up to 15 percent have been found in a small sheep population closed for more than 40 years (Lamberson, Thomas and Rowe, 1982; Vanwyk Erasmus and Konstantinov, 1992). Higher AR with lower inbreeding coefficient is indicative of high degree of relatedness between all individuals of the pedigree. This could lead to difficulties, when trying to avoid mating between unrelated or slightly related individuals.

The mean inbreeding (Figure 2) increased over the years and peaked during 1984 (>12 percent), after which, it dipped suddenly (<1.25 percent) in 1989. In the subsequent years, there has been a gradual and fluctuating increase to 2.5 percent for the current population. The sudden dip in inbreeding during 1989 is proportional to the shallowness in pedigree with low equivalent number of generations during 1987. The ancestors without pedigree during the period were purchased from farmers' flock where pedigree records were not available. The offspring analysis also shows lesser number of parents contributing more number of offsprings prior to the peak inbreeding value.

In order to distinguish between recent and cumulated inbreeding, the evolution of this parameter per year of birth was also computed, taking into account only the last three generations. Differences between the trend lines result from cumulated inbreeding due to good pedigree depth and uniform breeding management (Gutiérrez

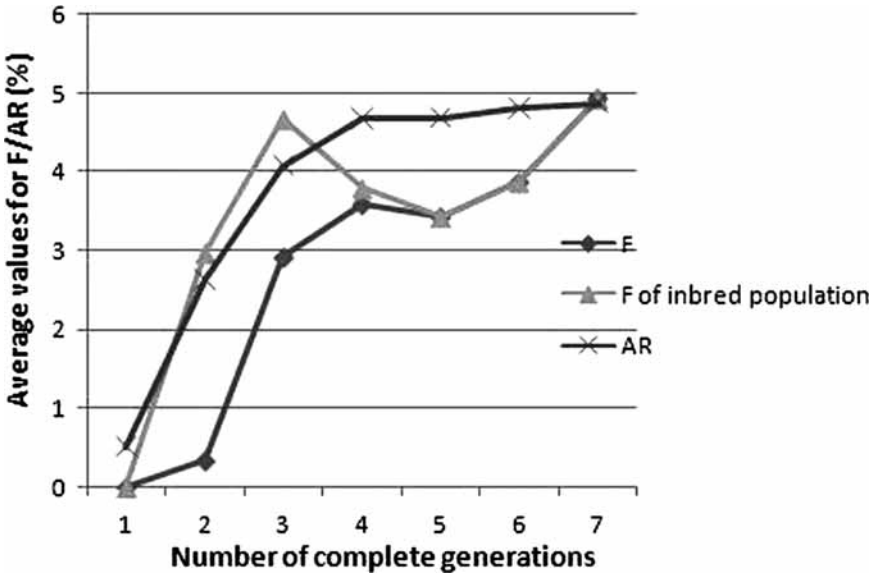

Figure 3. Inbreeding in the whole population, inbred population and average relatedness over complete generations.

Table 4. Average inbreeding (F), rate of inbreeding (ΔF), proportion inbred, mean inbreeding of inbred population, average relatedness (AR) and effective population size (N_e) over complete generations.

Generation	Number	F (%)	ΔF	Proportion inbred (%)	F of inbred (%)	AR (%)	N_e
0	759	0.00	0.00	0.00	0.00	0.52	
1	1 148	0.34	0.34	11.32	2.97	2.63	148.6
2	1 227	2.92	2.59	62.43	4.67	4.08	19.3
3	994	3.59	0.69	94.67	3.79	4.68	72.1
4	525	3.43	−0.16	100.00	3.43	4.69	*
5	333	3.87	0.46	100.00	3.87	4.81	170.3
6	65	4.95	1.11	100.00	4.93	4.87	45.1

*Negative value for ΔF.

et al., 2003). The higher value of average inbreeding in reference population, compared with the whole pedigree, also indicates cumulative inbreeding carried through the deep pedigrees. Gutiérrez *et al.* (2003) observed similar results for A-NI breed of cattle in Spain.

The F value of inbred population and AR per generation are presented in Table 4 and Figure 3. AR is higher than F throughout. After the fourth generation, the percent inbred population becomes 100 percent, where F and mean inbreeding of inbred population becomes the same. According to FAO guidelines and the recommendation by Bijma and Wooliams (2000), a rate of inbreeding of more than 1 percent per generation should be avoided to maintain fitness in a breed. The rate of inbreeding in the Nilagiri population was more than 2 percent in the second generation and just above 1 percent in the sixth generation (Table 4). Thus, the rate of inbreeding is marginally above the critical level and steps need to be taken to introduce genetic variability. One of the objectives of the conservation scheme described above is to open the flock to breeding animals from farmers' flock. The process of introduction is under progress from 2012.

Effective population size

Effective population size estimated from regression on birth dates was 544.54, and that from maximum generations was 298.83. Even though these values are encouraging in terms of genetic diversity, the fluctuations noticed in F value and equivalent generations, and negative values of rate of inbreeding make them the upper limits for "N_e". Figure 3 shows the trend for F and mean inbreeding of population inbred over generations. The negative rate of inbreeding after fourth generation leads to negative values for N_e. For these reasons, the method proposed by Gutiérrez *et al.* (2008, 2009) using individual increase in inbreeding coefficient (AF) appear to be more suitable to estimate the realized "N_e", which was computed as 106.82. The 50/500 rule, i.e. a population with N_e less than 50 is under immediate threat from inbreeding depression, while a minimum N_e of 500 is needed to prevent loss of genetic diversity over centuries, has been used as guidance in conservation schemes (Rieman and Allendorf, 2001). Meuwissen (1999) has recommended a critical N_e between 50 and 100. The Nilagiri population, though not vulnerable to immediate effects of inbreeding depression, is under threat from loss of adaptive genetic variation. This was also seen from the critical rates of inbreeding. Maiwashe and Blackburn (2010) found a lower N_e (92 animals) for Navajo Churro sheep (genealogical data of 2 950 animals) kept in four regions of the USA. Ghafouri-Kesbi (2010) reported the realized N_e at 71 animals for a closed population of Zandi sheep,

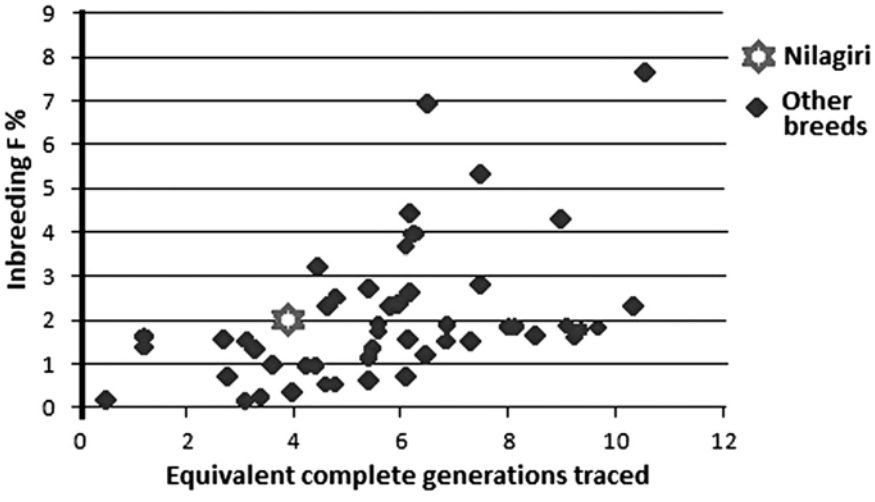

Figure 4. Average inbreeding and equivalent number of generations reported for other breeds of sheep compared with Nilagiri sheep.

whose reference population consisted of 2 566 animals. Li Strandén and Kantanen (2009) reported the mean increase in inbreeding at 0.148 percent and the realized N_e of 122 animals.

Founders and ancestors

The number of founders and ancestors for the whole and reference population were 759 and 154 and 469 and 154, respectively. The difference between f_e and f_a allows an evaluation of the extent that the genetic variability available in the founders has been reduced because of bottlenecks between the base population and the reference population (Boichard, Maignel and Verrier, 1997). In the present study, the difference between f_e and f_a in the Nilagiri population was not very high. An f_e/f_a ratio of 1.41 in the Nilagiri population is indicative of absence of stringent bottlenecks. A range of 1.3 to 2.0 was reported by Danchin-Burge *et al.* (2009) for seven small breeds of France. Oravcova and Krupa (2011) have reported an f_e/f_a ratio of 3.1 for the Former Valachian sheep. Very high values have been reported for Roussin de la Hague (11.7) and Charmoise (10.1) breeds of sheep. f_a contributing to 50 percent of the population (19) observed for the Nilagiri breed was also comparatively high. Thus, the genetic variability from the founders was not lost due to bottlenecks, unbalanced contribution or loss due to segregation.

Genetic conservation index

The maximum GCI value of an individual in the population was 48.71. The proportion of animals with GCI greater than 10 was 36.74 percent. This could be used as a scale to use such animals with higher GCI to maintain balanced contribution from the founders.

Conclusion

The Nilagiri breed of sheep is known for its adaptability and utility under the typical conditions of the Nilagiri hills. The population has been reduced to less than thousand and this warrants immediate conservative measures. Higher AR, rate of inbreeding greater than 1 percent and lower N_e can lead to loss of genetic variability. The breeding plan must be devised to check further inbreeding and loss of genetic variability. Introduction of genetic variability through animals from other farmers' flock is under progress. Less represented animals with lower AR value and better GCI index can be used for breeding. Ex-situ conservation in the form of cryopreservation can be thought of as a long-term plan for preservation of germplasm. Careful monitoring of breeding programme, along with other conservation measures, will help in conserving the breed.

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Identification and phenotypic characterization of goat ecotypes in the Bench Maji zone, southwestern Ethiopia

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Summary
The aim of the study was to identify and characterize the phenotype of goat genetic resources in the Bench Maji zone, south western Ethiopia. Focus group discussions, observation of physical attributes and morphology, and morphometrical measurements were employed for data collection. Descriptive statistics, chi-square tests, general linear model (GLM) and two-step cluster analysis were employed to analyse the data. The results of the analyses revealed that 90.7 percent of the female and 88.4 percent of the male goats have straight facial profile. Horns in the majority of females (85.7 percent) and males (73.4 percent) are straight with backward direction in 72.6 percent of females and 84.2 percent of males. In most cases the female goats lack ruffs (88.2 percent), wattles (73.8 percent) and beards (68.3 percent). Averaged quantitative traits of the female population were 56.97 ± 0.21 cm; 70.15 ± 0.27 cm, 60.08 ± 0.17 cm and 26.36 ± 0.21 kg for body length, chest girth, height at withers and body weight, respectively. The corresponding values of the male population were 60.81 ± 0.35 cm, 75.04 ± 0.50 cm, 64.47 ± 0.32 cm and 31.02 ± 0.50 kg, respectively. Goats from the different districts have shown significant ($P < 0.01$) differences in body length, height at withers and body weight of female and chest girth and body weight of males. 48 and 52 percent of the goat populations were distributed under two clusters indicating that the goat populations can be classified into two ecotypes (Meanit and Sheko).

Keywords: *Bench Maji zone, characterization, ecotype, goat, phenotype*

Résumé
Le but de cette étude a été d'identifier et de caractériser le phénotype des ressources génétiques caprines de la zone Bench Maji, dans le Sud-Ouest de l'Éthiopie. Pour la collecte de l'information, il a été fait recours à des groupes focaux de discussion, à l'observation d'attributs physiques et de la morphologie et à la prise de mesures morphométriques. La statistique descriptive, le test chi-carré, le Modèle Linéaire Généralisé et l'analyse de regroupement en deux étapes ont été utilisés pour analyser les données. Les résultats des analyses ont montré que, pour le 90,7 pour cent des femelles et le 88,4 pour cent des mâles, la tête a un profil rectiligne. Chez la plupart des femelles (85,7 pour cent) et des mâles (73,4 pour cent), les cornes sont droites, dirigées en arrière chez le 72,6 pour cent des femelles et le 84,2 pour cent des mâles. Dans la plupart des cas, les femelles manquent de crinière sur l'encolure (88,2 pour cent), de pendeloques (73,8 pour cent) et de barbiche (68,3 pour cent). Pour les femelles, la longueur du corps, la circonférence thoracique, la taille au garrot et le poids corporel ont été, en moyenne, de 56,97 ± 0,21vcm, 70,15 ± 0,27 cm, 60,08 ± 0,17 cm et 26,36 ± 0,21 kg, respectivement. Chez la population de mâles, les valeurs correspondantes ont été de 60,81 ± 0,35 cm, 75,04 ± 0,50 cm, 64,47 ± 0,32 cm et 31,02 ± 0,50 kg, respectivement. Des différences significatives ($P < 0,01$) ont été décelées, entre chèvres de différents districts, pour la longueur du corps, la taille au garrot et le poids corporel des femelles, et la circonférence thoracique et le poids corporel des mâles. Les populations caprines ont été regroupées en deux types (48 et 52 pour cent des effectifs), ce qui indique que celles-ci peuvent être classées selon deux écotypes (Meanit et Sheko).

Mots-clés: *zone Bench Maji, caractérisation, écotype, caprins, phénotype*

Resumen
El objetivo del estudio era identificar y caracterizar el fenotipo de los recursos genéticos caprinos de la zona de Bench Maji, en el Suroeste de Etiopía. Para la recogida de la información, se recurrió a grupos focales de discusión, a la observación de atributos físicos y de la morfología y a la toma de medidas morfométricas. Para analizar los datos, se utilizaron la estadística descriptiva, el test chi-cuadrado, el Modelo Lineal Generalizado y el análisis de conglomerados en dos fases. Los resultados de los análisis mostraron que el 90,7 por ciento de las hembras y el 88,4 por ciento de los machos tienen perfil recto. En la mayoría de las hembras (85,7 por ciento) y de los machos (73,4 por ciento), los cuernos son rectos, dirigidos hacia atrás en el 72,6 por ciento de las hembras y el 84,2 por ciento de los machos. En la mayoría de los casos, las hembras carecen de pelliza (88,2 por ciento), de mamellas (73,8 por ciento) y de perilla (68,3 por ciento). En la población de hembras, la longitud corporal, la circunferencia torácica, la alzada a la cruz y el peso corporal ascendieron, de media, a 56,97 ± 0,21 cm, 70,15 ± 0,27 cm, 60,08 ± 0,17 cm y 26,36 ± 0,21 kg, respectivamente. Los valores

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correspondientes, para la población de machos, fueron de 60,81 ± 0,35 cm, 75,04 ± 0,50 cm, 64,47 ± 0,32 cm y 31,02 ± 0,50 kg, respectivamente. Se han dado diferencias significativas ($P < 0,01$), entre cabras de distintos distritos, para la longitud corporal, la alzada a la cruz y el peso corporal de las hembras, y para la circunferencia torácica y el peso corporal de los machos. Las poblaciones caprinas quedaron agrupadas, en un 48 y 52 por ciento, en dos conglomerados, lo cual indica que las poblaciones caprinas pueden ser clasificadas de acuerdo con dos ecotipos (Meanit y Sheko).

Palabras clave: *zona de Bench Maji, caracterización, ecotipo, cabra, fenotipo*

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Introduction

Domestic goats (*Capra hircus*) are important and adaptable domesticated animals. They are found in all types of environments and in the whole range of production systems (Peacock, 2005; Tibbo, Philipsson and Ayalew, 2006; Devendra, 2007; Madsen, Nielsen and Henriksen, 2007; Abdul-Aziz, 2010). Goat production over the years is one of the major means of improving the livelihoods of poor livestock keepers, reducing poverty and attaining sustainable agriculture and universal food security due to their nature to produce in harsh climates with low quality roughages (Peacock, 2005; Madsen, Nielsen and Henriksen, 2007; Abdul-Aziz, 2010).

Goat genetic resources play an important socio-economic role in many rural parts of the world (Ogola and Kosgey, 2012). The increasing frequency of droughts, together with long-term environmental degradation, is causing many pastoralists to move away from keeping cattle to keeping goats. There is a marked trend towards keeping more small ruminants as a proportion of livestock holdings than large ruminants (Peacock, 2005). However, goats are an under-used and poorly understood resource as compared to cattle and sheep (Banerjee, Animut and Ermias, 2000; Abdul-Aziz, 2010). Moreover, little attention has been paid to their development in Ethiopia (FARM Africa, 1996; IBC, 2004; Umeta *et al.*, 2011).

Goats are among the most important livestock species in Ethiopia. The population of goats in the country is estimated to be 22.78 million (CSA, 2011). Based on physical characteristics, four families and 13 breeds of goats have been identified in Ethiopia (FARM Africa, 1996; DAGRIS, 2007). While, using microsatellite markers the goat populations showed only eight distinctively different types (Tucho, 2004). These wide range of breeds that have evolved in various environments represent unique sets of genetic resources.

Bench Maji zone of south western Ethiopia is known for the inhabiting diversified ethnic groups, varying agro climatic conditions, different production systems and a variety of livestock genetic resources. However, little was known regarding the phenotypic variability of goat genetic resources in the area. Therefore, the study was undertaken to identify and characterize the phenotype of indigenous goat genetic resources.

Materials and methods

Description of the study area

The study area was Bench Maji Zone of south western Ethiopia found at 34°45′ to 36°10′E longitude and 5°40′ to 7°40′N latitude. The altitude ranges from 500 to 3 000 m above sea level. The annual average temperature ranges from 15.1 to 27.5 °C, while the annual rainfall ranges from 400 to 2 000 mm (BMZFED, 2012). The study area consisted of three districts namely Sheko, Shei Bench and Meanit Shasha as shown in Figure 1. About 67 percent of the land area of Sheko and 80 percent of Meanit Shasha are lowland while 99 percent of Shey Bench is mid altitude. Mixed agriculture is the type of production system in Sheko and Shey Bench districts while pastoralism is common in Meanit Shasha.

Data collection

The study was conducted from December 2011 to August, 2012. Focus group discussions with key informants and elders constituting 7–12 members were held along with a developmental agent per peasant association. To identify the history of development of the goat population and any possible classification of the existing population, breed names, origins of breeds, qualities of breed and peculiar characteristics of the breed, past and present utility pattern of the breed, and its current status and major constraints to the maintenance of the breed have been assessed.

The number of goats sampled for phenotypic characterization was 631, of which 442 were female and 189 were male. District-wise 216, 211 and 204 goats were sampled form Sheko, Meanit Shasha and Shay Bench. Qualitative traits for physical description of the population were taken including the presence or absence of beard, ruff, wattles and horn, facial (head) profile, coat colour type and pattern, hair coat type, ear orientation, horn shape and orientation. Linear body measurements including body length, heart girth, pelvic width, ear length and horn length were taken using measuring tape while wither height was measured using a 1 m ruler. Body weight (kg) was taken through weighing in a spring balance (100 kg capacity and 500 gm graduation). The linear body measurements and the

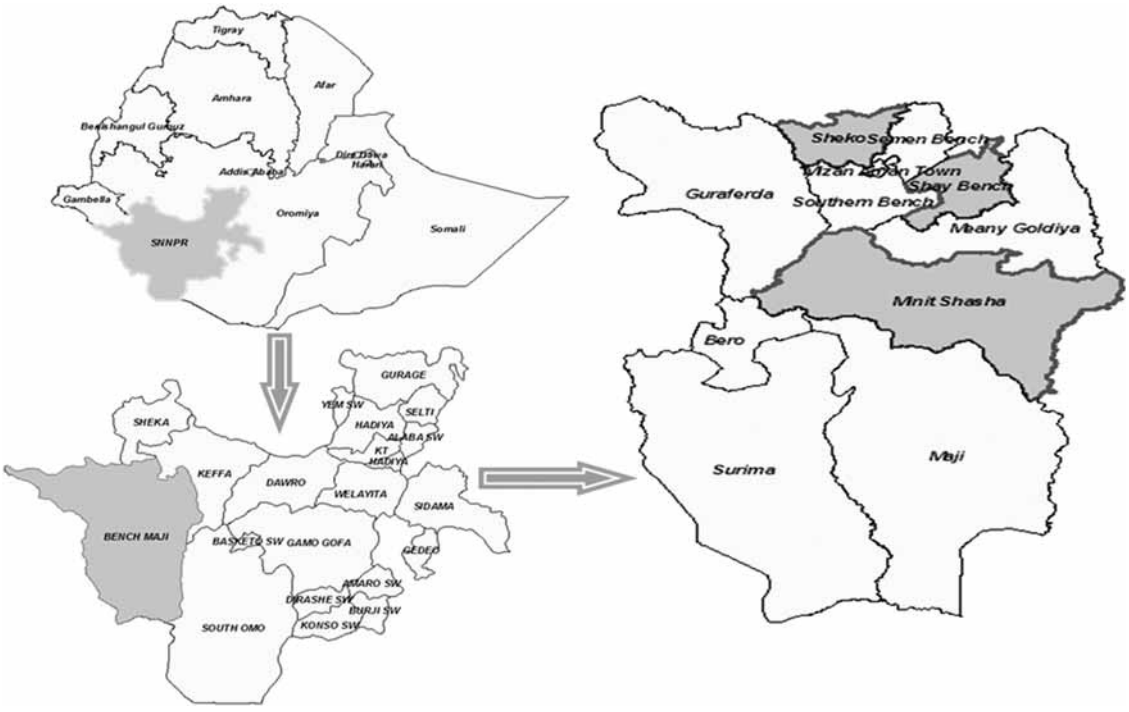

Figure 1. Map of the study area

qualitative traits collected were adapted from goat breed descriptor lists of FARM Africa (1996) and FAO (2011).

Data analysis

The qualitative and quantitative traits were coded and entered into a computer using Microsoft Office Excel 2007. Prior to data analysis for the quantitative traits normality of data was tested using SAS (SAS 9.0, 2002). Descriptive statistics and chi-square tests were employed to analyse the qualitative data. In addition, multiple mean comparisons were made for qualitative variables using Bonferroni's correction using Statistical Analysis System (SAS 9.0, 2002).

Quantitative traits for body measurements were analysed using the general linear model (GLM) procedures of the Statistical Analysis System (SAS 9.0, 2002). The model was fitted to main effects of district and age on body weight and linear body measurements for male and female separately. Least square means were separated using Tukey-Kramers. The model for both sex to analyse body weight and other linear body measurements are presented below. Besides, two-step cluster analysis was used to analyse the quantitative data of both sexes using SPSS (SPSS V.17.0, 2008).

$$Y_{ijk} = \mu + a_i + b_j + e_{ijk}.$$

Where: Y_{ijk} = the recorded k (body weight and linear body measurements) in the ith district and jth age group; μ = overall mean; a_i = the effect of ith district ($i = 1$, 2 and 3; 1 = Sheko, 2 = Meanit Shasha and 3 = Shay Bench); b_j = the effect of jth age group ($j = 1$, 2, 3 and 4; 1 = 1PPI (1 Pairs of Permanent Incisors), 2 = 2PPI (2 Pairs of Permanent Incisors), 3 = 3PPI (3 Pairs of Permanent Incisors), 4 = 4PPI (4 Pairs of Permanent Incisors); e_{ijk} = random residual error.

Results

Characterization of qualitative variation

The distribution of the various qualitative traits in the sampled goat population is presented in Table 1. Majority of females have straight (90.7 percent) facial profile. Horns were found in 98.4 percent of the goats. In most cases (85.7 percent) horns were straight with backward direction in 72.6 percent of the goats. Ruffs, wattles and beards were absent in 88.2, 73.8 and 68.3 percent of the female goats. Majority of them have the ear oriented forward (91.6 percent). The coat colour pattern was a plain coat colour in 56.6 percent of the goats, with 35.5 percent patchy and 7.9 percent spotted. The coat colour was 16.1 percent white, 12.2 percent brown, 8.5 percent light red, 15.9 percent black with white, 11.5 percent white with black and 35.6 percent other colours.

On the other hand, majority of males (88.4 percent) have a straight facial profile. Horns were found on 97.4 percent and the remainders (2.6 percent) were polled. Horns were straight (73.4 percent), which were directed backwards (84.2 percent). Ruffs were present on 59.3 percent, wattles on 46.6 percent and beards on 71.4 percent of males. Majority of them have ear oriented forward (92.1 percent). They have a plain coat colour 49.7 percent, with 42.9 percent patchy and 7.4 percent spotted. The

Table 1. Summary of the qualitative traits. Absolute and relative frequency of trait category by breed and sex.

Traits	Sheko		Shei Bench		Meanit Shasha		Overall (%)		*P*-value	
									Level	
	Male	Female	Male	Female	Male	Female	Male	Female	District	Sex
Beard										
Present	44 (66.7)	49 (32.7)	41 (66.1)	56 (39.4)	50 (81.9)	35 (23.3)	71.4	31.7	0.3225	<0.0001
Absent	22 (33.3)	101 (67.3)	21 (33.9)	86 (60.6)	11 (18.0)	115 (76.7)	28.6	68.3		
Ruff										
Present	35 (53.0)	4 (2.7)	38 (61.3)	31 (21.8)	39 (63.9)	17 (11.3)	59.3	11.2	0.0011	<0.0001
Absent	34 (46.9)	146 (97.3)	24 (38.7)	111 (78.2)	22 (36.1)	133 (88.7)	40.7	88.2		
Wattle										
Present	43 (65.1)	50 (33.3)	35 (56.5)	43 (30.3)	10 (16.4)	23 (15.3)	46.6	26.2	<0.0001	<0.0001
Absent	23 (34.8)	100 (66.7)	27 (43.5)	99 (69.7)	51 (83.6)	127 (84.7)	53.4	73.8		
Horn										
Present	66 (100.0)	150 (100.0)	61 (98.4)	140 (98.6)	57 (93.4)	145 (96.7)	97.4	98.4	0.0047	0.3711
Absent	0 (0)	0 (0)	1 (1.6)	2 (1.4)	4 (6.6)	5 (3.3)	2.6	1.6		
Horn shape										
Straight	44 (66.7)	118 (78.7)	49 (80.3)	117 (83.6)	42 (73.7)	138 (95.1)	73.4	85.7	0.0003	0.0004
Curved	21 (31.8)	23 (15.3)	11 (18.0)	23 (16.4)	11 (19.3)	5 (3.4)	23.4	11.7		
Spiral	1 (1.5)	9 (6.0)	1 (1.6)	0 (0)	4 (7.0)	2 (1.4)	3.2	2.5		
Horn orientation										
Upward	15 (22.7)	49 (32.7)	5 (8.2)	31 (22.1)	9 (15.8)	39 (26.9)	15.8	27.4	0.0315	0.0006
Backward	51 (77.3)	101 (67.3)	56 (91.8)	109 (77.9)	48 (84.2)	106 (73.1)	84.2	72.6		
Hair length										
Short	47 (71.2)	133 (88.7)	48 (77.4)	126 (88.7)	55 (90.2)	143 (95.3)	79.4	91.0	0.0133	<0.0001
Medium	15 (22.7)	17 (11.3)	11 (17.7)	14 (9.9)	5 (8.2)	6 (4.0)	16.4	8.4		
hair on their thighs	4 (6.1)	0 (0)	3 (4.8)	2 (1.4)	1 (1.6)	1 (0.7)	4.2	0.7		
Hair coat type										
Glossy	30 (45.5)	97 (60.7)	36 (58.1)	98 (69.0)	39 (63.9)	116 (77.3)	55.6	69.0	0.0052	<0.0001
Smooth	27 (40.9)	57 (38.0)	18 (29.0)	41 (28.9)	20 (32.8)	34 (22.7)	34.4	29.9		
straight long hair	8 (12.1)	2 (1.3)	7 (11.3)	3 (2.1)	2 (3.3)	0 (0)	9.0	1.1		
curly rough hair	1 (1.5)	0 (0)	1 (1.6)	0 (0)	0 (0)	0 (0)	1.1	0		
Facial profile										
Straight	57 (86.4)	139 (92.7)	57 (91.9)	134 (94.4)	53 (86.9)	136 (90.7)	88.4	90.7	0.3224	0.0886
Slightly concave	9 (13.6)	11 (7.3)	5 (8.1)	8 (5.6)	8 (13.1)	14 (9.3)	11.6	9.3		
Back profile										
Straight	20 (30.3)	20 (13.3)	14 (22.6)	16 (11.3)	24 (39.3)	48 (32.0)	30.7	19.0	<.0001	0.0028
Curved	4 (6.1)	23 (15.3)	6 (9.7)	27 (19.0)	5 (8.2)	7 (4.7)	7.9	12.9		
slopes up towards the rump	42 (63.6)	107 (71.3)	42 (67.7)	99 (69.7)	32 (52.5)	95 (63.3)	61.4	68.1		
Rump profile										
Sloping	66 (100.0)	150 (100.0)	62 (100.0)	142 (100.0)	61 (100.0)	150 (100.0)	100.0	100.0		
Ear orientation										
Lateral	5 (7.6)	13 (8.7)	7 (11.3)	9 (6.3)	3 (4.9)	13 (8.7)	7.9	7.9	0.3973	0.6512
Dropping	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1.3)	0	0.5		
Forward	61 (92.4)	137 (91.3)	55 (88.7)	133 (93.7)	58 (95.1)	135 (90.0)	92.1	91.6		
Coat colour pattern										
Plain	40 (60.6)	99 (66.0)	37 (59.7)	94 (66.2)	17 (27.9)	57 (38.0)	49.7	56.6	<.0001	0.2160
Patchy	17 (25.8)	27 (18.0)	22 (35.5)	39 (27.5)	42 (68.8)	91 (60.7)	42.9	35.5		
Spotted	9 (13.6)	24 (16.0)	3 (4.8)	9 (6.3)	2 (3.3)	2 (1.3)	7.4	7.9		
Coat colour type										
White	8 (14.0)	20 (14.7)	13 (22.0)	21 (16.3)	7 (11.9)	25 (17.4)	16.0	16.1		
Black	0 (0)	8 (5.9)	0 (0)	10 (7.7)	1 (1.7)	9 (6.2)	0.6	6.6		
Dark red	7 (12.3)	18 (13.2)	5 (8.5)	12 (9.3)	0 (0)	4 (2.8)	6.8	8.3		
Light red	11 (19.3)	16 (11.8)	6 (10.2)	17 (13.2)	3 (5.1)	2 (1.4)	11.4	8.5		
Brown	9 (15.8)	27 (19.8)	7 (11.9)	19 (14.7)	2 (3.4)	4 (2.8)	10.3	12.2		
Grey	5 (8.8)	10 (7.3)	6 (10.2)	11 (8.5)	4 (6.8)	11 (7.6)	8.6	7.8		
Black with white patch	8 (14.0)	11 (8.1)	10 (16.9)	14 (10.8)	18 (30.5)	40 (27.8)	20.6	15.9		
Brown with white patch	2 (3.5)	5 (3.7)	3 (5.1)	4 (3.1)	6 (10.2)	11 (7.6)	6.3	4.9		
White with red patch	1 (1.7)	9 (6.6)	3 (5.1)	7 (5.4)	2 (3.4)	3 (2.1)	3.4	4.6		
White with gray patch	1 (1.7)	4 (2.9)	0 (0)	2 (1.6)	3 (5.1)	8 (5.6)	2.3	3.4		
White with black patch	5 (8.8)	8 (5.9)	6 (10.2)	12 (9.3)	13 (22.0)	27 (18.7)	13.7	11.5		

dominant coat colour types were 16.0 percent white, 11.4 percent light red, 10.3 percent, brown, 20.6 percent black with white and 13.7 percent white with black.

The chi-square test showed that ruff, wattles, horn shape, coat colour pattern and back profile were highly significantly different ($P < 0.01$) across districts while horn

Table 2. Least square means (LSM) and standard error (±SE) of body weight (kg) and linear body measurements (cm) for effects of district and age of female goats.

Effects and level	N	BL	CG	HW	EL	PW	HoL	BW
Overall	442	56.97 ± 0.21	70.15 ± 0.27	60.08 ± 0.17	13.25 ± 0.08	12.93 ± 0.07	9.13 ± 0.16	26.36 ± 0.21
CV %	442	6.66	6.94	5.56	12.93	11.113	33.68	13.39
R2	442	26.36	30.50	18.00	4.06	9.83	18.60	36.93
District		**	*	**	**ns**	**ns**	*	**
Sheko	150	55.65 ± 0.36^{b}	68.47 ± 0.45^{ab}	58.56 ± 0.29^{b}	13.32 ± 0.17	12.81 ± 0.13	8.45 ± 0.29^{ab}	24.79 ± 0.34^{b}
Meanit Shasha	149	56.39 ± 0.36^{a}	68.98 ± 0.45^{a}	59.45 ± 0.28^{a}	13.05 ± 0.11	12.81 ± 0.12	7.71 ± 0.25^{b}	25.67 ± 0.41^{a}
Shei Bench	143	54.99 ± 0.35^{b}	67.44 ±0.45^{b}	59.89 ± 0.31^{a}	13.26 ± 0.14	12.49 ± 0.12	8.73 ± 0.29^{a}	23.95 ± 0.32^{b}
Age		**	**	**	**	**	**	**
1PPI	53	52.62 ± 0.36^{c}	63.197 ± 0.64^{d}	56.52 ± 0.53^{c}	12.91 ± 0.23^{b}	12.05 ± 0.23^{b}	6.87 ± 0.26^{b}	21.74 ± 0.36^{c}
2PPI	60	54.86 ± 0.42^{b}	67.167 ± 0.55^{c}	59.17 ± 0.49^{b}	12.97 ± 0.22^{b}	12.32 ± 0.18^{b}	6.72 ± 0.30^{b}	23.18 ± 0.31^{c}
3PPI	105	56.43 ± 0.31^{b}	70.367 ± 0.39^{b}	60.54 ± 0.34^{ab}	13.82 ± 0.20^{a}	13.33 ± 0.13^{a}	9.43 ± 0.31^{a}	25.69 ± 0.32^{b}
4PPI	224	58.79 ± 0.30^{a}	72.47 ± 0.36^{a}	60.96 ± 0.20^{a}	13.15 ± 0.10^{b}	13.12 ± 0.10^{a}	10.18 ± 0.23^{a}	28.59 ± 0.28^{a}

[a,b,c]means on the same column with different superscripts within the specified district and dentition group are significantly different ($P < 0.05$); ns = Non significant ($P > 0.05$); *$P < 0.05$; **$P < 0.01$; BL = Body Length; CG = Chest Girth; HW = Height at Wither; EL = Ear Length; PW = Pelvic Width; HoL = Horn Length; BW = Body weight; 1PPI = 1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3Pairs of Permanent Incisors; 4PPI = 4Pairs of Permanent Incisors.

orientation was also significant ($P < 0.05$) difference. There were no significant differences across districts in head profile and beards. On the other hand, sex showed highly significant ($P < 0.01$) differences in presence of beard, ruff and wattle, horn shape, hair length and back profile. Coat colour pattern variations were not significantly different between males and females.

Characterization of quantitative variation

Live body weight and linear measurements

Site effect: The least squares means and standard errors of body weight and other body measurements for female and male goats in the various districts and age groups are presented in Tables 2 and 3, respectively. In female goats, site had significantly larger ($P < 0.01$) influence on body length, height at wither and body weight while chest girth and horn length were found to be significantly ($P < 0.05$) influenced by site. No significant ($P > 0.05$) differences were observed across site for pelvic width and ear length.

In male goats, site had a significantly larger ($P < 0.01$) influence on chest girth and body weight while body length and pelvic width were found significantly ($P < 0.05$) influenced by site. Height at withers, ear length and horn length were not significantly ($P > 0.05$) influenced by site.

Age effect: Live body weight and the other body measurements were significantly ($P < 0.01$) affected by age group in female goats as indicated in Table 2. In female goats at dentition four (4 Pairs of permanent incisors), body length, chest girth and body weight had significantly higher ($P < 0.01$) values from the preceding age groups and this may imply body length, chest girth and body weight reached maximum at oldest age group. In contrast, the younger female goats (1 pairs of permanent incisors), body length, chest girth, pelvic width, horn length and

Table 3. Least square means (LSM) and standard error (±SE) of body weight (kg) and linear body measurements (cm) for effects of district and age of male goats.

Effects and level	N	BL	CG	HW	EL	PW	HoL	BW
Overall	189	60.81 ± 0.35	75.04 ± 0.50	64.47 ± 0.32	13.24 ± 0.09	14.67 ± 0.17	13.45 ± 0.28	31.02 ± 0.50
CV %	189	5.87	6.47	5.08	9.64	13.33	22.79	13.05
R^2	189	46.9	51.6	49.1	9.2	32.7	38.4	66.8
District		*	**	**ns**	**ns**	*	**ns**	**
Sheko	66	59.29 ± 0.67^{b}	72.57 ± 0.89^{b}	63.14 ± 0.63	13.22 ± 0.15	14.19 ± 0.25^{ab}	11.99 ± 0.39	28.13 ± 0.825^{b}
Meanit Shasha	61	60.48 ± 0.54^{a}	75.04 ± 0.63^{a}	63.42 ± 0.49	12.99 ± 0.18	14.56 ± 0.37^{a}	13.14 ± 0.60	30.25 ± 0.926^{a}
Shei Bench	62	58.69 ± 0.58^{b}	71.47 ± 0.97^{b}	62.79 ± 0.57	13.04 ± 0.17	13.58 ± 0.24^{b}	12.53 ± 0.43	27.29 ± 0.827^{b}
Age		**	**	**	**	**	**	**
1PPI	29	55.11 ± 0.54^{c}	66.36 ± 0.98^{d}	58.98 ± 0.58^{d}	12.44 ± 0.25^{b}	12.99 ± 0.24^{b}	9.51 ± 0.47^{b}	22.44 ± 0.38^{c}
2PPI	34	57.69 ± 0.66^{b}	71.32 ± 0.83^{c}	61.30 ± 0.78^{c}	12.99 ± 0.16^{ab}	12.89 ± 0.25^{b}	10.93 ± 0.55^{b}	24.84 ± 0.48^{c}
3PPI	31	61.80 ± 0.61^{a}	75.51 ± 0.87^{b}	65.09 ± 0.58^{b}	13.41 ± 0.22^{a}	14.78 ± 0.29^{a}	14.56 ± 0.58^{a}	31.08 ± 0.60^{b}
4PPI	95	63.37 ± 0.39^{a}	78.92 ± 0.53^{a}	67.09 ± 0.28^{a}	13.52 ± 0.14^{a}	15.78 ± 0.25^{a}	15.23 ± 0.32^{a}	35.87 ± 0.54^{a}

[a,b,c,d]means on the same column with different superscripts within the specified district and dentition group are significantly different ($P < 0.05$); ns = Non significant ($P > 0.05$); *$P < 0.05$; **$P < 0.01$; BL = Body Length; CG = Chest Girth; HW = Height at Wither; EL = Ear Length; PW = Pelvic Width; HoL = Horn Length; BW = Body weight; 1PPI = 1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3Pairs of Permanent Incisors; 4PPI = 4Pairs of Permanent Incisors.

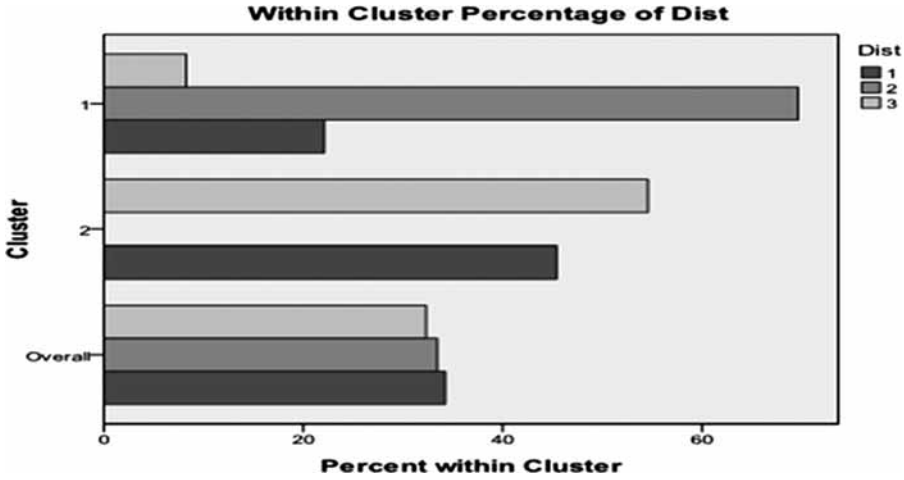

Figure 2. The weight (percentage) of each district in each cluster

body weight had significantly lower ($P < 0.01$) values than the elder age groups except pelvic width, horn length and body weight which were found to be the same with the values at 2 pairs of permanent incisors age groups. Moreover, pelvic width and horn length at 3pairs of permanent incisors had larger ($P < 0.01$) values than the youngest age groups (1 pairs of permanent incisors and 2 pairs of permanent incisors) but the values were also the same with the oldest age group (4 pairs of permanent incisors) implied that these measurements attain their maximum at 3 pairs of permanent incisors age group. On the contrary, height at withers had significantly lower ($P < 0.01$) values at 1 pairs of permanent incisors but the difference in values of this parameter were non-significant for 2 pairs of permanent incisors and 3 pairs of permanent incisors, and 3 pairs of permanent incisors and 4 pairs of permanent incisors age groups. Similarly, as age advanced, the influence on the difference in ear length between consecutive age groups was diminishing.

In males, live body weight and all other body measurements were significantly ($P < 0.01$) influenced by age as presented in Table 3. At dentition group four (4 pairs of permanent incisors), chest girth, height at withers and body weight had significantly higher ($P < 0.01$) values than in the preceding age groups. The nature of difference in the other variables as result age is similar to that of females.

Cluster analysis

Two-step clustering

The cluster distribution shows the number of cases in each cluster. Two clusters were found having 48 percent (303) and 52 percent (328) of goat population under cluster 1 and 2, respectively. The descriptive statistics for the three districts shows all goats at Meanit Shasha plus 31.0 and 12.3 percent goats at Sheko and Shey Bench were grouped at cluster 1 whereas 69.0 and 87.7 percent of goat at Sheko and Shey Bench at cluster 2. In Figure 2, the within cluster percentage plots showed the percentage of goats from each district, was distributed within each cluster.

Identified goat ecotypes

Besides the statistical output from the chi-square tests, the GLM and cluster analysis, focus group discussions were also employed to identify goat genetic resources distributed in the area. The goat population were characterized and classified in to two ecotypes named as Meanit and Sheko goat ecotypes. The identifying features of the ecotypes are discussed below.

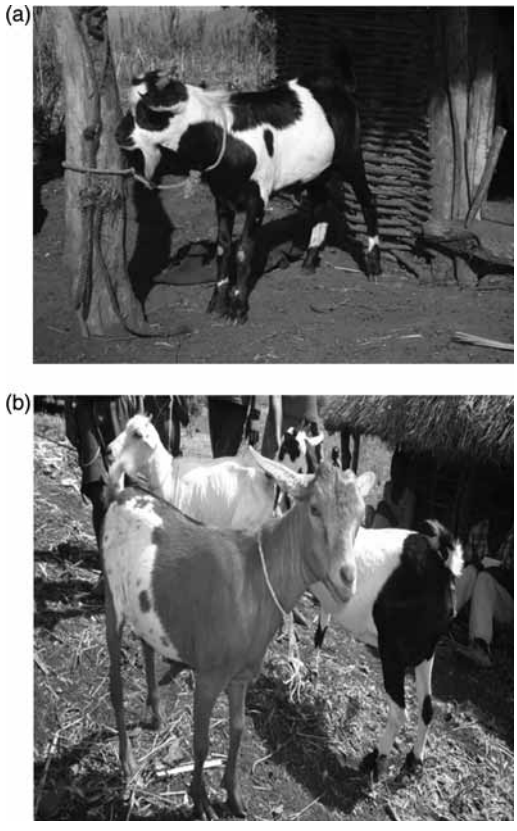

Figure 3. Meanit goat ecotype; Male(a) and Female(b)

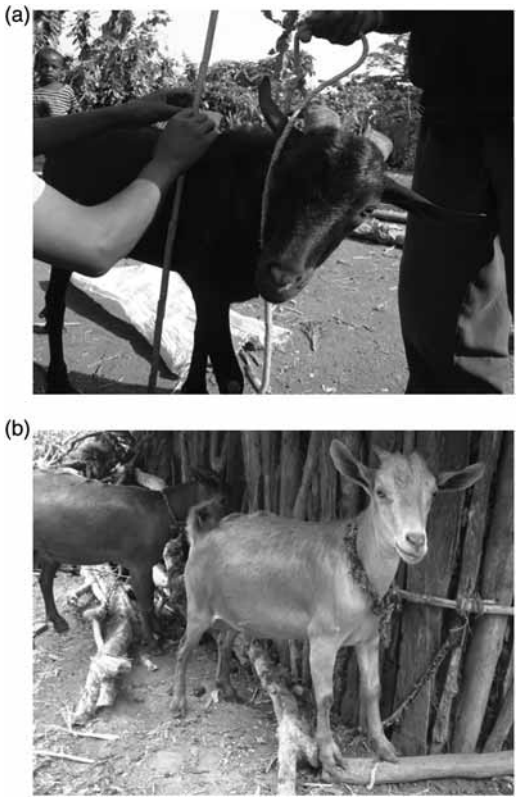

Figure 4. Sheko goat ecotype: Male(a) and Female(b)

Meanit goat ecotype

The Meanit goat derives its name from the ethnic group that maintains it. During focus group discussions no one was found to have any knowledge on the history and origin of the ecotype. Key identifying features of this ecotype are the coat colour patterns which are mainly patchy (60.7 percent of female and 68.8 percent of males). Black with white patches was observed in 27.8 percent of females and 30.5 percent of males while, white with black patches was observed in18.7 percent of females and 22 percent of males, In terms of size goats of Meanit ecotype have larger dimension than Sheko as shown by larger linear body measurements. Typical male and female goats from Meanit ecotype are presented in Figure 3a and 3b, respectively.

Sheko goat ecotype

Sheko goat ecotype derives its name from both the ethnic group and the geographic location. Key identifying features are the coat colour patterns which are mainly plain brown, white and red colours. This goat ecotype has smaller linear body measurements than Meanit. Typical male and female Sheko goat ecotypes are presented in Figure 4a and 4b, respectively.

Discussion

In the univariate analyses each variable was analysed separately, causing substantial overlapping of results and observations were not showing the variation between goat populations clearly. In multivariate statistical techniques, all variables were considered simultaneously in the differentiation of population. This approach resulted in a more powerful comparison of population that cannot be achieved with univariate analysis (Ogah, Momoh and Dim, 2011). Two clusters were obtained having the goat populations that were distributed more or less equally under each cluster. Thus, the goat population at Sheko and Shey Bench showed more similarities than the Meanit Shasha. As a result Sheko and Meanit ecotypes were identified. This result supports the chi-square and the GLM analyses. Moreover, the cluster analysis clearly showed the variation between the goat populations.

Sheko and Meanit goat ecotypes are closely related to each other. Moreover, the phenotypic characteristics of these ecotypes showed that they have close relationship with that of Keffa and Western Lowland goat types of Ethiopia (FARM Africa, 1996). This finding agreed with reports of Tucho (2004) and Hassen *et al.* (2012) who indicated that all the Ethiopian goat populations are very closely related to each other. Even though the ecotypes are closely related to each other, they have developed adaptive traits to their specific environments and should be used to their full potential to benefit goat production in their respective areas. In agreement to Hassen *et al.* (2012) report from the result of the current study also suggested that the close relatedness of the goat ecotypes, which might have happened due to the existence of uncontrolled animal breeding strategies resulting from uncontrolled movement of animals through various market routes, agricultural extension systems and geographic environment proximity.

Goat production serves different purposes mainly as a source of income and meat. However, in this study no respondent has reported use of the goats for milk. This is in agreement with the report of FARM Africa (1996) that goats were not milked in parts of Gojam, Wellega, Keffa and Wolayta. However, results from studies on short eared Somali goat (FARM Africa, 1996; Gebreyesus, 2010) showed that goats are milked in other parts of the country.

Higher twinning rate was obtained in this study (twinning rate of 60.6 percent of litter size of 1.6) from the goat ecotypes. However, the twinning rate computed for the goat populations in the current study are higher than rates reported by FARM Africa (1996) and Gebreyesus (2010). This result showed that these goat populations are relatively prolific. The Western Lowland, Western Highland, Keffa and Woyto-Guji goats have clearly been selected for prolificacy by societies for whom milk is not so important (FARM Africa, 1996). This result suggests that the higher preference for twinning by goat owners in this study area.

Even though different traits were considered in selecting breeding animals it appears high twinning ability with best kid growth, good mothering character and large

body size in females and large body size, good family history and fast growth in males were the most preferred traits (unpublished data). Therefore, goat breeding objectives of the community are to improve growth and increased number of kid crops of goat thereby improving meat production potential of the goats and increased income.

Conclusions

This study has identified and characterized goat genetic resources distributed in the study area. Goat populations at Meanit Shasha have shown differences, in some of their qualitative traits, with goats from the two other sites (Sheko and Shey Bench); whereas from Sheko and Shey Bench have comparatively more similarity in their qualitative traits. Therefore, the goats were categorized into two ecotypes, which are named as Meanit and Sheko goat ecotypes. Meanit goat ecotype was homogenous in their phenotypic characteristics and relatively larger than that of Sheko goat ecotype. In addition to that Meanit goat ecotype has larger proportion of patchy coat colour pattern than the Sheko ecotypes. Further work is required to quantify the productive performance of the ecotypes through monitoring. In addition to that advanced molecular characterization may need to be done to ascertain if there is sufficient difference at genotypic level and to help in identification of genes with potential for use as genetic markers. Large sexual dimorphism has been observed in both ecotypes, and that can be exploited to develop a smaller reproducing generation (female) and a relatively larger slaughter generation (male).

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Relationships between conformation traits and milk off-take of indigenous cattle breeds in north-western Ethiopia

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Summary
The phenotypic correlations between selected body conformation traits and milk off-take of three indigenous cattle breeds were evaluated against a backdrop of widespread traditional practice of identifying better milking cows and heifers using these traits. It was conducted in Fogera, Dembia and Wogera districts of northern-western Ethiopia. One-shot exploratory field visits were used to randomly identify sample cattle herds. Data were collected on eight quantitative and six qualitative body conformation traits as well as milk off-take from 126 sample cows. Pearson's correlation coefficients were determined between these traits and milk off-take for large, medium and small categories of navel flap-size categories. Results show that the average daily milk off-take varies significantly between categories of udder size, size of milk vein and neck length mainly not only in Fogera but also in Dembia and Wogera cows. Statistically significant phenotypic correlations exist between all the quantitative conformation traits and milk off-take in the three breeds but the type and strength of these associations are variable, indicating breed specificity of these associations. The significant correlations between width and length of navel flap with milk off-take are consistent with traditional knowledge of farmers of using navel flap size as an indicator of better milk production in these indigenous cows. The negative correlations of milk off-take with dewlap width in both Fogera and Wogera cattle, especially under the large navel flap category, are in agreement with the indigenous knowledge of these communities about these associations. It was therefore concluded that these traditional subjective practices can be improved by introducing convenient ways of objectively measuring these traits and using them in more conclusive and predictable ways.

Keywords: *conformation traits, milk off-take, phenotypic correlation, cattle, Ethiopia*

Résumé
Les corrélations phénotypiques entre des caractères de conformation corporelle sélectionnés et la production de lait de trois races bovines indigènes ont été évaluées dans un contexte où la pratique traditionnelle d'identification des meilleures vaches et génisses laitières selon ces caractères est de plus en plus généralisée. Cette évaluation a été menée dans les districts de Fogera, Dembiya et Wegera dans le Nord-ouest de l'Éthiopie. Des visites d'exploration sur le terrain ont été utilisées pour choisir au hasard les troupeaux échantillons de bovins. Les données de 14 caractères de conformation corporelle (huit caractères quantitatifs et six caractères qualitatifs) ont été prises chez 126 vaches des échantillons. Les coefficients de corrélation de Pearson ont été déterminés entre ces caractères et la production de lait pour les suivantes catégories de taille du pli ventral de peau: grand, moyen ou petit. Les résultats montrent que la production laitière moyenne journalière varie significativement entre les différentes catégories de taille du pis, de taille de la veine du lait et de la longueur du cou, principalement chez les vaches Fogera mais aussi chez le bétail Dembiya et Wegera. Des corrélations phénotypiques statistiquement significatives ont aussi été décelées entre tous les caractères quantitatifs de conformation et la production laitière pour les trois races, bien que le type et l'intensité des ces liaisons aient varié, ce qui indique qu'il existe des spécificités propres aux races quant à ces liaisons. Les corrélations significatives retrouvées entre la largeur et la longueur du pli ventral de peau et la production de lait sont en accord avec les connaissances traditionnelles des éleveurs qui utilisent la taille du pli ventral de peau comme indicateur d'une bonne production laitière chez les vaches indigènes. Les corrélations négatives entre la production de lait et la largeur du fanon, aussi bien pour le bétail Fogera que pour le bétail Wegera, particulièrement dans la catégorie de pli ventral grand, sont en accord avec les connaissances indigènes de ces communautés vis-à-vis de ces liaisons. Il a donc été conclu que ces pratiques traditionnelles subjectives peuvent être améliorées en introduisant des procédés appropriés à la mesure objective de ces caractères de façon à les rendre plus concluantes et prédictives.

Mots-clés: *caractères de conformation, production laitière, corrélation phénotypique, bovins, Éthiopie*

Resumen
Las correlaciones fenotípicas entre caracteres seleccionados de conformación corporal y la producción lechera de tres razas bovinas autóctonas fueron evaluadas en un contexto en el que se ha generalizado la práctica tradicional de identificar las mejores vacas y novillas lecheras en base a estos caracteres. Esta evaluación fue llevada a cabo en los distritos de Fogera, Dembiya y Wogera en el Noroeste

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de Etiopía. Se realizaron visitas exploratorias de campo para designar, al azar, unos rebaños como muestras. Se tomaron datos de 14 caracteres de conformación corporal (ocho caracteres cuantitativos y seis caracteres cualitativos), así como de producción de leche, de 126 vacas de las muestras. Se determinaron los coeficientes de correlación de Pearson entre estos caracteres y la producción de leche para las categorías grande, media y pequeña de tamaño del pliegue cutáneo colgante a la altura del ombligo. Los resultados muestran que la producción media diaria de leche varía significativamente entre categorías de tamaño de ubre, de tamaño de la vena de la leche y de longitud del cuello, principalmente en las vacas de Fogera pero también en las de Dembiya y Wogera. Asimismo, se han hallado correlaciones fenotípicas, estadísticamente significativas, entre todos los caracteres cuantitativos de conformación y la producción de leche en las tres razas, si bien el tipo y la fuerza de estas asociaciones varían, lo cual indica que existen especificidades de cada raza en estas asociaciones. Las correlaciones significativas halladas entre la anchura y la longitud del pliegue cutáneo colgante del ombligo con la producción de leche refrendan la práctica tradicional de los ganaderos que usan el tamaño del pliegue cutáneo del ombligo como indicador de buena producción de leche en estas vacas autóctonas. Las correlaciones negativas entre la producción lechera y la anchura de la papada, tanto en el ganado Fogera como en el Wogera, especialmente en la categoría de pliegue cutáneo del ombligo grande, concuerdan con los conocimientos locales de estas comunidades acerca de estas asociaciones. Se concluye, por tanto, que estas prácticas tradicionales subjetivas pueden ser mejoradas mediante la introducción de procedimientos adecuados a la medida objetiva de estos caracteres para así, usarlas de manera más concluyente y predictiva.

Palabras clave: *caracteres de conformación, producción de leche, correlación fenotípica, ganado bovino, Etiopía*

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Introduction

Observed phenotypic correlations between quantitative traits of dairy animals allow prediction of a future correlated response in a trait that is difficult to measure early enough in the productive life of the animals. Conformation traits can, therefore, be used as early predictors of key dairy production traits even in commercial breeds provided the predictions are adapted for the specific breeds (de Haas, Janss and Kadarmideen, 2007). These associations are also as relevant in traditional cattle farming systems of developing countries like Ethiopia, where farmers rely on visual appraisal as well as their recollection of milk production trends in trying to select replacement stock for breeding. However, phenotypic correlation *per se* does not reveal the nature and extent of genetic correlation between the traits, as phenotypic correlation is a function of both genetic and environmental causes of correlation such that neither the magnitude nor the direction of genetic correlation can be predicted from phenotypic correlation alone (Falconer, 1989). On the other hand, there are indications that when conformation traits with known medium to strong heritabilities have significant positive correlations with milk production traits, the observed correlations between body measurements and milk production traits can be used to predict milk yield both in cattle (Kadarmideen and Wegmann, 2003; Dechow *et al.*, 2004) and goats (Waheed and Khan, 2011).

If these associations can be verified in traditional cattle production systems, where systematic performance records do not exist, conformation traits that can be measured prelactation can provide a more objective way of selecting a replacement breeding stock. Recent studies showed that the traditional breeding practices of Ethiopian farmers, in which performance records are neither used nor collected, depend on visual appraisal of selected body conformation traits (Wuletaw, 2004; Wuletaw, Ayalew and Sölkner, 2006), such as teat size, navel flap width and length, dewlap width, and neck length. On that basis, Wuletaw (2004) argued that these conformation traits can effectively be employed as indirect indicators of milk production potential, and hence as criteria for identifying a desirable breeding stock. Objective assessment of these presumed relationships is the first step in developing useful tools to inform decision-making in the selection of breeding cows and bulls. Along this line, this study set out to investigate the phenotypic correlations between particularly selected conformation traits and milk off-take of indigenous cattle breeds under the traditional management system of north-western Ethiopia.

Materials and methods

Description of study area

The study was conducted in Fogera district of South Gondar zone, and Wogera and Dembia districts of North Gondar zone of the Amhara Regional State of north-western Ethiopia. These three districts (*Woreda*) were selected because of the known cattle breeds that are found in large population sizes. In addition, an earlier exploratory study (Wuletaw, 2004) reported that these cattle breeds have desirable milk producing attributes such as higher milk off-take and longer lactation length, and that the communities use body conformation traits to evaluate milk production potential of heifers and cows.

The natural breeding tract of the Fogera breed extends from 1 774 to 2 410 m above sea level, with mean annual rainfall and average temperature of 1 216 mm and 25.5 °C, respectively (IPMS, 2005). The capital of Dembia district,

Kola-Diba, is located 775 km north of Addis Ababa and 35 km from its zonal capital city of Gondar. The total area coverage of the district is 3 724 km^2, with an estimated human population of 291 000. The altitude ranges from 1 700 to 2 700 m above sea level. The average annual rainfall of this district is 930 mm. The temperature varies from 18 °C to 29 °C (DWAO, 2011).

The capital of Wogera district, Amba-Giworgis, is located 778 km north of Addis Ababa and 40 km from its zonal capital city of Gondar. The total area coverage of the district is 1 821 km^2. Its human population is 232 000. The altitude of the district ranges from 1 600 to 3 000 m above sea level. The average annual rainfall is 500 mm. The temperature varies from 10 °C to 28 °C (BSA, 2009).

Sampling procedure

This study was conducted on three dominant indigenous cattle breeds of the study area – the Fogera, Dembia and Wogera. Prior to the actual data collection work, a rapid (one-shot) exploratory field visit was carried out to gather general information regarding indigenous knowledge about how body conformation traits are used by cattle farmers as proxy indicators of milk production potential of heifers and cows. This was followed by a randomized data collection on a total of 225 cows with one to three parities. Data collected includes current milk off-take, stage of lactation and parity. The sample farmers were also asked whether or not they are willing to participate in the study. This dataset provided the basis for selecting at random a well-balanced set of 126 indigenous lactating cows from the study area for further data collection. These cows were registered and an identification number is given in preparation for repeated data collection on body conformation traits and milk off-take.

For the repeated data collection, the herd of experimental Fogera cows maintained at the Andassa Livestock Research Centre, near Bahir Dar, was employed, with the view to reducing possible confounding effect of the level of management on the relationship between the key variables. However, for the other two breeds, there were no experimental station herds anywhere in the study area or outside. Therefore, observations were made on-farm from the randomly selected farmers' cattle herds. The feeding systems were mostly grazing on natural pasture both for the station herds of Fogera cows and the on-farm herds of Dembia and Wogera cattle. No supplemental feed was provided to the sample cows. The housing systems were open barn.

Data collection

Collection of milk off-take data

Milk off-take data were collected from each registered and identified cow as per the following protocol:

- cows that calved only in May and June 2011 were included;
- milking and recording started one month after calving;
- calf suckling was also allowed for 20 s, mainly for the purpose of milk let down;
- to the extent possible milking continued until the udder was considered empty to ensure complete milking;
- volume of milk off-take from every milking session was measured by a given graduated cylinder and recorded in a given format; and
- milk off-take was recorded every 7 days on a specific test day for ten consecutive weeks.

Trained enumerators from the villages were used to milk and record data.

Measuring and observing conformation traits

The same cows selected for milk off-take recording were also used to collect data on body conformation traits. The quantitative conformation traits recorded were: navel flap width, navel length, teat length and width, body length, pelvic width, dewlap width, and height at wither, as described in detail by Wuletaw (2004). Visual observation was also made on some qualitative conformation traits of sample cows. These were udder size, teat tip shape, size of milk vein and neck size and shape. A standard data sheet was used to record data on all sample cows. In recognition of the relative high importance farmers attach especially to width of navel flap, as well as the broad within and between breed variations in this measured trait, sample cows were divided into three within breed categories as in Table 1.

Data analysis

Each of the quantitative traits was assessed using descriptive statistics prior to correlation analysis between milk off-take and measured conformation traits by using Pearson's square correlation. SPSS version 17.0 (SPSS, 2007) was employed to analyse the data.

Table 1. The number of sample cows by navel flap size category.

Cattle type		Navel flap width (cm)		
		Large	**Medium**	**Small**
Fogera	*N*	14.0	14.0	12.0
	Mean	14.4	11.0	7.8
	Min.	13.0	9.5	5.0
	Max.	18.0	13.0	9.0
Dembia	*N*	13.0	14.0	17.0
	Mean	10.6	6.9	4.0
	Min.	9.0	6.0	0.0
	Max.	14.0	8.0	5.0
Wogera	*N*	13.0	15.0	14.0
	Mean	7.9	4.4	1.2
	Min.	6.0	3.0	0.0
	Max.	10.0	5.0	2.5

Table 2. Least squares means (± SE) of daily milk off-take in litres by breed type and categories of conformation traits.

	Fogera		Dembia		Wogera	
	N	**LS (mean ± SE)**	***N***	**LS (mean ± SE)**	***N***	**LS (mean ± SE)**
Udder size		**		**		*
Small	10	$1.64^{a} \pm 0.22$	16	$0.65^{a} \pm 0.05$	11	$1.09^{a} \pm 0.2$
Medium	17	$1.73^{b} \pm 0.07$	20	$0.76^{b} \pm 0.04$	21	$0.97^{b} \pm 0.07$
Large	13	$1.84^{c} \pm 0.13$	8	$0.94^{c} \pm 0.09$	10	$0.95^{b} \pm 0.07$
Udder attachment		**		*		*
Pendulous	11	$1.47^{a} \pm 0.16$	11	$0.85^{a} \pm 0.08$	12	$1.11^{a} \pm 0.17$
Less pendulous	10	$1.78^{b} \pm 0.11$	15	$0.75^{b} \pm 0.06$	12	$0.91^{b} \pm 0.10$
Balanced	19	$1.87^{c} \pm 0.1$	18	$0.7^{b} \pm 0.04$	18	$0.99^{b} \pm 0.06$
Milk vein		**		Ns		**
Non-prominent	4	$1.4^{a} \pm 0.33$	10	$0.75^{a} \pm 0.06$	20	$0.95^{a} \pm 0.19$
Prominent	36	$1.78^{b} \pm 0.07$	34	$0.76^{a} \pm 0.04$	22	$1.13^{b} \pm 0.05$
Teat tip		*		Ns		Ns
Pointed	19	$1.79^{a} \pm 0.26$	19	$0.75^{a} \pm 0.046$	20	$0.95^{a} \pm 0.12$
Round	21	$1.7^{b} \pm 0.18$	25	$0.75^{a} \pm 0.052$	22	$0.99^{a} \pm 0.08$
Neck length		**		*		**
Short	17	$1.56^{a} \pm 0.12$	12	$0.67^{a} \pm 0.07$	18	$0.92^{a} \pm 0.08$
Long	23	$1.89^{b} \pm 0.08$	32	$0.79^{b} \pm 0.04$	24	$1.03^{b} \pm 0.07$
Neck size		**		*		Ns
Thin	23	$2.05^{a} \pm 0.11$	32	$0.78^{a} \pm 0.04$	22	$0.98^{a} \pm 0.07$
Thick	17	$1.6^{b} \pm 0.1$	12	$0.68^{b} \pm 0.06$	20	$0.97^{a} \pm 0.09$

**Significant at ($P < 0.01$), *significant at ($P < 0.05$), ns = non significant, N = number of cows. ^{a,b,c}LS means within each column not bearing a common superscript differ significantly at $P < 0.05$.

Results and discussion

Qualitative conformation traits and milk off-take

The mean of milk off-take was compared independently under each selected qualitative conformation traits and for each cattle type. The conformation traits considered were udder size, teat tip shape, size of milk vein, udder attachment, and neck size and shape.

Unlike the case for Wogera breed, the mean of milk off-take of Fogera cattle steadily increased from small to medium and large size of udder ($P < 0.01$) (Table 2). Cows that had pointed teat tips are good milk yielders than those with round teat tips ($P < 0.05$) (Table 2). Similarly milk off-take in Dembia cattle varied significantly with the size of udder ($P < 0.01$). For Dembia and Wogera cattle, the mean of milk off-take did not vary with whether the teat tip was pointed or round ($P > 0.05$) (Table 2).

Generally prominent milk veins appeared to be associated with higher average milk off-take in Fogera and Wogera cattle ($P < 0.01$), but this does not hold for Dembia cattle ($P > 0.05$) (Table 2). Longer neck indicated significantly higher milk off-take than short ones in all the three breeds but the association with the neck size was less distinct, although thicker neck tended to suggest less milk off-take.

Quantitative conformation traits and milk off-take

Phenotypic correlation between milk off-take and conformation traits of Fogera cattle

Navel flap width under the large category was highly and significantly correlated with milk off-take in Fogera ($r = 0.78$, $P < 0.01$) and Dembia cattle ($r = 0.695$; $P < 0.01$); a similar but less strong correlation was also observed in both breeds in the medium navel flap-size category (Tables 3 and 4). Similarly a significant correlation of navel flap length with milk off-take was observed but only in the large navel-size category. A significant but negative correlation of these variables was observed in the small navel flap category of Fogera cattle (Table 3). These indicate that larger sizes of navel flap width and length are associated with higher milk off-take, supporting the traditional practice of farmers using navel flap size as an indicator of better milk off-take in indigenous cows.

Dewlap width was significantly negatively correlated with milk off-take in both Fogera and Wogera cattle, especially under the large navel flap category (Tables 3 and 5). It was

Table 3. The phenotypic correlation (r) between milk off-take and some selected conformation traits of Fogera cattle breed.

Variables	**Average daily milk off-take (litre)**		
	Large navel flap size, $N = 14$	**Medium navel flap size, $N = 14$**	**Small navel flap size, $N = 12$**
Navel flap width	0.779**	0 0.662**	0.339
Navel flap length	0.538*	0.518	−0.580*
Dewlap width	−0.602*	−0.566*	−0.405
Teat length	0.240	−0.142	−0.665*
Teat width	−0.008	−0.106	−0.583
Pelvic width	0.544*	0.543*	0.327
Body length	0.562*	0.056	0.197
Wither height	0.662**	0.647*	−0.438

N, number of cows; r, Pearson's correlation.
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Table 4. The phenotypic correlation (r) between milk off-take and some selected conformation traits of Dembia cattle.

Variables	Average daily milk off-take (litre)		
	Large navel flap size, $N = 13$	Medium navel flap size, $N = 14$	Small navel flap size, $N = 17$
Navel flap width	0.695**	0.593*	0.369
Navel flap length	0.578*	0.266	0.168
Dewlap width	−0.483	−0.054	0.101
Teat length	0.038	0.521	0.595*
Teat width	0.658*	0.539*	0.619*
Pelvic width	0.567*	0.732**	0.545*
Body length	0.276	0.347	−0.124
Wither height	0.619*	0.477	0.243

N, number of cows; r, Pearson's correlation.
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

interesting to note that this negative association was also identified by farmers during formal interviews.

In Fogera cattle, the correlations between teat length and milk off-take were negative and significant especially within the small navel flap category. The other important conformation trait in Fogera and Dembia cattle was pelvic width which had strong and positive correlations with milk off-take in the large and medium navel flap categories (Tables 3 and 4). All focus group discussion sessions also identified a wide and slightly elevated pelvic width as a good indicator of milk yield.

Withers height and body length were also positively associated with high milk off-take in the large navel flap category in Fogera cattle (Table 3).

Phenotypic correlation between milk off-take and conformation traits of Dembia cattle

Milk off-take was positively correlated with navel width in Dembia cattle under large and medium navel flap categories ($r = 0.69$ and 0.59, $P < 0.01$ and 0.05, respectively) (Table 4). However, this correlation was weaker and non-significant in the small navel flap category of cows. Like in Fogera, the Dembia communities also believe that the navel flap size is a good indicator of high milking cows.

In Dembia, the correlations of dewlap size and teat length with milk off-take were not statistically significant ($P > 0.05$) (Table 4), but teat width showed strong positive and significant correlations with milk off-take across three categories of the navel-flap size. A similar strong association was also observed with pelvic width, which was consistent with the outcomes of the focus group discussions that showed pelvic width as a tool to identify especially desirable dry cows and heifers.

Wither height correlated significantly with milk off-take only under the large category of navel-flap size ($r = 0.62$, $P < 0.05$).

Phenotypic correlation between milk off-take and conformation traits of Wogera cattle

Generally the phenotypic correlation between navel width and milk off-take was positive in Wogera cattle, but the only significant correlation was in the large category ($r = 0.63$, $P < 0.05$) (Table 5). Navel length in the large and medium categories of navel-flap size showed high and significant correlations with milk off-take ($r = 0.82$ and 0.614, $P < 0.01$ and 0.05, respectively). Under the small category, the phenotypic correlations were small and non-significant.

The association of dewlap width with milk off-take was extremely variable but a strong ranging from a very negative to strong positive values ($r = -0.769$, -0.674 and 0.560, $P < 0.05$) (Table 5).

In the current study, body length was found to be strongly and significantly correlated with milk off-take under large and medium categories, but almost close to zero under the small category. Wither height maintained strong positive and significant association with milk off-take in all groups (Table 5).

Table 5. The phenotypic correlation (r) between milk off-take and some selected conformation traits of Wogera cattle.

Variables	Average daily milk off-take (litre)		
	Large navel flap size, $N = 11$	Medium navel flap size, $N = 12$	Small navel flap size, $N = 14$
Navel flap width	0.630*	0.525	0.279
Navel flap length	0.823**	0.614*	0.285
Dewlap width	−0.769**	−0.674*	0.560*
Teat length	−0.172	−0.102	0.673**
Teat width	−0.052	0.052	0.580*
Pelvic width	0.151	−0.723**	−0.286
Body length	0.666*	0.607*	0.077
Wither height	0.634*	0.607*	0.600*

N, number of cows; r, Pearson's correlation.
*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

Discussion

The findings of this study that showed strong positive correlation of milk off-take with udder size in both Fogera and Dembia cattle are consistent with those of Yakubu (2011) in Nigeria on Bunaji milking cows. However, Atkins, Shannon and Muir (2008) stated that a large udder does not always mean high milk yield, as was also observed in this study on Wogera cattle. Similarly Atkins, Shannon and Muir (2008) reported on a recent study in Canada that dairy cows which have strongly attached and well-balanced udder will support high and persistent production over the cows' lifetime. This is in contrast to the report by Van Dorp *et al.* (1998), which showed that in Holstein cows pendulous udder cows are more milk yielders than cows that have balanced udder, indicating possible breed differences in the type of associations observed.

Yakubu (2011) reported in Nigeria large but variable (r = 0.538 to 0.766) association of milk yield with some quantitative conformation traits in Bunaji cows, as was observed in the present study, indicating that these associations could be breed specific and variable. Kuczaj *et al.* (2000) reported a coefficient of correlation of 0.30 between the milk yield and height at withers in black-white cows. The current study obtained high and variable correlation values between milk off-take and wither height both for Fogera and Wogera cattle (r = 0.66–0.43). An earlier study by Rogers *et al.* (1991) also reported phenotypic correlations of 0.2 and 0.27 with the teat width and teat length, which is similar but weaker than those reported for Dembia cattle in the present study.

Conclusion

Statistically significant phenotypic correlations exist between some body conformation traits and milk off-take in Fogera, Dembia and Wogera but the type and strength of these associations are variable, indicating not only breed specificity of these associations but also the fact that phenotypic correlation is an interplay of genetic as well as an environmental covariance. The important conformation traits in this regard are udder and teat size, navel flap width, dewlap width, withers height, pelvic width and body length. The conventional wisdom of traditional cattle farming communities in using these traits to assess the milk production capacity of cows is therefore reasonable, even if the farmers do this by visual appraisal rather than objective measurements, although the underlying genetic relationships between the traits are more differentiated. The findings of this study indicate that these traditional subjective practices can be improved by scientifically verifying their validity for the specific breeds and introducing convenient ways of objectively measuring these traits and using this information as an additional tool in selecting desirable breeding animals.

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Caractérisation morphobiométrique de la poule locale en Centrafrique

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Résumé

Cette étude qui a pour principal objectif la caractérisation morpho-biométrique de la poule locale a été conduite de décembre 2010 à mars 2011 dans vingt villages de la Préfecture de la Lobaye en Centrafrique. Elle a porté sur 474 femelles et 183 mâles adultes. Les principaux résultats montrent que les caractéristiques morphologiques de la poule locale sont très hétérogènes. En effet, cinq principaux types d'emplumement ont été observés à savoir: l'emplumement normal (75.8%), le type huppé (10.4%), le cou nu (7.0%), le tarse emplumé (5.9%) et le type frisé (2.3%). La coloration de plumage est variée avec une prédominance des couleurs blanche (18.0%), sauvage (13.4%) et acajou (11.1%). La crête simple est plus fréquente (95.8%), de couleur généralement rouge (55.1%) ou rose (33.8%). Les oreillons sont rouges (24.7%), blancs (24.0%), blancs centrés (18.1%), jaunes (16.1%) ou roses (14.6%). Les barbillons sont surtout rouges (55.4%) ou roses (35.2%). Les tarses sont principalement jaunes (40.6%) ou blancs (37.9%). En ce qui concerne les caractéristiques biométriques, le poids moyen de la poule locale de la Lobaye est de 1176 ± 206 g chez les femelles et 1514 ± 296 g chez les mâles. Le poids vif et la plupart des mensurations corporelles varient en fonction du sexe et du type d'emplumement. Le poids vif ainsi que les mensurations corporelles sont significativement ($P < 0.01$) plus élevés chez les coqs. De même, les animaux à tarses emplumés sont plus lourds et d'un format plus élevé que les autres phénotypes.

Mots-clés: *caractérisation phénotypique, diversité, morphobiométrie, poule locale, République centrafrique*

Summary

The survey, which had for its main objective, the morphobiometrical characterization of the local chicken was carried out from December 2010 to March 2011 in 20 villages in Lobaye Division in the Central African Republic. It was carried out on 474 adult females and 183 adult males. The main results show that the morphological features are very heterogeneous. Indeed, five main types of feathering were observed: normal feathering (75.8%), crested type (10.4%), naked neck (7.0%), feathered tarsus (5.9%) and frizzle type (2.3%). The colouration of feathers is heterogeneous, with a predominance of the white (18.0%), wild (13.4%) and mahogany (11.1%) colours. The single comb is more frequent (95.8%), and is generally red (33.8%) or pink in colour (55.1%). Earlobes are red (24.7%), white (24.0%), white centred (18.1%), yellow (16.1%) or pink (14.6%). The wattles are mainly red (55.4%) or pink (35.2%). The tarsi are mainly yellow (40.6%) or white (37.9%). With regard to the biometric characteristics, the average weight of the local chicken of Lobaye is 1176 ± 206 g for females and 1514 ± 296 g for males. The live weight and most body measurements vary according to the sex and the feathering type. The live weight and the body measurements are significantly ($P < 0.01$) higher in the males. In the same way, the animals with feathered tarsi are heavier and bigger than the other phenotypes.

Keywords: *phenotypic characterization, diversity, morphobiometrical, local chicken, Central African Republic*

Resumen

Este estudio que tenía para principal objetivo la caracterización morfológica de la gallina local ha sido conducido de diciembre de 2010 a marzo de 2011 en veinte aldeas de la Prefectura del Lobaye en África Central. Ha llevado sobre 474 hembra y 183 machos adultos. Los principales resultados enseñan que las características morfológicas de la gallina local son muy heterogéneas. En efecto, cinco principals tipos de emplumement han sido observados o sea: el emplumement normal (75.8%), el tipo moñudo (10.4%), el cuello desnudo (7.0%), el tarso emplumado (5.9%), y el tipo rizado (2.3%). La coloración de plumaje es variada con un predominio de los colores blancos (18.0%), salvaje (13.4%), y acajú (11.1%). La cresta simple es más frecuente (95.8%), de color generalmente rojo (55.1%), o rosa (33.8%). Las paperas son rojas (24.7%), blancos (24.0%), blancos centrados (18.1%), amarillos (16.1%), o rosas (14.6%). Las barbillas son sobre todo rojas (55.4%), o rosas (35.2%). Los tarsos son principalmente amarillos (40.6%), o blancos (37.9%). En lo que concierne los característicos biométriques, el peso medio de la gallina local del Lobaye es de 1176 ± 206 g en las hembras y 1514 ± 296 g en los machos. El peso vivo y la mayoría de las medidas corporales varían con arreglo al sexo y del tipo de emplumement. El peso vivo lo mismo que las medidas corporales son significativamente,

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P < 0.01, más elevados en los gallos. Igualmente, los animales a tarsos emplumados son más pesados y de un formato más elevado que los otros tipos genéticos

Palabras clave: *caracterización fenotípica, divertira, morphobiométrie, gallina local, República Centroafricana*

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Introduction

La poule locale présente les qualités d'adaptation nécessaires à la réussite des projets d'élevage dans les conditions rurales surtout en Afrique. Par ailleurs, à cause de la priorité accordée à la race améliorée (Bessadok, Khochlf and El Gazzah, 2003), ces races locales sont aujourd'hui en grande partie menacées d'extinction et leur disparition continuelle, constitue un désastre pour le patrimoine génétique par la perte irrémédiable de caractères ignorés aujourd'hui et potentiellement utiles demain (Anonyme, 2003).

La connaissance de ces races locales en vue de leur préservation comme animaux de production représente donc un caractère crucial. C'est en ce sens que des nombreuses études ont caractérisé la poule locale au Cameroun (Keambou *et al.*, 2007; Fotsa *et al.*, 2010; Haoua, 2010), au Bénin (Youssao *et al.*, 2010) en Ethiopie (Nigussie *et al.*, 2010), au Sénégal (Missohou, Sow and Ngwe-Assoumou, 1998), au Congo Brazzaville (Akouango, Mouangou and Ganongo, 2004), en Tunisie (Bessadok, Khochlf and El Gazzah, 2003). Cependant aucune littérature n'a parlé de la caractérisation de la poule locale en Centrafrique, d'où la nécessité de cette étude.

Cette étude vise principalement à contribuer à une meilleure conaissance de la poule locale en vue de sa meilleure valorisation dans la Préfecture de la Lobaye en Centrafrique. De manière spécifique, il s'agit:

– D'évaluer les caractères morphologiques de la poule locale de la Lobaye;
– D'évaluer les caractéristiques biométriques de la poule locale de la Lobaye.

Méthodologie

Milieu d'étude

Ces travaux ont été conduits dans la Préfecture de la Lobaye au sud de la Centrafrique. La Lobaye est limitée au nord par la Préfecture de la Sangha-Mbaéré, au sud par le Congo, à l'est par le Congo Démocratique et à l'ouest par la Préfecture de l'Ombella-M'poko. Elle est située à 580 m d'altitude. C'est une zone qui se caractérise par un climat de type équatorial, avec une saison pluvieuse allant d'avril à novembre et une saison sèche de décembre à mars. Les précipitations sont réparties sur 8 mois avec 1200 à 1600 mm de pluie par an. La température varie de 23,8 à 26, 2 °C et l'humidité relative oscille entre 50 et 80% respectivement pour les mois les plus secs et les mois les plus humides. La végétation rencontrée est une forêt modifiée à certains endroits, une savane arbustive et des forêts claires par endroit. La caféiculture est la principale culture de rente, elle est suivie de la culture de palmier à huile. La culture vivrière est dominée dans l'ordre décroissant par le manioc, l'arachide, le maïs et le sésame. La cueillette quant à elle est beaucoup plus pratiquée par les Baka (Pygmées). Le petit élevage est dominant surtout celui de la volaille. La zone d'étude est présentée sur la Figure 1.

Echantillonnage des animaux

Cette étude a été conduite entre décembre 2010 et mars 2011 dans les ménages choisis dans vingt villages dans trois sous-Préfectures de la Lobaye (sous-Préfectures de Mbaïki (chef lieu de la Lobaye), sous-Préfecture de Boda et sous-Préfecture de Mongoumba). Les critères de choix ont principalement porté sur l'ancienneté du ménage dans les activités de l'élevage de la poule locale, de l'accessibilité de la zone, l'absence des élevages de la poule exotique et de la disponibilité de l'éleveur. La caractérisation de la poule avait porté sur un total de 474 femelles et 183 mâles en reproduction. Seuls les sujets produits dans les zones retenues sont étudiés.

Données collectées

Caractéristiques visuelles

Ces caractéristiques en fonction du sexe, ont porté sur la couleur de plume, la structure et la répartition de plume sur le corps, la forme et la couleur de la crête, les couleurs des barbillons et des oreillons, la couleur et la forme du bec, les couleurs de la face, des pattes et de la peau. Toutes ces données ont été collectées par les observations visuelles.

Données biométriques et pondérales

Le poids vif a été obtenu grâce à l'utilisation d'une balance électronique de portée 3000 g avec une sensibilité de 1 g. Pour les mensurations corporelles, un pied à coulisse électronique de précision 1 mm et de portée 150 mm a été utilisé. Ce matériel a servi pour les mesures des petites dimensions telles que la hauteur et la longueur de la crête, les longueurs du bec et du barbillon, la longueur et le diamètre du tarse. Le nombre de crétillons et le nombre de doigts ont été comptés. Les mensurations corporelles de la longueur du corps, de la longueur de l'aile et du périmètre thoracique ont été obtenues à l'aide d'un mètre ruban.

Ces données morpho-biométriques ont été ensuite enregistrées sur une fiche adaptée proposée par FAO

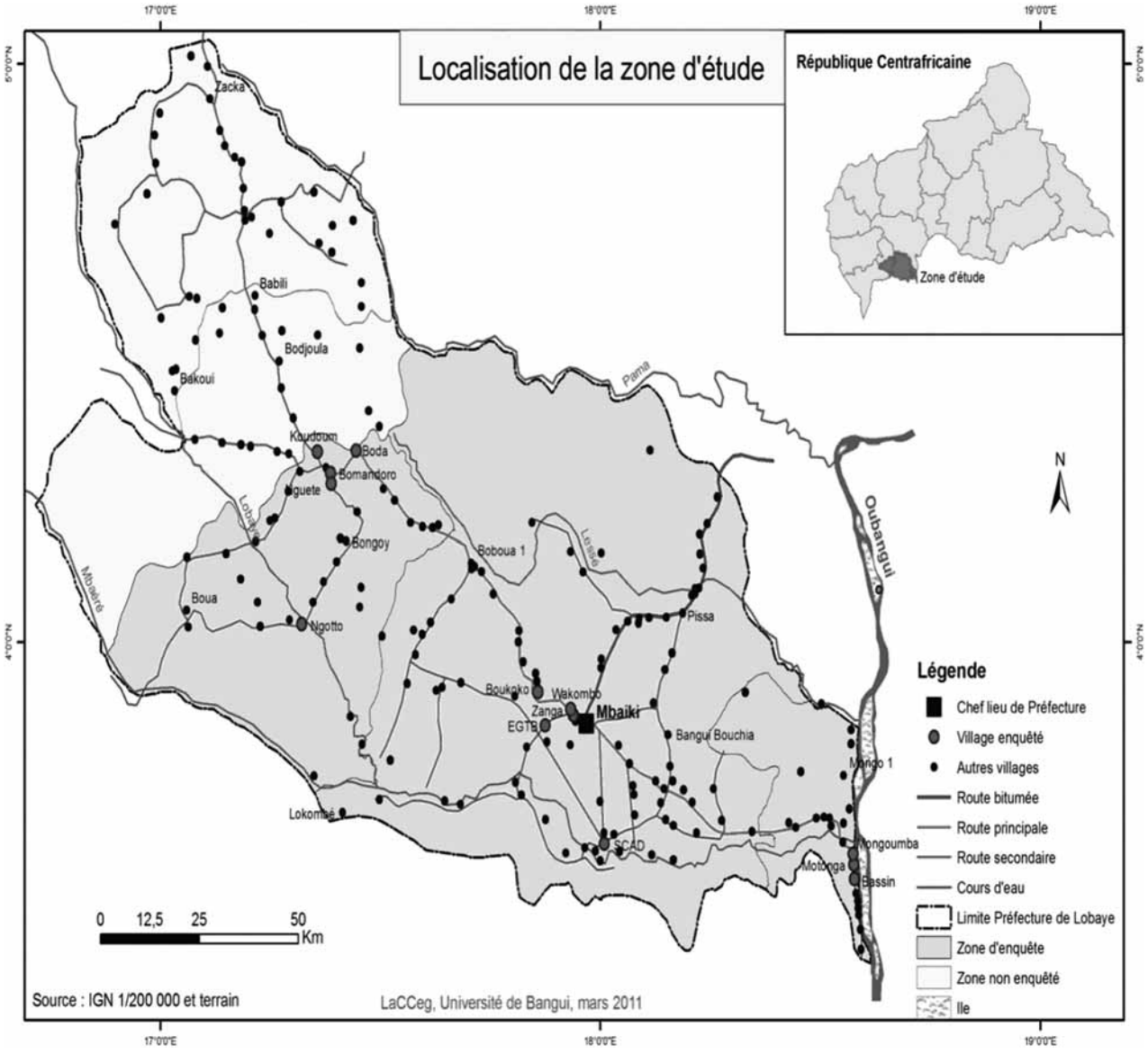

Figure 1. Localisation de la Préfecture de la Lobaye en Centrafrique.

(1987) pour la caractérisation des ressources génétiques avicoles locales.

Analyse statistique

La statistique descriptive a été utilisée pour tester la dispersion des données qualitatives. Les données quantitatives ont été soumises à l'analyse des variances (ANOVA). Le test de Duncan a permis de séparer les moyennes chaque fois que l'ANOVA a révélé des différences significatives. Le logiciel SPSS version 19.0 a servi pour toutes les analyses statistiques effectuées.

Le modèle statistique utilisé dans l'ANOVA est le suivant:

$$Y_{ijk} = \mu + S_i + P_j + (S \times P)_{ij} + e_{ijk}$$

Où : Y_{ijk} est la valeur observée sur le $K^{ème}$ individu dans le $i^{ème}$ sexe et le $j^{ème}$ phénotype;

μ est la moyenne générale de la performance;

S_i est l'effet fixe du sexe, i variant de 1 à 2;

P_j est l'effet fixe du phénotype (normal, huppé, cou nu, tarse emplumé et frisé), j variant de 1 à 5;

$(S \times P)_{ij}$ est l'interaction entre le sexe et le phénotype

e_{ijk} est l'erreur résiduelle sur le $K^{ème}$ individu de $i^{ème}$ sexe et $J^{ème}$ phénotype.

Résultats

Caractéristiques morphologiques de la poule locale

Répartition du type de plumage et d'emplumement des poules locales en fonction du sexe

La structure et la distribution des plumes sur le corps de la poule locale de la Lobaye sont présentées dans le Tableau 1.

Tableau 1. Répartition du plumage et du type d'emplumement des poules locales en fonction du sexe.

Caractéristiques	Mâles		Femelles		Total	
	n	(%)	*n*	(%)	*n*	(%)
Type de plumage						
Frisé	6	3.3	9	1.9	15	2.3
Lisse	7	3.8	456	96.2	463	70.5
Soyeux	170	92.9	9	1.9	179	27.2
Total	183	100.0	474	100.0	657	100.0
Type d'emplumement						
Tarses emplumé	10	5.5	29	6.1	39	5.9
Tarses emplumé et huppé	0	0.0	2	0.4	2	0.3
Huppé	18	9.8	50	10.5	68	10.4
Huppé et cou nu	0	0.0	4	0.8	4	0.6
Normal	139	76.0	359	75.7	498	75.8
Cou nu	16	8.7	30	6.3	46	7.0
Total	183	100.0	474	100.0	657	100.0

n = effectif, % = pourcent.

Trois structures du plumage sont observées (Tableau 1) avec une prédominance de plumage lisse (70.5%) plus dominant chez les femelles (96.2%). Le plumage frisé est le moins fréquent avec 2.3% de la population. Quant à la répartition de plume sur le corps, sept types d'emplumement sont identifiés. Les principaux emplumements observés sont l'emplumement normal (75.8%), la tête huppée (10.4%), le cou nu (7.0%) et le tarse emplumé (5.9%). 0.15% de la population a les rachis nus. Les photos 1, 2, 3, 4, 5, 6 illustrent les types du plumage et d'emplumement.

Planche 1. Types du plumage et d'emplumement de la poule locale. **Photo 1**: Poule locale huppée. **Photo 2**: Poule locale cou nu. **Photo 3**: Poule locale frisée. **Photo 4**: Poule locale rachi nu. **Photo 5**: Emplumement normal. **Photo 6**: Tarse emplumé. *Source*: Célestine Bembide.

Répartition des couleurs du plumage de la poule locale en fonction du sexe

Le Tableau 2 présente les différentes colorations du plumage de poule locale.

Ainsi que le montre le Tableau 2, la coloration du plumage dans notre échantillon est très variée. Le plumage est en général de couleur blanche (18.0%), suivie de la coloration sauvage (13.4%) et acajou. (11.1%). Le plumage bleu est le moins fréquent (2.0%). La couleur perdrix qui représente 2, 9% de la population n'est observée que chez les femelles alors que le rouge ne s'observe que chez les mâles (2.3%). Les principales couleurs du plumage identifiées dans cette étude sont illustrées par les photos 7, 8, 9, 10, 11, 12.

Répartition des couleurs et types de crête de la poule locale en fonction du sexe

La distribution des formes et celle des couleurs de crête de la poule locale sont présentées dans le Tableau 3.

Quatre types et quatre colorations de crête sont observés (Tableau 3). La proportion des poules avec la crête simple est la plus élevée (95.8%). La plus faible fréquence est observée pour la crête triple avec 0.3% de l'échantillon. La couleur de la crête la plus fréquente est le rouge (55.1%). La couleur rouge de la crête est la plus fréquente chez les mâles (90.2%) que chez les femelles (41.6%) tandis que le cas inverse est observé pour la couleur rose de la crête. Les couleurs pigmentée et noire sont également observées mais avec des faibles proportions

Tableau 2. Répartition des couleurs du plumage de la poule locale en fonction du sexe.

Couleur du plumage	Mâles		Femelles		Total	
	n	(%)	*n*	%	*n*	%
Acajou	18	9.8	55	11.6	73	11.1
Blanc	30	16.4	88	18.6	118	18.0
Blanc-noir	19	10.4	13	2.7	32	4.9
Bleu	1	0.5	12	2.5	13	2.0
Brun	15	8.2	39	8.2	54	8.2
Caillouté	9	4.9	20	4.2	29	4.4
Coucou	7	3.8	25	5.3	32	4.9
Doré	22	12.0	8	1.7	30	4.6
Gris	2	1.1	13	2.7	15	2.3
Herminé	6	3.3	19	4.0	25	3.8
Milfleur	16	8.7	22	4.6	38	5.8
Noir	13	7.1	31	6.5	44	6.7
Perdrix	0	0.0	19	4.0	19	2.9
Rouge	15	8.2	0	0.0	15	2.3
Sauvage	9	4.9	79	16.7	88	13.4
Vert	1	0.5	31	6.5	32	4.9
Total	183	100.0	474	100.0	657	100.0

n = effectif, % = pourcent.

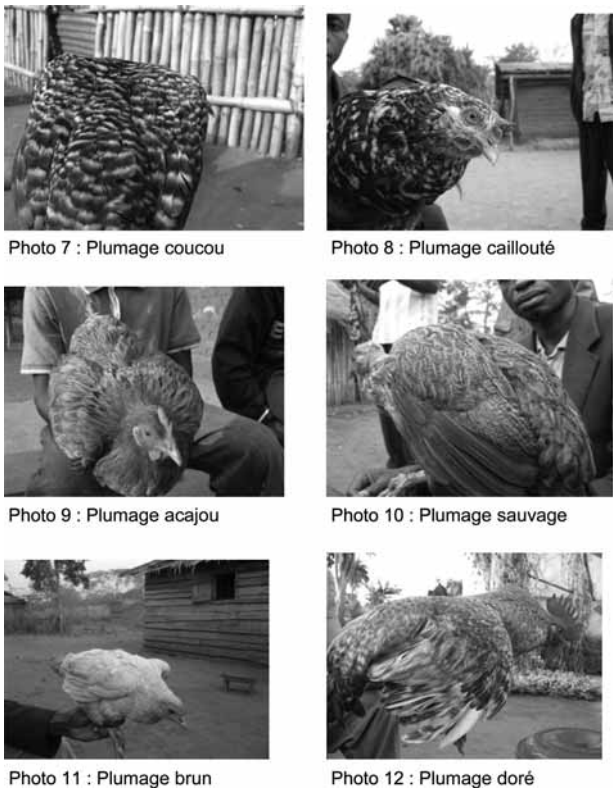

Planche 2. Diversité de couleur du plumage de la poule locale. **Photo 7**: Plumage coucou. **Photo 8**: Plumage caillouté. **Photo 9**: Plumage acajou. **Photo 10**: Plumage sauvage. **Photo 11**: Plumage brun. **Photo 12**: Plumage doré. *Source*: auteur.

(10.7% et 0.5% respectivement) et ne s'observent généralement que chez les femelles. Les types de crête identifiés sont présentés sur les photos 13, 14, 15, 16.

Répartition des caractéristiques des Barbillons et oreillons de la poule locale en fonction du sexe

Les caractéristiques des barbillons et des oreillons de la poule locale de la Lobaye sont mentionnées dans le Tableau 4.

Tableau 3. Répartition des couleurs et types de crête en fonction du sexe.

Caractéristiques	Mâles		Femelles		Total	
	n	(%)	*n*	(%)	*n*	(%)
Type crête						
Noix	1	0.5	4	0.8	5	0.8
Rose	7	3.8	14	3.0	21	3.2
Simple	175	95.6	454	95.8	629	95.8
Triple	0	0.0	2	0.4	2	0.2
Total	183	100.0	474	100.0	657	100.0
Couleur crête						
Noir	0	0.0	3	0.6	3	0.5
Pigmenté	6	3.3	64	13.5	70	10.6
Rose	12	6.6	210	44.3	222	33.8
Rouge	165	90.2	197	41.6	362	55.1
Total	183	100.0	474	100.0	657	100.0

n = effectif, % = pourcent.

Planche 3. Diversité de forme de crête de la poule locale. **Photo 13:** Crête simple. **Photo 14:** Crête en rose. **Photo 15:** Crête en noix. **Photo 16:** Crête triple. *Source*: auteur

Trois couleurs de barbillon sont identifiées dans la population de la poule locale de la Lobaye (Tableau 4). Les barbillons de couleur rouge sont les plus représentés (55.4%), suivis des roses (35.2%) et enfin de couleur pigmentée (9.4%). D'une manière générale, les mâles sont plus représentés par les barbillons rouges (89.1%) alors que les femelles ont des barbillons surtout roses (46.6%) mais aussi rouges (42.4%). Les barbillons pigmentés (couleur la moins fréquente) représentant 9.4% de l'échantillon total est abondant chez les femelles que chez les mâles.

Les oreillons sont surtout de couleur rouge (24.7%) ou blanche (24.0%), L'apparition des oreillons jaune-centrés et pigmentés étant plus faibles (1.8% et 0.7%

Tableau 4. Répartition des caractéristiques des barbillons et des oreillons de la poule locale en fonction du sexe.

Caractéristiques	Mâles		Femelles		Total	
	n	(%)	*n*	(%)	*n*	(%)
Couleur Barbillon						
Pigmenté	10	5.5	52	11.0	62	9.4
Rose	10	5.5	221	46.6	231	35.2
Rouge	163	89.1	201	42.4	364	55.4
Total	183	100.0	474	100.0	657	100.0
Couleur oreillons						
Blanc	21	11.5	136	28.6	157	24.0
Blanc centré	28	15.3	91	19.2	119	18.1
Jaune	10	5.5	96	20.3	106	16.1
Jaune centré	3	1.6	9	1.9	12	1.8
pigmenté	0	0.0	5	1.1	5	0.7
Rose	7	3.8	89	18.8	96	14.6
Rouge	114	62.3	48	10.1	162	24.7
Total	183	100.0	474	100.0	657	100.0
Forme oreillon						
Ovale	160	87.4	334	70.5	494	75.3
Rond	23	12.6	140	29.5	163	24.7
Total	183	100.0	474	100.0	657	100.0

n = effectif, % pourcent.

respectivement). Toutefois, la couleur rouge des oreillons est plus dominante chez les mâles (62.3%) tandis que les oreillons blancs sont plus observés chez les femelles (28.6%). Par ailleurs, les oreillons sont principalement de forme ovale (75.3%) contre la forme ronde (2.7%).

Répartition des couleurs de la face, de la peau et des pattes de la poule locale en fonction du sexe

Le Tableau 5 résume la coloration de la face, de la peau et des pattes de la poule locale.

Quatre couleurs de la face sont identifiées dans la population de la poule locale de la Lobaye (Tableau 5). La face rouge étant plus fréquente dans la population totale (52.4%) et beaucoup plus chez les mâles (86.3%). Quant à la peau de la poule locale, la couleur blanche est la plus fréquente (49.5%) suivie de peau jaune (28.8%) ou rose (21.8%). Pour les pattes, les couleurs jaune (40.6%) et blanche (37.9%) prédominent.

Répartition des formes et couleurs du bec de la poule locale en fonction du sexe

Le Tableau 6 présente les caractéristiques du bec de la poule locale de la Lobaye en Centrafrique.

De l'analyse du Tableau 6, il ressort que deux formes du bec peuvent être identifiées chez la poule locale de la Lobaye (le bec courbe (56.9%) et le bec droit (43.1%)). Le bec courbe est plus observé chez le mâle (76.5%) que chez les femelles (49.4%). Par ailleurs, plusieurs couleurs de bec sont également observées avec une dominance des couleurs jaune (34.6%) et noire (32.6%).

Tableau 5. Répartition des couleurs de la face, de la peau et des pattes de la poule locale en fonction du sexe.

Caractéristiques	Mâles		Femelles		Total	
	n	(%)	*N*	(%)	*n*	(%)
Couleur face						
Jaune	2	1.1	11	2.,3	13	2.0
Pigmenté	10	5.5	100	21.1	110	16.7
Rose	13	7.1	177	37.3	190	28.9
Rouge	158	86.3	186	39.2	344	52.4
Total	197	100	474	100	657	100
Couleur peau						
Blanc	102	55.7	223	47.0	325	49.5
Jaune	46	25.1	143	30.2	189	28.8
Rose	35	19.1	108	22.8	143	21.7
Total	183	100.0	474	100.0	657	100.0
Couleur pattes						
Blanc	78	42.6	171	36.1	249	37.9
Bleu	1	0.5	13	2.7	14	2.1
Jaune	88	48.1	179	37.8	267	40.6
Noir	8	4.4	66	13.9	74	11.3
Vert	8	4.4	45	9.5	53	8.1
Total	183	100.0	474	100.0	657	100.0

n = effectif, % = pourcent.

Tableau 6. Répartition des caractéristiques du bec de la poule locale en fonction du sexe.

Caractéristiques	Mâles		Femelles		Total	
	n	(%)	*n*	(%)	*n*	(%)
Couleur bec						
Blanc	35	19.1	58	12.2	93	14.2
Corne	9	4.9	67	14.1	76	11.6
Jaune	58	31.7	169	35.7	227	34.6
Jaune noir	25	13.7	17	3.6	42	6.4
Noir	54	29.5	160	33.8	214	32.6
Pigmenté	2	1.1	3	0.6	5	0.6
Total	183	100.0	474	100.0	657	100.0
Forme bec						
Courbe	140	76.5	234	49.4	374	56.9
Droit	43	23.5	240	50.6	283	43.1
Total	183	100.0	474	100.0	657	100.0

n = effectif, % = pourcent.

Caractéristiques biométriques de la poule locale

Pour les caractéristiques biométriques, 5 phénotypes sont retenus à savoir, les phénotypes normal, huppé, cou nu, tarse emplumé et frisé.

Poids vif et mensurations corporelles de la poule locale

Analyse des variances (ANOVA) du poids vif et des mensurations corporelles de la poule locale en fonction du phénotype et du sexe.

Les résultats de l'analyse des variances du poids vif et des mensurations corporelles de la poule locale de la Lobaye sont mentionnés dans le Tableau 7.

A l'exception de la longueur du tarse et du pourtour thoracique (Tableau 7), le phénotype affecte très significativement ($P < 0.01$) le poids vif et les autres mensurations corporelles. Par ailleurs, le poids vif et presque toutes les mensurations corporelles sont statistiquement influencés par le sexe au seuil de 1%.

Comparaison des poids vifs et des mensurations corporelles en fonction du sexe et du phénotype de la poule locale

Les valeurs moyennes du poids vif et des mensurations corporelles de la poule locale en fonction du sexe et du phénotype sont présentées dans le Tableau 8.

Le poids moyen de la poule locale de la Lobaye (les deux sexes confondus) est de 1270 g avec un écart-type de 279 g (Tableau 8). En général, les mâles sont supérieurs aux femelles pour toutes les mensurations étudiées. En fonction du phénotype, la poule locale à tarse emplumé est le plus lourd (1546 ± 321 g) ($P < 0.01$) alors que le type huppé est le plus léger (1067 ± 172 g) du groupe. Le frisé et le cou nu ont des poids plus élevés que la poule à emplumement normal. Cependant, ces différences ne sont pas significatives ($P > 0.05$). Le frisé et le cou nu sont plus lourds que le type huppé et inférieurs au tarse

Tableau 7. ANOVA du poids vif et des mensurations corporelles de la poule locale.

Sources de variation	Degré de liberté	Poids vif	Longueur Corps	Longueur aile	Pourtour thoracique	Dvpt. Pilon	Longueur tarse	Diamètre tarse
P	4	23.1**	6.399**	5.1**	3.2*	16.4**	0.8 ns	4.1**
S	1	97.3**	104.1**	58.6**	83.7**	170.1**	396.1**	16.1**
PXS	4	3.9**	5.3**	2.5*	2.5*	4.7**	1.8 ns	1.3 ns
Erreur	578							
CV		21.9	8.2	7.7	8.58	15.8	12.3	35.9

Dvpt. Pilon = Développement du pilon, P = phénotype, S = sexe, P × S = interaction phénotype – sexe, CV = coefficient de variation, ns = différence non significative, * = $P < 0.05$, ** = $P < 0.01$.

emplumé. Le phénotype tarse emplumé est caractérisé par des mensurations plus élevées pour la longueur du corps, le développement du pilon et le diamètre du tarse. Cependant, le frisé a la plus forte valeur pour la longueur de l'aile.

Mensurations des appendices de la poule locale

Analyse des variances des mensurations des appendices de la poule locale

Les résultats d'analyse des variances des mensurations des appendices de la poule locale de la Lobaye sont résumés dans le Tableau 9.

Deux mesures des appendices sont influencées par le phénotype (longueur du bec et hauteur de crête) (Tableau 9). Le sexe n'influence pas le nombre de doigts mais il affecte significativement ($P < 0.05$) la longueur de l'ergot. Les longueurs du barbillon et du bec, le nombre de crétillons, la hauteur et la longueur de la crête sont influencés par le sexe au seuil de 1%. Le dimorphisme sexuel est en faveur du mâle. L'interaction G × S n'affecte que la hauteur de la crête ($P < 0.01$) et la longueur de l'ergot ($P < 0.05$).

Comparaison des mensurations des appendices de la poule locale en fonction du sexe et du phénotype

Les valeurs moyennes des appendices de la poule locale sont présentées dans le Tableau 10.

Pour les mensurations des appendices (Tableau 10), le dimorphisme sexuel est à l'avantage des mâles sauf pour le nombre de doigts. En effet, le nombre de doigts est en moyenne 4, toutefois, 0.3% de la population est polydactyle avec 5 doigts. Le type huppé a la plus courte hauteur de crête. Le bec du tarse emplumé est significativement plus long que celui du type huppé au seuil de 1%.

Discussion

La poule locale de la Lobaye en Centrafrique se caractérise par un plumage et un emplumement normal bien que d'autres types du plumage et d'emplumement existent avec des taux faibles (huppé, cou nu, tarses emplumés et frisé). La fréquence des cous nus identifiés dans cette étude est supérieure à la proportion de 6% observée au Nigéria (Guèye, 1998), 3.6% au Botswana (Badubi, Rakereng and Marumo, 2006), 4.3% au nord du Cameroun (Haoua, 2010) et 2% en Ethiopie (Nigussie *et al.*, 2010). Ces résultats sont en accord avec ceux de Fayeye et *al.* (2006), Keambou *et al.* (2007), Fotsa *et al.* (2010), Nigussie *et al.* (2010) qui ont également rapporté des faibles fréquences des mutants à allèles dominants dans la population des poules locales. Par ailleurs, le caractère rachis nus que nous avons observé n'a pas été décrit par les auteurs cités ci-dessus et bien d'autres auteurs (Missohou, Sow and Ngwe-Assoumou, 1998; Bessadok, Khochlf and El Gazzah, 2003; Akouango Mouangou and Ganongo, 2004).

Ces faibles proportions des mutants peuvent s'expliquer par le fait que certains éleveurs de la poule locale ne préfèrent pas des poules portant des caractères mutants (Fayeye *et al.*, 2006; Aklilu, 2007). En effet, nos investigations auprès des éleveurs enquêtés ont révélé que certains éleveurs considèrent les caractères mutants comme des fétiches et les éliminent de leurs troupeaux. Ces observations rejoignent celles de Sonaiya et Olori (1990) selon lesquelles les éleveurs trouvent que les cous nus et frisées sont vilains, et par conséquent, ne sont élevés que par des personnes âgées pour des buts occultes. Par contre, Fayeye *et al.* (2006) ont mentionné que ces animaux portant ces gènes jouent des rôles importants sur le plan culturel. D'autre part, l'allèle dominant tel que celui qui détermine le caractère frisé est létal à l'état homozygote comme l'ont souligné Haaren-kiso, Horst and Zarate (1995). Toutes ces observations convergent vers celles de Ikeobi *et al.* (2000) qui stipulent que la faible fréquence des ptylopodes est due aux effets de préférence sociale, de sélection naturelle et à la capacité d'adaptation de ceux-ci à leur milieu d'élevage.

La coloration des plumes de la poule locale dans la Lobaye est très variée avec une prédominance de plumes blanches. Cette forte proportion peut s'expliquer par la sélection pratiquée par les éleveurs selon leurs préférences. En effet, l'exploitation minière dans la zone d'étude nécessite les poules avec le plumage blanc pour des sacrifices aux esprits. Ce qui conduit les éleveurs à préférer cette coloration de plume pour satisfaire ce marché. Les résultats de Nigussie *et al.* (2010) confirment les nôtre. Selon ces derniers, le fait que les éleveurs considèrent la couleur de plumage comme l'un des critères de sélection dans l'élevage traditionnel a un impact

Tableau 8. Comparaison des poids vifs et des mensurations corporelles de la poule locale en fonction du sexe et du phenotype.

Caractéristiques	Sexe	Phénotypes					Moyenne générale
		Normal	Emplumé	Huppé	Frisé	Cou nu	
Poids vif	F	1168 ± 194	1416 ± 232	1023 ± 148	1231 ± 156	1263 ± 178	1176 ± 206
	M	1524 ± 273	1923 ± 229	1187 ± 183	1572 ± 189	1516 ± 289	1514 ± 296
	MF	1266 ± 270^{b}	1546 ± 321^{a}	1067 ± 172^{c}	1367 ± 238^{b}	1351 ± 251^{b}	1270 ± 279
Longueur du corps	F	36.47 ± 2.3	37.50 ± 2.2	36.27 ± 2.4	37.20 ± 2.6	37.33 ± 1.6	36.59 ± 2.3
	M	40.88 ± 2.7	44.02 ± 3.0	38.37 ± 2.6	40.63 ± 2.5	40.10 ± 2.4	40.73 ± 2.9
	MF	37.69 ± 3.1^{bc}	39.17 ± 3.7^{a}	36.82 ± 2.6^{c}	38.57 ± 3.0^{ab}	38.29 ± 2.3^{ab}	37.75 ± 3.1
Longueur de l'aile	F	14.46 ± 0.8	14.51 ± 0.6	14.07 ± 0.9	15.13 ± 0.6	14.64 ± 0.8	14.45 ± 0.8
	M	15.79 ± 1.2	16.47 ± 0.9	14.91 ± 0.8	16.00 ± 0.9	15.42 ± 1.4	15.72 ± 1.2
	MF	14.82 ± 1.1^{bc}	15.01 ± 1.1^{b}	14.30 ± 0.9^{c}	15.48 ± 0.8^{a}	14.91 ± 1.1^{b}	14.80 ± 1.1
Pourtour du thorax	F	35.92 ± 2.7	35.82 ± 2.5	34.90 ± 2.7	35.52 ± 2.4	36.68 ± 2.5	35.85 ± 2.7
	M	39.40 ± 2.8	41.22 ± 2.2	37.67 ± 2.0	41.05 ± 2.2	38.68 ± 3.1	39.32 ± 2.8
	MF	36.88 ± 3.1^{ab}	37.20 ± 3.4^{ab}	35.63 ± 2.8^{b}	37.73 ± 3.5^{a}	37.37 ± 2.8^{a}	36.82 ± 3.1
Développement du pilon	F	23.54 ± 2.7	26.39 ± 2.5	22.12 ± 2.2	24.22 ± 1.5	24.70 ± 1.9	23.66 ± 2.7
	M	29.83 ± 3.2	34.46 ± 3.0	26.13 ± 1.6	30.23 ± 2.0	28.40 ± 3.9	29.61 ± 3.5
	MF	25.27 ± 4.0^{b}	28.46 ± 4.4^{a}	23.18 ± 2.7^{c}	26.62 ± 3.4^{b}	25.99 ± 3.3^{b}	25.31 ± 4.0
Longueur tarse	F	62.71 ± 4.6	61.93 ± 3.6	62.55 ± 3.4	63.86 ± 3.0	62.21 ± 3.4	62.65 ± 4.3
	M	76.59 ± 6.5	80.61 ± 8.4	76.70 ± 3.5	78.67 ± 4.6	78.00 ± 7.7	77.01 ± 6.4
	MF	66.53 ± 8.1	66.72 ± 9.7	66.30 ± 7.1	69.79 ± 8.3	67.70 ± 9.2	66.65 ± 8.1
Diamètre tarses	F	11.67 ± 1.6	13.75 ± 1.6	10.36 ± 1.2	12.11 ± 1.1	12.48 ± 1.4	11.72 ± 1.7
	M	15.37 ± 8.8	17.55 ± 1.7	11.73 ± 1.5	14.57 ± 1.6	14.26 ± 2.3	15.01 ± 7.6
	MF	12.69 ± 5.1^{ab}	14.72 ± 2.3^{a}	10.70 ± 1.4^{b}	13.09 ± 1.8^{ab}	13.09 ± 1.9^{ab}	12.64 ± 4.5

F = femelle, M = mâle, MF = mâle et femelle, $^{a\ b\ c}$ sur la même ligne pour chaque paramètre, les valeurs affectées de même lettre ne sont pas statistiquement différentes ($P > 0.05$).

Tableau 9. ANOVA des mensurations des appendices de la poule locale.

SV	DDL	LBr	LBc	NCr	HCr	LCr	ND	LEp
P	4	0.191 ns	3.461**	1.334 ns	8.445**	11.07 ns	0.046 ns	1.346 ns
S	1	13.27**	58.530**	13.985**	502.76**	668.87**	0.018 ns	4.915*
PXS	4	0.092 ns	1.361 ns	1.960 ns	5.05**	8.789 ns	0.068 ns	1.784*
Erreur	578							
CV		–	8.12	37.82	60.29	42.01	1.37	88.46

P = phénotype, S = sexe, P × S = interaction phénotype – sexe, CV = coefficient de variation, ns = différence non significative, * = $P < 0.05$, ** = $P < 0.01$.

sur les fréquences des couleurs de plume observées. Le plumage blanc ou clair est devenu un facteur important en élevage car il est plus facile d'apprécier leur état de salubrité. L'hétérogénéité de la couleur de plume témoigne de la variabilité génétique de la poule locale étudiée. Cette variabilité pourrait être le résultat des multiples accouplements non contrôlés entre les animaux avec différentes couleurs de plume, ou encore, serait liée à la dérive d'échantillonnage, et plus particulièrement au faible effectif des phénotypes les moins représentés. Les accouplements non contrôlés donnent naissance à d'autres combinaisons en très faibles proportions comme l'ont souligné Akouango Mouangou and Ganongo (2004).

Les pattes, la face et la peau présentent de multiples couleurs dans la zone d'étude. Les pattes jaunes (40.6%), la face rouge (52.4%) et la peau blanche (49.5%) sont les plus représentées. Ces résultats sont en contradiction avec ceux de Youssao *et al.* (2010) qui ont observé une plus faible fréquence (4.96%) des pattes jaunes chez les poules locales au Bénin. Toutefois, Keambou *et al.* (2007), Fotsa *et al.* (2010) ont également rapporté des fréquences importantes (39.14% et 33.8% respectivement) de pattes jaunes dans les différentes zones du Cameroun. Ces pattes jaunes résulteraient de l'introduction des races exotiques dans la population des poules locales (Youssao *et al.*, 2010). Cependant, la coloration de la peau et des pattes dépend aussi de la combinaison des pigments dans le derme et l'épiderme; ce qui est particulièrement associé à la présence ou l'absence de la mélanine dans la peau. La présence ou l'absence des pigments est due aux allèles W^+ et w. l'allèle W^+ est dominant et donne une patte blanche de type sauvage, tandis que l'allèle w récessif donne une coloration jaune car il permet à l'état homozygote le dépôt des pigments xanthophylles dans le bec, la peau et le tarse (Coquerelle, 2000). Les bonnes pondeuses auraient des pattes moins jaunes car elles exportent les pigments xanthophylles dans le jaune d'œufs. La peau jaune pourrait aussi être associée à la présence des caroténoïdes contenus dans les rations alimentaires.

Les couleurs et types de crête, des oreillons, et des barbillons sont variables dans la population de poules locales de la Lobaye. Les crêtes simples ainsi que la couleur rouge de

Tableau 10. Comparaison des mensurations des appendices de la poule locale en fonction du sexe et du phenotype.

Caractéri stiques	Sexe	Phénotypes					Moyenne générale
		Normal	Emplumé	Huppé	Frisé	Cou nu	
Nombre de crétillons	F	5.59 ± 2.1	5.59 ± 1.0	5.72 ± 1.2	5.67 ± 1.0	5.93 ± 1.1	5.62 ± 1.9
	M	6.77 ± 1.8	6.57 ± 0.9	8.57 ± 7.3	7.20 ± 1.3	6.20 ± 0.8	6.88 ± 2.7
	MF	5.89 ± 2.1	5.78 ± 1.0	6.42 ± 3.9	6.21 ± 1.3	6.02 ± 1.0	5.95 ± 2.2
Hauteur crête	F	11.97 ± 4.5	14.23 ± 6.1	10.32 ± 2.8	11.84 ± 3.7	13.16 ± 3.3	12.01 ± 4.5
	M	31.65 ± 7.4	39.22 ± 6.7	24.64 ± 5.3	35.78 ± 5.5	30.27 ± 6.3	31.35 ± 7.5
	MF	16.99 ± 10.1^{b}	19.09 ± 11.7^{ab}	13.84 ± 7.1^{c}	20.39 ± 12.6^{a}	19.27 ± 9.4^{ab}	16.99 ± 10.0
Longueur crête	F	31.36 ± 6.6	33.85 ± 6.0	29.78 ± 3.9	32.16 ± 3.6	33.78 ± 3.9	31.51 ± 6.2
	M	65.45 ± 12.3	78.39 ± 6.6	52.07 ± 6.1	73.63 ± 7.9	64.05 ± 13.9	64.94 ± 12.7
	MF	40.06 ± 17.1	42.50 ± 18.9	35.2 ± 10.6	46.97 ± 21.2	44.59 ± 17.0	40.12 ± 16.8
Longueur barbillon	F	11.50 ± 5.8	10.66 ± 2.8	6.24 ± 1.5	8.92 ± 2.3	9.40 ± 1.8	10.70 ± 4.5
	M	32.20 ± 7.5	41.54 ± 10.4	26.88 ± 4.3	32.19 ± 5.7	30.71 ± 7.8	31.99 ± 7.8
	MF	16.77 ± 11.5	16.67 ± 7.3	11.31 ± 4.2	17.23 ± 3.1	17.01 ± 4.4	16.18 ± 5.5
Longueur bec	F	31.39 ± 2.1	31.47 ± 2.2	30.72 ± 2.3	31.71 ± 2.2	31.91 ± 2.2	31.37 ± 2.1
	M	33.91 ± 2.6	35.01 ± 2.7	31.92 ± 1.9	35.03 ± 2.5	34.70 ± 3.0	33.89 ± 2.7
	MF	32.04 ± 2.5^{ab}	32.17 ± 2.7^{a}	31.01 ± 2.3^{b}	32.90 ± 2.8^{a}	32.91 ± 2.8^{a}	32.02 ± 2.5
Nombre de doigts	F	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0
	M	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0
	MF	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0	4.00 ± 0.0
Longueur éperon	F	4.48 ± 4.2	4.38 ± 3.6	4.41 ± 4.1	5.45 ± 3.7	5.05 ± 4.5	4.52 ± 4.2
	M	7.40 ± 5.3	7.66 ± 3.8	5.28 ± 3.9	1.22 ± 1.7	6.46 ± 5.9	6.92 ± 5.2
	MF	5.23 ± 4.7	5.02 ± 3.8	4.62 ± 4.0	3.94 ± 3.7	5.55 ± 5.0	5.14 ± 4.6

F = femelle, M = mâle, MF = mâle et femelle, $^{a\ b\ c}$ sur la même ligne pour chaque paramètre, les valeurs affectées de même lettre ne sont pas statistiquement différentes ($P > 0.05$), LCr = longueur de crête, HCr = hauteur de crête, NCr = nombre de crétillons, LBr = longueur de barbillon, LBc = longueur du bec, LEp = longueur de l'éperon.

crête, des oreillons et des barbillons dominent dans l'échantillon de la poule locale dans la Lobaye. Des résultats similaires ont été rapportés par Keambou *et al.* (2007) à l'ouest du Cameroun, Badubi Rakereng and Marumo (2006) au Botswana, Wani (2008) au Soudan, FAO (2005) au Bangladesh. Nos résultats sont en contradiction avec ceux de Nigussie *et al.* (2010) qui ont observé que la crête en poix est la plus fréquente dans la population de poules locales dans les zones de Farta, Mandura, Horro, Konso et Sheka en Ethiopie. La crête en poix a un effet important en élevage dans les conditions tropicales. Le gène P qui détermine ce type de crête réduit la fréquence d'emplumement du bréchet et améliore la croissance tardive chez les jeunes (Horst, 1989). L'étude des caractéristiques des appendices de la poule se révèle d'une importance capitale. La crête et les barbillons larges ainsi que les longues pattes assurent une meilleure dissipation de la chaleur dans les conditions tropicales. La crête et les barbillons assurent les pertes des chaleurs (Duguma, 2006). Ces organes contribuent à environ 40% à la perte des chaleurs (Nesheim *et al.*, 1979 cités par Duguma, 2006). Les tailles et couleurs de la crête et des barbillons sont associées au développement des gonades et la sécrétion des hormones sexuelles (Nesheim *et al.*, 1979 cité par Duguma (2006).

Comme l'ont mentionné plusieurs auteurs (Missohou, Sow and Ngwe-Assoumou, 1998; Keambou *et al.*, 2007; Hako *et al.*, 2009; Fotsa *et al.*, 2010; Haoua, 2010; Nigussie *et al.*, 2010), le poids et les mensurations corporelles sont significativement différents entre les mâles et les femelles. Le dimorphisme sexuel est en faveur des mâles pour tous les caractères étudiés, sauf pour le nombre de doigts. Les valeurs obtenues dans cette étude sont en général inférieures à celles observées par Keambou *et al.* (2007), Fotsa *et al.* (2010), Nigussie *et al.* (2010) mais supérieures à celles de Missohou, Sow and Ngwe-Assoumou (1998) et Youssao *et al.* (2010). Ces différences des résultats peuvent s'expliquer par les conditions du milieu d'élevage des animaux étudiés. Des facteurs endogènes tels que le phénotype, l'âge de l'animal et son état physiologique (particulièrement chez la femelle) pourraient également influencer les résultats.

Par ailleurs, les valeurs du poids vif et celles de la majorité des mensurations corporelles varient entre les phénotypes. La supériorité de poule à tarse emplumé serait due au gène Pti (responsable de la mutation tarse emplumé) qui améliore la croissance pondérale de la poule locale comme l'ont mentionné Ikeobi *et al.*, 2000; Keambou et *al.,* 2007 et Hako *et al.*, 2008. Les gènes Na (cou nu) et F (frisé) ont des effets désirables sur la tolérance thermique et sur le poids adulte (Horst 1989; Hako, 2008). Ces caractères permettent à la poule d'auto-réguler sa température en cas de stress thermique. De ce fait, l'énergie obtenue à travers l'alimentation est utilisée pour l'entretien et la croissance. Des résultats similaires ont été rapportés par (Mérat, 1986; Hako, 2008) lorsqu'ils ont observé qu'en température élevée, le gène Na ainsi que celui du frisé F améliore la production de viande et des œufs. L'utilisation du gène Na est alors nécessaire pour l'élevage de la poule locale en milieu tropical pour sa capacité d'autorégulation thermique. En outre, ce gène réduirait les besoins de la poule en nutriment en termes de protéine utilisée pour la production des plumes, donc la poule cou nu utiliserait mieux la protéine contenue dans l'aliment pour la production de viande et des œufs.

Les animaux caractérisés sont constitués de 0.3% des poules polydactyles. Cette proportion est strictement inférieure à celle observée par Akinokun (1990), Ikeobi *et al.* (2000) qui ont respectivement mentionné des fréquences de 10% et 8% de gènes polydactyles au Nigéria. Cependant, Fayeye *et al.* (2006) n'ont identifié que 2 à 3% de poules polydactyles. Ces derniers ont pensé de ce fait que ces gènes dominants sont menacés de disparition. Au Cameroun, ce caractère n'a pas été décrit ni dans les Hautes terres de l'Ouest (Keambou *et al.*, 2007), ni dans les zones forestières à pluviométrie bimodale (Fotsa *et al.*, 2010), ni dans la zone soudano-sahélienne (Haoua, 2010). Cette rareté serait probablement due au problème d'adaptation de ce type à son milieu de production d'une part, ou plutôt à la létalité probable de ce gène à l'état homozygote.

La longueur moyenne de l'ergot (éperon) de la femelle et du mâle est de 4,52 mm et 6,92 mm respectivement. Elle est de 5,14 mm indépendamment du sexe. Ces valeurs sont inférieures à celles de Keambou *et al.* (2007) et supérieures à celles de Haoua (2010). La présence de l'ergot est un défaut chez la poule qui cause des blessures lors de combat entre les animaux. En plus, les femelles non ergotées casseraient moins des œufs que les poules ergotées. Toutefois, Bauer (1931) cité par Coquerelle (2000) n'a pas trouvé d'anomalie sur l'ovaire et les autres glandes endocrines des poules ergotées. Il a en plus constaté que les poules ergotées pondent autant que les poules non ergotées.

Conclusion

Les poules locales de la Préfecture de la Lobaye en Centrafrique présentent une grande diversité morpho-biométrique.

Le maintien de l'hétérogénéité de la couleur de plumage et d'autres caractéristiques morphologiques est un signe de la primarité de la race locale étudiée. Cette hétérogénéité montre que la population de la poule locale caractérisée n'est pas standardisée et constitue une banque génique indispensable aux défis présents et futurs de la sécurité alimentaire. La population de la poule locale de la Lobaye est caractérisée par une faible fréquence des gènes dominants responsables des caractères mutants (Tarse emplumé, cou nu, frisé, type huppé, polydactylie). Ces gènes courent donc un risque d'extinction si des mesures ne sont pas prises pour limiter la pression sélective négative orientée contre ceux-ci.

Le poids vifs et les mensurations corporelles de la poule locale varient avec le sexe et le type d'emplumement. On note un dimorphisme sexuel en faveur du mâle pour tous les caractères quantitatifs excepté le nombre de doigts. Le phénotype tarse emplumé est plus lourd avec des mensurations corporelles plus élevées à l'exception du nombre de doigts. Il est par conséquent le plus indiqué pour l'amélioration de performances de croissance.

La poule locale de la Lobaye est toutefois caractérisée par un faible poids par rapport à la souche commerciale. Son exploitation en vue d'une meilleure valorisation devrait tout d'abord relever ce poids par la sélection massale avant d'envisager tout croisement.

Pour des prochaines recherches, nous suggérons :

– Que l'étude de la caractérisation phénotypique soit étendue sur d'autres zones agro-écologiques de la Centrafrique;
– Qu'un programme de collecte des échantillons des phénotypes menacés de disparition soit mis en place en vue de leur conservation;
– Qu'une étude des performances de production des différents phénotypes soit entreprise en milieu contrôlé;
– Qu'une caractérisation moléculaire des phénotypes (emplumement normal, tarse emplumé, frisé, cou nu, huppé, polydactyle) soit entreprise pour évaluer leurs distances génétiques;

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Phenotypic and genetic parameters for production traits of local chickens in Ghana

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Summary
Characterization of indigenous animal genetic resources is a first step in providing much needed information for the conservation and utilization of useful genotypes for future needs. The study was undertaken to estimate heritability of traits of economic importance in local chicken populations from the forest and savannah zones of Ghana. A restricted maximum likelihood animal model was applied to growth data of local chickens from hatch to 40 weeks to estimate heritability, phenotypic and genotypic correlations of body weight and shank length. Heritability, phenotypic and genotypic correlations were also calculated for egg number and egg weight. High genetic and phenotypic correlations were obtained between body weight and shank length. Average heritability estimates were 0.54, 0.42, 0.30 and 0.47 for body weight, shank length, egg number and egg weight, respectively. These moderate-to-high heritability estimates indicate that these traits could be targeted in genetic improvement programmes for local chickens.

Keywords: *phenotypic characterization, genetic characterization, animal model, body weight, egg number, egg weight, chickens, Ghana*

Résumé
La caractérisation des ressources zoogénétiques indigènes s'avère un premier pas dans la fourniture de l'information nécessaire à la conservation et utilisation des génotypes utiles aux besoins futurs. Cette étude a été entreprise dans le but d'estimer l'héritabilité de caractères à importance économique chez les populations de poules locales des zones de forêt et de savane du Ghana. Un modèle animal d'estimation du maximum de vraisemblance restreint (REML, de par ses sigles en anglais) a été appliqué aux performances de croissance de poulets locaux, depuis l'éclosion jusqu'aux 40 semaines, pour estimer l'héritabilité et les corrélations phénotypiques et génotypiques du poids corporel et de la longueur des tarses. L'héritabilité et les corrélations phénotypiques et génotypiques ont aussi été calculées pour le nombre d'œufs et le poids de l'œuf. Des corrélations génétiques et phénotypiques élevées ont été obtenues entre le poids corporel et la longueur des tarses. Les estimations moyennes d'héritabilité ont été respectivement de 0,54, 0,42, 0,30 et 0,47 pour le poids corporel, la longueur des tarses, le nombre d'œufs et le poids de l'œuf. Ces estimations d'héritabilité modérées à élevées indiquent que ces caractères pourraient faire l'objet de programmes d'amélioration génétique des poules locales.

Mots-clés: *caractérisation phénotypique, caractérisation génétique, modèle animal, poids corporel, nombre d'œufs, poids de l'œuf, poules, Ghana*

Resumen
La caracterización de los recursos zoogenéticos autóctonos es un primer paso en la generación de la información necesaria para la conservación y utilización de los genotipos útiles para las necesidades futuras. Este estudio fue emprendido con el fin de estimar la heredabilidad de los caracteres de importancia económica en las poblaciones de gallinas locales de las zonas de selva y de sabana de Ghana. Se aplicó un modelo animal de máxima verosimilitud restringida (REML, por sus siglas en inglés) a los datos de crecimiento de pollos locales, desde la eclosión hasta las 40 semanas, para estimar la heredabilidad y las correlaciones fenotípicas y genotípicas del peso corporal y la longitud de los tarsos. La heredabilidad y las correlaciones fenotípicas y genotípicas también fueron calculadas para el número de huevos y el peso del huevo. Se obtuvieron unas altas correlaciones genéticas y fenotípicas entre el peso corporal y la longitud de los tarsos. Las estimas medias de heredabilidad fueron, respectivamente, de 0,54, 0,42, 0,30 y 0,47 para el peso corporal, la longitud de los tarsos, el número de huevos y el peso del huevo. Estas estimas de heredabilidad medias a altas sugieren que estos caracteres podrían ser considerados en programas para la mejora genética de las gallinas locales.

Palabras clave: *caracterización fenotípica, caracterización genética, modelo animal, peso corporal, número de huevos, peso del huevo, gallinas, Ghana*

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Introduction

In tropical Africa, local chickens are kept for meat, eggs, sold for emergency cash needs and also for their socio-cultural values (Osei-Amponsah, Kayang and Naazie, 2012). Increasing the production efficiency of local chickens requires genetic improvement of their economically important traits. Genetic improvement depends on access to genetic variation and effective methods for exploiting it through selection. Local chickens in the tropics have high genetic variability within their populations (Muchadeyi *et al.*, 2007; Mwacharo *et al.*, 2007; Halima *et al.*, 2009; Osei-Amponsah *et al.*, 2010) indicating high potential for genetic improvement of these chickens through selective breeding (Dana, vander Waaij and van Arendonk, 2011). Economic traits are generally controlled by many genes, each with a rather small effect on the trait. For such traits, improvement depends on measuring genetic parameters such as heritability which are then used to predict response to selection. Genetic and phenotypic parameters are important for breeding value estimation and selection decisions (Melo *et al.*, 2006; Kamali *et al.*, 2007; Grosso *et al.*, 2010; Adeleke *et al.*, 2011; Dana, vander Waaij and van Arendonk, 2011; Hidalgo *et al.*, 2011).

Genetic parameters describe genetic and environmental variation and might vary among populations and environments and should thus be estimated in different populations in their specific environments (Besbes *et al.*, 1992; Khaldari *et al.*, 2010). Furthermore, the relationship between production traits (body weight, egg size and egg number) and reproduction traits (fertility and hatchability) are of interest as they can affect the rate of genetic progress (Savegnago *et al.*, 2011). No work has been done on the evaluation of genetic parameters of productive traits of local chickens in Ghana. Such knowledge would enable optimization of breeding programmes to maximize genetic improvement of local chickens. The objective of this study was therefore to estimate the (co)variance components and hence the genetic and phenotypic parameters for economically important traits of local chickens as part of characterization of animal chicken genetic resources of Ghana.

Materials and methods

Experimental birds and management

The source of experimental chickens and their management have been described by Osei-Amponsah, Kayang and Naazie (2012). In brief, chickens from the same ecozone (forest or savannah) were grouped into families comprising a cock and five hens and the collection of fertile eggs began a week later. All eggs were labelled and incubated artificially using table top incubators. After hatching the chicks were tagged according to the sires and ecotype and reared on deep litter. All chicks were fed chick starter for 4 weeks, grower ration from 4 to 18 weeks and layer ration after 18 weeks. The diets were formulated using commercial protein concentrate and the composition of the ration fed to the experimental chickens as described by Osei-Amponsah *et al.* (2011). Feeding and other management practices were the same for all groups and routine vaccination and drug administration schedule were strictly adhered to.

Traits measured and estimation of genetic parameters

The chicks were weighed at hatch and subsequently fortnightly till the 12th week and then monthly till the 40th week for the purpose of describing their growth. Genetic parameters were estimated by variance components using a paternal half-sib animal model described by Becker (1992). A restricted maximum likelihood (REML) animal model was applied to body weight and shank length data of 422 local chickens (196 forest chickens and 226 savannah chickens) from hatch to 40 weeks to estimate (co)variance components, heritabilities, phenotypic and genotypic correlations of body weight and shank length. These components were also estimated for egg number and egg weight of local hens. Genetic parameter estimates of egg number and egg weight were made at the following age periods: 21–30 weeks, 31–40 weeks, 41–49 weeks as well as the entire period (21–49 weeks). In all cases, only sire components of variance were estimated as there were no trap nests and so dams could not be identified. All the REML analyses were carried out using the multiple trait derivative free restricted maximum likelihood (MTDFREML) software package (Boldman *et al.*, 1995). The REML method (Boldman *et al.*, 1995) allows for more accurate estimates of genetic parameters and estimates of breeding values (Zhang *et al.*, 2005; Thompson, 2008). The REML animal model used in matrix notation was

$$\boldsymbol{y} = X\boldsymbol{b} + Z\boldsymbol{a} + \mathrm{e}$$

where $\boldsymbol{y}$ is a vector $N \times 1$ of observations for body weight, shank length, egg number or egg weight; X is the design matrix of 0s and 1s describing which elements of $\boldsymbol{b}$ correspond to observations in $\boldsymbol{y}$; b is an unknown vector of fixed effects; Z is the design matrix of 0s and 1s relating elements of $\boldsymbol{a}$ to observations in $\boldsymbol{y}$; $\boldsymbol{a}$ is the vector of random additive direct genetic effects; $\boldsymbol{e}$ denotes the vector of random residual effects (temporal environmental).

Heritability of body weight and shank length was estimated using single-trait analysis. Genetic and phenotypic correlations between body weight and shank length were estimated using a two-trait analysis. A two-trait analysis was also employed to estimate variance components and heritability of egg number and egg weight at three different periods (21–30, 31–40 and 41–49 weeks) of the laying cycle and the entire laying period (21–49 weeks). Genetic correlations between egg weight and egg number were estimated for each period using the two-trait analysis.

Table 1. Variance components and heritability estimates of body weight of local chickens by age[8].

Trait	σ^2a	σ^2e	σ^2p	h^2
BW0	12.37	6.37	18.74	0.66 ± 0.20
BW2	139.89	115.28	1392.67	0.55 ± 0.19
BW4	719.30	673.25	4473.12	0.52 ± 0.21
BW6	2490.47	1982.63	8806.76	0.56 ± 0.21
BW8	5561.79	3244.64	8806.03	0.63 ± 0.22
BW10	9618.77	7214.49	16833.26	0.57 ± 0.21
BW12	14793.88	12980.55	27774.43	0.53 ± 0.22
BW16	34210.21	23944.32	58154.53	0.59 ± 0.05
BW20	43759.11	32137.09	75896.20	0.58 ± 0.05
BW24	56972.48	24456.63	81429.11	0.70 ± 0.06
BW28	51193.56	41130.29	92323.85	0.55 ± 0.05
BW32	64710.58	7251.82	137226.40	0.47 ± 0.00
BW36	47710.98	85581.73	133298.71	0.36 ± 0.00
BW40	44935.66	100018.10	144953.70	0.31 ± 0.00

σ^2a, additive genetic variance; σ^2e, residual variance; σ^2p, phenotypic variance; h^2, heritability; BW0, body weight at hatch; BW2, body weight at 2 weeks, etc.

Results

Variance components of growth traits

There were increases in additive genetic variance, residual variance, and phenotypic variance of body weight of local chickens from hatch to the 40th week. Additive heritability estimates of body weight based on the animal genetic model ranged from 0.31 to 0.70 with an overall estimate of 0.54 (Table 1).

Additive genetic variance, residual variance and phenotypic variance of shank length of local chickens increased with age. Overall heritability estimates of shank length ranged from 0.12 to 0.60 with an average of 0.42 (Table 2).

In general, there was high genetic correlation between body weight and shank length of local chickens (Table 3).

Table 2. Variance components and heritability estimates of shank length of local chickens by age.

Trait	σ^2a	σ^2e	σ^2p	h^2
SL0	1.05	1.66	2.71	0.39 ± 0.14
SL2	4.26	4.18	8.45	0.50 ± 0.19
SL4	12.43	14.88	27.31	0.46 ± 0.20
SL6	18.58	28.49	47.07	0.39 ± 0.19
SL8	28.83	28.20	57.04	0.51 ± 0.21
SL10	44.76	30.05	74.81	0.60 ± 0.24
SL12	39.37	46.56	85.95	0.46 ± 0.20
SL16	50.54	107.05	157.60	0.32 ± 0.18
SL20	54.04	99.13	153.17	0.35 ± 0.20
SL24	64.07	97.54	161.62	0.40 ± 0.21
SL28	72.72	67.49	140.22	0.52 ± 0.28
SL32	71.10	97.83	168.94	0.42 ± 0.25
SL36	48.29	75.42	123.73	0.39 ± 0.23
SL40	15.66	115.99	131.65	0.12 ± 0.17

σ^2a, additive genetic variance; σ^2e, residual variance; σ^2p, phenotypic variance; h^2, heritability; SL0, shank length at hatch; SL2, shank length at 2 weeks, etc.

Table 3. Genetic and phenotypic correlations between body weight and shank length of local chicken ecotypes by age.

Traits	r_a^2	r_p^2
BW0-SL0	0.75	0.14
BW2-SL2	0.94	0.86
BW4-SL4	0.73	0.93
BW6-SL6	0.12	0.93
BW8-SL8	0.96	0.95
BW10-SL10	0.12	0.95
BW12-SL12	0.97	0.87
BW16-SL16	0.97	0.95
BW20-SL20	0.91	0.77
BW24-SL24	0.88	0.98
BW28-SL28	0.80	0.97
BW32-SL32	0.90	0.95
BW36-SL36	0.65	0.94
BW40-SL40	1.00	0.91
Mean	0.76	0.86

r^2a, genetic correlation between body weight and shank length; $r_{p,}^2$ phenotypic correlation between body weight and shank length; BW0, body weight at hatch; SL2, shank length at week 2, etc.

Variance components of reproductive traits

Table 4 shows that overall additive genetic variance fluctuated with age for egg number but decreased with age for egg weight. Phenotypic variance increased with age for egg number but decreased with age for egg weight except for the savannah ecotype. Overall, heritability of egg number fluctuated with age while heritability of egg weight decreased with age. Furthermore, heritabilities of both egg number and egg weight were higher in the savannah chicken ecotype than the forest ecotype. However, there was a stronger genetic correlation between egg number and egg weight of the forest than savannah chicken ecotype. A positive genetic correlation between egg number and egg weight (0.50) was obtained in local chickens.

Discussion

The additive component of the genetic variance is of particular interest because it is the primary determinant of the degree of resemblance between parent and progeny, and this governs the response rate of traits to selection (Larivière *et al.*, 2009). The high additive genetic variance within the local chicken could be due to the lack of selection within the local chicken population. Relatively high additive genetic variance could also be due to absence of inbreeding as the families of birds were formed with samples from different parts of the country. The environmental variances were low as the birds were all kept at the same station or in a similar environment. Body weight of local chickens has enough additive genetic variation to enable selection and significant genetic gains would be expected if selection for body weight was carried out in the local chicken population. Selection to increase body weight to a level that allows local chickens to survive in

Table 4. Heritability, genetic and phenotypic correlations of egg number and egg weight of local chicken ecotypes by age.

	σ^2a_1	σa_1a_2	σ^2a_2	σ^2p_1	σp_1p_2	σ^2p_2	h^2a_1	h^2a_2	$r^2a_1a_2$
21–30 weeks									
Forest	1.29	−1.91	3.22	5.58	0.52	30.07	0.23 ± 0.42	0.11 ± 0.35	−0.94 ± 2.01
Savannah	1.74	0.96	9.61	10.26	2.92	10.36	0.17 ± 0.33	0.93 ± 0.53	0.23 ± 0.68
Overall	1.46	0.35	13.88	7.19	1.50	22.51	0.20 ± 0.20	0.62 ± 0.36	0.08 ± 0.56
31–40 weeks									
Forest	1.60	0.53	3.36	4.91	0.69	20.02	0.33 ± 0.30	0.17 ± 0.23	0.23 ± 0.81
Savannah	0.11	0.23	2.05	11.18	1.70	23.69	0.01 ± 0.19	0.09 ± 0.21	0.48 ± 6.66
Overall	1.13	−0.24	2.31	8.02	2.18	21.09	0.14 ± 0.13	0.11 ± 0.13	−0.15 ± 0.78
41–49 weeks									
Forest	0.74	0.58	0.96	6.61	−2.96	13.75	0.12 ± 0.23	0.07 ± 0.18	0.68 ± 2.13
Savannah	6.92	0.21	2.55	14.56	6.31	22.99	0.48 ± 0.36	0.11 ± 0.23	0.05 ± 1.05
Overall	2.98	0.16	0.01	10.14	1.46	18.46	0.29 ± 0.20	0.00 ± 0.13	1.00 ± 0.00
21–49 weeks									
Forest	0.17	1.14	7.82	7.18	2.38	23.76	0.02 ± 0.18	0.33 ± 0.29	1.00 ± 2.87
Savannah	4.19	1.57	9.73	11.61	3.62	15.30	0.36 ± 0.26	0.64 ± 0.36	0.25 ± 0.41
Overall	2.71	2.46	8.81	8.89	4.05	18.71	0.30 ± 0.00	0.47 ± 0.00	0.50 ± 0.00

σ^2a_1, genetic variance of egg number; σa_1a_2, genetic covariance between egg number and egg weight; σ^2a_2, additive genetic variance of egg weight; σ^2p_1, phenotypic variance of egg number; σp_1p_2, phenotypic covariance between egg number and egg weight; σ^2p_2, phenotypic variance of egg weight; h^2a_1, heritability of egg number; h^2a_2, heritability of egg weight; $r^2a_1a_2$, genetic correlation between egg number and egg weight.

the crude extensive systems of rural farmers of the developing world, while maintaining genetic diversity ought to be good objectives to aim at, as it is not likely these birds can be improved within a reasonable period of time to be competitive under intensive management.

Genetic and phenotypic correlations between body weight and shank length were generally high and positive. This means that similar genes affect body weight and shank length. Hence, selection and improvement in body weight will automatically increase shank length. The best age to select local chickens based on shank length is 10 weeks although the high positive and unfavourable genetic and phenotypic correlations with body weight suggest some caution be exercised. There is no commercial interest in having chickens with very long shanks. Consequently, selection within the local chicken population will be more useful if based on body weights, perhaps with some amount of negative pressure on shank length. The high phenotypic correlations between body weight and shank length represent an adaption for survival in the kinds of systems of management in which local chickens are kept. Longer shanks enable them to chase down insects and out compete each other in the process. Other researchers have documented the high and positive genetic and phenotypic correlations between body weight and shank length (Kabir *et al.*, 2006) as has been obtained in this study.

There was no clear trend between heritability of body weight and age but heritability estimates reduced with age after 24 weeks of age. An estimate of 0.45 was obtained for body weight at 5 weeks in a male broiler line raised under tropical conditions in Brazil (Argentão *et al.*, 2002) which is lower than what was obtained at either 4 or 6 weeks for local Ghanaian chicken. The heritability estimates of 0.59, 0.55 and 0.52 for body weight at 8, 10 and 12 weeks are all higher than heritability estimates of 0.42, 0.30 and 0.30 for body weight of free range broiler chickens in Argentina at 54, 68 and 75 days of age (Melo *et al.*, 2006), indicating the lack of selection or inbreeding in these chickens. Heritability estimates of 0.51 and 0.86 have been reported for body weights of 8 months old roosters from a population selected for egg traits and a control line (Segura *et al.*, 1990). Kiani-Manesh, Nejati-Javaremi and Saneei (2002) reported heritability estimates of 0.47, 0.69, 0.24 and 0.14 for 8-week body weights for native Iranian chicken raised at four breeding stations, while Kabir *et al.* (2006) reported heritability estimates of 0.89 and 0.70 at 20 weeks of age; 0.68 and 0.56 at 30 weeks of age; 0.60 and 0.42 at 40 weeks of age for two strains of Rhode Island Red chickens.

This study therefore confirms the moderate-to-high heritability estimates of body weight of unselected chicken populations. This ranged from 0.52 to 0.63 within the first 8 weeks after hatch indicating the possibility of early selection. However, low heritability estimates of between 0.07 and 0.21 have been reported for Creole chickens from South Eastern Mexico from hatch to 16 weeks of age (Prado-González, Ramírez-Avila and Segura-Correa, 2003). It was explained that dominance, epistatic and environmental effects were more important than genetic additive effects on body weight of Creole chickens. Adeyinka *et al.* (2006) obtained heritability estimates of 0.32, 0.22, 0.31, 0.24 and 0.20 for body weights at hatch, 2 weeks, 4 weeks, 6 weeks and 8 weeks, respectively, for naked neck broiler chickens. Adeleke *et al.* (2011) also reported heritability estimates of between 0.05 and 0.45 in Nigerian indigenous chickens. These estimates are low compared with those obtained at the respective ages in local Ghanaian chicken ecotypes, but is to be expected as broilers are intensively selected for their body weight and so should have reduced additive genetic variance.

The overall heritability of egg number of local chickens in this study, 0.30 falls within the low-to-moderate values (0.12–0.41) recorded for this trait by Besbes and Gibson (1998) for purebred and crossbred chickens. The overall heritability of egg number for savannah chickens (0.36) was higher than the forest chickens (0.02), which could indicate different response to the experimental environment by the local chicken ecotypes. Wei and van der Werf (1995) reported heritabilities of 0.04–0.51 for egg number. Overall heritability of egg weight of local chickens was 0.47 with 0.33 in the forest ecotype and 0.64 in the forest. The higher heritability of egg weight than egg number, a fitness trait, is expected and is in line with findings of other researchers. For instance, among local chickens in Nigeria, estimates of heritability were low (0.07) for egg number and moderate (0.31) for egg weight, with low genetic and phenotypic correlations between the two traits (Adedeji *et al.*, 2006). A high heritability of 0.7 has been reported for egg weight in purebred and crossbred laying hens (Besbes and Gibson, 1998). In another study on purebred and crossbred chickens, a heritability range of 0.23–0.45 was reported for egg weight in purebred and crossbred chickens (Wei and van der Werf, 1995). Zhang *et al.* (2005) reported heritabilities of egg weight of 0.63 in brown-egg dwarf layers. Kamali *et al.* (2007) also reported heritabilities of 0.40 and 0.64, respectively, for egg number and egg weight in Iranian native fowls. The results of this study and of other researchers are in agreement that the heritability of egg weight is higher than that of egg number. Progress at improving egg number will therefore be slower than that for egg weight.

The best way to improve on egg number will be to reduce the length of the inter clutch interval by collecting the eggs as soon as they are laid and thus discouraging broodiness. Furthermore, heritability of egg weight in local chickens decreased with the laying period (0.62 between 21 and 30 weeks as against 0.39 between 31 and 49 weeks) and therefore selection for high egg weight should be carried out during the first phase of the laying cycle. The challenge now is to carry out selection within local chicken ecotypes to ensure that body weight, egg number and egg weight are improved upon. The moderate-to-high heritability of body weight of local chickens as well as their short generation interval should make this attainable.

Conclusions

Heritability estimates of body weight (0.54), shank length (0.42), egg weight (0.47) and egg number (0.30) are all moderate to high and indicate that these traits could be targeted in future improvement programmes for local chicken. Conservation strategies in local chicken will achieve the best results if body weight and egg weight are targeted in breeding programmes. Once hatch weight is improved and increased, the market age can be reduced or bigger birds could be sold at the current market ages. Compared with similar studies in chickens elsewhere, the heritability estimates of the productive traits studied are moderate to high. There is the need for some selection and improvement of local chickens to take full advantage of their adaptive potential as regards various environmental challenges and their genetic variability.

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Characterization of primary immune response in Ghanaian local, Sasso T-44 and broiler chickens to sheep red blood cell antigens

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Summary
Animals should have the capacity to adapt to changing environmental pressures to ensure sustainable productivity. The easier an animal can adapt to disease burdens without extra cost to the farmer, the more profitable the enterprise becomes. Effective immune response protects organisms against disease insults and contributes to improved productivity. Primary immune response of Ghanaian local, Sasso T-44 and broiler chickens to sheep red blood cell (SRBC) antigens was measured 5 days post-inoculation. Antibody levels were determined by haemagglutination. Local ecotypes and Sasso T-44 chicken were superior to broilers in terms of their ability to respond to antigens. Female chickens produced more antibodies in response to increased concentration of SRBC antigens while the opposite was true in the male population. Further investigation of the genetic correlation between production performance and immune response of various chicken breeds will help establish the effect of, for example, high growth rate of broilers on their immunological status.

Keywords: *local chickens, genotypes, antibodies, disease resistance*

Résumé
Les animaux devraient avoir la capacité de s'adapter aux pressions d'environnements changeants afin d'assurer une productivité durable. Plus un animal s'adapte facilement, sans coût supplémentaire pour l'éleveur, au stress causé par les maladies, plus l'élevage devient rentable. Une réponse immunitaire efficace protège les organismes face aux attaques des maladies et contribue à améliorer la productivité. La réponse immunitaire primaire de poulets locaux ghanéens, Sasso T-44 et broiler aux antigènes d'érythrocytes de mouton a été mesurée 5 jours post-inoculation. Les niveaux d'anticorps ont été déterminés par hémagglutination. Les écotypes locaux et les poulets Sasso T-44 ont été supérieurs aux poulets broiler pour ce qui est de la capacité de réponse aux antigènes. Les femelles ont produit plus d'anticorps en réponse à l'augmentation de la concentration des antigènes d'érythrocytes de mouton alors que le contraire a été observé chez la population de mâles. Une recherche plus approfondie sur la corrélation génétique entre les performances productives et la réponse immunitaire de différentes races de poulets aidera, par exemple, à déterminer l'effet d'une vitesse de croissance élevée sur l'état immunologique des poulets broiler.

Mots-clés: *poulets locaux, génotypes, anticorps, résistance aux maladies*

Resumen
Los animales deberían tener la capacidad de adaptarse a las presiones de ambientes cambiantes para garantizar una productividad sostenible. Cuanto mayor es la facilidad del animal para adaptarse, sin coste extra para el ganadero, al estrés causado por las enfermedades, más rentable pasa a ser la ganadería. Una respuesta inmune eficaz protege a los organismos de los ataques de las enfermedades y contribuye a mejorar la productividad. La respuesta inmune primaria de pollos ghaneses locales, Sasso T-44 y broiler a antígenos de eritrocitos de oveja fue medida 5 días post-inoculación. Los niveles de los anticuerpos fueron determinados por hemaglutinación. Los ecotipos locales y los pollos Sasso T-44 fueron superiores a los broilers desde el punto de vista de la habilidad para responder a los antígenos. Las hembras produjeron más anticuerpos en respuesta a una concentración creciente de antígenos de eritrocitos de oveja mientras que se observó lo contrario en la población de machos. Una más profunda investigación de la correlación genética entre los parámetros productivos y la respuesta inmune de varias razas de pollos ayudará, por ejemplo, a determinar el efecto de una elevada velocidad de crecimiento sobre el status inmunológico de los pollos broiler.

Palabras clave: *pollos locales, genotipos, anticuerpos, resistencia a enfermedades*

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Introduction

Immune response is broadly defined as the defence of the host as a result of its immune system to pathogens and parasites (Geng, 2007). Improvement of disease resistance might be achieved through selection for increased immune response (Bovenhuis *et al.*, 2002; Dorshorst, Siegel and Ashwell, 2011). Improving genetic resistance to disease would reduce the cost of vaccination and other disease prevention procedures and reduce mortality and loss in performance during disease outbreaks (Li *et al.*, 2000; Siwek, 2005; Barbour *et al.*, 2012). The World Health Organization (WHO) has encouraged the use of poultry vaccination together with biosecurity measures to counteract H5N1 outbreaks (Pose *et al.*, 2011). Although vaccines and medicines are widely used for prevention and treatment, they represent an expense and leave residues in meat and other products. Therefore, a reduction in their use may be required for ethics, food safety and health concerns of consumers. It is important to find effective methods to reduce chronic use of antibiotics and enhance the effectiveness of vaccine protection by improving, via genetic selection, the innate ability of birds to respond to antigenic challenges.

Environmental stress can alter the susceptibility of animals to infective agents and it is therefore important to learn how stress affects the immune system of food animals, the adaptive capacity of animals to respond and the time it takes for animals to return to homoeostasis (Hangalapura *et al.*, 2003). Local breeds raised in natural environments have the potential to offer more flavourable products for the increasingly health-conscious consumer (Moula *et al.*, 2009). Genetic selection for resistance of chickens to major infectious agents has been recognized for a long time as an adjunct to non-genetic means of disease control (Boa-Amponsem, Dunnington and Siegel, 1997; El-Safty, Ali and Fathi, 2006; Chatterjee *et al.*, 2007). Genetic resistance has several advantages including enhancing response to vaccines (Gavora *et al.*, 1990) and can be improved indirectly by selecting for broad immune response (Dorshorst, Siegel and Ashwell, 2011).

Many kinds of antigens have been used to monitor immune responsiveness in poultry (Li *et al.*, 2000). Non-infectious antigens can be used to mimic and measure the response of the immune system as an estimate of the predicted immune activity level that would occur in an actual challenge situation (Lamont *et al.*, 2003). The use of red blood cells (RBC) from a different host as an antigen to compare RBC-specific humoural immunities in different breeds of animals is well documented (Barbour *et al.*, 2012). The sheep RBC (SRBC) (Van der Zijpp and Nieuwland, 1986) antigen is one of the most frequently used antigens because it is non-pathogenic, does not interfere with the measurement of antibody response, is a multideterminant and strongly immunogenic (Geng, 2007).

Little work has been carried out on natural disease resistance abilities of local chicken ecotypes of Ghana. The purpose of this study therefore was to characterize the immune response of local chickens, commercial broilers and Sasso T-44 chickens. The results of the study will provide information on disease resistance for development of sustainable breeding programmes for local chickens in line with the Global Plan of Action for Animal Genetic Resources (FAO, 2007).

Materials and methods

An immunological study to determine the response of chickens to SRBCs was undertaken on local chickens from the forest and savannah zones of Ghana, commercial broilers and Sasso T-44 chickens from France. The experimental chickens were kept at the University of Ghana Livestock and Poultry Research Centre, Legon under the same management practices as described by Osei-Amponsah, Kayang and Naazie (2012). Birds aged between 8 and 9 months old were injected with 0.1 ml of either 0.25 percent or 1.00 percent suspension of SRBC diluted in phosphate buffered saline (PBS) (Pinard *et al.*, 1992) into the brachial vein (Boa-Amponsem *et al.*, 1998). Ten birds from each genotype were inoculated with one concentration of the SRBC antigen (0.25 percent or 1.00 percent). The antibodies in the serum agglutinate to SRBC when added in a test tube, resulted in a specific pattern at the bottom of the tube.

Blood was drawn after 5 days from the inoculated birds to determine haemagglutination or total SRBC haemagglutinating antibody response. If RBC are used as a source of antigen, the assay is called haemagglutination (Schulten, Yates and Taylor, 2007). Haemagglutination measures the relative concentration of antibody in serum and is expressed as titre (Boa-Amponsem *et al.*, 2001). Total antibody titres to SRBC were determined by agglutination with routine procedures (Van der Zijpp and Leenstra, 1980). Primary immune response was measured as antibody titres against SRBC expressed as $\log_2$ of the reciprocal of the highest plasma dilution giving complete agglutination. Only primary immune response was measured. Antibody titres of the chicken ecotypes were analysed using analysis of variance (ANOVA) procedures in GENSTAT for Windows (Payne *et al.*, 2007).

The model used for the analysis was:

$$Y_{ijk} = \mu + G_i + S_j + C_k + GS_{ij} + GC_{ik} + SC_{jk} + GSC_{ijk} + e_{ijkl},$$

where Y_{ijk} is the antibody titre value, μ is the overall mean, G_i is the genotype, S_j is the sex, C_k is the SRBC concentration, GS_{ij} is the ecotype–sex interaction, CG_{ik} is the genotype–SRBC concentration interaction, SC_{jk} is the sex–SRBC concentration interaction, GSC_{ijk} is the genotype–sex–SRBC concentration interaction and e_{ijkl} is the error.

Results

There were significant differences ($P < 0.05$) in antibody response among the chicken ecotypes (Table 1). In the female population, the differences in response to SRBC antigens of the local chickens and the broiler were statistically significantly ($P < 0.05$) but not in the male population. Males of the local and Sasso T-44 chicken populations had significantly lower immune response than the females.

Variations between the Ghanaian local chickens and the Sasso T-44 chicken in terms of response to SRBC antigens were not significant ($P > 0.05$).

Response of local chickens to SRBC antigen decreased with increased dosage of the antigen, while for the broiler and Sasso T-44, the response increased (Table 2). Furthermore, irrespective of the dosage level, response to SRBC antigen dosage was lowest in the broiler.

Antibody titre values decreased with increased SRBC concentration in males (negative correlation) but increased in females (positive correlation) with increased SRBC concentration (Table 3).

Table 2. Antibody response of chicken genotypes to different concentrations of SRBC[1].

Chicken genotype	Concentration of SRBC antigens			
	0.25%	*n*	1.00%	*n*
Savannah	4.71 ± 0.43^{a}	14	4.36 ± 0.57^{a}	14
Forest	4.38 ± 0.44^{ab}	13	4.18 ± 0.59^{a}	11
Sasso T-44	4.33 ± 0.45^{ab}	12	4.54 ± 0.55^{a}	13
Broiler	3.23 ± 0.46^{b}	13	3.31 ± 0.62^{a}	13
Overall	4.18 ± 0.26^{a}	52	4.09 ± 0.26^{a}	51

[1]Within columns means followed by different superscripts are significantly different ($P < 0.05$).
n = sample size.

Discussion

Antibody levels are important dynamic parameters of immune response as they partially reflect the potential of an animal to resist pathogen infection (Geng, 2007). Immune response provides vertebrates with an important mechanism to fight pathogens and reduce disease incidence. Local, Sasso T-44 and broiler chickens responded differently to inoculation of SRBC antigens. Local and Sasso T-44 chickens showed the best immune response to inoculation with SRBC antigens compared with commercial broilers. This could be attributed to the fact that the Sasso T-44 is a scavenging chicken genotype in France and therefore could have similar immunological abilities as local Ghanaian chickens. Local chickens raised in extensive scavenging systems are likely to face more health challenges and hence are likely to be more immunocompetent. For instance, Egyptian indigenous naked neck and normally feathered chickens have been reported to have better immune response than commercial chicken lines (El-Safty, Ali and Fathi, 2006). Rajkumar *et al.* (2011) also reported higher antibody response in naked-neck breeds of chicken. In a study on antibody responses to different dosages of SRBC in lines of chickens selected for high and low antibody response to SRBC, Boa-Amponsem *et al.* (2000) found differences in patterns of antibody response to SRBC according to line, resulting in interactions of line by dosage by day.

Results of antibody titre values reported for the experimental chickens in the present study (3.27–4.54) are higher than the range of 1.2–2.8 reported for white leghorns for inoculation periods of between 3 and 10 days (Boa-Amponsem *et al.*, 2000). This can be attributed to both genotype and environment and their interaction specifically for the imported Sasso T-44 chicken. Antibody titre values for the male experimental chicken ranged from 3.16 to 4.15 and this falls within the 1.3–8.9 range reported for White Leghorn male chicken (Kuehn *et al.*, 2006). However, average antibody titres of 0.3–2.5 recorded for White Leghorn males (Syrjanen and Naukkarinen, 1982) and 1.4–3.0 (Boa-Amponsem *et al.*, 2000) are below what was observed for males (3.16–4.15) in the present study due probably to the higher immune response status of local chickens. Results of the present study confirm previous findings that highly selected chicken populations have less immunity than unselected stocks (Siwek, 2005). This can be attributed to the fact that intensive selection for production traits impairs the capability of poultry to generate protective

Table 1. Antibody response of chicken genotypes to SRBC inoculation by sex[1]

Ecotype	Sex of chickens					
	Female	*n*	Male	*n*	Overall	*n*
Savannah	4.87 ± 0.47^{a}	15	4.15 ± 0.49^{a}	13	4.54 ± 0.35^{a}	28
Forest	4.47 ± 0.48^{a}	15	3.56 ± 0.59^{a}	9	4.29 ± 0.37^{ab}	24
Sasso T-44	4.75 ± 0.48^{a}	16	3.89 ± 0.52^{a}	9	4.44 ± 0.36^{a}	25
Broiler	3.06 ± 0.49^{b}	16	3.60 ± 0.57^{a}	10	3.27 ± 0.38^{b}	26

[1]Within columns means followed by different superscripts are significantly different ($P < 0.05$).
n = sample size.

Table 3. Antibody response of male and female chicken to different concentrations of SRBC antigens.

Sex	Concentration of SRBC antigens	
	0.25%	1.00%
Male	4.15 ± 0.38	3.50 ± 0.39
Female	4.20 ± 0.28	4.48 ± 0.34
Overall	4.18 ± 0.26	4.09 ± 0.26

immune response and disease resistance (Adriaansen-Tennekes *et al.*, 2009) The local chicken ecotypes, therefore, have good immune status that should be maintained or improved through selection. Chickens selected for high antibody response to SRBC showed higher resistance to some infectious diseases such as Marek's and Newcastle diseases (Gross *et al.*, 1980; Dunnington *et al.*, 1986).

Differences were observed in antibody titres between male and female local chickens; hens had higher antibody titres against SRBC than cocks. This finding agrees with the results of other studies and might be because of male and female antibody titres being genetically different traits, because of the genes being located on the sex chromosome (Bovenhuis *et al.*, 2002). Our results of antibody titre values reported for local chickens and Sasso T-44 chicken are also higher than the range of 1.2–2.8 reported for White Leghorns for inoculation periods of between 3 and 10 days although the titre value of the broiler fall within this range. Kuehn *et al.* (2006) reported antibody titre values in response to SRBC inoculation ranging from 1.3 to 8.9 for White Leghorn males which captures our observed values for the male chicken population.

Conclusions

Local chicken ecotypes and Sasso T-44 chicken have comparable primary sensitivity to SRBC inoculation. This sensitivity is higher compared with broilers because of the adaptability of local chickens to environmental stressors including disease antigens. Female chickens express more antibodies when inoculated with SRBC than their male counterparts. Increasing the concentration of SRBC antigens was responded to positively with increased antibody titres in all the ecotypes except the savannah local chickens. In addition male chickens responded negatively to increased SRBC inoculation. It is recommended that further work be carried out to determine secondary immune responses in local chicken as well as genetic correlations between immune response and production traits especially on farm. For instance, it will be useful to know if the low immune response of broilers is a result of their superior growth rates. This information will be vital for the development of a breed improvement programme for local chickens.

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Egg and meat production performances of two varieties of the local Ardennaise poultry breed: silver black and golden black

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Summary
The Ardennaise breed is emblematic of the Belgian poultry diversity. We compared two varieties of the breed, the golden black and the silver black. The comparison encompassed: (i) the morphology of adult birds, (ii) the growth, carcass characteristics and meat quality of broilers 22 weeks old, (iii) the laying rate during 52 weeks and the egg quality. Significant differences were observed in the size of mature males and females: body weight, diameter and length of the tarsus, size of the comb and wattles. The two varieties did not differ concerning the carcass and meat quality traits. The golden black has a higher laying rate and a higher yolk / albumen ratio, but lays lighter eggs. It could be interesting to complete this study by molecular markers analysis to evaluate the degree of genetic diversity between the two varieties.

Keywords: *Ardennaise breed, poultry diversity, morphology, breeding, broiler and laying performances*

Résumé
La poule Ardennaise est une race emblématique de la biodiversité avicole belge. Cette étude est consacrée à la comparaison de deux variétés de la race Ardennaise (Noire dorée et Noire Argentée). La comparaison est réalisée par le biais de trois études: (1) caractérisation morpho-biométrique des deux variétés; (2) caractérisation de la croissance et de la qualité de la carcasse et de la viande; (3) suivi du taux de ponte pendant 52 semaines et étude de la qualité des œufs à 30, 45, 60 et 75 semaines d'âge. Des différences significatives ont été enregistrées entre les deux variétés au niveau des poids corporels, du grand diamètre du tarse, de la longueur du tarse et de la taille de la crête. La variété de la poule Ardennaise n'influence significativement aucun des caractères quantitatif et qualitatif de production de viande (rendement, poids après abattage, pH, couleur de la viande). Cependant, elle influence significativement le poids de l'œuf entier, le poids du blanc, le pourcentage du blanc, le pourcentage du jaune, le rapport jaune/blanc et le pH du blanc ($p < 0.05$). Il serait intéressant de compléter cette étude par une analyse moléculaire permettant de préciser le degré de similitude génétique entre les deux variétés et éventuellement avec les autres variétés de la race.

Mots-clés: *race Ardennaise, diversité aviaire, morphologie, sélection, poulet de chair et performances de ponte*

Resumen
La raza Ardenesa es una raza emblemática dentro de la diversidad avícola belga. Se han comparado dos variedades de la raza, la negra dorada y la negra plateada. La comparación comprendió (i) la morfología de aves adultas, (ii) el crecimiento, características de la canal y calidad de la carne de pollos broiler de 22 semanas de edad, (iii) la tasa de puesta durante 52 semanas y la calidad del huevo. Se observaron diferencias significativas en el tamaño de machos y hembras maduros: peso corporal, diámetro y longitud de los tarsos, tamaño de la cresta y de las barbillas. Las dos variedades no difirieron en lo que respecta a parámetros de la canal o de calidad de carne. La variedad negra dorada presenta una mayor tasa de puesta y un mayor ratio yema/albumen, pero pone huevos de menor peso. Podría resultar interesante completar este estudio con un análisis de marcadores moleculares para evaluar el grado de diversidad genética entre las dos variedades.

Palabras clave: *raza Ardenesa, diversidad avícola, morfología, mejora, rendimientos cárnicos y de puesta*

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Introduction

All through the industrialization process of western countries in the nineteenth and twentieth centuries, modern poultry production has turned to a true landless, input and capital intensive production system, exclusively based on

highly productive and specialized hybrid strains. Sustained by the rapid genetic progress allowed by the short life-cycle of the poultry as well as by the economies of scale (increasing returns), a highly concentrated economic sector has emerged, where the global production hardly relies on a few major genetic types (Lariviere and Leroy, 2008). Nowadays, a rapid demand-driven expansion of the livestock sector in developing countries is taking place (Delgado *et al.*, 1999). In this so-called Livestock Revolution, the intensive peri-urban poultry sector did more than its fair share in the satisfaction of the rising demand for animal products in developing urban centres. However, this industrialization process of egg and chicken production constitutes a serious threat to the genetic diversity of poultry around the world. This trend could be particularly damaging to backyard small-scale poultry rearing that emerged these last few years as a powerful tool in poverty alleviation, in which the need for wide genetic resources cannot be overvalued, as a result of the wide array of environmental conditions to be considered. In developed countries also, a major evolution of consumption habits is converting the animal production sector to more qualitative concerns, for which valorization of local breeds should be of prime interest.

In Belgium, where 95 percent of local poultry breeds are greatly endangered (Larivière and Leroy, 2005), a local breed named Ardennaise is considered as promising in the context of quality terroir production (Moula *et al.*, 2009a, 2009b), the flavour of its flesh being largely renowned. By its remarkable robustness and its resistance to humid climates, this breed has also been proposed for amelioration projects of village chicken production in Sub-Saharan Africa (Youssao *et al.*, 2009). The Ardennaise breed is actually composed of 12 recognized varieties, of which the white one is sometimes considered as a different breed, named the Famennoise (Moula *et al.*, 2009a, 2009b, 2009c; Moula *et al.*, 2012). As the selection process that gave birth to those varieties has been realized on the basis of non-productive phenotypic traits (plumage and eye colour and morpho-biometric characteristics), the question of the relevance of their differentiation regarding production objectives must be considered. In this context, the present study aims at evaluation of egg and meat production abilities of the two major Ardennaise varieties, namely, the silver black feathered and the golden black feathered Ardennaise.

Material and methods

This study was implemented from January 2008 till December 2009 and involved three phases. The first phase consisted in the morpho-biometric characterization of Ardennaise individuals from both silver and golden varieties available at the Animal Production Department of the Faculty of Veterinary Medicine of the University of Liege (Belgium). In the second phase, the meat production performances were recorded through the follow-up of live weight for a growth period of 22 weeks and the assessment of meat quality at slaughter. Quantitative and qualitative egg production performances were then studied during a third phase for a 52-weeks laying period.

Morpho-biometry

Adult birds (over 10 months of age) of the silver black and the golden black varieties from breeding flocks were used for the morpho-biometric characterization. The different body measurements were recorded in accordance with the FAO recommendations (FAO, 1981), by means of a digital balance (precision 1 g), an electronic sliding caliper (precision 0.01 mm) and a tape measure.

The collected data were thus the sex and age of the bird, the comb's length and height, wattles height, the length and diameter of the tarsus and the beak.

Growth and carcass and meat quality

A total of 304 eggs, among which 130 of the silver black Ardennaise and 174 of the golden black Ardennaise, were incubated. All the eggs were less than 10 days old and originated from the flock of the Veterinary Faculty. The number of chicks obtained was 90 for the silver black and 124 for the golden black variety. All the chicks were vaccinated against Marek's disease at day 1.

All the chicks were floor-bred on a sawdust litter in the same ventilated building, both varieties being separated by netting. The chicks were first put under a heating lamp and the room temperature was regulated manually according to the chicks' behaviour. Continuous light program was adopted for the whole experiment period. The chicks were fed *ad libitum* with a starter mix until the age of 14 days (energy: 2 870 kcal/kg, density: 0.732 kg/l) and a traditional poultry mix (energy: 2 950 kcal/kg, density: 0.723 kg/l) from day 14 to slaughter. Between days 14 and 21, both feed types were mixed to provide an adaptation period. Both mixes contained wheat, corn, soyabean, soyabean oil, methionine, lysine, vitamins and BHT ethoxyquine anti-oxidant. Their compositions are listed in Table 1.

Each bird was identified individually, first by a numbered plastic ring at the leg then by metallic ones after week 5. Sexing was achieved visually at week 9 by comb inspection. The birds were weighed individually once a week from week 1 till week 16 with an electronic balance (accuracy 0.01 g). The birds were weighed once again, at week 22, before slaughter. An overall feed conversion index was calculated for each variety from the total feed intake and the total gain.

Mortality was recorded during the growing period.

Four birds of each sex were randomly chosen among each variety ($n = 16$) and were slaughtered at week 22, which is the regular slaughter age for slow-growing local breeds

Table 1. Feed mix composition for starting, growth and laying.

Ingredients	Broiler Starter mix	Broiler mix	Layer hens
Soyabean oil cake	32.00	30.00	20.00
Wheat	37.00	31.00	11.00
Corn	25.00	33.00	50.00
Soyabean oil	2.30	2.00	3.00
Calcium phosphate	1.50	1.80	1.00
Minerals (vitamins, micronutrients)[1]	1.10	1.00	1.00
Calcium carbonate	1.08	1.20	7.50
Methionine	0.02	0.20	0.10
Alfalfa	–	–	2.40
Beets molasse	–	–	1.50
Wheat middlings	–	–	2.50
Composition			
Metabolizable energy (kcal/kg)	2870.00	2950.00	3060.40
Fat content (g/kg)	55.13	52.18	54.53
Lysine (g/kg)	12.45	8.46	11.28
Methionine (g/kg)	5.39	3.45	4.36
Calcium (g/kg)	9.50	38.00	10.00
Phosphorus (g/kg)	6.03	5.62	5.68
Dry matter (g/kg)	612.90	749.60	561.26
Crude protein (g/kg)	220.00	170.00	189.00

[1]Vitamin A 13 500 UI/kg, vitamin D3 3.000 UI/kg, vitamin E 25 mg/kg and copper sulphate 15 mg/kg.

such as the Ardennaise. The birds were deprived of feed for 15 h before last live weight record and slaughter. They were bled, plucked under warm water, weighed again and eviscerated. The legs were sectioned at the tibiotarsus–metatarsus joint and the head was cut at the skull–atlas joint. The warm carcass was then weighed. The dressing out percentage was then calculated as the ratio between warm carcass weight and live weight at slaughter.

The carcass was then cut and the wings, legs and drumsticks were sampled and weighed after being skinned. The left pectoral muscles (*Pectoralis major* and *Pectoralis profondus*) were sampled about 8 h post-slaughter, weighed and packed in plastic bags for conservation at 4 °C for 24 h. Water loss was calculated as the difference between muscles' weight at sampling and after 24 h of draining on absorbent paper.

pH was measured with a Portamess 751 pH-meter (Knick GmbH&Co, Berlin, Germany) combined with a Mettler-Toledo electrode (LoT406-DXKS7/25; Mettler-Toledo International Inc., Urdorf, Switzerland). Meat colour of the left pectoral muscles was determined on three different parts of each sample after exposition to air, with a spectrocolourimeter Hunterlab Lab-Scan II (Hunter Associates Laboratory, Reston, USA). Colour was expressed in CIE units: L* a* b* with L* being a value indicating the darkness (lightness), high values of a* indicating an intense red colour of meat (redness) and high values of b* indicating an intense yellow colour of the meat (yellowness).

Egg production and quality

Egg laying rate was assessed in 40 silver black and 30 golden black. The hens were first housed under natural light conditions. At week 24, the hens began to produce small eggs and were transferred at week 28 in a building under artificial lighting where a 16 h light/8 h dark programme was applied. The hens were fed with a mix for layers, containing 10 g/kg calcium (see Table 1 for composition). Laying was followed-up for 52 weeks. The eggs were collected every day and conserved at 6 °C except abnormal eggs (cracked and broken) which were eliminated. Quality analysis was implemented the day after egg collection and conducted at different hens' ages: 30, 45, 60 and 80 weeks. Total weight was measured (electronic balance, accuracy 0.01 g) and average egg weight was obtained by dividing total eggs weight by eggs number. Then, their length and width were measured by means of an electronic sliding caliper (precision 0.01 mm), so that an egg shape index could be calculated as the ratio between length and width multiplied by 100 (Monira, Salahuddin and Miah, 2003; Parmar *et al.*, 2006). The yolks were carefully separated from the albumen. The shells including the membranes and yolks were weighed separately (accuracy of 0.01 g). Albumen weight was determined by subtracting yolk and shell weights from the total egg weight. The shell thickness was measured at three different random points in the equatorial shell zone using an electronic micrometer (precision 0.01 mm) and average calculated. Tyler and Geake (1964) indeed reported the eggshell thickness to be slightly thinner but more stable in the equatorial shell zone compared with the other shell zones. Yolk and albumen pH was then measured with a pH-meter (ORION, model 290A, 1990 Orion Research Inc. Boston, MA 02129, USA).

Statistical analyses

The analysis of data was conducted by using the SAS package (procedure GLM, SAS, 2001) and least square means (LSM) and standard errors were calculated, allowing ranking of variety and sexes according to Duncan's procedure.

The following models were used.

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where Y_{ijk} are the mature body weight and measurements and meat quality traits in 22-week-old chicks, μ is the overall mean, A_i is the fixed effect of the ith variety (golden black and silver black variety), B_j is the fixed effect of the jth gender (male, female) and e_{ijk} is the random residual effect.

$$Y_{ijkl} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkl}$$

where Y_{ijkl} is the body weight, μ is the overall mean; A_i is

the fixed effect of the *i*th variety (golden black and silver black variety), B_j is the fixed effect of the *j*th gender (male, female), C_k is the fixed effect of the *k*th age (1 to 22 weeks), and e_{ijkl} is the random residual effect.

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where Y_{ijk} is the egg quality traits, μ is the overall mean, A_i is the fixed effect of the *i*th variety (golden black and silver black variety), B_j is the fixed effect of the age (30, 45, 60 and 80 weeks) and e_{ijk} is the random residual effect.

The Gompertz equation was used to model the growth of the chickens (Porter *et al.*, 2010). This equation has the form: $Y = \alpha e^{-\beta e^{-\gamma t}}$

where Y is the weight of the chicken in grams, α is the asymptotic weight, β is constant, γ is growth speed factor (maturation factor), and t is the age in days.

The growth curve parameters of the Gompertz equation were estimated (proc NLIN, SAS, 2001). The age at inflexion when the growth rate is maximum was calculated using the following formula (Porter *et al.*, 2010): $t_i = (1/\gamma) \times \ln|\beta|$

To compare the egg-laying rate, hatching rate and mortality rate between the silver black and the golden black varieties, the Chi squared test was used.

Results

Morpho-biometric characteristics

The least squares means of the live weight and body measurements of mature animals are given in table 2 along with the significance of the fixed effects of sex and variety.

The sex effect is highly significant ($P < 0.001$) on all studied traits. The effects of variety and interaction variety × sex were significant ($P < 0.05$) on body weight, large diameter and length of the tarsus and on the comb length. The males of the golden black variety were significantly ($P < 0.05$) heavier (2 674 g) than the males of the silver golden black variety (2 290 g) but the live weight was not significantly different between the hens of the two varieties.

Golden black males had body measurements (length of the tarsal, the length and height of the comb and the length of the wattles) greater ($P < 0.05$) than the silvery black variety. In females, there was no significant difference in comb height and wattles length between the two varieties (Table 2).

Growth

Figure 1 shows the live weight growth of the birds from 1 day old (36 g for all sex and varieties) up to 22 weeks

Table 2. Body weight (g) and measurements (mm) of adult Ardennaise chicken according to variety (V) and sex (S), least squares means and standard error and significance level of the effects of variety, sex and their interaction (V × S).

	Golden black		Silver black		Level of significance			R^2
	n	LSM ± SE	*n*	LSM ± SE	V	S	V × S	
Body weight (g)					**	***	**	0.28
Male	10	2 674 ± 95[a]	26	2 290 ± 59[b]				
Female	52	1 956 ± 42	97	1 972 ± 30				
Small diameter of tarsus					NS	***	NS	0.37
Male	10	11.98 ± 0.30	26	11.41 ± 0.19				
Female	52	9.64 ± 0.13	97	9.79 ± 0.10				
Large diameter of tarsus					*	***	*	0.18
Male	10	15.62 ± 0.43[a]	26	14.43 ± 0.27[b]				
Female	52	13.24 ± 0.19	97	13.28 ± 0.14				
Length of tarsus					*	***	**	0.21
Male	10	94.53 ± 2.60[a]	26	85.90 ± 1.61[b]				
Female	52	77.88 ± 1.14	97	79.53 ± 0.83				
Beak length					NS	***	NS	0.22
Male	10	36.84 ± 0.87	26	35.35 ± 0.54				
Female	52	32.22 ± 0.38	97	32.17 ± 0.28				
Comb length					*	***	*	0.34
Male	10	122.39 ± 8.41[a]	26	96.02 ± 5.21[b]				
Female	52	58.73 ± 3.69	97	57.22 ± 2.70				
Comb height					NS	***	NS	0.55
Male	10	74.78 ± 5.00	26	63.69 ± 3.10				
Female	52	22.41 ± 2.19	97	23.57 ± 1.61				
Wattles length					NS	***	*	0.56
Male	10	61.01 ± 3.93[a]	26	50.11 ± 2.44[b]				
Female	52	16.95 ± 1.72	97	19.26 ± 1.26				

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least squares means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

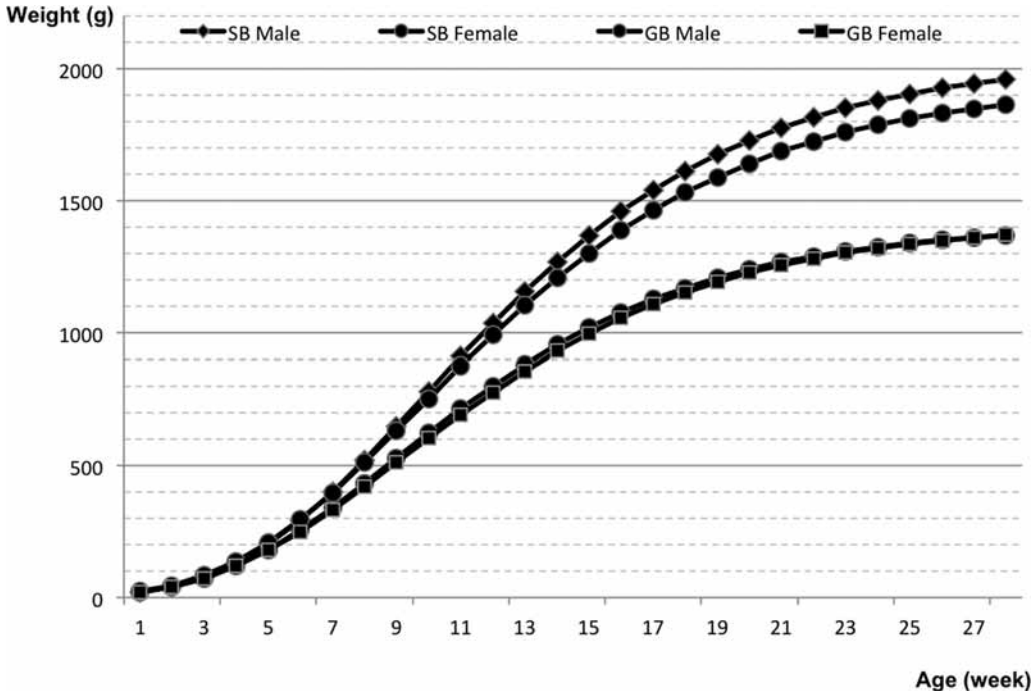

Figure 1. Gompertz growth curve parameters of Ardennaise broilers by varieties (SB, Silver black; GB, Golden black) and sex.

of age. Mean weight at 22 weeks of age was 1 550 and 1 513 g in golden and silver varieties, respectively. The body weight was significantly ($P < 0.01$) influenced by the fixed effects of the variety, the sex, the age and the interaction between sex and age (Table 3).

The parameters of the Gompertz curve, the average daily gain (ADG) and the feed conversion ratio (FCR) of the two Ardennaise varieties and sexes are shown in Table 4. Asymptotic weights were 2 042 and 1 946 g in males and 1 411 and 1 420 g in females for the silver

Table 3. Body weight of Ardennaise broilers by variety (V), sex (S) and age (A). LSM ± SE and significance level of the effects of variety, sex and age and their interactions.

	Golden black			Silver black			Level of significance						
	Male (41)	Female (39)	Total (90)	Male (55)	Female (69)	Total (124)	V	S	A	V × S	V × A	S × A	V × A × S
Day 1	35.8	35.6	35.6	36.5	35.4	35.9	**	***	***	NS	NS	***	NS
Week 8	609	501	555	618	494	556							
Week 12	1 139	870	1 007	1 111	848	977							
Week 16	1 518	1 147	1 338	1 446	1 126	1 282							
Week 22	1 814	1 258	1 550	1 752	1 266	1 513							

(), number of specimens; V, varieties; S, sex; A, age. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS, $P > 0.05$.

Table 4. Gompertz growth curve parameters, average daily gain (ADG) and feed conversion ratio (FCR) of Ardennaise broilers by variety and sex.

Variety	Sex	*N*	Parameters of the Gompertz growth curve				ADG by age (g/j)				Global FCR by age (g/g)			
			α (g)	β	γ (j^{-1})	t (j)	0–8 weeks	0–12 weeks	0–16 weeks	0–22 weeks	0–8 weeks	0–12 weeks	0–16 weeks	0–22 weeks
Silver black	Males	41	2042.3	4.66	0.1725	62.45	10.23	13.13	13.23	11.55				
	Females	39	1410.6	4.279	0.1841	55.27	8.31	9.93	9.92	7.94				
	Total	90	1760.3	4.48	0.1752	59.65	9.27	11.56	11.63	9.83	3.03	4.01	4.49	6.71
Golden black	Males	55	1945.7	4.454	0.1718	60.86	10.40	12.80	12.59	11.14				
	Females	69	1419.9	4.203	0.1766	56.91	8.19	9.67	9.74	7.99				
	Total	124	1691.3	4.308	0.1714	59.92	9.28	11.20	11.12	9.59	2.98	3.99	4.60	6.19

α is the asymptotic weight; β is constant; γ is the growth rate parameter (maturing factor); t is age in days.

black and the golden black, respectively. The age of inflexion was near 60 days for the silver and golden varieties.

The overall FCR was similar for the two varieties during the first 16 weeks and slightly higher in silver black thereafter. The birds of the silver black and golden black variety

Table 5. Carcass and meat quality traits of Ardennaise broilers by variety and sex. LSM ± SE and significance level of the effects of sex.

	Silver black variety		Golden black variety		Level of significance
	n	LSM ± SE	*n*	LSM ± SE	Sex
Slaughter body weight (g)					***
Male	4	1 856 ± 28	5	1 803 ± 25	
Female	4	1 441 ± 28	5	1 399 ± 25	
Carcass weight (g)					***
Male	4	1 249 ± 27	5	1 237 ± 24	
Female	4	931 ± 27	5	913 ± 24	
Yield (%)					**
Male	4	67.30 ± 0.95	5	68.56 ± 0.85	
Female	4	64.59 ± 0.95	5	65.29 ± 0.85	
Head weight (g)					***
Male	4	62.38 ± 1.06	5	58.82 ± 0.95	
Female	4	35.33 ± 1.06	5	35.76 ± 0.95	
Legs weight (g)					**
Male	4	67.05 ± 1.00	5	69.41 ± 0.89	
Female	4	38.60 ± 1.00	5	36.91 ± 0.89	
Abdominal fat weight (g)					**
Male	4	63.51 ± 2.30	5	69.59 ± 2.06	
Female	4	76.16 ± 2.30	5	72.90 ± 2.06	
Drumsticks + thighs weight (g)					***
Male	4	418.14 ± 16.82	5	417.86 ± 15.04	
Female	4	329.70 ± 30.55	5	293.00 ± 15.04	
Drumsticks and thighs weight without skin (g)					***
Male	4	392.85 ± 15.50	5	385.73 ± 13.86	
Female	4	305.54 ± 15.50	5	272.01 ± 13.86	
Wings weight (g)					***
Male	4	169.33 ± 1.38	5	165.98 ± 1.24	
Female	4	129.88 ± 1.38	5	128.29 ± 1.24	
Pectoral muscle weight (g)					**
Male	4	282.21 ± 10.83	5	287.30 ± 9.69	
Female	4	246.41 ± 10.83	5	239.30 ± 9.69	
Drip loss after 1 day of storage (%)					NS
Male	4	0.55 ± 0.13	5	0.80 ± 0.12	
Female	4	0.68 ± 0.13	5	0.62 ± 0.12	
Drip loss after 3 days of storage (%)					NS
Male	4	3.03 ± 0.27	5	2.98 ± 0.24	
Female	4	2.69 ± 0.27	5	2.41 ± 0.24	
Drip loss after cooking (%)					NS
Male	4	18.52 ± 1.43	5	20.72 ± 1.43	
Female	4	22.60 ± 1.43	5	20.71 ± 1.16	
pH ultimate					NS
Male	4	5.68 ± 0.04	5	5.73 ± 0.04	
Female	4	5.70 ± 0.04	5	5.67 ± 0.04	
Temperature (°C)					NS
Male	4	17.67 ± 1.69	5	16.84 ± 1.51	
Female	4	15.80 ± 1.69	5	19.16 ± 1.51	
b*					NS
Male	4	12.41 ± 1.53	5	12.66 ± 1.53	
Female	4	13.19 ± 1.53	5	13.60 ± 1.25	
a*					NS
Male	4	2.88 ± 0.45	5	3.43 ± 0.45	
Female	4	3.02 ± 0.45	5	2.27 ± 0.37	
L*					NS
Male	4	52.46 ± 1.33	5	53.13 ± 1.19	
Female	4	48.35 ± 1.33	5	52.03 ± 1.19	

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least squares means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

Note: The variety × sex interaction had no significant effect on any trait.

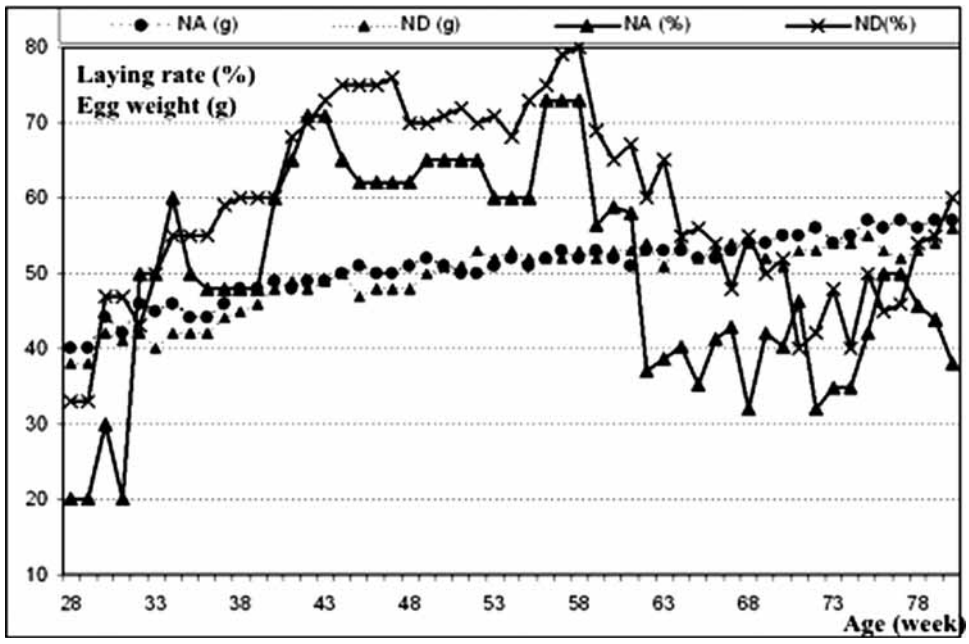

Figure 2. Evolution of laying rate (%) and egg weight (g) during the 80 weeks laying period of the Ardennaise breed by variety (NA: Silver black; ND: Golden black).

had cumulative FCR of 3.03 and 2.98 at 8 weeks of age, 4.01 and 3.99 at 12 weeks of age, 4.49 and 4.60 at 16 weeks of age and 6.71 and 6.19 at the end of the rearing.

Reproductive traits

The hatching rate is not significantly different between the silvery black variety (69.2 percent) and the golden black variety (71.3 percent).

The mortality at 22 weeks of age, was similar ($\chi^2 = 0.094$, $P = 0.7$) for the two varieties and reached 6.92 and 6.32 percent for the silver black and the golden black, respectively.

Carcass characteristics and meat quality

Carcass characteristics and meat quality of the broilers at 22 weeks of age were compared for sex, variety and two factors interaction in Table 5.

The variety and the interaction of variety × sex had no significant effect on these various traits. The male showed significantly higher weights for the body, head, legs, wings, drumsticks and thighs ($P < 0.01$).

None of the various traits of meat quality were affected by any of the three factors studied.

Egg production

From the age of 28 weeks up to 80 weeks, the laying rate varied between 20 and 78 percent for the silver black and between 33 and 80 percent for the golden black (Figure 2). Over the whole laying period, the laying rate was not different between the two varieties ($\chi^2 = 0.57$, $P = 0.32$) neither at 30, 45, 60 and 80 weeks. The golden black produced on average 199 eggs per year and the silver black 183 eggs per year. The changes in egg weight during laying period are shown in Figure 2. The mean of the egg weight during the production period was 54.4 and 49.6 g for the silver black and the golden black, respectively.

Egg quality

Table 6 shows the mean values of the various traits of egg quality per variety and indicates the significance of the effects of variety, age and interaction variety × age. Only the variety has an effect ($P < 0.05$) on the egg and the albumen weights, the albumen percentage, the yolk/albumen ratio and the albumen pH. Age influenced ($P < 0.05$) all traits related to egg quality. The weight of egg, albumen, yolk and shell and the yolk percentage increased with age. The interaction between variety and age was significant ($P < 0.05$) for the egg and yolk weights and the albumen pH.

The two Ardennaises varieties had significant differences in the egg weight at 30 and 45 weeks of age, albumen weight at 30, 45 and 80 weeks, yolk weight at 45 and 60 weeks, albumen percentage at 60 weeks, ratio yolk/albumen at 60 weeks, egg shape at 60 weeks and the albumen pH at 30 weeks.

Discussion

Morpho-biometric characterization

The first visible difference between silver black and golden black is the colour of the plumage. The colour of the hackle is easily observable, white (silver) in the silver variety and red (gold) in the golden black variety.

Table 6. Egg quality of Ardennaise hens by variety and age. LSM ± SE and significance level of the effects of variety, age and interaction.

	Silver black varieties		Golden black varieties		Level of significance			R^2 (%)
	n	LSM ± SE	*n*	LSM ± SE	Variety	Age	Variety × age	
Egg weight (g)					***	***	**	85.11
At 30 weeks of age	10	45.28 ± 0.60[a]	15	41.93 ± 0.49[b]				
At 45 weeks of age	20	51.34 ± 0.42[a]	30	48.04 ± 0.35[b]				
At 60 weeks of age	15	53.06 ± 0.49	25	53.16 ± 0.38				
At 75 weeks of age	10	57.24 ± 0.60	15	55.89 ± 0.49				
Albumen weight (g)					***	***	NS	69.46
At 30 weeks of age	10	26.65 ± 0.48[a]	15	24.19 ± 0.39[b]				
At 45 weeks of age	20	29.67 ± 0.34[a]	30	27.88 ± 0.28[b]				
At 60 weeks of age	15	30.49 ± 0.39	25	29.53 ± 0.30				
At 75 weeks of age	10	32.61 ± 0.48[a]	15	31.28 ± 0.39[b]				
Yolk weight (g)					NS	***	**	68.80
At 30 weeks of age	10	13.24 ± 0.42	15	12.57 ± 0.34				
At 45 weeks of age	20	15.72 ± 0.30[a]	30	14.50 ± 0.24[b]				
At 60 weeks of age	15	16.34 ± 0.34[a]	25	17.45 ± 0.26[b]				
At 75 weeks of age	10	18.35 ± 0.42	15	18.36 ± 0.34				
Eggshell weight (g)					NS	***	NS	28.35
At 30 weeks of age	10	5.39 ± 0.19	15	5.17 ± 0.16				
At 45 weeks of age	20	5.96 ± 0.14	30	5.67 ± 0.11				
At 60 weeks of age	15	6.23 ± 0.16	25	6.18 ± 0.12				
At 75 weeks of age	10	6.29 ± 0.19	15	6.24 ± 0.16				
Albumen (%)					*	**	NS	18.2
At 30 weeks of age	10	58.85 ± 0.73	15	57.73 ± 0.59				
At 45 weeks of age	20	57.77 ± 0.51	30	58.08 ± 0.42				
At 60 weeks of age	15	57.46 ± 0.59[a]	25	55.55 ± 0.46[b]				
At 75 weeks of age	10	56.94 ± 0.73	15	55.98 ± 0.59				
Yolk (%)					NS	***	NS	25.76
At 30 weeks of age	10	29.23 ± 0.69	15	29.94 ± 0.56				
At 45 weeks of age	20	30.63 ± 0.49	30	30.12 ± 0.40				
At 60 weeks of age	15	30.80 ± 0.56[a]	25	32.83 ± 0.44[b]				
At 75 weeks of age	10	32.05 ± 0.69	15	32.85 ± 0.56				
Eggshell (%)					NS	*	NS	9.10
At 30 weeks of age	10	11.91 ± 0.35	15	12.33 ± 0.28				
At 45 weeks of age	20	11.61 ± 0.25	30	11.79 ± 0.20				
At 60 weeks of age	15	11.74 ± 0.28	25	11.63 ± 0.22				
At 75 weeks of age	10	11.00 ± 0.35	15	11.17 ± 0.28				
Yolk/albumen ratio ($\times 10^{-2}$)					*	***	NS	23.65
At 30 weeks of age	10	49.72 ± 1.90	15	52.03 ± 1.55				
At 45 weeks of age	20	53.18 ± 1.34	30	52.12 ± 1.10				
At 60 weeks of age	15	53.80 ± 1.54[a]	25	59.49 ± 1.20[b]				
At 75 weeks of age	10	56.38 ± 1.90	15	58.85 ± 1.54				
Eggshell thickness (10^{-2} mm)					NS	*	NS	8.29
At 30 weeks of age	10	33.08 ± 0.87	15	32.59 ± 0.71				
At 45 weeks of age	20	31.88 ± 0.62	30	31.40 ± 0.50				
At 60 weeks of age	15	31.18 ± 0.87	25	30.90 ± 0.71				
At 75 weeks of age	10	30.65 ± 0.72	15	30.84 ± 0.55				
Egg shape index					NS	**	NS	15.92
At 30 weeks of age	10	74.93 ± 0.88	15	74.45 ± 0.72				
At 45 weeks of age	20	75.53 ± 0.62	30	75.28 ± 0.51				
At 60 weeks of age	15	77.67 ± 0.72[a]	25	75.12 ± 0.56[b]				
At 75 weeks of age	10	77.39 ± 0.88	15	77.78 ± 0.72				
Albumen pH					**	***	**	43.70
At 30 weeks of age	10	8.62 ± 0.27[a]	15	8.79 ± 0.02[b]				
At 45 weeks of age	20	8.88 ± 0.02	30	8.88 ± 0.01				
At 60 weeks of age	15	8.91 ± 0.02	25	8.90 ± 0.02				
At 75 weeks of age	10	8.85 ± 0.03	15	8.89 ± 0.02				
Yolk pH					NS	*	NS	7.29
At 30 weeks of age	10	6.08 ± 0.05	15	6.13 ± 0.04				
At 45 weeks of age	20	6.22 ± 0.04	30	6.21 ± 0.03				
At 60 weeks of age	15	6.21 ± 0.04	25	6.20 ± 0.03				
At 75 weeks of age	10	6.25 ± 0.05	15	6.23 ± 0.04				

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least square means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

The golden black cocks are significantly bigger than the silver black cocks, but the golden black hens tended to be smaller (1 956 versus 1 972 g), increasing the sexual dimorphism in the golden black. Nevertheless, our results for mature body weight (2 674 g and 1 956 g and 2 290 g and 1 972 g, for male and female of the golden and silver varieties, respectively) are well above those reported at the beginning of the last century by Carpiaux (1921) and Voitellier (1925) which barely exceeded 2 and 1.5 kg for male and female, respectively. However, these weights are close to those reported by N'Dri (2006) for the Gauloise breed (2.5 kg for rooster and 1.5–2.0 kg for hen).

Growth

The silver black and golden black Ardennaise performed similar weights at hatching (35.84 versus 36.53 g for males and 35.56 versus 35.42 g for females) and at 22 weeks (1 814 versus 1 752 g for males and 1 258 versus 1 266 g for females).

At 12 weeks of age, the average weight was 1 139 and 1 111 g in males and 870 and 848 g in females, for the golden black and silver black, respectively, lower than the weight at 12 weeks of the white Ardennaise variety, 2 000 and 1 500 g in males and females, respectively (Moula *et al.*, 2009a).

The ADG is also always higher in males, which explains the higher final weight in cocks compared with females.

The FCR was similar for the two varieties during the first 16 weeks and slightly lower in the golden black over the last 6 weeks.

Carcass characteristics and meat quality

Comparison between the two varieties of the Ardennaise breed of carcass characteristics and meat quality traits of animals slaughtered at 22 weeks of age revealed no significant difference. The results only showed that the weights of different body parts are higher in roosters compared with hens. Similar results were recorded by Youssao *et al.* (2009) in the Coqard chicken, which is a crossbred between traditional Ardennaises cock and hen from a French commercial slow growing strain. However, dressing percentage was better in the Ardennaise than in the French industrial red label, 67 and 65.5 percent, respectively.

After cooking, the average loss in the Ardennaise is about 20 percent which is considerably lower than the recommendations of Sauveur (1997) for the Label Rouge chicken (25 percent). However, the slaughter age of the latter is 12 weeks, while it is 22 weeks for the Ardennaise. The choice of this slaughter age (22 weeks) by the connoisseurs of Ardennaise, can be explained by the improved flavours and taste with age but at the expense of the tenderness (Touraille *et al.*, 1981).

The ultimate pH of the muscles stabilizes to a value between 5.7 and 5.9 in poultry (Sante, Fernandez and Monin, 2001). The values measured in the pectoral muscles of the two varieties of Ardennaises, around 5.7, are very close to this range and with the values found in different genetic groups by Debut *et al.* (2005) and Quentin *et al.* (2003) where ultimate pH ranged from 5.59 to 6.01.

The colour, which represents the first criterion for assessing meat by the consumer and the absence of difference between the varieties of Ardennaise is interesting from the point of view of the uniformity of the commercial product. L* values recorded in the present study (48.35–53.13) are lower than those recorded by Quentin *et al.* (2003) ranging from 54.5 in fast growing strains to 53.5 in slow growing strains including the French red label. The values of a* of Ardennaises, 2.3–3.4, are higher than those recorded in many studies, ranging from −0.8 to 0.28 (Quentin *et al.*, 2003; Debut *et al.*, 2005). These high values of a* indicate that the meat of Ardennaise is redder, in fact these values are closer to those recorded in turkeys (a* of about 5) in the study of Molette *et al.* (2005). The average value of b* (approximately 13) in the Ardennaise is much higher than those recorded (6.89–11.8) by Debut *et al.* (2005) and Quentin *et al.* (2003), therefore, a yellow colour is more pronounced in the Ardennaise.

The laying rate and egg quality

The hens of both varieties begin to lay at the age of 24 weeks, an age identical to that recorded by Hocking *et al.* (2003) on a group of traditional breeds (Barnvelder, White Sussex). However, this age remains well above that of industrial strains such as ISA-Brown (22 weeks of age) (Benabdeljelil *et al.*, 2003). However, they are precocious compared with Indian breeds (Danki, Kalasthi and Ghagus) whose age at first egg varies from 25 to 32 weeks on average (Vij *et al.*, 2006) and the Egyptian Fayoumi breed whose first egg is generally laid at the age of 28 weeks (Zaman, Sorensen and Howlider, 2004).

Even if there is no difference in the laying rate of the two varieties of Ardennaise, golden black hens lay more eggs than silver black hens (199 eggs vs 183 eggs). However, the weight of the latter is slightly higher (50.74 versus 49.53 g). Similar differences were recorded in different varieties of the Gauloise (N'Dri, 2006).

The influence of age on the composition of the egg is already reported by numerous studies (Marion *et al.*, 1964; Akbar *et al.*, 1983; Fletcher *et al.*, 1983; Nys, 1986; Rossi and Pompei, 1995; Hartmann *et al.*, 2000; Dolgokorova, 2006).

The comparison of the two varieties of eggs had revealed some differences for certain traits at given age (Table 6).

The freshness of the egg is represented in this study by the pH. Except at the age of 30 weeks where albumen pH was significantly higher in black golden Ardennaise (8.79

versus 8.62), the pH of the white and the yellow were similar at the other ages. These values are comparable with those recorded by Moula *et al.* (2009a, 2009c).

The soundness of the shell is the second most important economic quality of the eggs (Wells, 1968). The fragility of the shell is the cause of about 6–8 percent of the losses in the egg industry (Washburn, 1982). In this study, the two Ardennaise varieties presented similar thicknesses at all ages (ranging from 30.65 to 33.08×10^{-2} mm), values close to those recorded by Moula *et al.* (2009c) in Ardennaise.

The third important criterion of the egg quality is the yellow-to-white ratio. High proportions of yellow are sought because it has a significant effect on the dry matter of the eggs (Harms and Hussein, 1993; Hartmann *et al.*, 2003) which is an essential criterion in the industry (Flock, Preisinger and Schmutz, 2001). In this study, the Ardennaises golden black yellow/white ratio exceeds that of the silvery black Ardennaise (52.03–59.49 versus 49.72–56.38).

Conclusion

Most of the growth and laying traits as well as most of the quality characteristics of meat and egg did not differ significantly among the golden and silver varieties. These results might indicate that these varieties could be managed as one same population in order to face the problem of small population size.

It could be very interesting to complete this study by molecular markers analysis to evaluate the degree of genetic similarity between the two varieties. A wider study extended to the other ten varieties of Ardennaise would be welcome to fully assess the variability of the breed. This project should need the collaboration between public authorities, academic institutions and local race fans associations.

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Description of production systems and morphological characteristics of Abergelle and Western lowland goat breeds in Ethiopia: implication for community-based breeding programmes

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Summary

A household survey and measurements of different body traits from 120 households and from 1 009 goats were collected to characterize the production system and morphological features of Western lowland and Abergelle goat breeds of Ethiopia. Goats were kept for multifunctional roles in both areas, but mainly to generate cash. The average ± SD of flock sizes per household were 10.8 ± 7.25 and 48.56 ± 52.21 for Western lowland and Abergelle, respectively. Production characters such as body conformation, multiple births and milk yield were reported as major selection criteria of breeding goats. The majority of Abergelle goats have red brown (23.8 percent) and brown (19.7 percent) coat colours with short and smooth hair. All Abergelle goats have horns, 11.1 percent have wattles, 8.0 percent of males have ruff. White (20.4 percent) and a mixture of white with other colours were the predominant coat colours of Western lowland goats. A total of 42.3 percent males and 5.1 percent females of the Western lowland population have ruff. The least square means of body weight, chest girth, body length and height at withers of Western lowland female goats were 24.00 ± 0.19 kg, 65.27 ± 0.23 cm, 54.8 ± 0.21 cm and 62.60 ± 0.22 cm, respectively. The corresponding values for Abergelle female goats were 18.34 ± 0.22 kg, 61.03 ± 0.27 cm, 51.00 ± 0.24 cm and 58.99 ± 0.25 cm, respectively. Breed improvement programmes in these areas should take into account the multifunctional roles of goats, goat breeding practices and traits preference of the farmers.

Keywords: *body measurements, selection criteria, production system, Abergelle goat, Western lowland goat, Ethiopia*

Résumé

Afin de caractériser le système de production et les traits morphologiques des races caprines des terres basses de l'Ouest de l'Éthiopie et de la race Abergelle, 120 foyers ont été enquêtés et différents paramètres corporels de 1 009 chèvres ont été mesurés. Dans les deux zones, les chèvres jouaient des rôles multifonctionnels, bien qu'elles soient principalement élevées pour générer de l'argent liquide. La taille moyenne (±écart type) du troupeau par foyer a été de 10,8 ± 7,25 et 48,56 ± 52,21 pour les races des terres basses occidentales et la race Abergelle, respectivement. Des caractéristiques productives comme la conformation corporelle, les mises-bas multiples et la production laitière se sont révélées comme étant les principaux critères de sélection pour l'amélioration génétique des chèvres. La plupart des chèvres Abergelle présentent une robe marron rougeâtre (23,8 pour cent) ou marron (19,7 pour cent), le poil étant ras et souple. Toutes les chèvres Abergelle ont des cornes, le 11,1 pour cent ont des pendeloques et le 8,0 pour cent des mâles présentent une crinière sur l'encolure. Le blanc (20,4 pour cent) et la combinaison du blanc avec d'autres couleurs sont les couleurs prédominantes pour la robe des chèvres des terres basses occidentales. Pour le 42,3 pour cent des mâles et le 5,1 pour cent des femelles de la population caprine des terres basses occidentales, le poil est long sur le cou. La valeur moyenne, calculée par la méthode des moindres carrés, du poids corporel, la circonférence thoracique, la longueur du corps et la hauteur au garrot des chèvres des terres basses occidentales a été de 24,00 ± 0,19 kg, 65,27 ± 0,23 cm, 54,8 ± 0,21 cm et 62,60 ± 0,22 cm, respectivement. Les valeurs correspondantes pour les chèvres Abergelle ont été 18,34 ± 0,22 kg, 61,03 ± 0,27 cm, 51,00 ± 0,24 cm et 58,99 ± 0,25 cm, respectivement. Les programmes d'amélioration des races de ces zones devraient tenir compte des rôles multifonctionnels des chèvres, des pratiques d'élevage et des préférences des éleveurs.

Mots-clés: *mesures corporelles, critères de sélection, système de production, chèvre Abergelle, chèvre des terres basses occidentales, Éthiopie*

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Resumen
Con el fin de caracterizar el sistema de producción y los rasgos morfológicos de las razas caprinas de las tierras bajas del Oeste de Etiopía y de la raza Abergelle, se realizó una encuesta doméstica a 120 hogares y se tomaron medidas de diferentes parámetros corporales de 1 009 cabras. En ambas áreas, las cabras cumplían roles multifuncionales, si bien se mantenían fundamentalmente como fuente de dinero en efectivo. El tamaño medio (±desviación típica) del rebaño por hogar fue de 10,8 ± 7,25 y 48,56 ± 52,21 para las razas de las tierras bajas occidentales y la raza Abergelle, respectivamente. Caracteres productivos como la conformación corporal, los partos múltiples y la producción lechera resultaron ser los principales criterios de selección para la mejora genética de las cabras. La mayoría de las cabras Abergelle presentan capas de color marrón rojizo (23,8 por ciento) o marrón (19,7 por ciento), siendo el pelo corto y suave. Todas las cabras Abergelle tienen cuernos, el 11,1 por ciento tienen mamellas y el 8,0 por ciento de los machos presentan pelliza. El blanco (20,4 por ciento) y la mezcla del blanco con otros colores fueron los colores predominantes para la capa de las cabras de las tierras bajas occidentales. El 42,3 por ciento de los machos y el 5,1 por ciento de las hembras de la población caprina de las tierras bajas occidentales presentan pelliza. La media por mínimos cuadrados para el peso corporal, la circunferencia torácica, la longitud del cuerpo y la alzada a la cruz de las cabras de las tierras bajas occidentales fue de 24,00 ± 0,19 kg, 65,27 ± 0,23 cm, 54,8 ± 0,21 cm y 62,60 ± 0,22 cm, respectivamente. Los valores correspondientes para las cabras Abergelle fueron 18,34 ± 0,22 kg, 61,03 ± 0,27 cm, 51,00 ± 0,24 cm y 58,99 ± 0,25 cm, respectivamente. Los programas para la mejora de las razas de estas áreas deberían tener en cuenta los roles multifuncionales de las cabras, las prácticas de manejo y cría y las preferencias de los ganaderos.

Palabras clave: *medidas corporales, criterios de selección, sistema de producción, cabra Abergelle, cabra de las tierras bajas occidentales, Etiopía*

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Introduction

Indigenous goat populations in tropical countries are a valuable genetic resource, because of their adaptation to harsh climatic conditions, their ability to better utilize the limited and poor quality feed resources and their tolerance to a range of diseases (Kosgey and Okeyo, 2007). Under these prevailing conditions, goat production is an important activity for smallholders. This also holds true for Ethiopia, where 21.9 million goats are kept by resource poor farmers across the country (CSA, 2010b). They provide owners with multipurpose functions such as source of income, meat, milk, manure, insurance and cultural values (Legesse *et al.*, 2008; Assen and Aklilu, 2012). Despite their importance and potential, goats are the most neglected in livestock research and development activities of the country (Tsegahun *et al.*, 2000).

Designing and implementation of appropriate management and breed improvement programmes based on indigenous breeds, which are appropriate to the existing conditions can contribute substantially to improving the livelihood of farmers. Description of production system and environment, knowledge of management of the breed, characterizing morphological characters and productivity level of the breeds in their habitat are the first step to develop sustainable improvement and conservation programme of farm animal genetic resources (Sölkner, Nakimbugwe and Valle-Zárate, 1998; Duguma *et al.*, 2010; FAO, 2010; Gizaw *et al.*, 2011). The objectives of this study were to describe the production systems and the morphological characteristics of Western lowland and Abergelle goats in Ethiopia for designing possible breeding strategies.

Materials and methods

Description of the study areas

The study was conducted during July 2011 to September 2011 in Metema and Abergelle districts of the Amhara National Regional State of Ethiopia (Figure 1). Metema and Abergelle districts were purposively selected for this study to address goat production in two different agro-ecological zones, farming systems and goat breeds. Metema district is located in a wet-lowland agro-ecological zone and in the North Western part of the country, 860 km from the capital Addis Ababa. The altitude ranges from 550 to 1 608 m and the latitude from 12°40′N to 13°14′N. The rainfall pattern is unimodal with a mean annual range from 850 to 1 100 mm, occurring from June to September (IPMS, 2005). Temperature ranges from a minimum of 22 °C to a maximum of 43 °C (IPMS, 2005). The production system is a mixed crop–livestock system with dominance of crop production as there is a high potential for biomass production. The dominant goat breed is Western lowland. The second study area, Abergelle district is in the dry/submoist highland agro-ecological zone of the northern part of the country, 780 km from Addis Ababa. The altitude ranges from 1 150 to 2 500 m with the latitude of 12°18′N to 13°06′N. The mean annual rainfall ranges from 250 to 750 mm, falling mainly from July to September (DOARD, 2010). The rainfall pattern is very erratic and uneven. Owing to this erratic nature of rainfall, frequent crop failure and drought are common phenomena in the area. The production system is a mixed crop–livestock system with a focus on livestock, mainly Abergelle goat production.

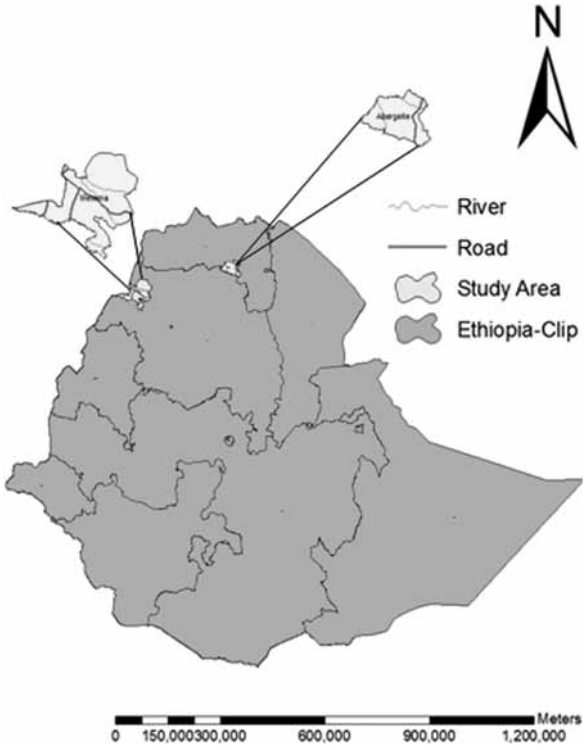

Figure 1. Map of the study areas.

Data collection

Description of production systems

Two villages, one from each district, were selected as the study sites based on goat production potential and willingness of the farmers to participate in a community-based goat improvement programme. A total of 120 goat keepers (60 from each district) were randomly selected and interviewed. For the interviews structured questionnaires were used that covered the following topics: general household characteristics, purpose of keeping goats, livestock ownership, flock structure, performance of goats, management and breeding practices and goat production constraints. Before the survey was conducted, enumerators were trained and the questionnaire was pretested. General information and environmental conditions of the study areas were obtained through secondary data, field observation, informal interviews with farmers and the reports of District Office of Agriculture and Rural Development.

Morphological characterization

A total of 476 Western lowland and 534 Abergelle goats with different dentition classes were used for the morphological characterization. They were classified into six age groups based on their dentition; kids (<6 months), young (between 6 and 12 months), 1 pair of permanent incisors (1PPI) (1 year), 2PPI (2 years), 3PPI (3 years) and 4PPI (≥4 years) (FAO, 1994). The kids and the young were differentiated by asking the age of animals from the owners. Qualitative characteristics (coat colour and pattern, presence or absence of wattles and ruff and hair type) and linear measurements (body weight, body length, chest girth and height at withers) were recorded and measured by using the standard format adapted from the FAO (1986) breed descriptor list. Body weight (kg) was determined using suspended spring scales and other body measurements were taken using a flexible metal tape after restraining and holding the animals in natural position. A total of 726 female animals were available for body weight and other body measurements. Pregnant animals were excluded from the measurement to avoid overestimation.

Data analysis

Both the survey and morphological characterization data were analysed using the Statistical Analysis System (SAS, 2009). The survey data were analysed using descriptive statistics. Chi-square or *t*-test was employed when required to test the independence of categories or to assess the statistical significance. Indices were calculated for ranked variables (reasons of goat keeping, selection criteria and production constraints). Indices were computed as: sum of ($3x$ for rank $1 + 2x$ for rank $2 + 1x$ for rank 3) given for a given reason divided by the sum of ($3x$ for rank $1 + 2x$ for rank $2 + 1x$ for rank 3) for overall reasons. Qualitative characteristics of the breeds from morphological characterization data were analysed by frequency procedures. A general linear < B> </B > model (GLM) procedure was used to analyse body weight and other linear body measurements. The male animals were excluded in the model in analysis of body weight and other body measurements because only a few male animals were available at older age/dentition classes. Homogeneity of variance test for body weight in natural scale and log transfer scale at different age classes were also done to see within breed variability.

The statistical model used was

$$Y_{ijk} = \mu + A_i + B_j + (A \times B)_{ij} + e_{ijk},$$

where Y_{ijk} is the observation on body weight, chest girth, body length and height at withers; μ is the Overall mean; A_i is the fixed effect of age ($i \leq 6$ months, 6–12 months, 1PPI, 2PPI, 3PPI, 4PPI); B_j is the fixed effect of breed (j = Western lowland, Abergelle); $(A \times B)_{ij}$ is the interaction effect of age with breed; and e_{ijk} is the effect of random error.

Results and discussion

General household characteristics

The majority (91.7 percent) of the respondents in both study areas were male. The mean (SD) age of the respondents was 42.50 (12.01) and 42.00 (12.29) years for Western lowland and Abergelle goat keepers, respectively. The mean family size was 5.40 ± 1.85 and 6.30 ± 2.34 for

Table 1. Ranks of purpose for keeping goats.

Purpose	Study communities							
	Western lowland goat owners				Abergelle goat owners			
	Rank				Rank			
	1st	2nd	3rd	Index	1st	2nd	3rd	Index
Income	52	8	–	0.50	38	13	7	0.41
Manure	–	1	3	0.014	8	14	21	0.205
Meat	3	31	25	0.27	1	4	13	0.067
Milk	–	–	–	–	12	28	15	0.3
Saving	5	20	25	0.22	–	–	3	0.01
Skin	–	–	4	0.01	–	–	–	–

The highest index value means the highest importance.

Western lowland and Abergelle, respectively. This was higher than the national average of 4.80 (CSA, 2010a). In Western lowland goat keepers, the majority of respondents (56.6 percent) were able to read and write, whereas in Abergelle only 18 out of 60 farmers were literate. The relatively higher proportion of literate household heads for Western lowland goat owners would be a good opportunity to implement a goat improvement programme as it might be easier for them to record performance and pedigree information. The average land holding (5.03 ± 2.78 ha) of Western lowland goat owners was significantly higher ($P < 0.05$) than land holding of Abergelle goat owners (1.00 ± 1.47 ha). These figures include only privately owned land for crop production. For grazing, communal grazing areas are used.

Purpose of keeping goats

Table 1 shows the purpose of keeping goats and their respective rank by study areas. Better understanding of the purposes of keeping goats is a prerequisite for defining breeding goals (Jaitner *et al.*, 2001). The purpose of goat keeping identified in this study is in line with previous studies from Ethiopia and other African countries (Kosgey *et al.*, 2008; Legesse *et al.*, 2008; Assen and Aklilu, 2012). The role of goat as a source of cash income was found to be the primary reason of keeping goat in both study areas with index values of 0.5 and 0.4 for Western lowland goat keepers and Abergelle, respectively. Milk production was ranked as the second most important role in Abergelle, while consumption of goat milk was considered as a cultural taboo in Western lowland goat breeders. The value of manure was ranked third in Abergelle, whereas for Western lowland goat breeders it was ranked fourth.

Western lowland goat breeders gave higher priority to meat production (Rank 2) and savings (Rank 3) compared with Abergelle goat keepers. These results clearly show that goat rearing is seen as an option not only to generate income through sale of slaughter animals but also contribute to the household consumption through meat and milk production. Based on the above, we conclude that the main breeding goal of Western lowland goat breeders is to increase meat production for marketing and consumption, whereas Abergelle goat breeders wish to increase meat as well as milk production.

Livestock holding and flock structure

This study revealed that farmers keep mixed livestock species. The average ± SD ownership per household of cattle, goats, sheep and donkeys for Western lowland goat owners were 10.1 ± 7.8, 10.8 ± 7.2, 0.3 ± 1.5 and 1.0 ± 0.3, respectively. The corresponding values for Abergelle were 7.6 ± 6.8, 48.5 ± 52.2, 6.4 ± 11.6 and 1.3 ± 1.4, respectively (Table 2). Goats were found to be an important species owned by respondents in both study areas, particularly in Abergelle. The average flock size of goats in Metema was significantly ($P < 0.05$) lower than the average flock size in Abergelle. FARM Africa (1996) reported 11 goats per household for Western lowland flocks and 20 goats per household for Abergelle flocks. The relatively higher flock size of Abergelle goats indicates the importance of goat production and a strong scope for breeding activities in the community.

The proportion of goats at different sex and age classes in both study areas follow similar trends, where breeding does represent the largest class, followed by kids (Table 2). These findings are in line with the results of Deribe (2008) and Tsegaye (2009) who reported 48.1

Table 2. Age structure of goats in flocks of the different study communities.

Age class	Study communities							
	Western lowland goat owners ($N = 60$)				Abergelle goat owners ($N = 60$)			
	Mean (number of goats)	SD	Range	%	Mean	SD	Range	%
Doe	4.2	2.32	1–10	44.79	25.9	36.29	2–240	51.80
Buck	0.6	0.92	0–4	4.14	2.8	2.94	0–15	6.65
Castrated	0.4	0.80	0–4	2.27	0.6	2.07	0–13	0.56
Young Buck	1.0	1.42	0–5	7.21	4.6	5.38	0–30	9.60
Young Doe	1.6	1.81	0–8	12.80	6.6	7.33	0–35	12.89
Kid	3.1	2.58	0–10	28.75	9.5	14.29	0–90	18.40

N, number of households; SD, standard deviation.

percent breeding does for Metema and 56.6 percent breeding does for Abergelle region, respectively. In Western lowland goat, breeding does make up to 44.8 percent of the flock followed by kids (28.75 percent), young does (did not give birth) (12.8 percent), young bucks (not sexually active) (7.21 percent), bucks (4.14 percent) and castrates (2.27 percent). A similar pattern was also observed in Abergelle with 51.8 percent breeding does, 18.4 percent kids, 12.89 percent young does, 9.60 young bucks, 6.65 percent bucks and 0.56 percent of castrates. The lower the proportions of the kids in the Abergelle area were because of seasonal kidding. As the area is drought prone area, most of the kidding happened between November and December following the active mating at the wet season (June and July).

The ratio of breeding buck to breeding does was 1:7 for Western lowland goat and 1:12 for Abergelle, which was higher than the recommended ratio of 1:25 for tropical traditional production system (Wilson and Durkin, 1988).

Selection criteria and breeding practice

Selection criteria for breeding does and bucks are summarized in Table 3. For Western lowland goat owners, the most important selection criteria for breeding does were multiple births, body conformation, mothering ability and kid growth with index values of 0.34, 0.16, 0.15 and 0.11, respectively. Coat colour, fertility traits (kidding interval and age at 1st kidding) were also mentioned as selection criteria but with lower ranking. The probable reason for high emphasis on multiple births as the preferred trait by Western lowland goat keeper could be because of the high availability of the feed throughout the year and the breed potential. Around 1.6 litres per kidding were reported by Western lowland goat breeders. For Abergelle goat owners, milk yield, body conformation and multiple births were ranked as first, second and third important selection criteria with index values of 0.32, 0.21 and 0.12, respectively. Drought resistance, coat colour, kidding interval, kid growth, mothering ability and pedigree information were also described as selection criteria. Body conformation followed by coat colour were found as the most important selection criteria of breeding bucks in both study communities with the index values of 0.33 and 0.22 for Western lowland goat keepers and 0.31 and 0.25 for Abergelle, respectively. The preferred colours in Western lowland goat breeders were white, red and patchy of those colours. The preferred colours for Abergelle goat breeders were red brown and red. Plain black was the less preferred colour in both communities. Owing to the relatively large flock sizes per household in Abergelle goat, farmers paid high emphasis on sexual activity of breeding bucks. In general, goat owners in both study sites preferred size and other performance traits. The improvement of traits related with growth performance can be achieved easily through village-level selection as the traits are easy to measure and have high heritability.

In both study areas, mating was uncontrolled and random, since bucks were mixed with the does throughout the year. Most of the goat keeper respondents (91.67 percent) in Western lowland practiced mixing of their flock during the grazing period on an average with five other flocks. However, in Abergelle only 15 percent of the respondents allowed their flocks to mix with other flocks during grazing. As explained by Kosgey *et al.* (2006), uncontrolled

Table 3. Selection criteria for breeding does and bucks.

Selection criteria	Western lowland goat owners				Abergelle goat owners			
	Rank			Index	Rank			Index
	1st	2nd	3rd		1st	2nd	3rd	
Breeding does								
Body conformation	4	15	13	0.156	14	13	5	0.211
Twinning	32	9	7	0.340	6	10	5	0.124
Milk yield	2	–	1	0.019	20	20	10	0.317
Mothering ability	7	12	8	0.151	2	3	10	0.063
Kidding interval	4	7	3	0.082	7	3	3	0.086
Kid growth	2	12	9	0.110	3	4	8	0.072
Colour	2	4	12	0.074	1	3	11	0.057
Age of 1st kidding	–	–	1	0.003	–	–	–	–
Drought resistance	–	–	–	–	5	1	2	0.055
Pedigree (ancestor performance)	6	–	2	0.0560	–	1	2	0.0110
Breeding bucks								
Appearance	20	25	5	0.330	20	18	12	0.310
Colour	11	11	16	0.225	9	24	16	0.254
Libido	2	3	4	0.045	20	5	13	0.232
Growth rate	13	1	15	0.216	3	8	8	0.092
Pedigree	8	3	11	0.116	7	1	4	0.075
Horn	–	–	4	0.017	–	2	4	0.022
Drought resistance	–	1	2	0.011	1	2	1	0.030
Age at 1st mating	–	15	1	0.003	–	–	–	–

mating together with a small flock size would increase the level of inbreeding. On the other hand, practice of mixing flocks would minimize the problem of inbreeding by increasing the chance of mating of unrelated animals (Jaitner *et al.*, 2001). The implication of these results is that a cooperative village-level breeding scheme would be appropriate for Western lowland goat breeders, while selection within individual flocks could be possible in Abergelle goat given the individual flock grazing practice and the large flock size. There is a significant (χ^2, $P < 0.05$) difference in buck ownership between the two communities. Only 40 percent of the respondents of Western lowland goat keepers had their own buck; however, higher proportions of (86.67 percent) Abergelle goat keepers had their own buck. The farmers, who had no buck, used bucks from their neighbours and grazing lands. Regardless of the communities, farmers kept bucks mainly for mating and later fattening and slaughter.

Castration of bucks after mating/service was a common practice in both the study areas. Fattening was the most important reason of castration (77.5 percent for Western lowland goat keepers and 82.32 percent in Abergelle). Castration to control mating and temperament were reported by a few respondents. The average age (2.10 ± 0.68 years) of castration for Western lowland goat was significantly ($P < 0.001$) lower than that of Abergelle (4.40 ± 1.05 years). Keeping of intact male in the flock for a prolonged period would increase the hazard of inbreeding through increasing the chance of mating of bucks with their daughters. The practice of castration reported in both communities would be good for implementing village-level selection through avoiding of mating of unwanted bucks and it would also increase the value of culled bucks.

Reproductive performance

The average reproductive performances of goats as reported by the respondents are given in Table 4. There was a significant ($P < 0.001$) difference between the two breeds for all aspects of reproductive performance considered. The better performance of Western lowland goats may be because of the genetic superiority of the breed and/or better feed situation of the area. Age at first kidding reported in female Western lowland goat (12.4 months) and Abergelle (15.5 months) goat were comparable to the report of 13.6 months for Metema area (Tsegaye, 2009) and 14.9 months for Abergelle (Deribe, 2008). The kidding interval, 6.29 months for Western lowland and 8.28 months in Abergelle, observed in this survey was lower than that given in the earlier reports of 8.4 months for Western lowland goat (Tsegaye, 2009) and 11.31 months for Abergelle goat (Deribe, 2008).

Production constraints

A good understanding of the existing production constraints in the study regions is essential for planning appropriate interventions. In both the study areas, high prevalence of disease and parasites were mentioned by the goat owners as the most limiting factor for goat production. All respondents complained about the low efficiency of veterinary service provided by the government. Feed shortage and recurrent droughts were also identified as important constraints for Abergelle goat owners. Goat keepers moved their goats to other areas where enough feed was available as a possible mitigation strategy. Feed shortage was mentioned by only a few goat owners of Western lowland. This is because the area receives good rain and there is a relatively large area of communal grazing land. Predators, input (mostly veterinary service), lack of improved genotypes, labour and capital, theft, lack of market and lacking extension service were also reported as limiting factors of goat production in both study areas. This result is in line with goat production constraints reported for Southern Ethiopia (Tibbo, 2000; Legesse *et al.,* 2008) and Northern Ethiopia (Tsegaye, 2009; Assen and Aklilu, 2012).

Morphological characteristics

Qualitative characteristics

Qualitative characters observed for female and male goats of the two breeds are presented in Tables 5 and 6. The study revealed that the two breeds have a wide range of coat colours. Most of (54 percent) Abergelle goats have a plain coat pattern, while most (60 percent) of Western lowland goats show a mixture of different colours with

Table 4. Reproductive performance of goats as reported by respondents in the surveyed area.

Trait	Breed								Test
	Western lowland				Abergelle				
	N	Mean	SD	Range	*N*	Mean	SD	Range	*P*-value
Age at 1st mating of male (months)	60	7.4	2.01	4–12	60	12.3	4.48	6–24	0.0001
Age at 1st kidding (months)	60	12.4	1.39	9–18	59	15.5	5.48	10–18	0.0001
Kidding interval (months)	59	6.3	0.64	6–9	57	8.3	3.37	6–24	0.0001
Longevity of female goats (years)	57	6.6	1.47	3–10	59	8.0	2.20	4–15	0.0001
Life time number of kids	54	17.3	5.98	6–30	54	12.2	5.98	5–25	0.0001

N, number of respondents; SD, standard deviation.

Table 5. Qualitative characteristics of Abergelle goat.

Characters		Male		Female		Total	
		N	%	*N*	%	*N*	%
Colour	Red brown	33	21.85	92	24.66	125	23.85
	White and brown	26	17.22	56	15.01	82	15.65
	Brown	36	23.84	67	17.96	100	19.66
	Red brown and white	17	11.75	50	13.4	67	12.79
	Brown and white	7	4.64	28	7.51	35	6.68
	Others	32	21.18	92	24.66	124	5.34
Coat pattern	Plain	81	64.8	203	54.42	284	54.2
	Patchy and spotted	70	35.2	170	45.58	240	45.8
Hair type	Short and smooth	151	100	373	100	524	100
Wattle	Present	12	7.95	41	10.99	53	10.11
	Absent	139	92.05	332	89.99	472	89.89
Ruff	Present	42	27.81	–	–	42	8.02
	Absent	109	72.19	373	100	492	91.98

N, number of goats observed.

patchy and spotted patterns. Red brown, brown and the combination of these colours with other colours are the predominant coat colours observed in Abergelle goat (Figures 2 and 3). White and the combination of white with other colours were the major coat colours of Western lowland goat (Figures 4 and 5). Irrespective of breeds and sex groups, all observed goats had short and smooth hair. There is a very small number (3.36 percent) of animals of the Western lowland goat breed, which have a long and coarse hair type. Wattles were found in Western lowland goats (24.53 percent) and Abergelle goats (10.11 percent). A variation in the existence of ruff was observed between breeds and sex groups. Only 8.0 percent of males of Abergelle goats have a ruff and 42.28 and 5.11 percent of males and females of Western lowland goats have a ruff, respectively. Almost all males and females of Abergelle goats had horns and around 5 percent of Western lowland goats were polled. Most of the qualitative characters of both breeds obtained in this study were in agreement with the results of FARM-Africa (1996).

Quantitative characteristics

The male animals were excluded from the model owing to only a small number available at older age. However, the sexual dimorphism was observed at lower age groups (data not shown). Male goats showed higher values for all measurements than their female counterparts. The least square means and standard error of body weight, chest girth, body length and height at withers of female Abergelle goats were 24.00 ± 0.19 kg, 65.27 ± 0.23 cm, 54.8 ± 0.21 cm and 62.60 ± 0.22 cm, respectively. The corresponding value for Abergelle goats were 18.34 ± 0.22 kg, 61.03 ± 0.27 cm, 51.00 ± 0.24 cm and 58.99 ± 0.25 cm, respectively (Table 7).

Breed had significant effect on all body measurements. The Western lowland goat had the highest values for all

Table 6. Qualitative characteristics of Western lowland goat.

Characters		Male		Female		Total	
		N	%	*N*	%	*N*	%
Colour	White	37	30.08	60	17	97	20.38
	Brown and White	20	16.26	67	18.98	87	18.28
	Brown and Red brown	12	9.76	29	8.22	41	8.61
	Red brown and White	17	13.81	77	21.81	94	19.75
	Red black and white	12	9.76	35	9.92	47	9.87
	Others	25	20.32	84	25.63	109	23.1
Coat pattern	Plain	55	44.72	126	35.59	181	37.95
	Patchy and spotted	68	55.29	228	64.4	296	62.05
Hair type	Short and smooth	116	95.08	344	97.18	460	96.64
	Long and course	6	4.92	10	2.82	16	3.36
Wattle	Present	36	29.27	81	22.88	117	24.53
	Absent	87	70.73	273	77.12	360	75.47
Ruff	Present	52	42.28	18	5.11	70	14.74
	Absent	71	57.72	334	94.89	405	85.26

N, number of goats observed.

Figure 2. Adult male of Abergelle goat.

Figure 4. Young buck of Western lowland goat.

measurements. Age strongly influenced ($P < 0.001$) body weight and other linear body measurements. Except for age classes 1PPI and 2PPI, there was a significant increase in weight from the lower dentition class to the higher. A similar trend was observed for chest girth, body length and height at withers. This situation is expected since the size and the shape of animals change as the age increases.

The interaction effect of breed with age affected body weight ($P < 0.01$) and chest girth ($P < 0.05$). But, there was no significant ($P > 0.05$) age by breed interaction effect on body length and height at withers. Western lowland goats at dentition group 3PPI and 4PPI were significantly heavier than other categories. Western lowland and Abergelle goats at older age (3PPI and 3PPI) had the highest chest girth compared with other age breed interaction groups. The weight of 32.62 kg for Western lowland and 25.64 kg for Abergelle goat obtained for mature females were slightly lower than the mature weight of 33.9 kg of Western lowland and 28.4 kg of Abergelle goat reported by FARM Africa (1996). The average weight at young age of 14.11 kg of Abergelle goat was similar to the report of Deribe (2008) for the same breed, who reported 13.5 kg of weight at yearling age.

There was a significantly higher within-breed variation of body weight of Western lowland goats compared with the Abergelle goats in natural scale for most of the age categories. However, there was no significant difference for many of the age categories except for the age group 3PPI after transformation to the log scale (Table 8). The relatively higher variation observed in Western lowland goat could be a larger scope for genetic improvement of Western lowland goats through selection compared with the Abergelle goats.

Conclusions

This study provided insight into production systems and physical characteristics of Western lowland and Abergelle breeds of goat in Ethiopia. Goat farming was found to be an important component for livelihoods of both communities, with higher importance for Abergelle goat breeders. The goat keepers in both communities keep goats for multiple purposes. Keeping goat for cash income was important for both communities, while milk production was important only for Abergelle goat breeders. Selection criteria are similar, but with different emphases on specific traits. Farmers give emphasis to growth (body conformation) and other performance (such as milk

Figure 3. Adult female of Abergelle goat.

Figure 5. Adult female of Western lowland goat.

Table 7. Least square means and standard error of body weight, body length and height at withers at different breed and age groups.

Level	Body weight(kg)		Chest girth (cm)		Body length(cm)		Height at Wither (CM)		*N*
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	
Breed	***		***		***		***		
WL	24.00	0.19	65.27	0.23	54.80	0.21	62.60	0.22	340
Abergelle	18.34	0.22	61.03	0.27	51.00	0.24	58.99	0.25	368
Age	***		***		***		***		
Kids	10.35^{a}	0.42	48.84^{a}	0.51	41.26^{a}	0.46	49.50^{a}	0.49	95
Young	17.08^{b}	0.28	58.98^{b}	0.33	49.55^{b}	0.30	58.27^{b}	0.32	157
1PPI	21.91^{c}	0.41	64.62^{c}	0.50	54.36^{c}	0.45	62.43^{c}	0.47	66
2PPI	23.07^{c}	0.41	66.36^{c}	0.49	55.28^{c}	0.44	63.42^{cd}	0.47	72
3PPI	25.50^{d}	0.38	68.92^{d}	0.45	57.49^{d}	0.41	65.12^{de}	0.43	79
4PPI	29.13^{e}	0.22	71.19^{e}	0.26	59.44^{e}	0.24	66.02^{e}	0.25	239
Age × Breed	**		*		NS		NS		
Kid × WL	12.25^{b}	0.38	50.64^{b}	0.45	43.00	0.41	50.95	0.43	76
Kid × Abergelle	8.46^{a}	0.76	47.05^{a}	0.91	39.52	0.82	48.05	0.87	19
Young × WL	20.04^{d}	0.45	62.13^{d}	0.55	51.85	0.50	60.22	0.53	52
Young × Abergelle	14.11^{c}	0.32	55.82^{c}	0.39	47.24	0.35	56.32	0.37	105
1PPI × WL	24.73^{fg}	0.63	66.36^{e}	0.77	56.37	0.69	64.59	0.73	27
1PPI × Abergelle	19.10^{d}	0.53	62.89^{d}	0.64	52.35	0.57	60.28	0.61	39
2PPI × WL	25.38^{g}	0.48	68.12^{f}	0.58	56.81	0.52	65.06	0.55	47
2PPI × Abergelle	20.76^{de}	0.66	64.60^{de}	0.80	53.76	0.72	61.78	0.76	25
3PPI × WL	29.01^{h}	0.48	71.35^{gh}	0.58	59.58	0.52	66.89	0.55	47
3PPI × Abergelle	21.99^{ef}	0.58	66.50^{ef}	0.70	55.40	0.63	63.35	0.67	32
4PPI × WL	32.62i	0.34	73.02^{h}	0.41	61.18	0.37	67.88	0.40	91
4PPI × Abergelle	25.64^{g}	0.27	69.35^{fg}	0.32	57.70	0.29	64.16	0.31	148

Column means within each sub-class with different superscript letter are statistically different. NS, non-significant, $*P \leq 0.05$, $**P \leq 0.01$, $***P \leq 0.001$. PPI, pair of permanent incisors; SE, standard error; WL, Western lowland.

Table 8. Variability of the body weight at different age groups.

Age classes	WL		Abergelle		*P*-value	WL	Abergelle	*P*-value
	N	SD	*N*	SD		CV	CV	
Kid	76	2.61	19	1.55	0.0198	0.21	0.18	0.2642
Young	52	3.20	106	2.59	0.0748	0.16	0.18	0.7201
1PPI	27	3.10	39	2.09	0.0342	0.12	0.10	0.3807
2PPI	47	3.63	25	3.05	0.3198	0.18	0.14	0.8935
3PPI	47	4.73	32	2.45	0.0028	0.16	0.11	0.0383
4PPI	94	4.61	148	3.12	<0.0001	0.14	0.12	0.1127

WL, Western lowland goat; *N*, number of animals; SD, standard deviation; CV, coefficient of variation.

yield and litter size) traits. Individual flock mating is a major practice for Abergelle goat keepers, whereas group flock mating is the dominant practice for Western lowland goat keepers. Furthermore, morphological characterization revealed that there is a variation between and within the studied breeds. Western lowland goats are on an average not only bigger than Abergelle goats but also show considerably higher variation in body size. This indicates a large scope of genetic improvement by selecting best young males. Community-based breeding programmes considering the multifunctional roles of goats and the breeding objectives of farmers should be implemented.

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Infrastructure for sustainable use of animal genetic resources in Southern and Eastern Africa

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Summary
The Global Plan of Action (GPA) for Animal Genetic Resources (AnGR) adopted by FAO recognizes the role of AnGR for food security through improved productivity while maintaining genetic diversity. A critical issue for conservation and genetic improvement programmes is the availability of supportive infrastructure. The objective of the present study was to assess existing and needed infrastructure for sustainable use of AnGR in a sample of countries in Southern and Eastern Africa. Information was primarily obtained from semi-structured interviews with key personnel in animal breeding during country visits. Countries studied are at different stages of development. No complete breeding programmes are in place but some conservation programmes exist in most countries. Except for a few cases, livestock recording as basis for R&D and breeding practice is lacking. The institutional setup to support animal breeding programmes is fragmented and needs to be better integrated. Shortage of skilled personnel is noted as the most serious constraint for development. Countries with least university training in animal breeding have least developed AnGR activities. However, since the GPA was agreed upon, many countries have re-casted their policies and make efforts to develop breeding policies. A change in mindsets aiming at closer collaboration among institutions, farmer involvement and capacity development and strengthening at all levels is suggested.

Keywords: *breeding programme, livestock recording, policy, human resource, institution*

Résumé
Le Plan d'Action Mondial pour les Ressources Zoogénétiques adopté par la FAO reconnaît le rôle que les Ressources Zoogénétiques jouent dans la garantie de la sécurité alimentaire en améliorant la productivité tout en conservant la diversité génétique. La disponibilité d'une infrastructure de soutien s'avère une question cruciale pour les programmes de conservation et d'amélioration génétique. L'objectif de cette étude est d'évaluer l'infrastructure existante et celle requise pour l'utilisation durable des Ressources Zoogénétiques dans un échantillon de pays de l'Afrique Méridionale et Orientale. L'information a été essentiellement obtenue au moyen d'interviews semi-structurés réalisés, pendant les visites aux pays, à du personnel clé en matière d'élevage. Les pays étudiés se trouvent à différents niveaux de développement. Il n'y a pas de programmes complets d'amélioration génétique en place mais des programmes de conservation existent dans la plupart des pays. À quelques exceptions près, les pays manquent de systèmes d'enregistrement du bétail servant de base à l'exercice de la R&D (recherche et développement) et de l'amélioration génétique. La structure institutionnelle de soutien aux programmes d'amélioration génétique animale est fragmentée, une meilleure intégration de celle-ci étant donc nécessaire. Le manque de personnel qualifié a été identifié comme étant la contrainte la plus grave pour le développement. Les pays avec le moins de formation universitaire en sélection animale sont ceux qui présentent les activités les moins développées en matière de Ressources Zoogénétiques. Néanmoins, depuis l'adoption du Plan d'Action Mondial, plusieurs pays ont reformulé leurs politiques et sont en train de faire des efforts pour développer des directives de sélection. Un changement de mentalité est suggéré, à tous les niveaux, en vue d'une collaboration plus étroite entre institutions, l'engagement des éleveurs et le développement et renforcement des capacités.

Mots-clés: *programme de sélection, enregistrement du bétail, politiques, ressources humaines, institutions*

Resumen
El Plan de Acción Mundial sobre los Recursos Zoogenéticos adoptado por la FAO reconoce el papel que los Recursos Zoogenéticos desempeñan en la garantía de la seguridad alimentaria mejorando la productividad y manteniendo a la vez la diversidad genética. Disponer de una infraestructura de apoyo es una cuestión crucial en los programas de conservación y mejora genética. El objetivo del presente estudio es evaluar la infraestructura existente y la necesaria para el uso sostenible de los Recursos Zoogenéticos en un conjunto de países de África Meridional y Oriental. La información fue fundamentalmente obtenida a través de entrevistas semiestructuradas realizadas, durante las visitas a los países, a personal clave en la cría animal. Los países estudiados se hallan a distintos niveles de desarrollo. No hay programas integrales de mejora genética implantados pero en la mayoría de los países existen algunos programas de conservación. Exceptuando unos pocos casos, se carece de registro ganadero como base para la práctica de la I + D (investigación y desarrollo) y la mejora genética. El sistema institucional de apoyo a los programas de mejora genética animal está fragmentado, con lo que se hace necesaria una mejor integración del mismo. La escasez de personal cualificado ha sido identificada como la limitación más

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grave para el desarrollo. Los países con la menor formación universitaria en cría animal son aquellos que presentan las actividades menos desarrolladas en materia de Recursos Zoogenéticos. No obstante, desde la adopción del Plan de Acción Mundial, son muchos los países que han replanteado sus políticas y están haciendo esfuerzos por desarrollar directrices de mejora. Se sugiere un cambio, a todos los niveles, en el modo de pensar con vistas a un estrechamiento de la colaboración entre instituciones, la implicación de los ganaderos y el desarrollo y fortalecimiento de capacidades.

Palabras clave: *programa de mejora, registro ganadero, políticas, recursos humanos, instituciones*

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Introduction

Sustainable conservation and improvement of animal genetic resources (AnGR) are important for food security and for adaptation to possible future changes in production environments, such as climate, market and disease challenges (FAO, 2007b; Boettcher *et al.*, 2010; Hoffmann, 2010). To achieve sustainable genetic improvement of livestock, identification of appropriate breeding objectives and implementation of long-term breeding programmes are required. Traditions, culture and national rules and their variation across countries determine the setup of infrastructure needed to support livestock breeding (Fimland and Oldenbroek, 2007). For animal breeding strategies to be successful certain activities are essential, such as livestock recording, evaluation of data and supporting the farmers with selection tools.

Most breeds have been developed based on traditional knowledge and improved through human interventions and natural selection (FAO, 2009a). However, only structured and systematic breeding programmes have resulted in the impressive genetic improvements starting in the 20th century. For these programmes livestock identification and performance recording that enable use of information for selection of superior breeding stock of appropriate breeds have been essential. On the contrary, in low to medium input systems functioning infrastructure to support breeding activities is often lacking, or is underdeveloped (Wollny, 2003; Rewe *et al.*, 2009; Rege *et al.*, 2011). In order for breeding programmes to succeed, infrastructure such as physical facilities, functioning recording and genetic evaluation systems, are required (Cardellino and Boyazoglu, 2009). Supportive policies, efficient organizations and institutions, competent staff, long-term financial support and strong links between these components are also needed (FAO, 2009b, 2010, 2011; Philipsson *et al.*, 2011; Rege *et al.*, 2011). In many cases systematic breeding programmes, especially for smallholders, have failed (Wurzinger, Solkner and Iniguez, 2011). Most countries in Africa and Asia lack functioning breeding programmes, whereas some Latin American countries developed commercially viable breeding programmes for indigenous breeds and crosses (Madalena, 2012). Common reasons for the failures are lack of involvement and engagement of farmers and other stakeholders (Rewe *et al.*, 2009; Faco *et al.*, 2011; Wurzinger, Solkner and Iniguez, 2011). There is therefore a need to have long-term plans for breeding programmes, which adequately respond to both the present and anticipated future market needs. Both farmers and governments, through supporting policies, need to be engaged and collaborate (Faco *et al.*, 2011).

In the FAO report "The State of the World's Animal Genetic Resources for Food and Agriculture" (SoW) (FAO, 2007b), presented at the first "International Technical Conference on Animal Genetic Resources for Food and Agriculture, Interlaken", a first assessment of global status of livestock biodiversity was reported. Drawing on 169 country reports, contributions from a number of international organizations and 12 specially commissioned thematic studies, an analysis of the state of agriculture biodiversity in the livestock sector was presented. Information on origins and development of the AnGR, their uses and values, distribution and exchange, risk status and threats, as well as the capacity to manage these resources (i.e. institutions, policies and legal frameworks, structured breeding activities and conservation programmes) were presented.

The report provides an overview of AnGR in the world and indicated that countries in Africa are short of the technical, physical, institutional and financial resource capacity needed to enable sustainable utilization and genetic improvement of their livestock. In particular, the critical mass of trained human resources for the management of AnGR is highly insufficient (Ojango *et al.*, 2010, 2011). The SoW report also underlines the importance of research for development of sustainable breeding programmes. So far, most research has been directed towards characterization of indigenous breeds, especially by use of neutral molecular genetic markers, with emphasis on domestication process, trends, and genetic diversity and relationships between populations (Bruford, Bradley and Luikart, 2003; Kugonza *et al.*, 2011; Muigai and Hanotte, 2013), but rather little on different breeding strategies for improvement of indigenous breeds (Cardellino and Boyazoglu, 2009).

Following the Interlaken Declaration (FAO, 2007b), a Global Plan of Action (GPA) for AnGR was internationally agreed upon (FAO, 2007a). The plan spells out the needs for improved productivity and drawing of long-term and sustainable breeding programmes, which are currently mostly

non-existent for the indigenous livestock breeds. Four strategic priority areas were listed: (1) Characterization, Inventory and Monitoring of Trends and Associated Risks, (2) Sustainable Use and Development, (3) Conservation and (4) Policies, Institutions and Capacity Building. The latter emphasizes the strengthening of all institutions involved in AnGR management. Comprehensive assessments of the existing institutional frameworks and capacities need to precede such strengthening to be effective. So far very little has been done to investigate the situation in Sub-Saharan Africa, except for the review by Rewe *et al.*, (2009) of breeding indigenous beef breeds, and an assessment of the Kenyan organization of dairy and beef recording by Kosgey *et al.* (2011). The latter revealed that even though the country has large potentials, relatively few records on livestock are captured and organizations lack coordination. The study concluded that a comprehensive mapping of all institutions and their interests in the sector is necessary and that appropriate reorganization is required to enable closer institutional working relationships and collaboration, as opposed to competition.

The main objectives of this study were to describe and critically assess the existing and needed infrastructure for sustainable utilization of ruminant breeds in a sample of countries in Southern and Eastern Africa. An additional objective was to suggest priority areas for development of sustainable breeding programmes regarding ruminants in the various countries.

Materials and methods

The study comprised three Eastern African countries: Kenya, Tanzania and Uganda, and three Southern African countries: Botswana, Mozambique and Zambia. The countries chosen show a wide variation in production systems, yet are thought to be representative of their region. In-depth examples of infrastructure are given for Tanzania and Zambia.

Livestock in countries studied

In all the countries livestock contributes significantly to people's livelihoods and to the respective countries' Agricultural Gross Domestic Product (percentage of GDP). Table 1 presents a brief summary of general statistics about the number of livestock (ruminants) and the relative importance of agriculture and livestock in each country.

In total there are about 54 million cattle, 47 million goats and 17 million sheep in the six countries. Although large populations of ruminants are kept in Kenya and Tanzania, the relative contribution of livestock to the agriculture GDP is less than 50 percent. Botswana's livestock's contribution to the agriculture GDP is the highest although agriculture contributes to only 2 percent of the total national GDP.

Sources of data

The study is based on materials providing information collected from three sources: the SoW country reports of the six countries prepared between 2003 and 2004 (FAO, 2007c), a workshop with targeted persons in 2009, and from semi-structured interviews carried out at country visits undertaken during 2010. Furthermore, the authors have continued to collate information on relevant issues through various ongoing projects in the countries studied until 2012. Websites of relevant ministries and organizations were also visited to collate recent developments.

Priority has been given to identify the appropriate structures and frameworks needed to achieve the sustainable use of AnGR. Information about the existence and functionality of relevant infrastructure is usually not published, hence specific qualitative methods are needed to gather and analyse pertinent information. In this study we have based the information primarily on interviews and presentations including discussions with highly ranked people as regards knowledge on animal breeding or conservation activities in the chosen countries.

The first type of information consisted of a brief review of the country reports delivered to FAO as basis for the SoW report (FAO, 2007c). Grey literature such as annual reports, project and industry reports and websites were also used. These sources were used to indicate issues that could be followed up in the workshop and in semi-structured interviews when visiting targeted people of the countries in question.

The second source of information was the results of a joint workshop, held in 2009, by members of the AnGR groups of the International Livestock Research Institute (ILRI), the Food and Agriculture Organization of the United Nations

Table 1. General livestock information (The World Bank, 2011; FAO, 2012b, 2013).

General livestock information	Botswana	Kenya	Mozambique	Tanzania	Uganda	Zambia
Number of cattle (1 000)[1]	2 750	18 000	1 265	21 300	8 103	3 000
Number of goats (1 000)[1]	2 000	13 400	5 000	15 200	9 251	2 300
Number of sheep (1 000)[1]	285	10 000	205	4 300	1 902	225
Agr share of total GDP (%)[2]	2	23	32	27	23	21
Livestock share of Agr GDP (%)[1]	82	49	14	21	13	30

Agr = Agriculture; GDP = gross domestic product.
[1]FAOSTAT.
[2]The World Bank.

(FAO) and of the Swedish University of Agricultural Sciences (SLU), in collaboration with the East African Community (EAC) and Southern African Development Community (SADC). Participants at the workshop were drawn from key persons responsible for AnGR issues or related research and development programmes of national institutions including ministries within the countries of the EAC and SADC region. Participants presented and discussed AnGR-related institutions for their respective countries, their activities and current working relationships, and, what priorities and constraints the institutions were facing.

The third type of information was obtained at visits to the six study countries. Qualitative research interview methods, as described by Kvale (1996) were used. Interviews focussed on a number of thematic issues that relate to livestock policies and infrastructure that support AnGR improvement and conservation. The subjects covered during interviews are presented in Table 2. To study the various networks and organizations involved in a given country, a two-stage snowball method was used (Hanneman and Riddle, 2005). First the stakeholders in the countries provided a listing of all organizations with any kind of involvement in AnGR. Thereafter, through on-site interviews, representatives of each institution listed were asked which bodies they were collaborating with, using snowball selection. This method gave the opportunity to successively highlight institutions that were not initially known to the interviewer. Thus, the risk of missing important institutions was minimized. The interviews were semi-structured in order to ensure that the same questions were put forward to all interviewees. Each interview lasted 1–2 h and was transcribed, summarized and analysed separately for each country. Three to ten key persons were interviewed per country, and were later followed up by correspondence for completing questions where needed. The institutions visited and engaged in each of the six countries gave an opportunity for direct contact with people highly involved with different aspects or parts of the livestock sector, such as livestock ministry directors, deans and professors of agricultural schools, representatives from different institutions and organizations responsible for livestock production development or animal breeding issues. In total 15 ministry institutions (excl. research), 11 universities and research institutes and 11 non-governmental organizations or companies were visited.

Table 2. Main topics covered in semi-structured qualitative interviews.

Subject	Question/topic
Role of institution	Vision, mission, livestock and AnGR-related issues, policy and work related to AnGR
Value and importance	Relevance/priority of AnGR and agriculture for the institution and the country
Collaborations	Linkages and partnerships between governmental, parastatal and non-governmental institutions within country, international institutions/organizations
Priorities and constraints	Within institution; between institutions; nationally
Farmers role	Direct role; indirect role
Economy	Contribution to sector development
Market for animal products	Demand, availability, imports and exports, formal and informal market
Breeding and conservation programmes	Programmes reported to be implemented
Human capacity	Specifically in AnGR, Ph.D. holders available

Results and discussion

An overview of the existing institutional frameworks and indications of human capacity is given in Table 3. This is followed by organograms showing more of the details and the relationships between institutions and organizations within Zambia and Tanzania (Figures 1 and 2) and the other countries (Appendix).

As shown the six countries use different institutional setups to tackle the livestock breeding issues, albeit with quite variable ambition and success. Although the animal production conditions and institutions involved vary substantially between the countries, clear common trends and coherent results have been obtained across the countries.

Policies

A livestock breeding policy is an important tool to show the direction of priorities and activities to be conducted in livestock breeding. All the countries have policies on agriculture or livestock development, and in all countries livestock are considered important and thus recognized at government level (Table 3). Since the SoW and the GPA were developed and agreed upon, many countries have recasted their policies and are making efforts to develop breeding policies, although much remains to be done as regards infrastructure and organization. Uganda has legislated a breeding policy with a Livestock Improvement Act since 2009. Also Botswana has a livestock improvement act since 2009. Kenya has a draft livestock breeding policy, but it is not yet published. Tanzania has prepared an animal breeding policy act that is under review by the cabinet.

Higher education and research institutions including animal breeding

All study countries except Mozambique and Zambia offer training at M.Sc. and Ph.D. level including Animal Breeding (AnBr, Table 3). In Mozambique, the animal breeding training is a minor part of the veterinary studies, and in Zambia the subject is covered in the M.Sc. animal production programme. The latter two countries have limited teaching and research support resources for AnBr. The number of Ph.D. holders who are actively involved in higher education (teaching), research or in ministries or organizations

Table 3. Existing components of infrastructure as regards institutional and organizational frameworks related to livestock breeding activities (AnBr and AnGR) in countries studied.

Institutional frameworks and human resources	Botswana	Kenya	Mozambique	Tanzania	Uganda	Zambia
Livestock policy	Agricultural development policy (incl. livestock) available	Available	Draft available	Available	Available	In draft status
Livestock breeding policy/Act	Available	Draft available	None	Draft in progress	Available	None
University training in AnBr	Botswana College of Agriculture M.Sc. and Ph.D. training	University of Nairobi and Egerton University M.Sc. and Ph.D. training More universities BSc courses in AnBr	Eduardo Mondlane University Veterinary studies incl. AnBr	Sokoine University M.Sc. and Ph.D. training	Makerere University M.Sc. and Ph.D. training. More universities B.Sc. courses in AnBr	University of Zambia Animal production programme incl. lectures in AnBr
Human Capacity (Ph.D. holders in AnBr)[1]	Few	Several	Few	Several	Several	None
Research institutes (animal production)	Available, none specifically for AnGR	Several available, none specifically for AnGR	Available, mandate to include AnGR	Available, mandate to include AnBr and AnGR	Several available. Specific institute for AnGR	Available, mandate to include AnBr and AnGR
Farmer and herdbook organizations	Available for different breeds and species	Available for different breeds and species. Extensive activity	Limited availability for different breeds but government and private sector institutions	Available for different breeds and species	Available for different breeds and species	Available for different breeds and species Limited activity

[1]Few meaning 1–3, several meaning >3; AnBr = animal breeding; AnGR = animal genetic resources.

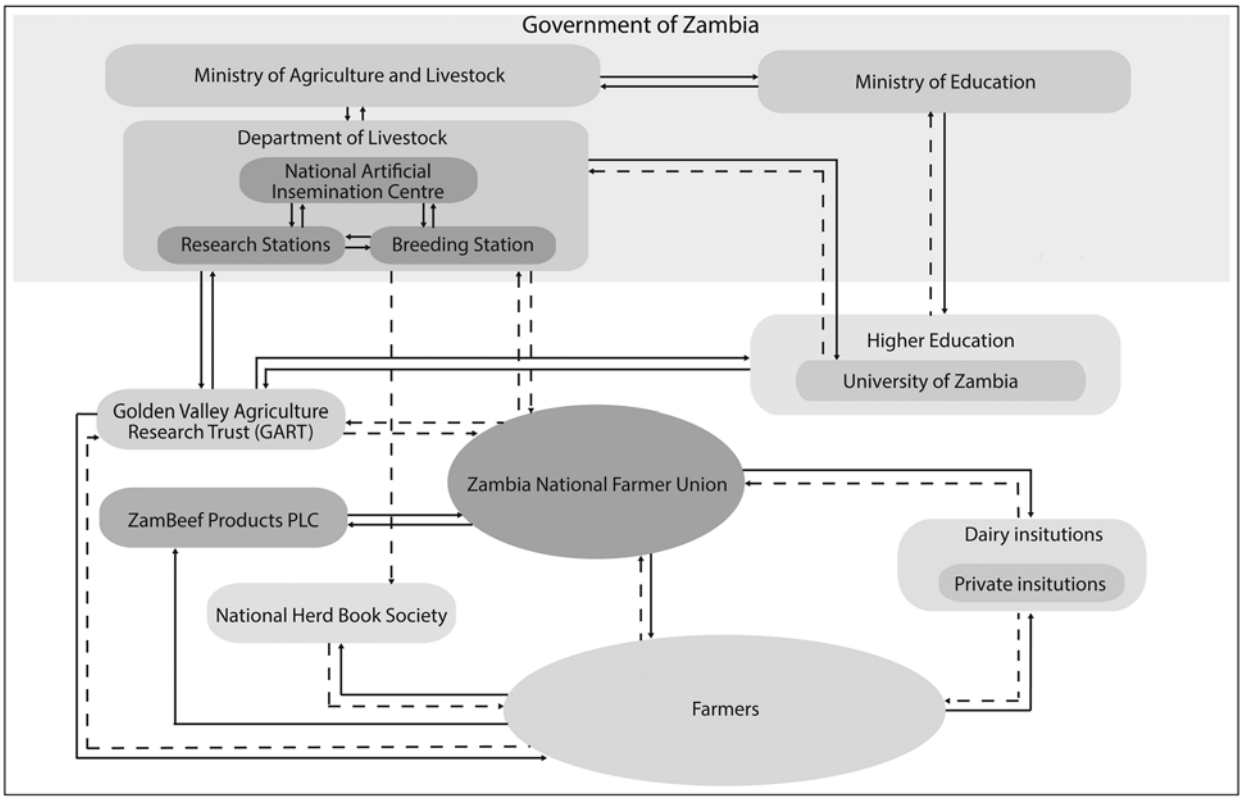

Figure 1. Organogram of institutions related to work with animal genetic resources in Zambia, where a solid line shows high level of interaction and a dotted line shows some degree of interaction. Institutions in circular shape are farmer owned.

directly supporting practical livestock breeding, is an important indicator of the ability of a country to develop and implement breeding programmes. Kenya is best resourced with trained staff holding Ph.D. in AnBr. Uganda and Tanzania have also several Ph.D. holders in AnBr, whereas Botswana and Mozambique have few and Zambia none, at the time of the study. Botswana has, however, gained in its development of recording schemes from cooperation with neighbouring South Africa. Also Zambia and Mozambique are gaining from expertise in South Africa.

Reasons for limited training in AnBr in most of the study countries depend on few or no teachers trained in AnBr. This makes a downward spiral where few teachers train few students. Furthermore, many students think that AnBr is a difficult subject to grasp and it requires well-trained teachers (Ojango *et al.*, 2011).

Farmer and herdbook organizations

Organizations that support farmers exist in many forms. In Botswana breed associations exist for both cattle and small ruminants. According to their livestock improvement act, cattle should be recorded in a national herdbook. To some extent, the South African Stud Book Association undertakes such recordings. The act also aims at supporting the formation of local breederś societies in Botswana.

Kenya has a national livestock breeding organization that runs a studbook and keeps records on performance of dairy cattle. The country also has associations for the different species and livestock breeds (Kosgey *et al.*, 2011). The organizations are governed independently by farmers, and are thus directly less influenced or controlled by government compared with the other countries. More recently, in 2012, the Kenya Animal Genetic Resource Centre (former Central Artificial Insemination Station) was created; its mandate includes conservation of the national AnGR.

Mozambique has a few commercial farms that support various breed developments, but there is no national breeders' association. Government run institutions are, however, responsible for breed conservation. Tanzania has several farmer associations and proposals for breeders' associations. Uganda has several breeders' associations. Zambia has a herdbook society for cattle and a farmers union including livestock breeding associations.

Whatever is to be implemented, it is important that farmers are part of it (FAO, 2007a; Philipsson *et al.*, 2011). Although some farmer organizations with a mandate to improve livestock exist in most countries, they are usually weakly organized, partly due to shortage of trained staff to technically support them. Thus, supporting farmer organizations, or facilitating their formation, to enable them take active part in development of breeding programmes is extremely important (Rewe *et al.*, 2009). This would enable the farmers to not only own the process, but also effectively and sustainably run the activities. For these reasons an active extension service with well-trained

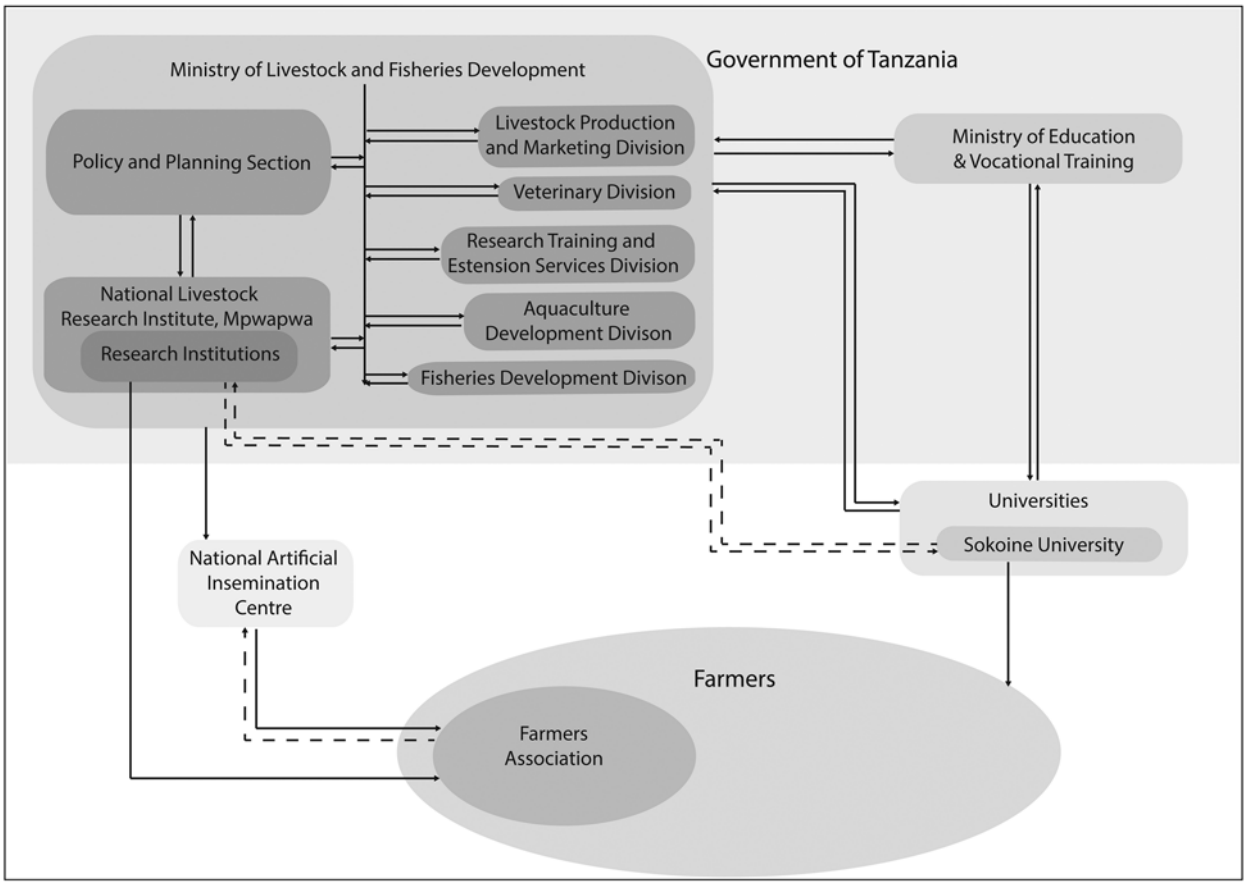

Figure 2. Organogram of institutions related to work with animal genetic resources in Tanzania, where a solid line shows high level of interaction and a dotted line shows some degree of interaction. Institutions in circular shape are farmer owned.

advisors are also needed in all the countries. Relevant universities through innovative and well thought-out partnerships with government extension services can play this role.

Institutional relationships – organograms

Livestock issues usually fall under a ministry of agriculture, but in a few cases separate ministries are responsible for livestock development. In the countries studied, research institutes either fall under a ministry responsible for agricultural affairs or livestock development, or are semi-autonomous government institutions (Figures 1 and 2 and Appendix). Universities offering higher education in AnBr are, however, invariably under a ministry of education or higher education in all the countries except for Botswana, where the university falls under the Ministry of Agriculture.

Figure 1 shows the organogram for Zambia, where the Department of Livestock is responsible for research and artificial insemination (AI). A semi-autonomous research trust (GART) was developed in 1993 jointly by the government and Zambia National Farmers Union and is working with farmers to promote agricultural and livestock conservation and improvement. The National Herd Book Society registers animal identities in hard copy registries without continuous trait recording. The largest national market player of animal products is the public limited company ZamBeef Products PLC, which mainly benefits the large-scale farmers.

In Tanzania, a number of divisions and sections are organized directly under the Ministry of Livestock and Fisheries Development and are responsible for the related development activities and services to the livestock sector. The country has an AI centre, but there is presently no herdbook system for performance recording and registration of livestock at farm level. However, the ministry is presently launching a pilot project on animal identification and traceability. The National Livestock Research Institute at Mpwapwa is the only institute directly responsible for livestock genetic improvement. Other institutions, such as the Sokoine University of Agriculture, also play a role in research and training in animal breeding and genetics. Farmers are increasingly organizing themselves into breeding and marketing societies or associations.

AnGR activities in Botswana are centralized and are mainly run by the ministry with few institutions covering most important issues in livestock breeding (see Appendix). Within the Department of Agricultural Research there are six programmes: beef, small stock, range and pasture, dairy, feeds and nutrition, and the animal genetic resources programme. Infrastructure is set up for the market and specifically for export of beef. Kenya has fewer institutions under the government, yet there are many institutions

working on livestock issues. Their roles are often overlapping, with reportedly weak interactions between the programmes and related institutions (Kosgey *et al.*, 2011). In Mozambique, there are few institutions related to AnGR and emphasis is on the National Agriculture Research Institute. Overall the country has a severe shortage of resources and human capacity in AnBr. Uganda shows a well-developed infrastructure for use of AnGR with institutes covering most topics. However, limited activities are being carried out compared with what the institutions are mandated for, owing to limited resources and infrastructure within the institutions. A special institute is organizationally and legally devoted to AnGR, with a full-fledged livestock breeding policy in place. However, livestock recording and its application to support effective selection and national livestock breeding programmes is not yet practiced by the farmers. For all countries, limited collaboration between the institutions is a big constraint.

Well coordinated institutions and organizations constitute important parts and roles for the development of the livestock sector (Philipsson *et al.*, 2011; Rege *et al.*, 2011). As would be expected, all the countries have some institutional setup to support or carry out animal breeding activities, e.g. research and development institutions, universities, AI centres etc., but a general finding is that the institutions are weakly linked to each other and are severely underresourced. This is in agreement with the previous findings of Kosgey *et al.* (2011) and Philipsson (2000) for Kenya.

Reported activities related to animal genetic resources

Table 4 shows the activities reported to be supported by the infrastructure as outlined in the previous section. They include: Livestock recording and evaluation, AI and semen distribution, Conservation and breeding programmes, Extension services, and Products and market development.

Livestock recording, evaluation of data and extension service

Livestock registration and some limited performance recording exist in all countries, mostly at research stations (Table 4). At the general farmers' level, only in Kenya cattle recording is being implemented at a rather large scale. In Botswana, large export beef producing herds and few dairy animals that are inseminated are recorded and can be traced from animal to export. Although Uganda has initiated a performance recording scheme for dairy animals, it is yet to take off. In Mozambique, Tanzania and Zambia, no regular livestock recording at farmer's level is practiced, although Tanzania has plans to implement a recording and traceability system. Genetic evaluations of dairy cattle and beef cattle are currently being undertaken for some breeds in Kenya and Botswana. Otherwise no routine genetic evaluations, or applications of modern evaluation methods, are undertaken in any of the other countries.

In all the countries, the government provides extension services, but activities specifically focused on animal breeding are limited, due to dwindling financial support and shortage of trained advisors.

The lack of livestock recording, or limited use of it, is a serious bottleneck in all countries despite that it is at the core of any animal breeding programme. It is very important that existing institutions are empowered and are well linked with each other in order to execute essentials of a livestock recording scheme. It is not enough to record identities and some morphological traits as has been common for herdbook registrations, but more important are systematic recording of production, reproduction and health traits.

Products and market development

The informal market dominates in all countries but the formal markets are emerging, with variable levels of market growth (Table 4). The livestock policies implemented are mainly supporting large-scale farmers whose main focus is on the commercial market. For meat, all countries in the study import more than they export, except for Botswana and Kenya. For milk, all countries also import more than they export except for Uganda, where the amount of imported and exported milk is almost equal as reported by the FAOSTAT food balance sheet (FAO, 2013). In the southern African countries in the study, multi-national dairy companies dominate the formal dairy market. In the eastern African countries the domestic marketing of animal products is larger. In Kenya, domestic companies for both dairy and meat are major industry operators. In Uganda, a conglomerate company is a major processor of dairy products. However, Botswana is the only country with a traceability system to allow export of beef to Europe. The growing formal domestic and regional markets for milk and meat in all the studied countries are likely important drivers for an economic elevation of the livestock sector. This process would benefit from improved and efficient use of the livestock resources. In relation to climate change policies aimed at increasing livestock productivity are generally seen important and should be another driver for increased attention to the sustainable use of AnGR in development of agricultural policies. Careful considerations to the market are therefore necessary when designing breeding strategies.

AI and semen distribution

AI services have been developed in all countries studied, but vary considerably among countries as regards volume and direction of use (Table 4). All countries except Mozambique have national semen distribution systems from established AI centres, which are usually government run. Semen is domestically produced in all countries but only to a limited extent in Mozambique and Zambia. In all countries a considerable amount of imported semen is also distributed. Such imports and choice of breeds are usually driven by private and foreign agencies and comprise primarily Holstein semen. Kenya and Tanzania have a long

Table 4. Existing components of infrastructure as regards functions related to livestock breeding activities in countries studied.

Functions	Botswana	Kenya	Mozambique	Tanzania	Uganda	Zambia
Livestock recording and evaluation, cattle	Inseminated animals recorded by farmers under ministry supervision. Recording at research stations	Recording and genetic evaluations of some dairy and beef cattle breeds	Limited recording of cattle incl. recording at research stations	Recording at research stations	Limited recording for farmers and recording at research farms.	Recording at research stations
Livestock recording and evaluation, small ruminants	None	Recording at research farms, limited recording at farmerś level	None	Recording at research stations	Limited recording in breeding projects	None
Extension Services	Ministry provides service	Research institutes and farmerś organizations provide services	Limited activity by ministry	Ministry service by projects and by farmers' associations	Provided by different ministry and farmerś institutions	Services by joint ministry and farmerś institution
Products and market development	Meat market established with traceability system for export to Europe. Dairy less developed	Markets for dairy and beef are rapidly developing. Exports beef and milk to neighbouring countries	Undeveloped with most products imported	Mostly informal markets for meat and milk but commercial market developing quickly	Commercial dairy market developing quickly. Commercial meat market limited but growing	Growing but limited commercial markets. Big imports of meat and milk
Artificial insemination (AI) and semen distribution	Government AI service Domestic and imported semen	Parastatal and private AI services Domestic and imported semen	Limited AI service by commercial farms with imported and domestic semen. Limited semen storage at government institutions	Government AI service with domestic semen. Imported semen by private organizations	Government and parastatal AI service with domestic semen. Private companies import semen	AI Centre established by ministry but limited activity. Mostly imported semen
Conservation and breeding programmes	Some breeding and conservation programmes for cattle, sheep and goats	Research institutions carry out conservation programmes. Breeding programmes run by farmers for cattle and goats	Breeding stations for indigenous cattle breeds	Breeding programmes conducted at research farms for cattle and small ruminants	Breeding programmes carried out by government for cattle and goats	Limited conservation programmes for cattle and goats

history of AI service based on domestically produced semen of exotic dairy breeds. Private AI service provision has been ongoing in Kenya since the early 1990s and is increasing. In Mozambique, some commercial farms are assisting the government in supplying semen of Nguni, Brahman and other indigenous cattle breeds. Distribution of semen of some well known indigenous breeds takes place in more countries, among others of the Ankole breed in Uganda, the Mpwapwa cattle breed in Tanzania and the Tswana cattle breed in Botswana. Moreover, in all countries there are externally funded development projects that support and promote AI services, mostly with exotic breeds.

Conservation and breeding programmes

Genetic improvement programmes are important for increased productivity of livestock breeds and for their sustainable use, whereas conservation programmes are essential in order to secure important indigenous breeds or alleles that otherwise would be in danger of extinction (Rewe *et al.*, 2009; Philipsson *et al.*, 2011). However, it is most important that breeds are continuously developed in harmony with environmental and market needs in order to stay competitive for economic or cultural reasons, thereby avoiding endangerment. Genetic improvement programmes are scarce in the countries studied, yet interesting initiatives have been taken in a few countries, but with very little documentation. Research, development or pilot breeding projects are undertaken in most of the countries, although to variable extent. Such initiatives involve recording and breeding schemes and are mainly research station based.

Kenya has reached further than the other countries, with some livestock recording and genetic evaluations being practiced. Improvement schemes exist for all exotic dairy breeds and for some local beef or dual-purpose breeds, e.g. the Boran and Sahiwal cattle breeds.

In Botswana, beef cattle breeding programmes are in place, but are so far only limited to a small part of the country's farmers (i.e. the commercial beef producers only). Breeding organizations are in place for most species and breeds, both exotic and local. Conservation programmes are, just like in all the other countries, to some extent available for indigenous ruminant breeds, as for the Tswana cattle breed. In Mozambique breeding stations are used for conservation of indigenous cattle and small ruminant breeds, such as Nguni, Angoni and Landim cattle breeds. Semen of both exotic and indigenous cattle breeds is stored in semen banks, but not regularly used.

In Tanzania breeding programmes exist for Mpwapwa and Boran cattle breeds at research stations. For the Mpwapwa breed, early reports are showing promising results from breeding schemes at research station (Kasonta and Nitter, 1990; DAD-IS, 2013). For goats, breeding strategies exist for pure breeding of Blended, Newala, Ujiji and Gogo breeds. In Uganda, breeding schemes are practised within research and development programmes for Ankole cattle as well as for some other cattle, goat and sheep breeds. In Zambia, characterization and conservation programmes are undertaken for some indigenous cattle, e.g. for the Angoni, Barotse, Tonga and Baila breeds. The focus is on multiplication of cattle and goats rather than genetic improvement programmes as such. Indigenous cattle breeds are being conserved *in vivo* at government stations, where also a goat project for multiplication of imported Boer goats is conducted.

No fully functioning breeding programmes with active farmer participation are available in any country. Conservation programmes are, however, conducted for a few ruminant breeds in most countries. Usually nucleus herds at research stations are used for multiplication of indigenous breeds that are considered threatened. Recent documentations to quantify the extent of applied breeding programmes of any kind, as well as their results, are scarce. In general, institutional and organizational frameworks are too weak to support sustainable breeding programmes.

Constraints and priorities

Table 5 shows the unranked main constraints and priorities as reported by the country representatives during the 2009 workshop and in interviews. All countries reported that shortage of trained and skilled personnel in AnBr is the single biggest constraint to development and implementation of AnGR improvement programmes. Lack of facilities, weak interactions and linkages between and within different institutions or constant institutional reorganization were also reported as important constraints in four of the countries. Lack of breeding policies and/or definitions of breeding objectives are frequently reported as key constraints. Some countries also report insufficient funding for breeding activities as an important constraint.

Increased emphasis on capacity building at all levels and recruitment of trained staff was prioritized by all countries followed by the needs for establishing various breeding activities. Formulation and implementation of breeding policies are highly prioritized in several countries, especially following the 2007 adoption of the Global Plan of Action on Animal Genetic Resources and the Interlaken Declaration.

Higher education, capacity building and institutional collaboration – keys to improvement of infrastructure

In developing and implementing sustainable breeding programmes it is important that key principles are considered and best practices adhered to. Addition and application of more advanced strategies may be made as infrastructure and industry develops. Rewe *et al.* (2009) emphasized the involvement of livestock keepers by forming breed societies or breeder groups at community level for livestock recording and breeding, as they inevitably are the breeders and producers. Feedback information from recording schemes to the livestock keepers must be communicated promptly

Table 5. Constraints and priorities reported for development of AnGR in each country.

Country	Constraints	Priorities
Botswana	◦ Lack of human resources ◦ Inadequate equipment and facilities ◦ Lack of policies and strategic plans ◦ Lack of breeding societies ◦ Difficulties to control interaction between livestock and wildlife	◦ Funds for training ◦ Sources for funding and collaboration ◦ Implementation of Livestock Breeding Act ◦ Equipment and facility improvements
Kenya	◦ Lack of funding ◦ Lack of integration between and within institutions ◦ Inadequate skills and lack of human capacity	◦ Implementation of policies and strategic plans ◦ Increase distribution of semen ◦ Recruitment of trained personnel ◦ Staff training
Mozambique	◦ Constant restructuring of institutions ◦ No livestock policy in place ◦ Lack of human resources and decision makers ◦ Lack of strategic policy plans ◦ Lack of collaborations between institutions	◦ Design and implementation of policies and strategic plans ◦ Capacity building ◦ Reformation of learning centre curriculum ◦ Formation of breed societies for indigenous breeds
Tanzania	◦ Limited human resources ◦ Inadequate infrastructure ◦ Limited financial resources ◦ Poor linkage between institutions	◦ Training of manpower ◦ Improvement of facilities ◦ Increase productivity of indigenous livestock
Uganda	◦ Insufficient infrastructure within institutions ◦ Insufficient network among stakeholders ◦ Shortage of manpower ◦ Insufficient market linkages ◦ Brain drain	◦ Encourage recruitment of trained staff ◦ Expand the mandates for the institutions ◦ Develop AnBr projects among stakeholders
Zambia	◦ Lack of human capacity ◦ Lack of breeding animals ◦ Lack of defined breeding programme ◦ Lack of adequate facilities and equipment	◦ Increased efforts on animal breeding and implementation of national breeding programme ◦ Capacity Building ◦ Efforts on characterization and conservation of indigenous breeds
Summary (No. of countries reporting constraints/priorities)	◦ 6 human resources ◦ 4 institutions/facilities ◦ 4 institutional integration ◦ 2 policies ◦ 2 financial recourses	◦ 6 human resources ◦ 5 increased breeding activities ◦ 3 policies ◦ 2 facilities

to allow improved herd management and keep their interest. Mobile telephone communication tools, if smartly used, may provide practical and important ways of data capture and for giving feedback to farmers. The data need to be correct, appropriately analysed, stored and retrieved to produce value-added information for farmer's use. To develop such programmes there is a great need for well-trained staff and capacity building of all actors in the chain. The gap is obviously big between best practice known and what is practised in all countries of the study.

All countries report that shortage of skilled personnel in animal breeding is a big constraint for development. The analysis made in this study confirms this, thus emphasizing the need for more people trained in animal breeding in order to develop AnGR for sustainable use. Without adequately trained people in charge of possible AnBr activities, it will be difficult to formulate relevant breeding policies, breeding objectives, livestock recording or evaluation systems of livestock.

The country with most Ph.D. holders, Kenya, has more advanced breeding programme activities than any of the other countries. Also Uganda and Tanzania have several Ph.D. holders, and typically these three countries, and Botswana supported by South Africa, have livestock breeding policies available or drafts in process. Countries lacking Ph.D. holders and university training in animal breeding have the least developed activities related to animal breeding. Thus, there is a clear relationship between efforts in higher education and research on issues related to AnGR and the advancement of livestock breeding policies and animal breeding programmes for sustainable use of AnGR.

Obviously more animal breeders need to be trained, retrained, motivated and empowered to initiate and run breeding and conservation programmes. However, very little emphasis is put specifically on university training to reach an advanced level of competence. One way that has shown demonstrable success is to have common university/higher education training within a region in the field of animal breeding (Wooliams *et al.*, 2005). In this way the limited infrastructural and human resources could be shared in a better way and a higher level of expertise could be financed and used to effectively harness the regional resources more sustainably.

The need for more advanced university training is even more critical now given the big wave of focusing more on molecular genetics without better understanding and application of both quantitative and molecular genetics. Implementation of livestock identification and recording schemes for collection and genetic analysis of phenotypic data for genetic improvement is a prerequisite for almost any use of molecular information. Countries with least developed animal breeding courses in their academic programmes are bound to produce fewer qualified people with animal breeding skills. This is consequently reflected in the entire country's livestock breeding status and opportunities for future developments; this applies equally to the improvement of local breeds and controlled upgrading and crossbreeding programmes.

Insufficient collaboration between and within institutions is seen as one of the most serious constraints in most countries. In fact, a change in mindset among people responsible for various institutions and organizations related to animal improvement is a necessity. Some countries have necessary policies and institutions in place, but they lack the ownership by the farmers to effectively meet their demands of tools for livestock improvement and implementation of the policies. The need to support forming of, or empowering existing, farmers' or breeders' organizations must be emphasized. The farmers are the real actors finally selecting available tools and individual animals for livestock breeding.

Emphasis on policies is brought up as a priority for development support in several countries. Policies are necessary, but even more important are allocation of resources and actions to implement the policies and reaching out to farmers. Again a shift in mindset and better use of existing resources by closely integrated activities would improve the opportunities for efficient development of breeding programmes.

Considering the weaknesses shown in this study regarding institutions to support development of the sustainable use of AnGR, and constraints and priorities expressed by the countries represented, increased efforts on animal breeding education at M.Sc. and Ph.D. level appears essential. Capacity building to further empower earlier trained scientists, staff and officers in charge of practical livestock development programmes is equally important. ILRI and FAO have developed relevant training materials for this purpose including guidelines on development of policy, breeding and conservation programmes, and on scientific, technical and evidence-based aspects of AnGR management (FAO, 2009b, 2010, 2011, 2012a, 2012c; Ojango *et al.*, 2011). FAO guidelines on animal identification, performance recording and traceability are being developed.

Conclusions

This study shows that by far the most serious constraint for the development of sustainable animal breeding programmes in the countries studied is the shortage of skilled personnel in animal breeding at all levels and in all types of institutions. More university training and capacity building in animal breeding is needed. The paper argues that to support sustainable use of AnGR it is important to have clear national policies and institutions that are appropriately mandated. Institutions need to be linked to each other to effectively execute the activities needed for the country to succeed in livestock breeding. Such activities need to be clearly documented. Development of livestock recording schemes, including innovative methods for communication, is seen as a critical investment for development of sustainable breeding programmes. For any improvement strategy to be successful farmers' involvement at all stages is necessary and their organizations need to be empowered.

Acknowledgements

Financial support for this study was provided by the Food and Agriculture Organization of the United Nations (FAO), International Livestock Research Institute (ILRI) and Swedish University of Agricultural Sciences (SLU), which is gratefully acknowledged. We would also like to thank all institutions visited and people interviewed, especially to Ministry of Agriculture, Department of Agriculture Research, Department of Animal Production and Botswana Agriculture Union in Botswana; to Ministry of Livestock Development including research centres, Kenya Agriculture Research Institute, Central Artificial Insemination Station, Kenya Stud Book, Dairy Recording Services of Kenya and Egerton University in Kenya; to Ministry of Agriculture, National Directorate of Veterinary Services, National Directorate of Animal Science and Department of Research on Animal Production and Health at the National Agriculture Research Institute including research stations, Reproduction Station of Mozambique, University of Eduardo Mondlane in Mozambique; National Livestock Research Centre, Sokoine University, National Artificial Insemination Centre in Tanzania; National Animal Genetic Resources Centre and Databank and Makerere University in Uganda; and Department of Livestock at Ministry of Agriculture and Livestock including research centres, National Artificial Insemination Services, Mulaikwa Breeding Centre, University of Zambia, Zambia National Farmer Union and National Herd Book Society in Zambia for generously providing us with pertinent information for this study.

Statement of interest

No conflict of interest.

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Appendix

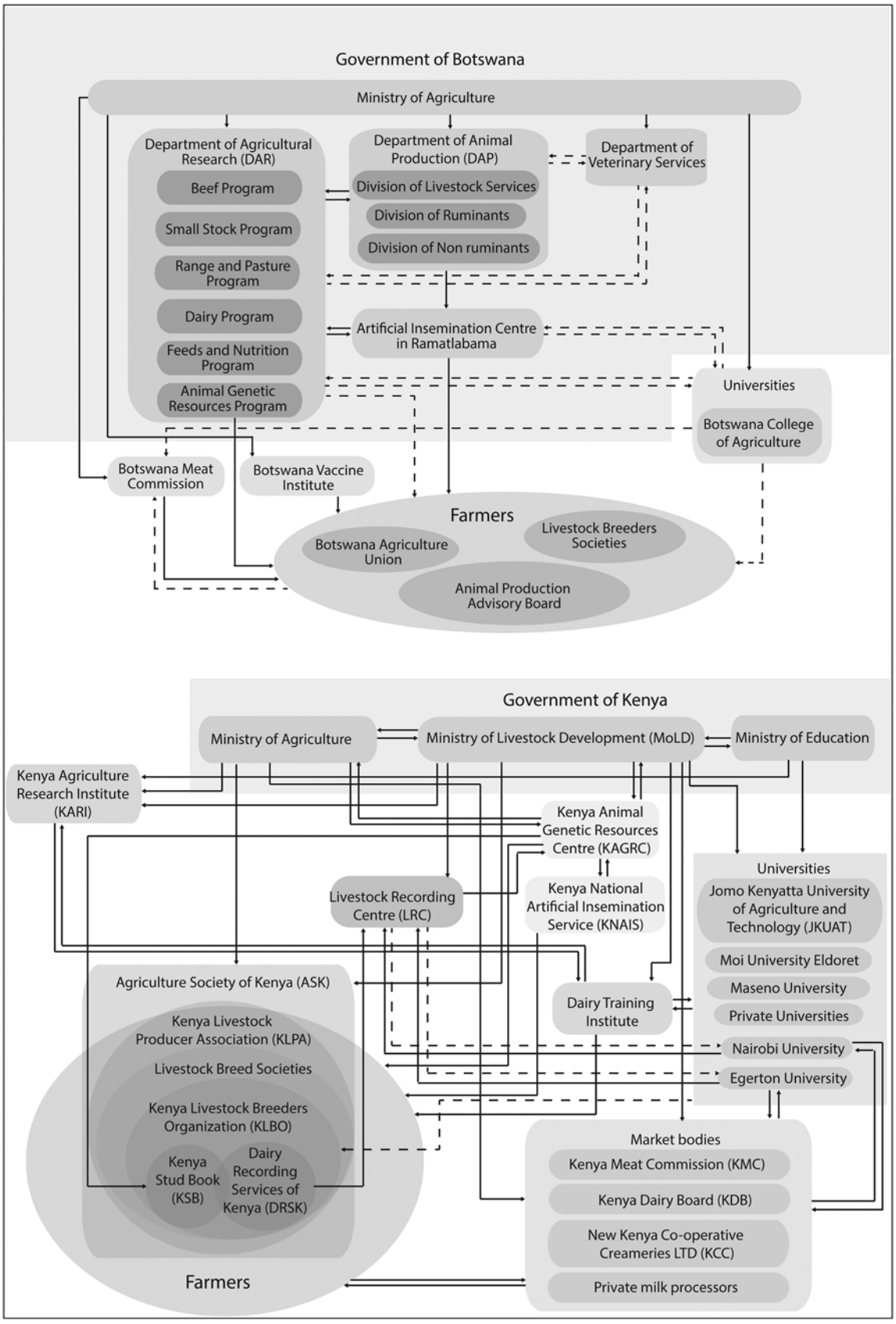


Figure A1 Organogram of institutions related to animal genetic resources in Botswana, Kenya, Mozambique and Uganda. A solid line shows high level of interaction and a dotted line shows some degree of interaction. Institutions in circular shape are farmer-owned.

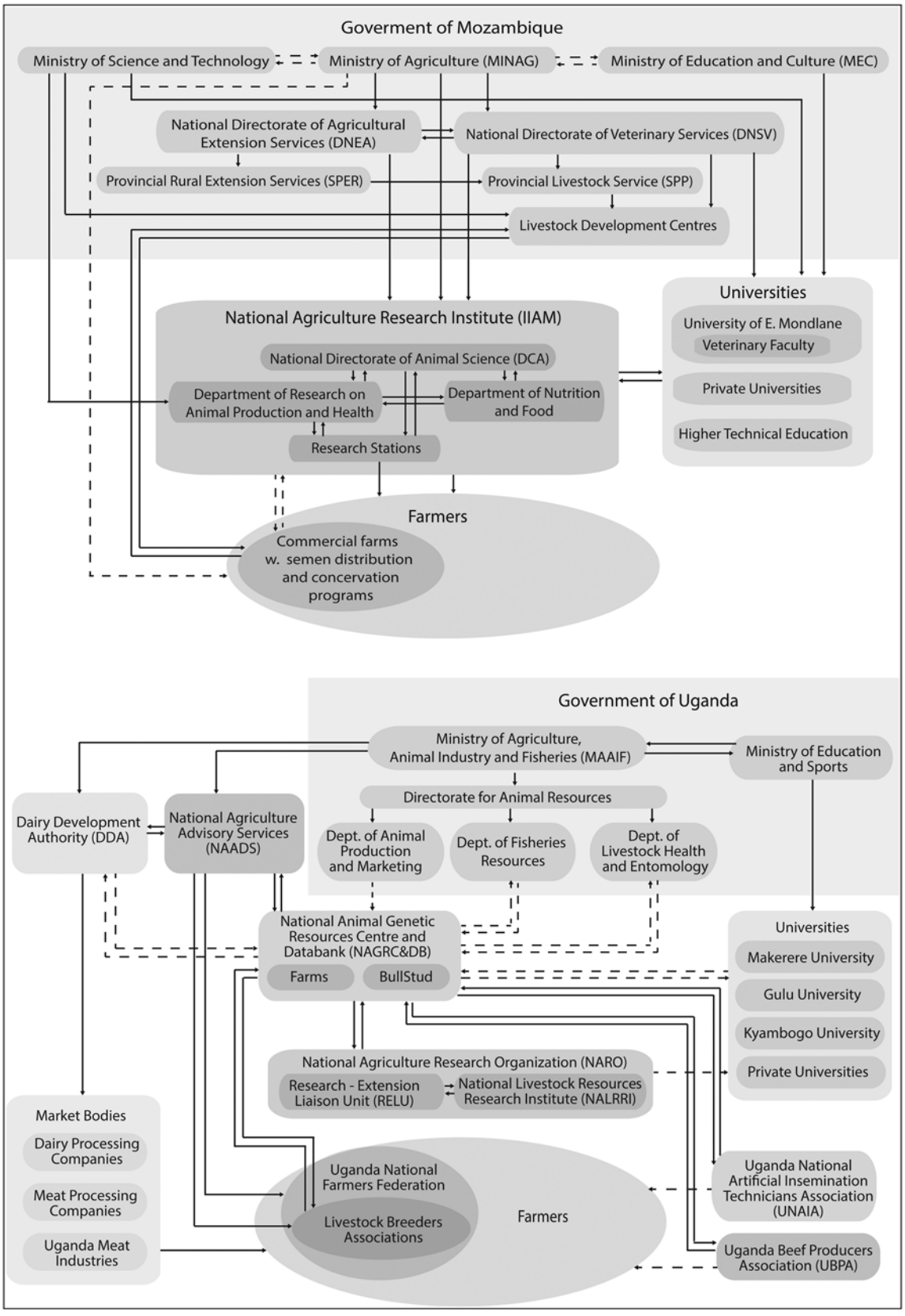


Figure A1 (*Continued*).

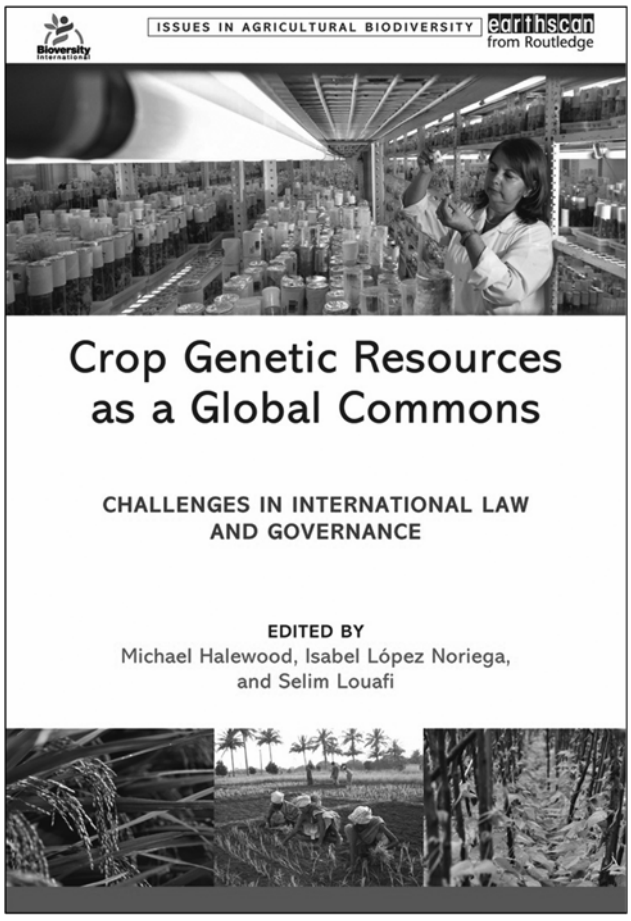
Animal Genetic Resources, 2013, 53, 95–96.

Recent Publication

Crop genetic resources as a global commons. Challenges in international law and governance

Edited by M. Halewood, I.L. Noriega & S. Louafi
Earthscan from Routledge
Published in 2013, pp. 399
ISBN 978-1-84407-893-6

doi:10.1017/S2078633613000404



This book discusses the role of international law in supporting the collective pooling and management of plant genetic resources. It focuses particularly on the functioning of the International Treaty on Plant Genetic Resources for Food and Agriculture. It provides an in-depth analysis, extending to 19 chapters. The first part of the book sets the scene by describing countries' interdependence in the use of plant genetic resources and the imperative for international cooperation in the use of these resources. This section includes discussions of the importance of internationally sourced genetic material in recent developments in crop breeding, the significance of international exchanges of crop and forage genetic resources in efforts to address problems associated with climate change, and changing rates of acquisition of plant genetic resources by international gene banks. These chapters are followed by section that focuses in detail on the International Treaty's multilateral system for access and benefit sharing. It begins with a history of the negotiations that eventually led to the Treaty being agreed, beginning with international and technical discussions ranging back to the 1950s and moving through the political negotiations that led to the creation of the International Undertaking on Plant Genetic Resources and on to the negotiation of the Treaty itself, all framed within a description of the scientific and political developments that created the context for the negotiations. This is followed by a description of the design and mechanics of the multilateral system itself, presented in the form of answers to basic questions: What is the legal basis of the system? How does access work? How does benefit sharing work? Who maintains the system? and so on. A further chapter considers the Treaty's Standard Material Transfer Agreement (SMTA) in more detail, focusing in particular on the way in which the SMTA, unlike normal material transfer agreements, not only establishes the rights and obligations of the contracting parties (in this case the provider and recipient of the genetic material), but serves the interests of the multilateral system itself (i.e. ensuring that benefits flow into the multilateral system and can then be passed on to farmers in support of the conservation and sustainable use of plant genetic resources). A further chapter considers the scope of the multilateral system, i.e. what material is and is not covered by the system. It focuses in particular on what is meant by the phrase "under the management and control of the Contracting Parties and in the public domain" (particularly the question of the "public domain", which it is concluded should be understood in the context of intellectual property rights). The section concludes with an overview of efforts made to get the multilateral system "up and running", i.e. a review of activities coordinated by the Secretariat of the Treaty. The third section (approximately the whole second half of the book) is devoted to "critical reflections". These include a number of chapters that, from various perspectives, reflect on the strengths and weaknesses of the Treaty, review progress made in its implementation and discuss the various challenges involved. Again in this section, the broad overview chapters are complemented by those that address more specific topics. The latter include discussions of the "moving scope of Annex 1" (i.e. history of negotiations relating to the scope of the list of crops covered by the multilateral system); the challenge of building a global information system to support the Treaty (i.e. the development, in line with the Treaty's Article 17, of a system to facilitate the exchange of information on scientific, technical and environmental matters related to plant genetic resources, and to serve as an early warning system for

hazards threatening these resources); the roles of the centres of the Consultative Group on International Agricultural Research in overcoming problems associated with collective action related to the multilateral system; international and regional cooperation in the implementation of the Treaty; the place of the Treaty in the evolving global system for the conservation and sustainable use of plant genetic resources; and the question of "institutionalizing global genetic resources commons for food and agriculture" (including a discussion of emerging theories related to the evolving global commons in plant genetic resources – and touching also on the differences between the plant sector and the microorganism and animal sectors with respect to the exchange and use of genetic material).

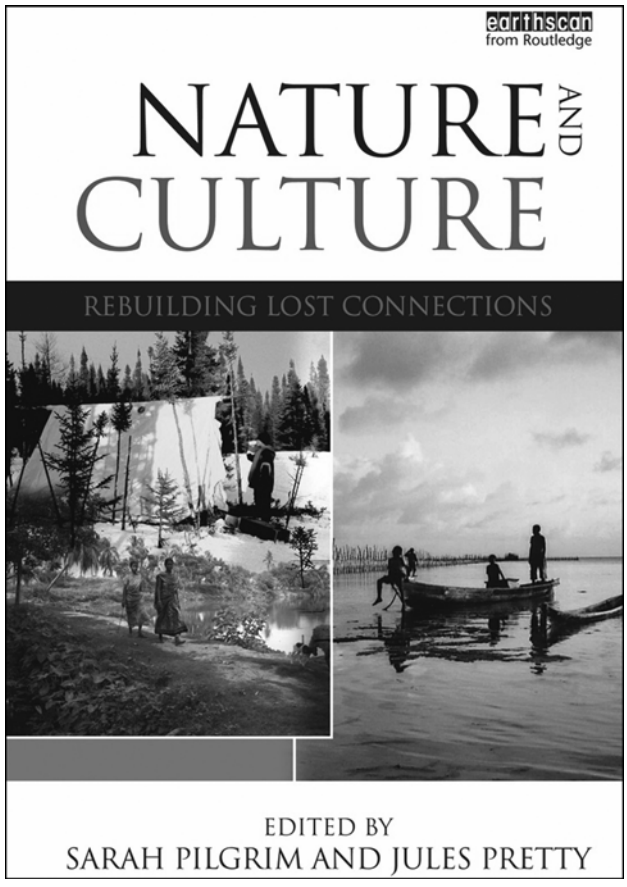
Animal Genetic Resources, 2013, 53, 97.

Recent Publication

Nature and culture. Rebuilding lost connections

Edited by S. Pilgrim and J. Pretty
Earthscan from Routledge
First published in 2010; this edition published 2013, pp. 275
ISBN 978-0-425-81354-9

doi:10.1017/S2078633613000416



This book addresses the links between biological diversity and cultural diversity: exploring the nature and significance of these connections, factors that contribute to their loss and – as the subtitle implies – means by which they can be renewed. It argues that success in the conservation of biodiversity can only be achieved if accompanied by greater appreciation for, and protection of, cultural diversity. The first of the book's five sections focuses the question of how "modern" science is responding to these challenges. One aspect of this response has comprised attempts to "bridge the gap" between scientific disciplines – to reduce, for example, the constraints that the traditional compartmentalization of science into (*inter alia*) biological and social disciplines has created with respect to understanding interactions between nature and culture or to viewing them in a holistic way. As well as discussing the emergence of disciplines such as ethnobiology and conservation biology, this section also includes a chapter devoted to the topic of measuring and monitoring the status of, and trends in, biological and cultural diversity. The following three sections address, in turn, the themes of landscape, hunting and agriculture. The first of these themes is introduced by a chapter that explores the ways in which concepts such as nature, wilderness, landscape and the pastoral have evolved over the last few centuries in Western thought and how this has affected land use and the theory and practice of conservation both in Europe and in regions colonized by European powers. The next chapter has a more specific focus. It describes the "cosmovision" of Andean peasant communities, within which nature and culture are not separated, and discusses its differences from, and relationships with, Western science (generally a strong contrast, with some recent steps towards engagement by some scientific subdisciplines). The final chapter in this section discusses the erosion of biological and cultural diversity. These are treated not as two parallel processes, but as the erosion of a "biocultural whole" that is (or was) the product of a long interaction between humans and the environment. Several examples of anthropogenic stress on "eco-cultural health" (an expansion of the concept of ecosystem health) are presented, along with a discussion of how such changes can be measured and what can be done to address them. The section on hunting includes a chapter on how the imposition of wildlife management laws have transformed the roles of beluga whales and polar bears in Inuit culture in certain areas (to the detriment of both culture and biodiversity, it is argued) and another on recreational hunters and their engagement with the natural world. The section on agriculture begins with a chapter that discusses the significance of culture in the creation and maintenance of agrobiodiversity and the role of agrobiodiversity in the development of cultural diversity. A further chapter looks at "food cultures", and particularly at how systems that involve the use of diverse local resources have been eroded. Topics addressed include the ways in which landscapes are transformed by food production and the roles of knowledge and religion in food systems. The final section discusses potential ways of reconnecting nature and culture. It includes chapters on the roles of sacred sites and community conservation areas in the maintenance of biological and cultural diversity; the concepts of "sostaligia" (the lived experience of negative environmental change) and "sophilia" (a positive affiliation with a loved home environment); and ecocultural revitalization through projects linked to traditional foods, traditional healthcare, ecotourism, education, language, culture or rights to local resources.

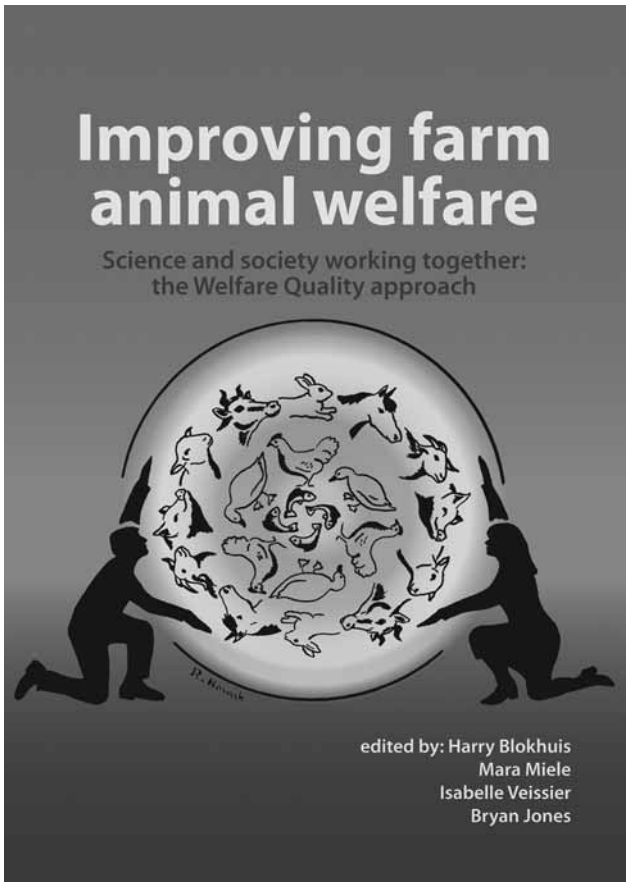
Animal Genetic Resources, 2013, 53, 98–99.

Recent Publication

Improving farm animal welfare. Science and society working together: the Welfare Quality approach

Edited by H. Blokhuis, M. Miele, I. Veissier & B. Jones
Wageningen Academic Publishers
Published in 2013, pp. 232 ISBN: 978-90-8686-216-0
Doi: 10.3920/978-90-8686-770-7

doi:10.1017/S2078633613000428



As a concept the 'Welfare of Farm Animals' is easy to grasp. It means recognising that domestic animals are sentient creatures, treating them with respect by ensuring their well-being and comfort and by avoiding pain and distress. But it is difficult to move from the concept to practical decisions on how to manage them.

This book presents the findings of 'Welfare Quality', a large international 5 year (2004–2009) multi-disciplinary project funded by the European Union that brought together partners in universities and research institutes in many European countries, Brazil, Mexico and Uruguay. The aim was to assess all the issues from production to consumption and to promote the development of animal welfare. The researchers took as the basic question: 'What is a good quality life for a farmed animal?' The net was cast wide to collect data from the many stakeholders and beyond and included public interest groups, ethicists, sociologists, animal and human health specialists. Four areas were seen as fundamental: housing, feed. health and behaviour. The researchers made an important policy decision at the start; namely, to try to assess welfare from the animals' point of view. This is, of course, the ideal. But the inner experiences of animals remain largely unavailable. Attempts to document animal feelings and experiences and to codify them into meaningful statements for legislation, farm practice and enforcement contain a large element of anthropomorphism: namely what an average human might feel in the same circumstances. In view of the evident higher standards that define human expectations for a quality life, the boundaries of acceptable animal welfare in practice remain malleable. The authors recognize this difficulty and ask what alternative indirect measures can be used to indicate animal comfort. They seem to favour animal behaviour as a good indicator of welfare; for example, by asking if the confined animal can perform functions that would be normal in natural, non-restricted environments. However, these criteria are not completely satisfactory shown by the issue of reproduction since this natural function is deliberately excluded from the large-scale livestock unit designed to bring the animal to market without time or space for reproduction. Eating is another natural function of all animals and feed is provided in industrial livestock units. But these circumstances not only preclude the animal from selecting a wider range of feeds that is available in the more extensive systems but also provide feed which, while well balanced nutritionally, can only be viewed by humans as lacking variety. Do animals feel this lack also

The authors also explore the utilitarian route of animal welfare which posits that high physiological performance, such as growth rate, feed conversion efficiency, high milk yield and good carcass quality indicate that the animal lives a contented life. While this attempt to assess welfare clearly has the merit of identifying poor and uncomfortable circumstances for the animal, the motivation of this approach is suspect as maximizing profit is the ultimate criteria. Stereotypic behaviours such as feather-pecking in birds and tail biting in pigs are clear indications of poor animal care; but some business interests in the past tried to prevent animals from doing such things rather than removing the cause of stereotypical behaviours. The EU has legislated against over-crowding that provokes such behaviours and has also forbidden, for example, de-beaking birds. Undoubtedly, it is easier to fix negative boundaries and define protocols for animal care at specific

stages of life such as the transport and killing of animals than to define parameters that will ensure the well-being of animals in their daily lives.

The authors say that this project was the largest ever collaborative project in animal welfare science. They collected, documented and analysed an enormous wealth of new information from widespread stakeholders and other interested sources that provides a comprehensive and integrated set of issues considered relevant to animal welfare. They also examined how these issues should or could be measured. In this way the project makes an original contribution. But, inevitably the authors recognize that they have also raised new questions that remain unanswered and will thus fuel further research. The project clearly indicates that almost everyone has an expectation that animals kept for food should be treated well and also finds that people representing different sectors in modern society have definite and often conflicting views on how livestock should be managed. As may be expected, such wide consultations among stakeholders and interested parties brings together expectations based upon different economic, political, technological, social, ethical, religious and cultural factors. The authors tested their analyses of factors on juries to ensure they had adequately understood the issues.

The project increases awareness of the number and complexity of animal welfare issues. It also reveals the large amount of time and effort needed to complete an welfare assessment on an individual farm. The authors do not make any specific recommendations for legislation, but devote much time during the project to making the information available to interested groups. Extensive reference lists of quoted publications are given and the main body of data and important conclusions are available at a dedicated website: Animal Welfare Quality, http://ec.europa.eu/research/era/index_en.htm The book provides the reader with a brief but comprehensive review of current thinking on animal welfare and the difficulties in ensuring good practice in this age of industrialised livestock production.

Animal Genetic Resources, 2013, 53, 100–101.

Recent Publication

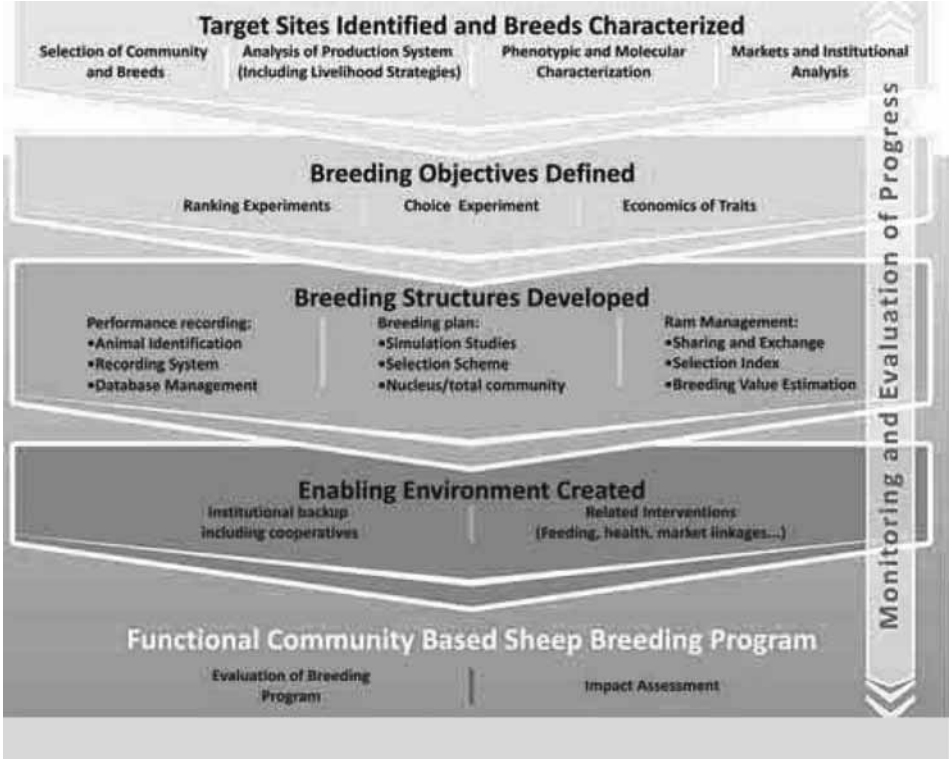
Guidelines for setting up community-based sheep breeding programs in Ethiopia. Lessons and experiences for sheep breeding in low-input systems

A. Haile, M. Wurzinger, J. Mueller, T. Mirkena, G. Duguma, O. Mwai, J. Sölkner and B. Rischkowsky

ICARDA Tools and Guidelines 1
International Center for Agricultural Research in the Dry Areas
Published in 2011, pp. 37
ISBN 92-9127-255-8
Available at https://apps.icarda.org/wsInternet/wsInternet.asmx/DownloadFileToLocal?filePath=Tools_and_guidelines/Guidelines_for_sheep_breeding.pdf&fileName=Guidelines_for_sheep_breeding.pdf

doi:10.1017/S207863361300043X

Drawing on experiences in four different agro-ecological zones in Ethiopia, these guidelines present advice on the design and implementation of community-based breeding programmes, with the aim of facilitating the scaling-up of the existing scheme in Ethiopia and the planning of similar projects elsewhere. They are intended for use by any stakeholders involved in planning and implementing sheep-breeding projects for resource-poor farmers in developing countries. Community-based breeding programmes are presented as an alternative to centralized government-run breeding schemes (which have generally failed to sustainably provide the desired genetic improvements or to engage end users) and to the practice of introducing exotic genetic resources without adequate pretesting of their suitability (which has also often failed to produce the desired results and, if it leads to indiscriminate cross-breeding, creates problems of genetic erosion in the original locally adapted population). The guidance presented is intended for use under conditions where a developed infrastructure for animal genetic improvement in smallholder production system is not in place, systematic processes for identifying and delivering genetically superior breeding stock from the local populations are lacking, and national research and development organizations have limited experience and a limited number of qualified staff. The main body of the guidelines consist of three sections: the first on the core activities involved in the implementation of a community-based programme; the second on the creation of an enabling environment for such programmes; and the third on their monitoring and evaluation. The description of the core activities begins by addressing the question of how to identify the site for the programme and the group or groups of livestock keepers to be targeted. This includes advice on the factors to consider and steps to follow when making these choices and on the characterization of breeds and their production environments. Step-by-step advice is then offered on the definition of breeding objectives (including descriptions of various



"tools" that can be used in this process – individual interviews, focus groups, choice card experiments, ranking of animals, etc), the assessment of alternative breeding plans and the establishment of the structures needed for the implementation of the programme (animal identification, data recording and management, procedures for selecting and using breeding rams, and the provision of institutional backup for the programme during its initial phases – i.e. support from researchers, extension personnel, or NGO or project staff). Advice on the creation of an "enabling environment" includes guidance on how to establish and maintain a good relationship between the community and the "implementers" of the project, complementary interventions such as improving access to animal health services and market information, establishment of cooperatives or farmers' organizations, capacity development for the various different types of stakeholders involved in the programme, provision of appropriate government support in the form of ensuring sufficient access to credit land and other resources, and the establishment of links to other ongoing development projects and activities.

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ERRATUM

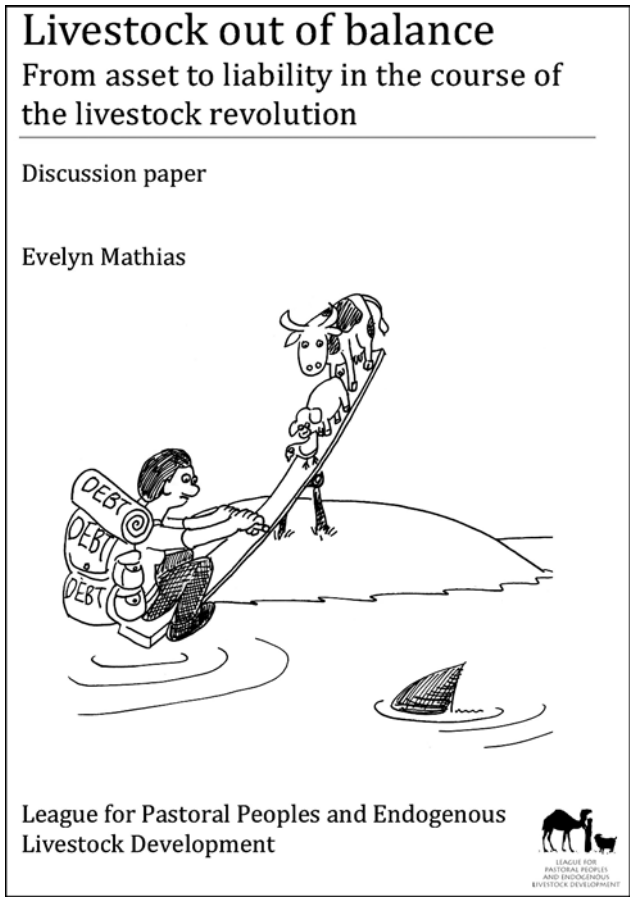
Livestock out of balance. From asset to liability in the course of the livestock revolution – ERRATUM

Animal Genetic Resources, volume 51, page 156.

The text of the recent publication announcement for *Livestock out of balance. From asset to liability in the course of the livestock revolution* was inadvertently replaced by that of another publication. We apologize for this oversight and reproduce the correct announcement here.

Livestock out of balance. From asset to liability in the course of the livestock revolution

E. Mathias
League for Pastoral Peoples and Endogenous Development
Published in 2012, pp. 30
Available at http://www.pastoralpeoples.org/wp-content/uploads/2012/04/Livestock-from-asset-to-liability-11.pdf



This discussion paper prepared for the League for Pastoral Peoples and Endogenous Development seeks to evaluate the effect that the so-called livestock revolution – the rapid expansion of industrialized livestock production into developing countries – is having on small-scale livestock producers. A review of the development of the livestock sector over the last decade concludes that some, but not all, of the assumptions underpinning the "livestock revolution" analysis put forward by the International Food Policy Research Institute in 1999 have been borne out. It is argued, for example, that the revolution – rather than having become a global phenomenon – is largely restricted to a few fast-growing economies, with much of the rest of the developing world having experienced, at best, only marginal growth in livestock production. Also highlighted are the higher-than-predicted prices of cereals and other inputs and the emergence of new animal health problems such as highly pathogenic avian influenza. On the policy side, it is argued that the phenomenon of government support for high external input livestock production, via research, advisory services, credit, subsidies and legislation – previously restricted to the developed world and a small number of developing countries – is becoming more widespread, while at the same time non-industrialized livestock production is being neglected. The next section of the paper presents a short discussion of contract farming and similar arrangements that can provide entry points for the participation of small-scale producers in the livestock revolution. It is argued that while, particularly in their initial phases, such schemes may offer attractive benefits, such as inputs at low prices, there is a tendency for their terms to become harsher over time as intensification increases and the value chain becomes more specialized. This section is followed by a discussion of factors that lead farmers to invest in external inputs and link up with commercial buyers. A range of factors are highlighted, including advice from extensionists and other sources, a lack of alternative opportunities, and fear of losing out in competition with those who do invest. The next step in the analysis is a review the various pressures that farmers face once they have embarked on a more commercially oriented approach, including competition from larger producers who benefit from economies of scale, reduced bargaining power because of consolidation in the processing and retailing sector, the need to comply with an ever-expanding number of laws and regulations affecting the production and marketing of animal products, and a range of unfavourable conditions that may be

included in contractual arrangements. Moving on to the outcomes of the process, the paper discusses the rise of indebtedness among farmers and the tendency for specialization to reduce farmers' flexibility in the face of changing market demands and to leave them vulnerable to shocks such as disease outbreaks or increases in feed prices. At this point, the impact on animal genetic resources – growing dominance of a few higher-yielding breeds at the expense of a diverse range of locally adapted, often multipurpose breeds – is noted. The next section of the paper addresses consequences for the environment and for public health. It is argued that the financial pressures faced by farmers increase the risk that they will cut corners in terms of the proper disposal of waste products or will adopt dangerous production practices such as the misuse of antibiotics and other growth stimulants. The paper's concluding section calls on policymakers, scientists and development professionals to recognize that the negative consequences of the livestock revolution are not simply the unfolding of inevitable economic trends, but are also influenced by policies. What is needed – it is argued – are policies that create a level playing field for small producers and help them avoid falling into the trap of debt.

Special Issue

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ANIMAL GENETIC RESOURCES

Special Issue: Adding value

RESSOURCES GÉNÉTIQUES ANIMALES

Numéro Spécial: Ajouter de la valeur

RECURSOS GENÉTICOS ANIMALES

Número especial: Añadiendo valor

United Nations Decade on Biodiversity

CONTENTS

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Adding value to local breeds: challenges, strategies and key factors

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Summary
This paper analyzes the articles published in this special issue and also some material presented at the Session "Strategies to add value to local breeds" of the 61st Annual Meeting of the European Federation of Animal Science (EAAP) (August, 2010, Crete, Greece)[1] or at other workshops dealing with the issue of adding value to local breeds. The analysis refers to the challenges facing local breeds and the different strategies that can be used to increase their value and thereby enhance their sustainability. These strategies can be categorized, *inter alia*, according to the species, the specific characteristics of the targeted breeds or production systems, the existence or absence of markets and the characteristics and dynamics of the breeders and other stakeholders. The paper is structured as follows: presentation of an overview of the challenges involved; this is followed by a discussion of strategies for adding value to breeds, which is illustrated with examples; an analysis of the key factors affecting such strategies and ends with some conclusions. Questions remain regarding the society's responsibility for providing support to farmers that keep local breeds that are at risk of extinction and regarding what actions are appropriate when such a breed that was once at risk becomes self-sustainable or, in contrast, when a breed ceases to be self-sustained.

Keywords: *local breeds, added value, conservation, sustainable use*

Résumé
Cet article analyse les articles composant ce numéro spécial ainsi que quelques matériaux additionnels présentés dans la session "Stratégies pour ajouter de la valeur aux races locales" du 61ème congrès de la FEZ (Août 2010 dans l'île de Crète en Grèce)[1], ou dans d'autres ateliers traitant de ce thème. L'analyse s'appuie sur les enjeux qu'affrontent les races locales, les diverses stratégies envisageables pour accroître leur valeur en promouvant leur utilisation et en soulignant leur intérêt pour la durabilité. On peut classer ces stratégies dans différentes catégories, selon les espèces, les caractéristiques spécifiques des races et des systèmes de production, l'existence de marchés, les dynamiques des éleveurs et d'autres porteurs d'enjeux. L'article est structuré par une introduction qui discute les différents enjeux puis la description des stratégies illustrées par des exemples, et enfin l'analyse des facteurs-clés qui influent sur ces stratégies et les conclusions. La discussion des facteurs-clés est organisée autour de leur impact sur les stratégies pour ajouter de la valeur aux races locales. Demeure questionnée la responsabilité de la société pour soutenir les éleveurs qui maintiennent les races locales, pour assurer des solutions aux races qui atteignent un degré de durabilité par leurs propres moyens, ou au contraire qui n'y parviennent pas.

Mots-clés: *races locales, valeur ajoutée, conservation, usage durable*

Resumen
Este trabajo analiza los artículos publicados en este número especial así como algunos materiales presentados en la Sesión "Estrategias para añadir valor a las razas locales" del 61° Encuentro Anual de la Federación Europea de Ciencia Animal (EAAP, por sus siglas en inglés; Agosto de 2010 en Creta, Grecia)[1] o de otros talleres en los que se abordó la temática de la adición de valor a las razas locales. El análisis hace referencia a los retos a los que se enfrentan las razas locales y a las diferentes estrategias que pueden ser usadas para incrementar su valor y así, mejorar su sostenibilidad. Estas estrategias pueden ser catalogadas, entre otras maneras, según la especie, las características específicas de las razas objeto de estudio o de los sistemas de producción, la existencia o ausencia de mercados, y las características y dinámicas de los criadores y otros agentes implicados. El trabajo está estructurado como sigue: panorámica general de los retos en cuestión; a continuación, discusión de estrategias para la adición de valor a las razas, lo cual es ilustrado con unos ejemplos, un análisis de los factores clave que afectan a tales estrategias y finalmente, el trabajo termina extrayendo unas conclusiones. Quedan pendientes algunos aspectos como la responsabilidad de la sociedad en la prestación de ayuda a los ganaderos que mantienen las razas locales en peligro de extinción y las acciones que conviene tomar cuando una de estas razas vuelve a ser auto-sostenible tras haber estado amenazada, o cuando, por el contrario, una raza deja de ser auto-sostenible.

Palabras clave: *razas locales, valor añadido, conservación, uso sostenible*

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[1] http://www.eaap.org/Previous_Annual_Meetings/2010Crete/index.html

Introduction

The decline and disappearance of local breeds has been described sufficiently (FAO, 1992, 2007a; Simon and Buchenauer, 1993; Alderson, 2003; Gandini *et al.*, 2004). The decline of such breeds can be attributed, to some extent, to the failure of markets and the failure of institutions to provide advise to decision-makers. The main causes of this decline include: (1) the widespread use of a few highly productive breeds; (2) the mechanization of farming, which has meant that animals are no longer needed for draught power; and (3) the increasing abandonment of agricultural land in many marginal areas, where the majority of local breed populations are concentrated (Cicia, d'Ercole and Marino, 2003). In regions outside Europe, the main causes of the loss of local breeds can be assigned to policies implemented by governments, development projects and private companies that promote the use of international breeds either as pure-breeds or via cross-breeding to "improve" local breeds (Köhler-Rollefson and Mundy, 2010).

The first legally binding international instrument containing provisions to conserve agro-biodiversity was the Convention on Biological Diversity (CBD) (Article 8c), signed in 1992 at the Earth Summit in Rio de Janeiro. At the Rio Summit, Agenda 21, a plan of action to be undertaken by stakeholders at global, national and local levels was adopted. Agenda 21 included a chapter (Chapter 14) dealing with the promotion of sustainable agriculture and rural development, which covered issues related to the conservation and development of animal genetic resources (United Nations, 1993). Thus, society's increasing awareness of the loss of biodiversity, included awareness of the decline in livestock diversity.

Since the time of the Earth Summit, international debate was initiated and efforts have increasingly been made at global, regional and national levels to promote the role of livestock and their products in food security and rural development and to prevent the erosion of animal genetic resources (Ligda and Zjalic, 2011).

It is recognized that there is a need to enhance monitoring, characterization and research on the adaptive characteristics of local breeds. Specific actions are included in the Global Plan for Action for Animal Genetic Resources (FAO, 2007b). Within the framework of the Global Plan of Action, countries have developed, and others are in the process of developing, national plans for management of animal genetic resources. Furthermore, local initiatives are being taken by livestock keepers, producers and other stakeholders, focusing mainly on the promotion of local breeds by increasing their share in the market, but also by focusing on their role in management of the environment, and in the culture and history of their regions.

The material presented at the EAAP Session "Strategies to add value to local breeds", and in this special issue, covers various strategies that have been used to add value to local breeds in different countries and regions with the aim of increasing their competitiveness and their sustainability in the long term. This paper aims to present a general overview of these strategies, illustrated with examples, and to analyse their strengths and weaknesses in relation to the environments where they are implemented.

Strategies for adding value

The design of appropriate strategies for adding value to local breeds and thereby ensuring viable future for them has been a major concern for development agencies, breeders' associations and individual breeders. The management of local breeds is a complex issue that involves a range of different stakeholders, who have diverse economic, social, environmental and technical objectives. The stakeholders include direct users (livestock keepers, producers, manufacturers and consumers) and indirect users (the community, i.e. the inhabitants of rural areas who receive benefits from livestock farming). Obviously, the interests of various stakeholders may differ. Farmers and producers mainly focus on increasing the profitability of primary production, manufacturers and retailers are interested in adding value to the primary product and consumers are primarily interested in the safety and quality of the product. Price, and ethical and cultural issues are also important, to varying degrees, for various groups of consumers. It can be argued that, in the long term, society is the key stakeholder defining the framework in which livestock production is practised (Woolliams *et al.,* 2005).

The papers in this issue present case studies that feature a number of different species, breeds and countries. The strategies described can be grouped into three categories:

1. linkage of local breeds to traditional products and/or tourism/agritourism;
2. promotion of local breeds in specific farming systems, such as organic production, conservation grazing, silvi-pastoral systems and small-scale low-input farms and hobby farms; and
3. general strategies focusing on the promotion of local breeds, (marketing, legislation, organizational issues and raising public awareness) (Papachristoforou, Koumas and Hadjipavlou, 2013).

These strategies are interrelated and overlapping. The first two categories cover more specific initiatives, while the third focuses on enabling factors.

Valorization strategies can also be distinguished according to whether they originate as collective actions or as individual initiatives (Lauvie, Lambert-Derkimba and Casabianca, 2013). Collective actions involve farmers grouped into cooperatives or associations and companies that process products.

Gandini *et al.* (2010), describing motivations and values associated with 15 local cattle breeds in Europe, state that most farmers keeping these breeds need development

of activities that promote and help farming of such breeds. Among the three main reasons given for keeping local cattle breeds (see Figure 1), farmers ranked the functional traits of such breeds most highly, followed by tradition and the availability of external support. The relatively low importance given to external support from conservation programmes might indicate that such support is generally inadequate as a means of encouraging farmers to continue keeping local breeds.

It is important to note that the circumstances of different breeds and different countries vary greatly, which indicates that actions aimed at promoting local breeds should be flexible and adaptable to local requirements.

Links to traditional products and/or tourism/ agritourism

Linking a breed to a specific product or products is considered to be an effective way of increasing the breed's value, provided specific and well-defined steps are followed. There are several instruments in the European Union that can be used to promote such initiatives.

Increasing scientific knowledge of breed characteristics and the quality of their products – both nutritional characteristics and flavour – is a fundamental step in the development of a brand name for a product. Numerous studies describe the identification of product-quality traits in specific breeds as the initial step justifying the linkage of the breeds to the products and/or production systems.

Sanz *et al.* (2013) discuss the example of the Serrana de Teruel cattle breed of Southern Aragon, Spain, from the perspective of defining the standard requirements for a labelled meat product that will support a conservation programme in the medium term. Along with studying carcass and meat quality in three commercial categories, the authors investigated the opinions of farmers and consumers regarding "Serrana de Teruel" beef.

Karatosidi *et al.* (2013) describe two quite diverse cases: Italian Podolian cattle and Greek Katerini cattle. The former is found in the southern part of Italy (Abruzzo, Basilicata, Calabria, Molise and Apulia) and the latter (which has a population of only 217 heads) in Thessaly, Greece. The paper aims to compare the quality parameters of the two breeds and propose a plan for conservation of the Katerini through certification of meat quality.

Lauvie, Lambert-Derkimba and Casabianca (2013), in comparing two pig breeds, the Nustrale and the Blanc de l'Ouest, show that local breeds can have very contrasting development dynamics, even if they belong to the same species and are kept in the same national institutional context. These different dynamics are attributed to local specificities in the agro-food system.

Comparing the Nustrale with the Cinta Senese breed (from Tuscany, Italy), both of which are subject to applications for protected designations of origin (PDOs), Casabianca *et al.* (2010) show that the attractiveness of keeping both breeds has increased because of developments in product marketing. However, in both cases, the question of the environmental impact of the production units has not really been addressed by the projects.

An interesting case study from Morocco, related with the development of a Protected Geographical Indication (PGI) product for lamb meat under the name "Viande Agneau Béni Guil", was presented by Fagouri at a FAO Workshop (19–21 November, 2012, Rabat, Morocco). The group of producers involved in this initiative belong to the National Association of Sheep and Goat Breeders (ANOC). The actions taken include:

1. description of the main characteristics of the product (breed, age, live weight, carcass weight, composition, etc.) and the production system;
2. description of different types of products within the PGI; and
3. description of other specific characteristics such as the taste of the meat.

It is important to establish the criteria that justify the link between the product and the region (historical data), to define the production zone (altitude, climate, vegetation, etc.) and to list the operations that take place in the specific zone (selection, lambing, weaning, slaughter, etc.). All these steps should be clearly defined and ensure traceability of the product. Nevertheless, it is important to bear in mind that when a group of producers (farmers and manufacturers) start the process of establishing a PGI, the product already exists and is already recognized by consumers as a unique product that is connected to the region.

Furthermore, Araba, Chatibi and Casabianca (2012) analyse the importance of connection to the market in conservation of a local cattle breed in Morocco and the difficulties that breeders from a mountainous area far from large towns have in accessing remunerating markets.

In the case of the Tunisian Sicilo-Sarde Breed Association, a group of enthusiastic farmers succeeded in doubling the income coming from milk production by improving the production level (supported by research) and capitalizing on market opportunities for cheese production. Development of the dairy-sheep sector led to the establishment of a new collecting centre in Beja, linked to an artisanal dairy processing plant under the name of "Fromagerie artisanale de Béja". The possibility of another collection centre and artisanal processing plant in Mateur region is being considered. These products were developed as part of the FAO project (TCP 3202). The "Noire de Thibar" sheep breed of Tunisia provides another example of an organized process that aimed to identify meat-quality characteristics that could be used to distinguish the product from similar products from other breeds (Slimene *et al.*, 2013).

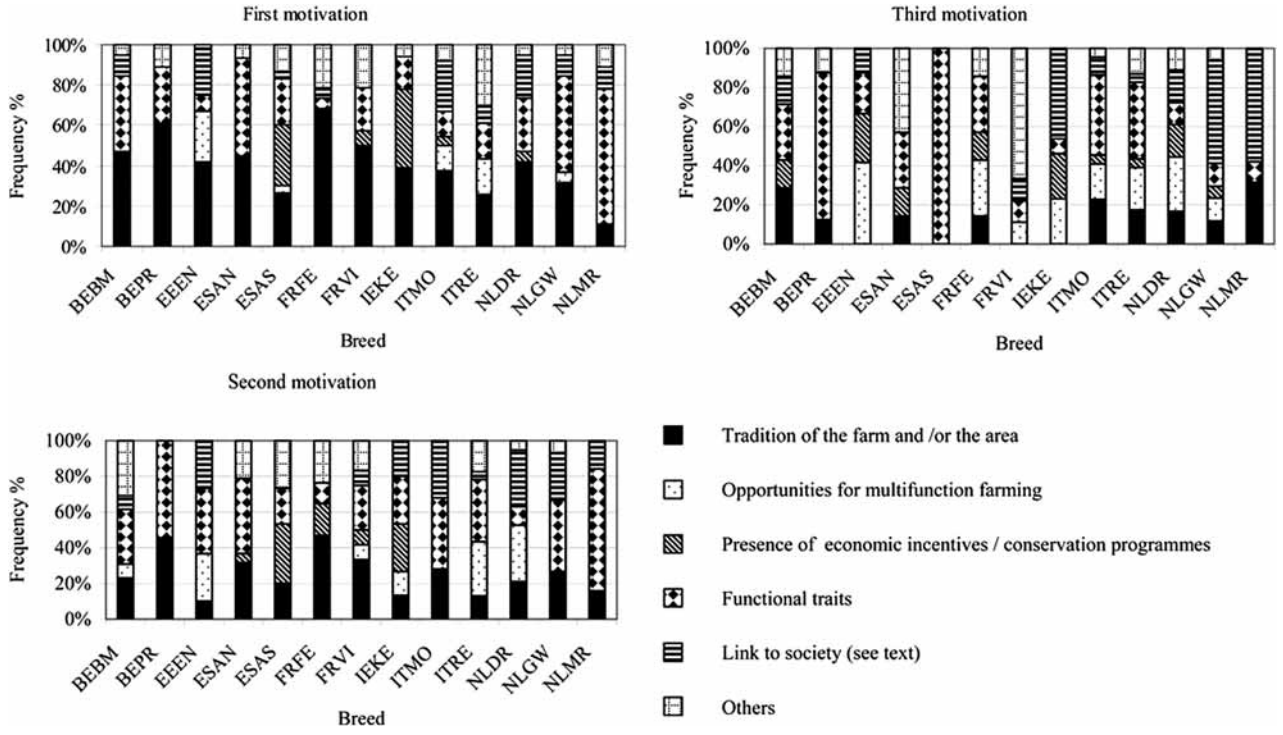

Figure 1. Three main factors motivating farmers to keep local cattle breeds. Source: Gandini *et al.* (2010).

Promote the use of local breeds in specific farming systems

A key element of strategies that aim to take advantage of the roles of local breeds in specific farming systems (e.g. for low-input and organic production systems) is improving knowledge of these roles. The evaluation of the performance of breeds in specific production systems may reveal characteristics that can be used to increase their value. The suitability of traditional breeds for low input and organic production systems depends on a balance between productivity, suitability for outdoor production and conformity with market demands. The review of Leenhouwers and Merks (2013) groups traditional pig breeds into two categories: (1) a group of prolific breeds with good finishing performance (e.g. Saddlebacks and Pulawska); and (2) breeds that are kept for specialized meat production (e.g. Iberico and Cinta Senese). The breeds belonging to the first category are suitable for organic production, especially when crossed with conventional breeds (e.g. Large White, Landrace and Duroc), while breeds of the second category are not suitable for commodity organic production, because of their low fertility and high carcass fatness. However, the latter group of breeds are suitable for production of breed-specific products, as shown by the case of the Nustrale and the Cinta Senese breeds (Casabianca *et al.*, 2010).

Cassandro (2013) addresses the question of valuing the environmental benefits that may be obtainable from the use of local breeds. The example focuses on lower greenhouse gas emissions of local cattle breeds, which are low input animals characterized by modest body weight. According to the author, local Italian cattle breeds studied are expected to have 10 percent lower daily methane emissions per kg of metabolic body weight than "cosmopolitan" breeds (Holstein–Friesian, Brown Swiss and Simmenthal). It is argued that such factors should be taken into consideration when defining the traits upon which local breeds should be evaluated and that local breeds should not be evaluated merely as food providers, but also as providers of public goods.

Papachristoforou, Koumas and Hadjipavlou (2013) provide another example of the use of local breeds for environmental purposes: in this case, Segurena sheep and Malaguena goats are used to clear forest in a mountainous area in Andalusia, Spain, and the farmers receive incentives for providing the service. Another example from Spain, in which local breeds are used in silvipastoral systems that link production and nature conservation, is described by Olea and Miguel-Ayanz (2006), who provide detailed information on major components of the Spanish dehesa system in which local livestock plays an important role in use of natural pastures and in preserving the ecosystem's biodiversity. In Austria, the risk of avalanches in the high Alps is reduced by keeping grazing animals on steep slopes above the tree limit (Berger, 2010). In Ireland, native cattle and sheep breeds are being looked at for their role in grazing specific habitats of environmental interest and in France local breeds are used for landscape management (mountains, wetlands) and for protecting Mediterranean forests against fire (Ligda and Zjalic, 2011).

The use of local breeds by small-scale and hobby farmers should also be considered in valorization strategies.

Examples from Europe include the Kempen Heath sheep in the Netherlands, which is not only kept for heath management, but also for wool and meat. Meat products from Kempen Heath sheep, together with Drenthe Heath sheep, are sold under the Slow Food label (http://www.slowfood.com). Different organizations and networks, such as Slow Food,[2] the ELBARN Project[3] and the World Initiative for Sustainable Pastoralism,[4] encourage and support small-scale and low-input production from local breeds.

General strategies

The selection process and the diffusion of genetic gain are important issues in management of local breeds and indirectly in all efforts to increase their value. Breeding programmes for local breeds are threatened by various forces, including competition from more productive and widespread breeds, economic constraints (lower demand for selected semen, lower return on investment) and the use of breeding animal exchanges. Labatut *et al.* (2013) provide important information on this topic, describing the situation of three local dairy sheep breeds from the Western Pyrenées of France. These three breeds (Manech Red Face, Manech Black Face and Basco Bearnaise) are used for production of Ossau-Iraty cheese. The results presented by the authors highlight the importance of the availability of breeding animals (specifically young ewes) and collective organization of the market for breeding animals for conservation of local breeds and for improving their competitiveness. These findings support the contention that it is necessary to take into account not only the genetic aspects of breeding programmes but also the organizational dimension. One suggestion that needs further investigation is the organization of a data bank on the animals provided by the nucleus flocks and a system for providing data to and accessing data from the data bank.

Related to the above is the management of local breeds and interaction with strategies for valorization of local breeds. Lambert – Derkimba *et al.* (2013) describe the cases of six local cattle breeds, five of which are connected to at least one PDO. Different approaches are followed depending on the goals of the breeders, which might be regarded as a drawback for development of breeds with small population sizes. The example of the Vosgienne breed illustrates this conflict. For breeders that sell milk to the dairy industry, the selection criterion is milk yield, while for those that process cheese on-farm, the most important selection criterion is specific milk quality that is needed for cheese production. When all the breeders are involved in production of a PDO product, as in the case of the Tarentaise breed and Beaufort PDO cheese, a consensus on selection objectives is easier to reach (Lambert-Derkimba *et al.*, 2010). An interesting example of breed valorization is illustrated in the same paper by the case of the Aubrac breed, which is used in a cross-breeding scheme with the Charolais breed to produce calves for the Italian fattening chain. This has led to an increase in demand for Aubrac cows, which are easy calving, have good mothering abilities and are able to make use of a harsh environment. The different labels used to valorize female calves and older animals generate better prices for meat and have contributed to keeping the breed in use in the region (Lambert-Dekirmba *et al.*, 2013).

The examples show that there is more than one way to valorize a breed. A valorization strategy should reflect real situation of the breed. Clearly, this requires an in-depth understanding of the breed, the production system and other relevant factors.

The organization of the "Noire de Thibar" sheep meat sector in Tunis (Slimene *et al.*, 2013) involves a producers group – which supports the organization of farmers, determines the production plan and organizes collection and sorting of lambs, and delivery of animals to the slaughterhouse – and a quality group representing the operators involved in the production process (farmers, slaughterers, meat companies and distributors). These operators will decide on the quality mark, whether a geographical indication or a collective trademark.

Marketing is an important element of valorization strategies for local breeds. It includes the steps that need to be taken to identify special characteristics of the targeted breed and its products, as well as market research, actions that facilitate access to new markets, awareness raising among consumers and so on. Marketing requires good knowledge of the breed and its production system. Institutional and legal frameworks may support the development of marketing initiatives and increase the efficiency of efforts undertaken by local communities.

Agritourism is another relevant activity. It is not a strategy for adding value to local breeds, but should be regarded as a distinct sector of agricultural activities that provides a favourable environment for sustainable development of local breeds and promotion of their products by increasing demand in the local market and economic activities in the local region.

In several countries in Europe (e.g. Austria, Ireland, Sweden and Switzerland), local rare breeds are considered to be tourist attractions and can generate a certain amount of income at sites visited by tourists. Farm parks in the United Kingdom carry out important work in the field of conservation and many provide educational services. Some of them are approved by the Rare Breeds Survival Trust (an NGO) and are involved in the conservation, breeding and promotion of rare breeds (www.rbst.org.uk) (Ligda and Zjalic, 2010).

Key factors in the success of valorization strategies

Strategies for adding value to local breeds vary according to the species, the characteristics of the breeds and their

[2] http://www.slowfood.com/
[3] http://www.elbarn.net/elbarn/
[4] http://www.iucn.org/wisp/

production systems, the nature of existing markets, the dynamics of breeders' associations or other stakeholders, the goals of the stakeholders, etc.

The successful implementation of any strategy requires use of reliable information on characteristics of the product and the production method. It is also necessary to ensure reliability of the process. Methods and systems for adding value to local breeds, range from the use of trademarks or official designations, to initiatives exploiting the breeds' non-direct use values, such as those associated with their cultural or environmental roles.

The main points that emerged from analysis of the cases examined are summarized in this section. It is not possible to offer straightforward guidelines that can be applied in all cases. Factors that are strengths for local breeds in one set of circumstances, may be weaknesses in others.

Factors related to the production environment

Local breeds have been raised for many years, or even centuries, in specific locations and have developed hardiness and adaptedness to these production systems. The main advantages of local breeds originating from this link between the breed and the production system, which can be analysed in terms of the production system are; the breed, the production of typical products for specialized markets, or values related to the ecosystem or cultural heritage.

Production system

The importance of the production system refers to the specific characteristics of the management system and the natural environment in which the breeds are raised. In principle, it is recognized that a breed is more likely to survive in the long term if it has a clear role in a sustainable production system. In this context, detailed information on production environment is required. The adaptation of local breeds to specific environment is important in the context of climate change, as many livestock production systems will face various stresses related to more extreme weather, new disease challenges, etc. The systematic description of breeds' production environments allows performance data to be better interpreted, and can be used for breed comparisons and also as an indirect means of characterizing the adaptations that a breed is likely to have developed as a result of the selective pressure imposed by its production environment (Pilling, 2008).

Breed-specific traits and products

One of the main reasons why farmers abandon local breeds is their lower productivity in comparison with other breeds. However, detailed information on production and other traits of local breeds is often not available and therefore our knowledge of the real potential of these breeds is limited. Appropriate performance-recording systems for local breeds might identify traits that could provide justification for breed conservation and promotion. In this context, numerous studies have investigated the quality of milk and its properties for cheese production, or traits related to meat quality and fat composition, as these traits may provide a basis for diversifying products. However, other traits, such as those related to longevity and other functional traits, which for the moment are not regularly recorded, are also very important for economic viability of local breeds (Gandini *et al.*, 2007). Therefore, it is important to increase efforts to extend recording to such traits, in order to include them in selection programmes for local breeds and thereby promote successful implementation of valorization strategies.

Special products and marketing systems

The development of niche markets for distinctive livestock products opens new opportunities for promoting the economic viability of local breeds. In a majority of the cases under consideration, the process of valorizing the breed has been linked to production of a typical product for a niche market. This is explained by the fact that, in general, local breeds are connected to specific regions, and are thus related to specific production systems. These links are exploited in developing strategies for marketing labelled products. European Legislation provides a number of schemes under which distinctive products can be registered, including (PDO and PGI. These schemes do not explicitly imply that a product should originate from a specific breed, but numerous local breeds nonetheless benefit from these schemes, which require traditional production systems in specified locations and thereby promote the continued utilization of respective local breeds (Zjalic *et al.*, 2010).

Key means of promoting success in marketing strategies include ensuring that local producers are involved from the beginning of the process and undertaking a strengths, weaknesses, opportunities, trends (SWOT) analysis that provides information on the product itself, relevant market demands and trends and the prospects for entering new markets. Box 1 presents a list of factors to be considered in developing a trademark (Lund, 2010).

Box 1. Factors to be considered in developing a trademark.

- Existence of a sustainable breeding programme
- High and stable product quality
- Transparency in the chain from producer to consumers
- Animal health
- Animal welfare
- Aesthetics
- Use of the breed in nature management
- Environmental sustainability
- Historical significance of the breed or production systems
- The breed's capacity to utilize natural resources
- The breed's links to handicrafts and the maintenance of recipes and other traditions
- National obligations

Source: Lund (2010).

Non-direct use values

As discussed above, many local breeds play roles in protection of the environment, cultural heritage, etc. Non-direct use values – i.e. values arising from all uses of livestock other than the production of meat, milk, wool, fibre, etc. – may become increasingly important. Examples include services such as landscape management and protection of forests from fire. Local animal breeds can make a positive contribution to landscape and environmental management. Grazing animals play an important role in maintenance and regeneration of pastures, heaths and moorlands. However, it should be noted that in some cases PDO requirements do not ensure any protection for the environment, as Casabianca *et al.* (2010) show for outdoor extensive pig production. Therefore, it is necessary to reconnect the pieces of the chain: land–plants–animals–people. In this context, local breeds can be important motivations for holding people in rural areas and mountains. They help agro-tourism and are connected to the traditions and cultures of their local areas. Gandini and Villa (2003) propose a methodology for analysing the cultural/historical value of local breeds, which includes seven parameters: antiquity, agricultural systems, role in landscape, gastronomy, folklore, handicrafts and presence in forms of higher artistic expression.

General environment

Legal and institutional framework

The sustainable future of local breeds is threatened when their products are not clearly differentiated from products obtained from imported or other mainstream breeds or when traditional processing methods are not adapted to changes in society. Building the institutional framework is a long-term process, mainly because of the need to reach a collective agreement. Furthermore, the initial costs of building such frameworks are higher for small- and medium-sized communities.

Improving the institutional framework and the services provided by administrative and extension services will empower local initiatives and help provide the tools needed by farmers to protect their production systems and incorporate new technologies and innovation into traditional processing methods and thereby ensure quality of their products and their differentiation in the market. Technical support to farmers may, depending on the circumstances, be a strong point or a weak point in a valorization initiative. As noted above, we need to improve our knowledge of local breeds in order to understand their potential and the possibilities for their development. In this context, the role of technical support is important: for performance recording, for implementing management and breeding schemes and for setting selection objectives. Furthermore, technical support will help farmers and processors to identify the steps that need to be taken to harmonize production with the needs of society, while maintaining the traditional characteristics that give the product its special and unique character.

In developing common policies, common factors that affect breed sustainability regionally (e.g. the age of farmers, the state cooperation among farmers and the level of awareness in society) should be considered. However, because there is a lot of variation between breeds and countries, it is also important to develop tailor-made support measures for each individual case (Hiemstra *et al.*, 2010).

Roles and responsibilities of stakeholders

In livestock production different stakeholders are involved and interact with different interests and concerns on production and utilization of local breeds. Some general recommendations regarding the responsibilities of all partners – from national authorities and policy makers, to farmers' organizations and individual farmers – in implementation of valorization strategies are provided in Box 2.

Box 2. Stakeholder responsibilities in development of valorization strategies.

National animal genetic resources authorities and National Coordinators for the Management of Animal Genetic Resources:

- Raise awareness and maintain interest among politicians and in markets
- Learn and use lessons from "success stories" and "failures"
- Contribute to the development of knowledge on production and product-quality traits, functional traits, welfare, animal behaviour, etc
- Initiate further research and trials to expand knowledge
- Identify sources of support
- Promote contact and understanding between farmers and authorities

General authorities and policy-makers:

- Bear in mind that animal genetic resources are a national obligation too! just like animal health and trade regulations
- Stimulate political interest and show enthusiasm by using existing business-development programmes
- Emphasize the importance of animal genetic resources, biological diversity and landscape maintenance in plans and strategies
- Encourage the development of regional competence centres
- Develop guidelines on how to keep "small breeds" in a "big society" with regard to rules and regulations

Industry and farmer organizations:

- Develop the will and competence to market products based on local breeds
- Contribute to increasing the status of local breeds by promoting value addition
- Motivate farmers to build and use networks
- Challenge research and development institutions to build the knowledge necessary for further development of new products

Farmers:

- Search for inspiration and knowledge
- Build competence
- Be aware of quality demands
- Cooperate and build networks
- Build businesses slowly, but surely

Research and development activities

Research activities enhancing our knowledge of production systems, the characteristics of breeds and products, product valorization and marketing (including the consumers' points of view) are a necessary part of developing valorization strategies for local breeds. Research initiatives address all aspects of local breeds, from investigating their special characteristics, adaptive traits and resistance to diseases, to defining product-quality traits. These initiatives are complemented by development activities undertaken by local or regional development offices and stakeholders, which provide an appropriate environment for success. Research work is necessary in order to justify why a given strategy should be used to add value to a local breed, i.e. to explain the link between the breed and the region, the unique characteristics of the breed's products or the environmental benefits provided by the breed. Research also needs to investigate new possibilities for local breeds in a changing environment – climatic changes, changing social concerns about environmental matters and animal welfare, etc. – as well as the inclusion of new traits in selection objectives, new recording methods, etc. Several research opportunities exist in this field at European level (e.g. (EC) No. 870/2004 AGRI GEN RES) and at international level (several activities are supported by FAO or other international organizations). Research activities organized at regional level contribute to the assessment of common problems and challenges and can propose solutions that can be applied regionally. The DoMEsTIc[5] project *(Mediterranean biodiversity as a tool for the sustainable development of the small ruminant sector: from traditional knowledge to innovation*) implemented within the ARIMNet[6] framework is relevant to the topic of valorization of local animal genetic resources in four countries of the Mediterranean region, as the project focuses on strategies to support the sustainable development of production systems and contributes to increasing the value of local breeds, their commercial valorization, their use in agriculture and their positive effect on rural economies (Ligda, 2012). Another activity relevant to Mediterranean countries is the GALIMED project (*Genetics of adaptation of cattle livestock and production systems in the Mediterranean area*), which implements an original approach combining population genetics and livestock farming knowledge in order to genetically characterize the adaptation of Mediterranean cattle breeds to agro-climatic conditions on both sides of the Mediterranean Sea (Laloe, 2012).

Local environment

Competition from high yielding breeds

The main threat to a local breed is that it may be substituted by another breed, either directly or by cross-breeding. The reasons for such substitutions are linked to the fact that non-local breeds often have higher production levels and are therefore preferred by farmers or to the fact that farmers may have easier access to breeding animals from these breeds than from local breeds. The reasons for the unpopularity of local breeds should be investigated in order to see whether these reasons are valid. Competition can, however, also be considered from a different point of view, i.e. from the perspective of adaptability to specific production environments, potential for production of typical products, potential for exploiting niche markets, etc. Considering such factors may produce major arguments in favour of local breeds.

Availability of breeding stock and services

The availability of breeding animals and services constitute an important factor of the capacity of a local breed to face competition from other breeds, for which the production and diffusion of breeding animals may be organized in a better manner. When artificial insemination is not widely used, as is the case in several local breeds, breeding organizations should concentrate on improving management of the market of breeding animals. Labatut *et al.* (2013) provide useful information on this topic discussing the organizational aspects of breeding programmes and the practices of farmers.

Organization of breeders and other stakeholders

Successful implementation of a breeding strategy requires organization among the breeders. Breeders face various challenges related to genetic management, the implementation of selection programmes, the management of inbreeding and the diffusion of genetic gain and threats posed by competition from other breeds. Given that a breed is a collective good, developed over many years by natural selection and human intervention, it is easy to understand that collective organization of farmers plays an important role in valorization. Farmer organization is affected by the general environment in which farmers and other stakeholders operate. Good organization can create opportunities for a breed, but organizational problems can be a major threat. The papers under discussion describe several organizational issues related to various valorization strategies.

In cases of the valorization of local cattle breeds in France through the development of PDO products, Lambert-Derkimba, Lauvie, and Verrier (2013) discuss the question of compromise between the objectives of breeders and those of other stakeholders, and show that stakeholder diversity does not guarantee compromise, because diversity brings additional points of view to the process.

A breed is not static, but dynamic. It is not only a biological entity – it also has a social and economic dimension. Breeders are not the only actors involved in strategies for adding value to local breeds. Other actors include manufacturers, retailers and consumers, who may have diverse targets. Breeders should consider the views of all these actors, as all steps in this process are important in increasing the value of a local breed.

[5] http://www.arim-domestic.net/
[6] http://www.arimnet.net/

Relevant stakeholders include both representatives of the individual breeders and, organizations involved in selection and production of the targeted breed. The valorization of a local breed depends on orientation of these stakeholders and the success of the initiatives they generate. As described by Lauvie (2007), such initiatives may concern local landscape maintenance, livestock production systems, valorization of products, direct selling or short supply chains.

Supply chain and access to the market

Understanding the supply chain – all local actors from producer to consumer – is an important step. In the case of local breeds, the main points to consider include the capacity to provide a regular supply of products to the market, to gain a distinct position in the market and to identify new potential markets. Prerequisites and key factors that enable farmers to access the market need to be carefully checked and defined when developing marketing strategies for local breeds. A list of these factors is presented in Box 3.

Box 3. Key questions for developing a marketing strategy.

- Can the farmer's idea be the starting point for a regional concept that involves cooperation with other producers?
- Is it possible to document the product's uniqueness?
- Are there brands and certification systems that the farmer's products could fit into?
- Have factors such as expected profits, costs and marketing needs been analysed well enough?
- Does the farmer have the financial strength to survive the process?
- Is there a training or business-development programme in which the farmer can participate?
- Is the farmer aware of all relevant rules and regulations and how he or she may be affected by them?
- Is any specific research needed to identify "promotable" traits?
- What will be the best sales channel for the products, initially and as the market grows?

Source: Lund (2010).

In this process, all local stakeholders, even if they have different short-term objectives, according to their position as farmers, processors, retailers or consumers, should try to compromise, with the aim of achieving the main objective (common to all actors in the medium and long term) of providing a sustainable future for local breeds and for the region.

Conclusions

Successful (or unsuccessful) experiences in different countries and with different breeds should be further exploited by exchanging information and promoting its use. In this context, regional workshops could contribute to the development of new initiatives involving more breeds and new actors.

PDO or PGI protection based on the use of local breeds is a valuable tool for local development, as such initiatives help to maintain economic activities in the respective region by supporting activities connected with the labelled products and with tourism. Do we have enough tools to use to promote trade marks? Numerous examples are available from small-scale/speciality/unconventional production. Local breeds often have a unique and special story connected with local history or culture, or with adaption to a particular climate or landscape. They may also have special qualities such as an easily recognizable appearance or unique behavioural, fibre, milk or meat qualities. All the special characteristics and qualities of local breeds should be exploited in order to find new roles for the breeds.

Activities that add value to local breeds also support biodiversity and promote local heritage and tradition. These non-direct use values are linked to the roles of local breeds as providers of public goods. This raises the question of whether and how farmers should be compensated by society for keeping these animals.

Information on local breeds should not be restricted to the farming sector, but diffused through society as a whole. This will contribute to enhancing society's knowledge of local breeds and increase awareness and appreciation of the work done by farmers.

However, despite the widely agreed statement that animal genetic resources are a national obligation, and their conservation, use and development should be regulated, just like animal health and trade, still the discussion in several aspects is open. Questions that need to be addressed include: Should society support farmers for keeping local breeds? What should be done when a breed reaches the level of self-sustainability? And, in contrast, if a breed cannot become self-sustained, is it legitimate that society should continue to support farmers for an indefinite period, or is it more reasonable to let the market solve the situation?

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Dissemination of genetic progress: a key aspect of genetic improvement of local breeds

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Summary
Researches on local breeds have mainly focused on the scientific and technical activities of genetic gain production and/or maintain genetic variability. The diffusion of the genetic gain used to be taken for granted, or considered as of little importance as the State was subsidizing official breeding schemes. However, diffusion and sustainability of small local-breeding schemes are threatened by current changes in breeding activities and organizations. Diversification of farming and breeding objectives, liberalization of public policies on breeding activities, decrease in public support change the business model of breeding organizations. Local breeds are particularly concerned, as they may be threatened by more competitive and widespread ones. Indeed, the management of the diffusion dimension of breeding activities gets a greater importance. Thus, there is a need for a better understanding of the market of genetic gain and the strategies of its participants. To investigate this issue, we study with quantitative and qualitative data, the way the genetic market works in the case of local dairy sheep breeds in the Western Pyrenees. In this area, the use of artificial insemination (AI) outside nucleus flocks is weak. The diffusion is mainly based on the exchanges of live breeding animals, but the number and substance of the exchanges are unknown. We analyse two types of markets, which are set up: the official sale of breeding animals, organized by the breeding centre; the parallel market of rams' exchanges by mutual agreement between farmers. We find several paradoxical results: the more expensive animals are sold outside of the breeding schemes, while the genetic value is more uncertain; the breeding centre does not find enough buyers for its rams, while there is a shortage of rams in the region; outside the breeding schemes, the parallel market of rams is dominant. We also identify that there is a diversity of prices on the market, which cannot be explained based on the scientific evaluation of animals. We show the existence of a second-hand market of rams. In conclusion, we argue that there are various ways of managing the diffusion of genetic gain, and that the market is only one of this.

Keywords: *dairy sheep, diffusion, genetic gain, local breeds, rams' market*

Résumé
La recherche sur les races locales s'est principalement concentrée sur les activités scientifiques et techniques concernant la réalisation du gain génétique et/ou la conservation de la variabilité génétique. La diffusion du gain génétique était auparavant considérée comme garantie, ou sans grande importance, car l'État subventionnait les projets officiels de sélection. Cependant, la diffusion et la durabilité des petits projets locaux sont menacées par les changements qui se réalisent à présent dans les activités et dans les organismes de sélection. La diversification des objectifs de l'agriculture et de la sélection, la libéralisation des politiques publiques dans les activités de sélection et la diminution du soutien public modifient les modes opératoires des organismes de sélection. Les races locales sont particulièrement concernées car la présence de races plus compétitives et répandues pourrait les menacer. En effet, la gestion de la diffusion des activités de sélection devient de plus en plus importante. Par conséquent, il est nécessaire de mieux comprendre le marché du gain génétique et les stratégies de ses participants. Pour analyser cette question, nous avons étudié les données quantitatives et qualitatives du marché génétique des moutons laitiers locaux dans les Pyrénées occidentaux. Dans cette région, l'utilisation de l'insémination artificielle en dehors du troupeau fondateur est faible. La diffusion se base surtout sur les échanges de reproducteurs vivants, mais le nombre et la nature des échanges sont inconnus. Nous avons examiné deux types de marchés: la vente officielle de reproducteurs, organisée par le centre d'élevage; et le marché parallèle d'échanges de béliers réalisés de commun accord entre les agriculteurs. Nous avons repéré plusieurs résultats paradoxaux: les animaux plus coûteux se vendent en dehors des projets de sélection même si leur valeur génétique est plus incertaine; le centre d'élevage ne trouve pas assez d'acheteurs pour ses béliers même s'il existe une pénurie dans la région; en dehors des projets de sélection, le marché parallèle est dominant. Nous avons également identifié une diversité de prix sur le marché qui ne peut pas s'expliquer uniquement par l'évaluation scientifique des animaux. Il existe également un marché d'occasion des béliers. En conclusion, nous affirmons que le marché ne représente qu'une des différentes façons de gérer la diffusion du gain génétique.

Mots-clés: *moutons laitiers, diffusion, gain génétique, races locales, marché des béliers*

Resumen
El campo de la investigación relacionado con las razas locales se ha centrado principalmente en actividades científicas y técnicas de ganancias genéticas en la producción y/o en mantener la variabilidad genética. La difusión de la ganancia genética ha sido utilizada para recibir ayudas o se le ha dado poca importancia, dado que el Estado estaba apoyando económicamente los esquemas oficiales de

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selección. Sin embargo, la difusión y la sostenibilidad de pequeños esquemas de selección de razas locales se están viendo amenazados a consecuencia de los actuales cambios acaecidos sobre las actividades relacionadas con la mejora y las organizaciones. La diversificación de los objetivos de cría y de selección, la liberalización de políticas públicas relativas a las actividades de mejora y el menor apoyo público, ha originado que el modelo de negocio de las organizaciones de mejora cambie. Las razas locales se están viendo especialmente afectadas, dado que pueden verse amenazadas por otras más competitivas y más ampliamente distribuidas. En efecto, la gestión de la dimensión de la difusión de las actividades de mejora alcanza una mayor importancia. Así pues, existe la necesidad de que se comprenda mejor el mercado y el comercio de la ganancia genética y las estrategias de sus partes interesadas. Para investigar este tema, se ha estudiado con datos cuantitativos y cualitativos la manera en la que el mercado de la genética trabaja en el caso particular de las razas locales de ovejas para la producción de leche en Pirineo occidental. En esta región el uso de la inseminación artificial fuera de los rebaños del esquema es muy poca. La difusión se basa, principalmente, en el intercambio de animales para vida, pero el número y fundamento de dichos intercambios se desconoce. Se analizan dos tipos de comercio, que se establecen de la siguiente manera: la venta oficial de animales para vida, organizado por el centro de selección; y el mercado paralelo de intercambios de carneros, de común acuerdo, entre los ganaderos. Se encuentran resultados muy paradójicos: los animales más caros son los vendidos fuera de los esquemas de selección, mientras que el valor genético es más incierto; el centro de selección no encuentran suficientes compradores para sus carneros, mientras que existe una gran escasez de carneros en la región; fuera de los esquemas de selección, el comercio paralelo de carneros es el dominante. También se identifica la existencia de una gran diversidad de precios en el mercado, que no se puede explicar solamente de acuerdo con la valoración científica de los animales. Se demuestra la existencia de un comercio de segunda mano de carneros. En conclusión, se sostiene la existencia de varias formas de gestionar la difusión de la ganancia genética y el comercio es solamente una de ellas.

Palabras clave: *oveja de leche, difusión, ganancia genética, razas locales, mercado de carneros*

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Introduction

The dissemination of genetic progress in breeds' selection is often taken for granted: as long as a "good" genetic progress is obtained and animals' performances improved, it should be diffused. By dissemination of the genetic progress, we mean here the sales or exchanges of improved breeding animals and their semen from nucleus farms and breeding companies to the whole population. Indeed, breeding activities in most domestic ruminant species in France are based on the separation between the production of genetic gain by breeding companies and nucleus farms, and its dissemination to "commercial" farmers. In the case of dairy sheep for example, this organizational model of diffusion established work division between farmers and technical organizations in order to design and implement an efficient breeding strategy for a whole population, and not for only a few pedigree breeders (Barillet *et al.*, 2001). This model was implemented in the 1960s, thanks to the cooperation between French government, farmers and scientists, through the Breeding Law of 1966. In this model, for dairy sheep, "the population was split into two groups: a selection nucleus (selected population), for which the size needed to range between 10 and 20% of the population to be improved" (Elsen and Mocquot, 1974), and the rest of the animal population (i.e. commercial flocks). Breeding tools (pedigree recording, official milk recording, artificial insemination (AI), progeny test, assortative matings, etc.) were exclusively or mainly used within the nucleus farms, first to achieve genetic progress and second to organize its dissemination by AI or natural mating towards the other farms (Barillet, 1997; Barillet *et al.*, 2001). The organizational and technical models of dairy cattle are slightly different. The dairy cattle population is not divided between the selected population and the commercial population, as most of the population uses AI, and milk recording, even if not all herds are involved in generation of genetic progress. However, the diffusion of genetic gain and the market of breeding animals and selected semen in terms of farmers' preferences and usages are not very well understood. Since practices and performances of breeding flocks and herds are recorded, the way in which genetic gain is produced is very well known. On the other hand only modelling is used to study how it is spread later to all dairy farms. The main questions usually explored by geneticists are: "what breeding practices in the nucleus flocks could ensure the production of enough genetic gain to improve the genetic level of the whole base population? How could we predict the annual genetic gain of the whole population?" The objective of such modelling efforts is to define an "optimal diffusion plan" and "a good diffusion method" (Elsen, 1993). However, the answers to such questions and the modelling rely on several hypotheses on how the genetic gain produced in the nucleus flocks is used. The main means considered in these models to assess dissemination of genetic gain are mainly sales of AI and breeding animals from breeding centres and breeders towards ordinary farmers (commercial flocks). Indeed, AI is considered as the essential method for reproducing dairy cattle (Wilmot, 2007). AI is now considered, by research programmes and agricultural extension, as the most efficient and profitable method to diffuse genetic gain, even if it never totally replaced natural mating for sheep breeding. Several questions have to be considered in the "dissemination" aspect

of breeding activities: what are the practices of farmers from the commercial flocks according to their uses of the genetic progress produced by breeding schemes? By practices we mean: what are their criteria for a "good" genetic progress supply? How do they choose between AI and other sources of genetic gain? How does the market of breeding sires work? How are the prices of breeding products constructed? What is the importance of disseminating genetic progress for the technical and economical sustainability of breeding programmes and local breeds?

The case of local/indigenous breeds exacerbates the problem of the diffusion of genetic gain. Indeed, genetic research works on local breeds have mainly focused on the production of genetic gain, while its diffusion used to be taken for granted, or considered as obvious as the State was subsidizing official breeding programmes. However, the actual diffusion and sustainability of small local-breeding programmes are threatened by current changes in breeding activities and organizations – diversification of breeding objectives, liberalization of markets for animal genetics, decrease in public support. Local breeds are particularly concerned, for multiple reasons.

- Local breeds are threatened by the competition of more productive and widespread breeds. For example, in the case of dairy sheep, the Lacaune breed, one of the most productive dairy sheep breed worldwide, threatens other indigenous and less productive dairy breeds in France.
- Local breeding programmes are usually small sized and may have economic difficulties because of lower sales of selected semen, lower return on investment.
- AI cannot be the only way for transfer of genetic progress for local breeds, exchanges of breeding animals are often necessary as there is no second possibility of the AI service if the first AI is not successful (at least for sheep, goats and beef cattle).

Thus, local access to breeding animals with a good sanitarian status and corresponding to farmers' criteria is a key factor for maintaining local breeds.

Several studies have addressed the question of maintaining local breeds (see special issue of Ecological Economics, in Drucker and Scarpa (2003) (45), on animal genetic-resources management), but very few have actually studied the market for animal genetic resources in industrialized countries, while these countries faced a huge decrease, in the past few decades, of their agro-biodiversity. The management of genetic gain diffusion and supply of genetic goods (semen and animals) corresponding to farmers' preferences and uses in breeding activities gets a greater importance, putting forward the need for a better understanding of genetic gain markets and the practices and behaviour of its participants according to genetic improvement strategies of their flocks or herds. In this paper, we study the specific cases of three local dairy sheep breeds to provide basis for a better understanding of the diffusion of genetic gain and the market for breeding animals.

Local breeds in the Western Pyrenees: diffusion of genetic gain at stake

In France, three regions contribute the largest part of the national sheep milk production, where the milk is processed into Protected Designation of Origin (PDO) products and where local breeds are used: the Roquefort region and the Lacaune breed; Western Pyrenees and their three local breeds (Manex Red Face, Manex Black Face and Basco-Béarnaise) producing Ossau-Iraty cheese, and Corsica with the Corsica breed producing Bruccio and other types of cheeses. The Lacaune breed, in the Roquefort region, has been the first local breed to benefit from the implementation of a science-based breeding programme. Geneticists from the INRA (National Institute for Agronomic Research), and local professional leaders and industries, developed a highly efficient breeding programme for this breed, which rapidly became one of the most productive dairy sheep breed worldwide. Lacaune sheep are diffused in other French regions and even worldwide although this breed is still considered as local because the largest part of its population is located in the Roquefort region. In this breeding programme, AI became the major way of dissemination of genetic progress into commercial populations, but this must be considered as an exception. In the two other regions, AI cannot be the main mean of diffusion of genetic gain to commercial flocks.

We tried to identify some of the factors explaining these differences in the Western Pyrenees. In this region, a breeding centre and three breeding programmes have been implemented in order to increase the three local breeds' efficiency and farmers' incomes. The following figure (Figure 1) represents the general organization of the breeding programmes in the Western Pyrenees.

In this region, the genetic improvement of the three local breeds has been successful according to technical criteria of realized response to selection (Barillet *et al.*, 2009) (see Figure 2). However, despite this technical efficiency, cooperation between farmers, the breeding centre, extension services and R&D organizations is difficult to maintain (Labatut, Aggeri and Girard, 2007), threatening the sustainability of these local breeds. Moreover, the Lacaune breed, sometimes replaces local breed in commercial flocks (between 100 and 150 farmers use the Lacaune breed in the Western Pyrenees) thanks to its lead on genetic improvement, the highest level of performance as well as its availability on the market (it is easy to find rams and ewe lambs at a cheap price).

The managers of the three breeding programmes along with scientists involved in the implementation of the breeding programme identified controversies on the breeding objectives for these breeds among farmers, and controversies on the quality of breeding products. They were also worried by an apparently low level of dissemination of genetic progress. In this region, the use of AI outside

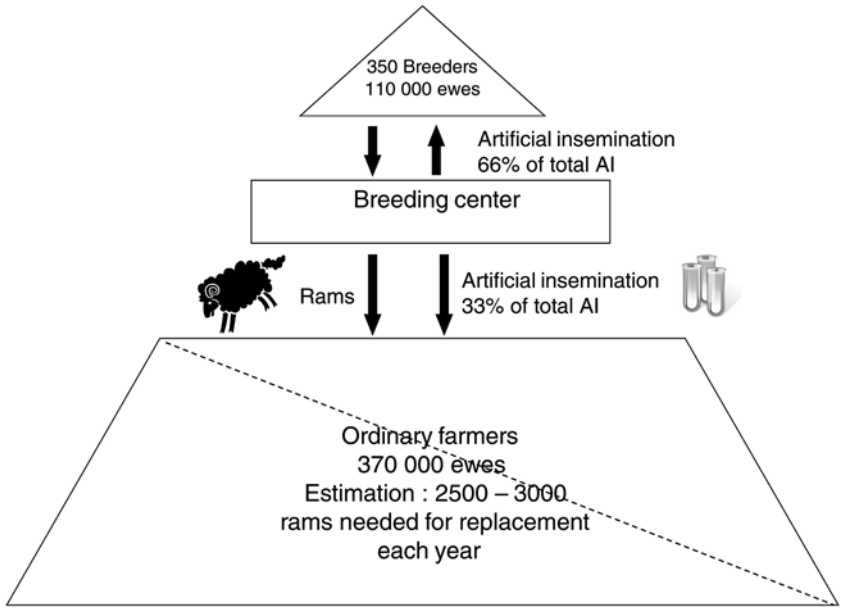

Figure 1. Organization of the breeding programs in the Western-Pyrenees.

nucleus flocks is low (Table 1). The diffusion seems to be mainly based on the exchanges of live breeding animals (especially rams), but the number and mechanisms of such exchanges are still unknown, and moreover (i) we do not know the rams used in the flocks and (ii) the pedigree are not known in the flocks out of the nucleus. The parallel market of rams seems to be more important than the breeding centre's one. The nucleus flocks breeders are used to sell rams to the base population. Until now the scope of this parallel market has not been precisely evaluated, but is often considered by managers and scientists as a market that breeders wish to extend because of the net income it can provide. The sanitarian requirements imposed by the French government to prevent from scrapie disease (increasing the proportion of breeding animals that are genetically resistant) (Sidani *et al.*, 2010) also encouraged the managers of breeding programmes to better understand the functioning of the market for breeding animals.

To better understand the mechanisms of diffusion of genetic gain and the market of breeding animals in this Western Pyrenees sheep industry, traditional genetic tools of analysis need to be complemented. We had to understand how the value of genetic goods (here mainly breeding animals) was built on the different market mechanisms observed. We developed a qualitative analysis on two dimensions involved in the market of animal genetics: the collective tools designed to allow market coordination, and the individual practices and strategies of farmers on this market.

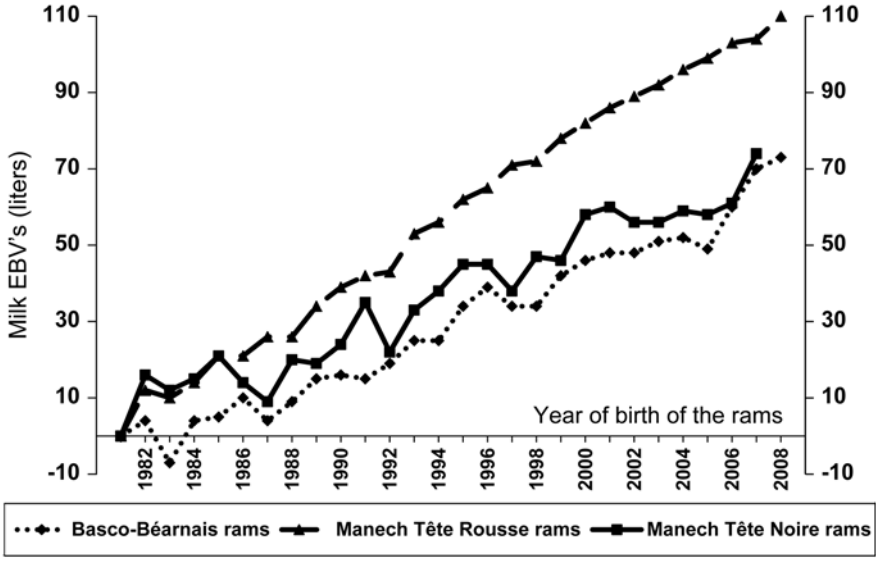

Figure 2. Evolution of estimated breeding values (EBVs) of Manex and Basco-Béarnais rams (average milk breeding value 2008) (Astruc *et al.*, 2009).

Table 1. Importance of AI per breed.

Breeds (or group of breeds)	Total number of ewes	AI rate in the nucleus flocks %	Number of AI out of the nucleus flocks
Lacaune	950 000	80	400 000
Pyrenean breeds	425 000	50	35 000
Corsican	85 000	30	500

Material and method

We studied two types of market mechanisms: (1) the qualification procedure and official sale of breeding animals, organized by the breeding centre; (2) the parallel "over the counter" market of rams exchanges by mutual agreement between farmers and based on results of animal competition during country fairs. We realized detailed observations of these two market mechanisms: we observed who was making the judgements of animals and how, and which procedure, tools or grading systems were used. We identified who were the participants and the role of these mechanisms in the development of the market for breeding animals, and in the pricing.

In order to identify individual practices on the market for breeding animals, we interviewed 35 farmers, both members and non-members of the collective breeding programme, and presented their "realized strategies" (Mintzberg and Waters, 1985) in a formalized way using an innovative categorization method (Girard *et al.*, 2001, 2007; Boisseau, 2007). We observed that between 25 and 35 interviews are needed to grasp the diversity of strategies and practices that can be found in the reality. The last interviews have not added any new elements to broaden our analysis. This method focuses on the categorization of farming practices instead of evaluating technical and economic variables. It expresses then the qualitative nature of these practices without reducing them to quantitative parameters (Girard *et al.*, 2007). The application of such a qualitative method for studying the diffusion of genetic gain allowed firstly to better understand the motivations of farmers justifying their breeding strategy (AI, breeding animals, scientifically evaluated or not, etc.) and secondly to better understand the market of breeding animals and its dynamics (social networks, price construction of breeding animals, etc.). This method is also linked to local specific practices in order to build a specific typology rather than a generic one, through a deep understanding of husbandry practices (Girard *et al.*, 2007). An important part of the work was to choose objectively 35 farmers to be interviewed. Our aim was not to build a representative sample in statistical terms (which is quite impossible with only 35 interviews), but to interview representative farmers in terms of their diversity. We chose several criteria to favour a wide variety of cases (location, age of farmers, farming system, breed reared, farming practices such as summer grazing or not, pluriactivity, farm cheese production or not, etc.).

We describe the results in two parts. The first one is a general level of analysis focusing on the history and general description of the market for breeding animals for dairy sheep. The second part of the results focuses on the fine-grained mechanisms and practices involved in this market.

Results

The market for breeding animals: compulsory for sheep breeding but uncertain

It is well known that in the field of dairy cattle breeding, the market for AI (semen + AI service) almost totally replaced the market for living breeding animals. The reality of the market in dairy-sheep breeding is different: the market for AI has not fully replaced the market for breeding animals. The presence of breeding rams is always needed on farms as return on AI is not supplied by breeding companies, due to the high number of animals to inseminate, heat synchronization, and the fact that AI is used only on part of the herd.

However, this need for breeding animals and the importance of their quality depends on the breed. In the Roquefort region, where the Lacaune breed was developed, the rate of AI is so high that the quality of individual breeding rams does not have a very high importance: their offspring are not kept for replacement but usually sold for meat consumption. In this case, the "over the counter" market for breeding animals almost disappeared.

In Western Pyrenees, on the contrary, AI has not been widely used in commercial population, as illustrated by the following chart. Thus, in this region, the market for breeding animals is still of major importance (Table 2).

The economic model of breeding programme: diversity of situations

The market for living breeding animals is needed, but low sales of AIs can weaken the cooperative basis and sustainability of the collective breeding programme. When a breeder sells individually a ram born from AI on his farm, he not only sells a part of his own breeding work, but also a part of the collective breeding work realized by the breeding programme. Thus this farmer gets individual benefits (sale of the ram) without giving back direct return to the breeding programme. Similarly, when farmers outside of the nucleus flock buy rams from these breeders, they

Table 2. Proportion (%) of inseminated ewes and natural mating in both regions, for the total ewe population (source: SIEOL, 2010)

	Western Pyrenees	Roquefort region
Inseminated ewes	50.5	80.0
Natural mating	49.5	20.0

benefit from the genetic gain produced by the collective breeding programme without supporting the costs of its implementation (milk recording, AI, etc.), and without providing any return to the breeding programme. These behaviours are often defined as "free riders" (Olson, 1978): without bearing the costs and efforts of collective action, participants benefit from it. However, these behaviours do not always lead to a failure in the collective action. In the case of the sheep breeding market, these behaviours contribute to the dissemination of the genetic progress and provide breeders in the nucleus flocks an opportunity to get a return on investment for their involvement in the collective breeding programme, which is costly on a short-term basis. As it will be described later in the results that this activity (producing rams for sales) is not something that farmers really seek to develop and enhance, and can be as much a constraint than a benefit for them.

In the past because of large financial support to the breeding programmes by the French government, the sales of breeding animals without any return to the collective breeding organization did not threaten the collective action. However, in the current context decrease in public financial support to breeding programmes and liberalization of the market for animal genetics, since the reform of the Breeding Law in 2006, the return on investment that small-scale breeding programmes can get is of the highest importance to ensure their autonomy. In the Roquefort region, as indicated earlier, the diffusion of genetic progress by AI is the predominant means of diffusion, compared with breeding-animals exchange and natural mating. Breeding animals are mainly dedicated to sales outside of the local region, by an organization called "Genelex" which is directly linked to the breeding programme. These sales provide a second source of income and return on investment for breeding programmes. In the case of Roquefort, thanks to the success of the diffusion, the investment of breeders in the breeding programme brings in two types of individual benefits. Nucleus flocks breeders obviously improve faster their flock genetic level. They also get back part of the collective benefits brought each year by the sales of breeding animals and through discounts on the cost of AI. These sales of breeding animals ensure the profitability of the breeding programme, and at the same time favour cooperation and its sustainability because of the decrease in public funding.

In the Western Pyrenees, the situation is different. Here, farmers have difficulties in finding breeding animals to replenish their flock or to start new flocks with the local breeds, especially due to hygiene problems. Several farmers, during their interviews, referred to the shortage of breeding rams: "we lack rams, everybody is looking for rams". In this region, the occurrence of several sanitarian problems such as scrapie disease (implying to buy only resistant breeding animals) or epididimytis contributed to this shortage of breeding animals. The following quote, from a farmer, illustrates this difficulty and the dilemma between temptation to buy breeding animals from an exogenous breed (in this example the Lacaune) for which breeding animals are easily available, and the willingness of using local breeds:

> "When I had the scrapie... I hesitated a lot because I had to renew 80 percent of my flock and I could not find any ewes on the market, the only animals that were offered on the market were female lambs at 90€ each... So I came to enquire about buying Lacaune ewes and they were less expensive, older – 4 or 5 months – and with a higher genetic level, I think... It is true that I hesitated a lot, but I don't know how to work with these ewes, I am used to my Manex".

In the Western Pyrenees, as well as in Roquefort, the breeding centres sell culled rams (i.e. rams that are not kept for producing semen for AI for several reasons such as morphological defects, or incapacity to give semen). However, one of the paradoxes identified in the Western Pyrenees during our study is that whereas there is a shortage of breeding rams in the region, only part of the rams from the breeding centre are sold, even if their parents have very good estimated breeding values (among the best breeding values of the nucleus flocks). Sometimes, for the Basco-Béarnaise and the Manex Black Face, very few breeding rams are sold for several reasons: standards not corresponding to farmers' criteria, animals considered as unsuitable for mountain grazing, etc.

Failures of collective organizations for the market of breeding animals

The above results confirm that the availability of breeding animals (more specifically young ewes) is an important criterion for the management of local breeds, their conservation and their competitiveness with regard to more productive breeds. The availability of breeding animals is thus an important factor of the capacity of a local breed to face external competition from exogenous breeds for which the production of breeding animals may be better organized. To provide a solution to this problem, in the Western Pyrenees, the breeding centre tried to organize the production of breeding animals in designing, in 1997, a "solidarity stock market". For example, they encouraged in the nucleus flocks AI of ewe lambs that breeders would have waited one more year to inseminate them, in order to produce ewe lambs for sales. This initiative was directed towards the constitution of a "bank of ewe lambs". However, producing ewe lambs from inseminated ewe lambs is a constraint in terms of workload and reproduction organization. To encourage breeders to produce these ewe lambs, a bonus of 15€ was paid by the breeding centres to breeders for each ewe lamb delivered. The "solidarity stock market" organized the production and diffusion of not only ewe lambs but also adult ewes, inseminated ewes, rams, etc. Buyers had to sign a contract to ensure that they would buy the ewe lambs produced by the breeders, to encourage them to make the effort of inseminating their young ewes.

This system lasted several years before being abandoned. A breeder who participated in the bank of ewe lambs explained the difficulty to produce a lot of animals that fit into the demands of buyers according to diverse criteria, without keeping animals too long on the farm:

> "In this bank of ewe lambs, there was very diverse quality of animals, the breeding centre would collect all the animals, even the undersized ewes, or under weighted, so some of the buyers were critics. I said that I did not want to be criticized, so I said: I will get the ewes ready for October. During three or four years, we inseminated 60 ewe lambs. The first year, I could sell 10 ewes, the second year, 20. But I reared them as if they were for my use! The breeding center said they would collect them at 40 days, I said "no", they are too young, they need 50 days before weaning. Sometimes, breeders delivered them without even cutting the tails. I did as if they were for my flock, even if one was the daughter of a very good ram, I would not keep it if it was crooked".

To sum up, this first part of the results revealed several important elements on the general functioning of the breeding stock market:

- The market for breeding animals is necessary but highly uncertain on the quality and supply of animals.
- It represents a core element to be managed for ensuring the conservation and competitiveness of local breeds.
- The financial equilibrium of breeding programmes can partly rely on this market.
- Its mechanisms are unknown and its management appears to be difficult.

Thus, the second part of the results focuses on the actual farmers' practices and mechanisms involved in this market for breeding animals.

Six types of individual breeding strategies

To understand the choices made by farmers on the market for breeding animals, we analysed a specific management area among farming practices, the "management of rams". Three categories of practices defined this management domain in farmers' practices: the strategy of rams' supply over years (location of the supply); the choice of the rams' genetic origin (natural mating or AI); the criteria for choosing rams according to the mode of knowledge available to assess the quality of the ram (scientific evaluation, genealogy, empirical experience, etc.). However, in order to understand farmers' rationalities, the study of other management domains was needed: the management of reproduction (how, when and with what methods farmers would manage the reproduction of the flock), the management of young ewes to renew the flock (would farmers accelerate their growth, keep them longer with dams, wait 1.5 year before mating them, etc.), the use of the territory (do farmers use summer mountain grazing or pastures close to the farm, etc.) and the involvement in collective breeding organization (do farmers participate in the breeding programme, why and how). In all, 13 categories of practices were defined and represented on 13 axes. On each axis, the two extremities represent the extreme practice of this category. For example, for the axis "age of first lambing for young ewes", one extremity of the axis is "lambing as soon as possible (at one year old)", the other is "avoid lambing before two years old". Each practice of each farmer has been positioned on these 13 axes. A software (Repgrid) helped us grouping farmers according to the similarity of their practices among these 13 categories, and thus building a typology of practices.

This method helped us to identify six types of individual breeding strategies of farmers at the farm level (see Table 3), ranging from an intensive use of genetic services (type 2 "Producing good ewe lambs using genetic gain produced by breeding scheme and accelerating flock replacement"), a moderate use aiming at improving steadily the genetic level of the flock (type 3 "Increasing progressively the genetic level of the flock, using collective genetic gain while using summer pasture"), to other strategies whose driving forces are not directly genetic improvement but territory use or cheese production (type 4 "Using mountain pasture and producing cheese while simplifying flock management and using rams born from artificial insemination", as AI is sometimes a constraint when animals are grazing in mountain pasture during their reproductive period, and type 5 "Having simple and natural breeding practices while using moderately collective genetic gain"). Other farmers in their strategy put forward the individual control of breeding for sanitarian and genetic reasons (type 1 "Controlling flock breeding on farm and improving its genetic level only by artificial insemination") or the animal standard (type 6 "Having a nice-looking flock without using collective breeding tools, and using mountain pasture as much as possible").

Links between types of breeding practices and the collective breeding programme

Beyond these individual strategies lead by the global coherence of farm management, describing individual practices such as "ways of obtaining rams" or "use of collective breeding tools" allowed us to characterize the relationship chosen by each farmer at the collective level, i.e. the breeding programme or local networks of farmers. These data revealed unexpected results on the functioning of the market of breeding rams. Firstly, even though AI is not very much used in the commercial flocks, only the type 6 does not use at all the genetic gain produced by the breeding programme (based on AI rams in the nucleus flocks). The majority of rams' purchases are directly or indirectly linked to the breeding scheme. Thus, despite controversies on breeding objectives, the genetic gain produced by the breeding programme is diffused to a large part of the base population, mainly because of the parallel market of breeding animals. Secondly, we also identified the existence of a second-hand market for rams, which

Table 3. Six types of individual breeding strategies (from Boisseau, 2007)

Type	Description
Type 1: Controlling flock breeding on farm and improving its genetic level only by AI	Type 1 breed raises Manex Red Face breed, sells milk to milk plants, has a high milk production level. This breeder manages individually his flock on private pastures close to his farm. He increases the genetic level of his flock by using AI and rams produced exclusively on his farm through AI. He practices late one-year lambing to match the heat cycle of his ewes.
Type 2: Producing good ewe lambs using genetic gain produced by breeding scheme and accelerating flock replacement	Type 2 breeder is young, owning a Manex Red Face flock of medium size. His aim is to improve the genetic level of his flock producing good ewes. For this purpose, he uses AI on at least 20% of his flock to produce replacement ewes. He buys exclusively rams born from AI in official recorded flocks. He practices one-year lambing and he decides to speed up the first lambing of his ewe lambs using melatonin implants or AI on one-year old ewes to group the lambings.
Type 3: Increasing progressively the genetic level of the flock, using collective genetic gain while using summer pasture	Type 3 breeder has a medium size Manex Black Face flock. His objective is to improve the genetic level of his flock using AI and producing on his farm good rams from AI. He does two-year lambing because he wants his ewe lambs to finish their growth before reproducing. For this type of breeders, the practice of summer mountain grazing is very important, allowing them to be autonomous in forage.
Type 4: Using mountain pasture and producing cheese while simplifying flock management and using rams from AI	Type 4 breeder produces on-farm cheese and raises Basco-Béarnaise. For him, the practice of summer mountain grazing is necessary because of shortage of forage on farm. Moreover, summer grazing gives him the opportunity to produce a high-quality cheese with low investment. He seeks to simplify the management of his flock in order to have enough time for cheese processing. He does late one-year lambing. This type also tries to improve the genetic level of his flock: he buys rams at breeders involved in official milk-recording or produces rams on his farm thanks to AI.
Type 5: Having simple and natural breeding practices while using moderately collective genetic gain	Type 5 breeder is a pluriactive breeder with Manex Red Face of Manex Black Face ewes. He tries to simplify the management of his flock in order to save more time for other activities. He does not use artificial reproductive methods in order to preserve the natural rhythm of his ewes. However, he seeks to improve the genetic level of his flock but with the minimum of investment: he buys rams from official milk-recording flocks but also keeps rams from his farm because rams from official milk-recording flocks are expensive.
Type 6: Having a nice-looking flock without using collective breeding tools, and using mountain pasture as much as possible	Type 6 breeder is a Manex Black Face breeder. He seeks a compromise between milk performance and morphological and aesthetic aspects of his flock. He chooses ewe lambs, thanks not only to their morphological standard but also to the milk performance of their dams. This breeder does exclusively natural mating. He produces his rams on his farm or buys sometimes his rams from "old farmers" breeding animals on aesthetic criteria. He tries to use as much as possible the natural resources of his environment through a long stay in summer grazing pastures.

allows a return on investment to farmers who buy expensive rams from breeders in the nucleus flock. This second-hand market was unexpected.

Reasons for choosing a market place

We analysed how farmers choose where to buy their breeding rams (the breeding centre or other farmers). Some farmers chose to buy rams from the breeding centre because they seek and value the maximal guarantee of the ram's genetic potential. Genetic indexes, for these farmers, are the best indicators of the value of a ram, and they know that the best rams according to genetic indexes are at the breeding centre:

> "We are very satisfied of the rams bought from the breeding centre. The last one, we bought it in 2003, at the price of 580€, we got it at random draw; it was the best indexed ram. It is expensive but it is worth it, it gives you 100 young ewes in three years, it is really worth it". For the farmer, buying a good ram is valuable both for its breeding value and for the fact that it gives more ewes than what would have been possible with the same amount of money by using AI.

However, most farmers gave various reasons during interviews to explain why they prefer to buy rams from individual breeders (born in the nucleus flocks) rather than rams sold by the breeding centre (also born in the nucleus flock):

- The morphology and standard of rams, which is not suitable enough for some farmers when rams come from the breeding centre. This reason is mainly underlined by farmers using the Manex Black Face breed:
  - "Rams at the breeding centre are ugly and really expensive also their horns are cut".
  - Even for farmers who are not really demanding on the aesthetic value of animals, cut horns is an important selection criteria: "The standard is not very important for me, but if the ram has its horns cut, it means that his horns would have gone into his face which is never good... even for ewes afterwards, young ewes will have a tendency of getting horns that grow

back into their face. We have ewes with white ears, white muzzle, we are not fussy about the aesthetic. But one of our ewes became blind of one eye because her horn grew back into it so now we are careful about that".

- The capacity of the rams to endure summer grazing: as rams from the breeding centre are reared indoor, with sufficient food, they are sometimes not adapted to the difficult conditions of mountain pasture.
  - "When we used to buy rams from the breeding centre, we had to prepare them in terms of feeding, to harden them before going to summer pastures because they were a little frail and they do not resist to summer pastures because of the change in feeding". Another farmer explained that he did not want anymore to buy rams from the breeding centre because his last two rams, bought 300€ each at the breeding centre, died during the summer grazing period.

The choice of the breeder from whom they buy breeding rams often depends on their own social network: family, neighbourhood, friends, etc. They are usually faithful to the same provider of rams every year ("I always buy rams from this breeder in the nucleus flock because my father used to buy rams there") though some of them care about inbreeding rate and change supplier regularly ("In general, every two years, I buy a ram but I always choose different breeders from the nucleus flock to renew the blood lines").

Another criterion to choose from whom they buy rams is the similarity between their farming practices and the practices of the seller. For example, if buyers do summer grazing, they would sometimes prefer to buy rams from a breeder who has the same practice. One of the farmers we interviewed explained that he buys his rams from breeders from the nucleus flocks, who do not have a really high level of production, but who have "rams that are healthy and who have a reasonable management of their flock, practices that are similar to mine (his) concerning PDO specifications and environmental aspects".

Another unexpected result was that breeding rams' production and sales are not so much sought-after by breeders in the breeding programme even if it is profitable. For them, producing rams for sales requires a specific organization, and involve risks of mortality before sale and of bad quality of the progeny as rams are not progeny-tested before sale. Sometimes, they prefer not to sell breeding rams instead of taking the risk to disappoint buyers. This result contradicts what is commonly understood about breeding animals markets: farmers in the Western Pyrenees do not deliberately limit the market for AI because they would like to protect their own market for breeding animals. They produce and sell rams because there is a local need, but for most of them it is more a constraint or something they do to help other farmers than something they absolutely seek to develop for their own profit. This is consistent with the fact that there is a shortage of rams in this territory. If producing rams for sales was profitable to farmers, everybody would do it and there would not be any shortage in rams' supply on the market.

Our qualitative analysis also provided useful information on the pricing for breeding animals.

Elements of pricing and links with qualification devices

Several types of breeding animals are sold on the market, based on availability of their breeding-value estimation:

- Breeding animals sold by the breeding centre. They are the ones that the breeding centre does not keep for producing semen, either because their genetic indexes are not good enough, or because they cannot give semen, etc.
- Breeding animals sold by farmers participating in the breeding programme to farmers who do not participate: they produce rams born from AI. These rams do not have genetic indexes but their parents do, giving some 'objective' indication on their potential genetic value.
- Breeding animals sold by farmers outside of the breeding programme. These rams do not have any 'objective' genetic information.

The general understanding of economic theory for price construction would consider that the more 'objective' information on animals genetic value available, the higher the price. According to this principle, the first category of rams would get the higher price on the market. However, the highest prices are observed in the third category, the animals with the lower assurance, according to scientific criteria, of the animals' genetic value. Breeding rams produced outside of the breeding programme, by the farmers from the base population, are sold at a higher price (sometimes twice as much) than the ones from the breeding scheme, while their performance and breeding values are not estimated, as they are not involved in the breeding programme.

The interviews conducted with farmers revealed some of the reasons why the prices of animals with no genetic indexes, could be twice higher than indexed animals. For example, rams from the Manex Black Face breed produced outside of the breeding programme can be sold up to 1 000€ for a high standard ones while the average price for rams in the breeding programme is 250€ (see Table 4). Our analysis of the functioning of the market also gives indications on the pricing of breeding animals. We identified that the diversity of prices on the market cannot be explained according to official and scientific evaluation of animals (including traits corresponding to the collective breeding objectives) and that aesthetic criteria and social networks of farmers are also taken into account.

Farmers appeared to value and price more other aspects of the animal than its estimated genetic value. The first criterion put forward by farmers was the morphology of the

Table 4. Prices of rams and lambs on the market for breeding animals.

	Breeding programme		Non-breeding programme (Manex Red Face) €	Non-breeding programme (Manex Black Face) €
	Born from AI €	Not born from AI €		
Lamb	125–200	70–100		150
Rams	120–400		150–350	700–1 000

animals, their aesthetics value. Some of the farmers considered that the animals from the breeding programme did not match the aesthetic standard of the breed: horns did not have the right shape; animals were not thin or elegant enough, etc. They also argue that their animals should not be considered only as machines to produce milk, but also as living organisms they had to enjoy working with.

The reputation of some farmers to produce animals with high aesthetic standard also contributed in building high prices.

These few examples reveal how the scientific ranking is not the only one to govern the valuation process of animal's genetic value in this industry. Aesthetic order, social relations between buyers and sellers and environment specificities play a key role in this valuation process. How qualification devices are organized for a breed is highly linked to these market mechanisms. Indeed, in most of the breed populations, only one breed's association organizes the qualification of breeding animals for the collective breeding programme and at the same time the promotion of the breed through the organization of animals' competitions. These two devices (qualification for breeding programmes and animals' competitions) take into account aesthetic and genetic value (genetic indexes) criteria. In the Western Pyrenees, such devices are not integrated in activities of the breeds' association (the *Organisme de Sélection*) but opposed and managed by different groups. The qualification procedure for the breeding programme, organized at the breeding centre, tries to disqualify animals with aesthetic and functional defects. However, there is no collective and shared definition of the "standard" of the breeds, and no scoring system to formalize the judgement. On the other side, local institutions organize animals' competitions, but they do not consider animals with genetic indexes, and thus judge animals only on aesthetic criteria. This contradiction reflects market mechanisms, as qualification devices are coordination tools on markets.

Discussion

Despite the existence of "free-riders", i.e. individual breeders who sell the collective genetic gain produced in the breeding scheme, the collective action of breeding is efficient: genetic gain is produced and diffused. But the economical equilibrium of the breeding programme is uncertain, as the benefit of private sales of collective genetic gain does not return, even partly, to the collective organization. The only solution considered by breeding programme managers is often to increase sales of AI. Since they are focused only on AI, they have poor knowledge of the market of breeding animals. Several ways of investigation may be proposed.

First, there is a need for quantitative data on the management of breeding animals' exchanges: how many, who are the sellers, who are the buyers, what are the prices, what are the criteria, where the natural mating rams come from, etc. Different local organizations own part of the data concerning rams' exchanges out of the breeding schemes, such as inter-professional and veterinary organizations. However, these data are diverse and not centralized in a unique system. Currently, it is not possible to know sheep movement as it is in cattle movement with obligatory individual traceability (also considering the price and the lifespan difference between cattle and sheep). However, recently in the Western Pyrenees, a database on rams owned by farmers has been implemented.

Secondly, how to provide a return on investment to the collective breeding scheme? Two types of solutions can be imagined: one about collective property rights or the creation of taxes on rams sold by breeders from the nucleus flocks, taxes which would contribute to the funding of the collective breeding scheme. However, both tools are already questioned in terms of social acceptability. There are also organizational solutions. Some have already been implemented:

- The collective property of rams, solution chosen by one of the breeding centre of the Lacaune breed in Roquefort: all the breeding rams are the property of the breeding centres.
- The creation of an activity of breeding rams production on the breeding centre (breeding rams are not only the leftover of the breeding programme, but rams that have been produced for sale), to meet the specific demands of farmers according to criteria such as morphological quality and hardiness (in Corsica for example).

In the case of the Corsica sheep breed, the local breeding company has developed this second solution. They rapidly understood, at the beginning of the breeding programme that they could not count on a wide diffusion of AI in this mountainous area to ensure the return on investment of the breeding programme. Thus, they developed an activity of managing the production and sales of breeding rams for commercial flocks. However, they encountered a similar problem as in the Western Pyrenees: the breeding rams produced by the breeding programme did not correspond to buyers' criteria, often because of the shape of

the horns. Thus, they conducted a study on the shape of horns, to understand whether it could be improved or not (Aragni, 2006). Thanks to this study, through an appropriate management, they succeeded in improving the shape of horns and increased their sales.

In the Western Pyrenees, to solve the problem of the lack of a shared definition for the standard of the Manex Black Face breed, we helped participants to develop different steps to collectively formalize and use a shared standard grid in the breeding programme.

Conclusion

In conclusion, when AI is not widely used within the whole animal population, breeding organizations should give more importance on the market management of breeding animals. This study opens a field of investigation on the market of genetic gain, the organizational and social dimensions of breeding programmes and the practices of farmers. Our results confirm the need to taking into account not only the genetic aspects of breeding programmes (producing genetic gain is not sufficient to insure its diffusion), but also their organizational dimension. For example, organizing a data bank between sellers and buyers on the animals provided by the nucleus flocks towards the commercial flocks and a system of contributions to provide and access to these information could be one of the solutions to investigate. This kind of study differs from the classical approaches of genetic selection, but reveals the interest of interdisciplinary work between genetic science and management science in the analysis of breeding activities.

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Comparing local and cosmopolitan cattle breeds on added values for milk and cheese production and their predicted methane emissions

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Summary

The aim of this study was to compare added values for milk yield and predicted methane emissions of cows from local and cosmopolitan breeds reared in Italian circumstances. A number of studies showed that milk from local breeds is more suitable to be processed into cheese than that of cosmopolitan populations, so that the development of payment systems which account for the added values of milk destined to cheese production could support the conservation and valorization of local animal genetic resources. Also, the link of local breeds with traditions and the environment might partially compensate their low milk production. Breeders of Burlina, Reggiana, Rendena and Valdostana cows sell products in niche markets and they realize an extra added values per kg of milk of 66 percent, compared with Holstein Friesian. Market-oriented strategies to payment systems that include the added values of milk yield could enhance profitability and interest in rearing and safeguarding of local animal genetic resources; but, not all countries can apply these market strategies. Therefore, other alternative strategies to enrich the added values of milk production might be based on the differences in greenhouse gases emissions among breeds. Indeed, local animal genetic resources are expected reducing the greenhouse gases emissions because of their lowest metabolic body weight, respect to high selected animals. Individual methane emissions might be indirectly calculated using dry matter intake; the latter can be estimated using milk and fat production, and body weight. A reduction of 10 percent of daily methane emissions per kg of metabolic body weight is expected for local compared with cosmopolitan breeds. In average, no differences were found among local and cosmopolitan breeds in terms of daily methane emission per kg of milk yield. In conclusion, animal genetic resources needs to be evaluated not only per unit of output but for other direct and indirect units of output related to social and human returns.

Keywords: *local breeds, added value, milk yield, cheese production, greenhouse gases*

Résumé

L'objectif de cette étude a été de comparer les valeurs ajoutées de la production laitière et les émissions de méthane prédites pour des races locales et cosmopolites élevées en Italie. Plusieurs études ont montré que le lait des races locales convient davantage à la production de fromage que celui de populations cosmopolites, comme quoi le développement de systèmes de paiement qui tiendraient compte de la valeur ajoutée du lait destiné à la production fromagère pourraient soutenir la conservation et valorisation des ressources génétiques animales locales. De même, le lien des races locales avec les traditions et l'environnement pourrait compenser partiellement leur faible production laitière. Les éleveurs des races Burlina, Reggiana, Rendena et Valdostana vendent leurs produits dans des niches de marché en rapportant une valeur ajoutée extra de 66 pour cent par kg de lait, par rapport à la race Holstein. Les stratégies de marché orientées à des systèmes de paiement incluant la valeur ajoutée de la production laitière pourraient augmenter la rentabilité et l'intérêt de l'élevage et la sauvegarde des resources génétiques animales locales, même si pas tous les pays peuvent appliquer ces stratégies de marché. Ainsi, d'autres stratégies alternatives visant à accroître la valeur ajoutée de la production laitière pourraient se baser sur les différences entre races dans les émissions de gaz à effet de serre. En effet, on s'attend à ce que les resources génétiques animales locales réduisent les émissions de gaz à effet de serre, du fait de leur plus faible poids métabolique, par rapport aux animaux hautement sélectionnés. Les émissions individuelles de méthane peuvent être calculées indirectement en utilisant la consommation de matière sèche; celle-ci peut être estimée à partir de la production de lait et de graisse et du poids corporel. Une réduction du 10 pour cent des émissions journalières de méthane par kg de poids métabolique est attendue pour les races locales par rapport aux races cosmopolites. En moyenne, aucune différence n'a été décelée entre les races locales et cosmopolites en termes d'émissions journalières de méthane par kg de lait produit. En conclusion, les resources génétiques animales ne peuvent pas être uniquement évaluées en raison de leurs performances productives mais aussi au moyen d'unités directes ou indirectes qui mettent en rapport la production avec les bénéfices sociaux et humains.

Mots-clés: *races locales, valeur ajoutée, production laitière, production fromagère, gaz à effet de serre*

Resumen

El objetivo de este estudio fue comparar los valores añadidos de la producción lechera y las emisiones de metano predichas para razas locales y cosmopolitas criadas en Italia. Múltiples estudios han mostrado que la leche de las razas locales es más apropiada para la

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producción de queso que la de poblaciones cosmopolitas, de tal manera que el desarrollo de sistemas de pago que tengan en cuenta el valor añadido de la leche destinada a la producción de queso podrían sostener la conservación y valoración de los recursos genéticos animales locales. Asimismo, la vinculación de las razas locales a las tradiciones y al medio puede compensar parcialmente su baja producción lechera. Los ganaderos de las razas Burlina, Reggiana, Rendena y Valdostana venden sus productos en nichos de mercado, logrando un valor añadido extra por kg de leche del 66 por ciento, en comparación con la raza Frisona. Las estrategias de mercado orientadas a sistemas de pago que incluyan el valor añadido de la producción lechera podrían mejorar la rentabilidad y el interés de la cría y salvaguarda de los recursos genéticos animales locales, aunque no todos los países pueden aplicar estas estrategias de mercado. Por tanto, otras estrategias alternativas destinadas a incrementar el valor añadido de la producción lechera podrían basarse en diferencias entre razas en la emisión de gases con efecto invernadero. De hecho, se espera que los recursos genéticos animales locales reduzcan las emisiones de gases con efecto invernadero, debido a su menor peso metabólico, en comparación con animales altamente seleccionados. Las emisiones individuales de metano pueden ser calculadas indirectamente usando el consumo de materia seca; este último puede ser estimado usando las producciones de leche y grasa y el peso corporal. Se cree que es posible reducir en un 10 por ciento las emisiones diarias de metano por kg de peso metabólico en razas locales con respecto a razas cosmopolitas. De media, no se encontraron diferencias entre razas locales y cosmopolitas para las emisiones diarias de metano por kg de leche producida. En conclusión, los recursos genéticos animales no pueden ser únicamente evaluados en términos de rendimiento productivo sino también en base a unidades directas e indirectas de producción relacionadas con los beneficios sociales y humanos.

Palabras clave: *razas locales, valor añadido, producción lechera, producción de queso, gases de efecto invernadero*

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Introduction

Over the next 50 years, farmers will be called upon to produce more food than has been produced in the past 10 000 years, and to do so in environmentally sustainable ways (FAO, 2007a,b). The population size of many local livestock breeds is in decline and local breeds (local breeds) may become endangered because they cannot compete with cosmopolitan (cosmopolitan breeds) and selected breeds. Preserving the local populations is important: many have unique traits, such as hardiness and disease resistance, may be vital for future livestock production (FAO, 2007a). One way to ensure their survival is to sell products from these breeds to niche markets in which higher prices can be achieved compared with conventional markets.

The development of markets for animal products obtained from local populations might increase the added value (AV) to the products as suggested by Global Plan of Action for Animal Genetic Resources (AnGR) of the FAO (2007b). Therefore, an important strategy to increase AV for animal products, to preserve the environment and biodiversity and to orientate tourism and food consumptions would be the promotion of the link among three key factors: breed, environment and product.

Several links between breed and product are available in Italy for local dairy cattle: Reggiana breed and Parmigiano Reggiano cheese (Gandini *et al.*, 2007), Rendena breed and Spressa cheese, Valdostana breed and Fontina cheese, Burlina breed and Morlacco cheese (Pretto *et al.*, 2009).

Methane emissions contribute significantly to the greenhouse effect; indeed, methane has many times the global warming potential of carbon dioxide (IPPC, 2001, Kebreab *et al.*, 2008). Among human activities, the FAO (2006) declared that agriculture sector accounts for 22 percent of total greenhouse gases (GHG) emissions and 3 percent is due to the livestock sector (Cassandro *et al.*, 2010). In Italy, cattle breeds account for 78 percent of total GHG emissions from livestock species; 54 percent is produced by dairy cattle and 24 percent by beef cattle. Typically, 2–12 percent of the gross energy intake in cattle is lost through the emission of enteric methane (Johnson and Johnson, 1995). As methane concentration in the atmosphere is increasing, there is a strong interest in developing strategies to reduce emissions, particularly from the livestock sector. A mitigation action to reduce the emission might be to reduce the GHG emission per kg of milk yield or per kg of metabolic weight. The CH_4 emission per unit of metabolic weight might be considered as a measure at net of the selection effect, while the CH_4 emission per unit of milk yield is a measure at gross of the selection effect.

The aim of this study was to compare AV of milk yield and estimated methane emissions of cows from local and cosmopolitan breeds reared in Italian circumstances.

Materials and methods

Added value for dairy chain

The definition, in a broad sense, of the AV can be the difference between the final selling price of a product and the direct and indirect inputs used to manufacture it. Therefore, the AV can be defined as the measurement of increment of *gross value* for a product made following a specific process.

In dairy chain the AV can be calculated as

$$\mathrm{AV} = V - K,$$

where V is the price value of final product (e.g. value of cheese produced by 1 kg of milk) and K is the price value of input (e.g. value of 1 kg of milk used as fluid milk).

If the AV is positive, the product has AV, whereas if the AV is negative, the product has reduced value. In other terms, if the AV is greater than the cost, the process is profitable; otherwise the process is not profitable.

The milk price used in this study was based on a standard milk payment of the north-east part of Italy, where the values for protein, fat and whey yield are 7 747, 2 582 and €0.01962/kg, respectively (Bozza, 2007). Cheese price was assumed €8/kg considering the Parmigiano Reggiano cheese yield.

Added value for environmental chain

In an environmental chain, the AV may be defined as the minimum air pollution due to enteric methane emissions. In this case, the AV is a measurement of an *environmental mitigation* and might be used as a *new brand* for the product deriving from the breed for a valorization project. Using an approach proposed by Cassandro *et al.* (2010), with an indirect method, predicted methane emissions in cattle might be estimated using predicted dry matter intake through the best equation for dairy cattle proposed by Ellis *et al.* (2007). Predicted dry matter intake was derived by milk yield, fat percentage and estimated body weight of cows, as reported by Chase and Sniffen (1985) and Cassandro *et al.* (1997).

Results and discussion

Added value for dairy chain

Table 1 summarizes milk yield and composition performances of seven cattle breeds, three cosmopolitan breeds and four local, reared in Italy (Bozza, 2007), along with the relative average body weight. Average values of 18.5 ± 5.84 kg/day of milk yield, 3.71 ± 0.21 percent of fat, 3.34 ± 0.11 percent of protein, 4.10 ± 0.40 of somatic cell count and 579 ± 122 kg of body weight were chosen as reference. The cosmopolitan breeds, namely Holstein Friesian, Brown Swiss and Simmental, produced 9.2 kg/day ($P < 0.05$) more milk compared with local breeds, namely Burlina, Rendena, Reggiana and Valdostana Red Pied. Fat percentage was significantly ($P < 0.05$) higher for cosmopolitan breeds (3.89 percent) compared with local breeds (3.56 percent), whereas no significant differences were found for protein percentage and somatic cell count. Regarding body weight, cosmopolitan breeds were 213 kg ($P < 0.001$) heavier than local breeds.

Table 2 reports the AV per kg of milk yield estimated assuming a standard milk and cheese prices adopted in Italy, and cheese yield as reported by Bozza (2007). The average AV for milk yield was €0.15 ± 0.03 per kg and it was lower for cosmopolitan breeds than local breeds (€0.13 vs €0.17 per kg; $P < 0.05$). Hence, because of higher AV, for milk yield of the local breeds, respect to cosmopolitan breeds, the milk yielded by local breeds is more suited to be destined to cheese production compared with milk from cosmopolitan breeds. Indeed, the highest AV was reported by Valdostana Red Pied with €0.189 per kg, whereas the lowest AV was reported by Holstein Friesian with €0.103 per kg.

However, in terms of lactation yield (Table 3), the overall average of AV was €813.7 ± 106.2 and the comparison between the AV of cosmopolitan breeds and local breeds showed that local breeds compared with cosmopolitan breeds in terms of AV was higher for cosmopolitan breeds than local breeds (€893 vs €754; NS). Assuming no variation on milk composition, price and cheese yield performances, the Brown Swiss, with an AV of €950 per lactation, could reduce its lactation yield of 221 kg to realize the same AV than Holstein Friesian, whereas the Valdostana Red Pied would need to increase its lactation yield of 1401 kg to realize the same AV than Holstein Friesian breed.

Table 1. Average values of milk yield and composition, and body weight of seven cattle populations.

Breed	Milk yield (kg/day)	Fat (%)	Protein (%)	SCS (score)	Body weight (kg)
Cosmopolitan breeds					
1. Holstein Friesian	29.2	3.70	3.31	4.37	750
2. Brown Swiss	21.3	4.01	3.51	4.30	650
3. Simmental	20.8	3.97	3.43	3.52	700
Local breeds					
4. Burlina	14.5	3.65	3.22	3.66	450
5. Rendena	15.6	3.56	3.28	4.45	500
6. Reggiana	16.9	3.61	3.40	4.32	550
7. Valdostana Red Pied	11.4	3.44	3.22	n.a.	450
Average ± SD	18.5 ± 5.84	3.71 ± 0.21	3.34 ± 0.11	4.10 ± 0.40	579 ± γ122
Least square means of CB vs LB[1]	23.8 vs 14.6, $P < 0.05$	3.89 vs 3.56, $P < 0.05$	3.42 vs 3.28, NS[2]	4.06 vs 4.14, NS	700 vs 487, $P < 0.001$

[1]One-way analysis of variance using the breed grouping in two levels as a fixed effect (local and cosmopolitan).
[2]NS = not statistically significant.
SCS = somatic cell count, CB = cosmopolitan breeds, LB = local breeds.

Table 2. Added value per kg of milk yield of seven cattle populations.

Breed	Value of cheese (€/kg)	Value of milk yield (€/kg)	Added value (€/kg)
Cosmopolitan breeds			
Holstein Friesian	0.502	0.399	0.103
Brown Swiss	0.569	0.423	0.146
Simmental	0.553	0.425	0.128
Local breeds			
Burlina	0.552	0.393	0.159
Rendena	0.565	0.393	0.173
Reggiana	0.574	0.411	0.162
Valdostana Red Pied	0.576	0.387	0.189
Average ± SD	0.556 ± 0.025	0.404 ± 0.015	0.151 ± 0.029
Least square means of CB vs LB[1]			0.17 vs 0.13, $P < 0.05$

[1]One-way analysis of variance using the breed grouping in two levels as a fixed effect (local and cosmopolitan).
CB = cosmopolitan breeds, LB = local breeds.

Table 3. Added value per 305-day lactation yield of seven cattle populations.

Breed	Value of cheese (€)	Value of lactation (€)	Added value (€)
Cosmopolitan breeds			
1. Holstein Friesian	4 472	3 553	918
2. Brown Swiss	3 698	2 748	950
3. Simmental	3 510	2 700	810
Local breeds			
4. Burlina	2 449	1 743	706
5. Rendena	2 690	1 867	822
6. Reggiana	2 951	2 116	835
7. Valdostana Red Pied	1 996	1 343	654
Average ± SD	3 109 ± 841	2 296 ± 750	813.7 ± 106.2
Least square means of CB vs LB[1]			893 vs 754; NS[2]

[1]One-way analysis of variance using the breed grouping in two levels as a fixed effect (local and cosmopolitan).
[2]NS = not statistically significant.
CB = cosmopolitan breeds, LB = local breeds.

Table 4. Added value for environmental chain, expressed as predicted methane emission (MJ/day) in absolute value, as predicted methane emission per kg of milk yield and as kg of metabolic weight.

Breed	Methane (MJ/day)	Methane/milk yield (MJ/kg/day)	Methane/metabolic body weight (MJ/kg)
Cosmopolitan breeds			
1. Holstein Friesian	21.33	0.7309	0.1488
2. Brown Swiss	18.22	0.8552	0.1416
3. Simmental	18.82	0.9041	0.1383
Local breeds			
4. Burlina	13.37	0.9185	0.1368
5. Rendena	14.31	0.9174	0.1353
6. Reggiana	15.38	0.9120	0.1354
7. Valdostana Red Pied	12.53	1.1029	0.1283
Average ± SD	16.28 ± 3.24	0.9059 ± 0.1098	0.1378 ± 0.0063
Least square means of CB vs LB[1]	19.47 vs 13.90, $P < 0.01$	0.8301 vs 0.9627, NS[2]	0.1424 vs 0.1339, $P < 0.05$

[1]One-way analysis of variance using the breed grouping in two levels as a fixed effect (local and cosmopolitan).
[2]NS = not statistically significant.
CB = cosmopolitan breeds, LB = local breeds.

Added value for environmental chain

In Table 4, predicted methane production was 16.28 ± 3.24 MJ/day with a maximum value of 21.23 MJ/day for Holstein Friesian and a minimum of 12.53 MJ/day for Valdostana Red Pied; the local breeds showed better AV than cosmopolitan breeds for environmental chain, because of lower predicted methane production (13.90 vs

19.46 MJ/day; $P < 0.01$). In terms of methane emission per kg of milk yield, the average value was 0.9059 ± 0.1098 MJ/day with a maximum value of 1.1029 MJ/day for Valdostana Red Pied and a minimum of 0.7309 MJ/day for Holstein Friesian; no statistically differences were found between local breeds and cosmopolitan breeds for daily methane production per kg of milk yield (0.9627 vs 0.8301 MJ/kg/day; $P > 0.05$). This result is very important, and it shows that GHG is a parameter to be used carefully when comparing the breeds. Moreover, in terms of methane emission per kg of metabolic weight, the average value was 0.1378 ± 0.0063 MJ/kg with a maximum value of 0.1488 MJ/kg for Holstein Friesian and a minimum value of 0.1283 MJ/kg for Valdostana Red Pied; the local breeds showed a better AV for environmental chain than cosmopolitan breeds, because of lower predicted methane emission (0.1339 vs 0.1424 MJ/kg of metabolic body weight; $P < 0.05$).

Comparisons at farm/system levels should be done, but in previous studies no data were available to do so. Moreover, indices based on production or emission per hectare of land used might be another important aspect for comparing local and cosmopolitan breeds, as the value of beef/veal/meat production may be higher for dual purpose and local breeds, with respect to cosmopolitan breeds.

Conclusions

Analyses on AV for dairy chain showed that AV for dairy breeds is around €0.15 per kg of milk. All local breeds showed a highest AV value, with respect to cosmopolitan breeds, suggesting that milk produced by local breeds is better for cheese yield than for milk fluid production. However, in terms of milk production in 305 days, the AV was on average equal to €814 per 305 days with the best value for Brown Swiss and lowest for Valdostana P. R. Assuming, no variation in milk composition and cheese yield, the local breeds with an average increment of 951 kg of milk yield in 305 days have shown to have the same AV of HF. The two local breeds that showed the lowest increment of milk yield to have the same AV equal to the HF breed were Rendena and Reggiana with only +500 and +550 kg/305 days, respectively.

Analyses on AV for environmental chain showed that AV for dairy breeds is around 16 MJ/day/cow, with all local breeds that showed to cope better with mitigation of predicted total CH_4 emission and per unit of metabolic weight than for unit of milk. Knowing that CH_4 emission per unit of metabolic weight might be considered a measure at net of the selection effect, while the CH_4 emission per unit of milk yield is a measure at gross of the selection effect, this study showed that AnGR have a dual role not only in food production but also in the provision of public good objectives including, biodiversity and landscape values and diffuse pollution to air and water.

AnGR need to be evaluated not only per unit of output but for the others direct and indirect units of output related to social and human returns.

Hence, AnGR should be evaluated in terms of environmental efficiency and not only in terms of economic efficiency. In this study, prices of cheeses are not varying a lot, but if local actors try to differentiate their products according to the breed, they may expect larger differences. Therefore, valorization projects based on AV for cheese yield, environment mitigation and other social and public goods, as territory preservation, consumer habits, tourists' requests and history and cultural aspects of link between breed and food should be considered.

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How the development of products valorizing local breeds changes breeding goals: examples from French cattle breeds

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Summary
A way of making local breeds more sustainable is to promote their products through individual or collective initiatives. Those initiatives can induce new points of view on the breed and lead to discussions or even tensions between stakeholders. We illustrate this statement with examples of French cattle breeds. Several kinds of changes in breeding goals are described in this paper, with the appearance of new challenges and/or new stakeholders linked to the development of strategies to add value to the breed. Then the several ways in which those changes occurred are explained. The situations analysed show configurations with easy consensus to build as well as situations of conflicts. Those case studies highlight the importance of the existence of arenas where the diverse points of view can be expressed. The role of the breed associations is then essential, but remains complex as, in some cases, breeding goals are strongly discussed. The question of the orientation of the breed then becomes a key question when initiatives to add value to local breeds are taken. New choices of add value generally have important consequences on the definition of breeding goals.

Keywords: *breeding goals, valorization, local breeds, cattle*

Résumé
Une façon de rendre les races locales plus durales consiste à promouvoir leurs produits au moyen d'initiatives individuelles ou collectives. Ces initiatives peuvent donner lieu à de nouveaux points de vue sur la race et mener à des débats et même à des tensions entre les agents impliqués. Nous illustrons cette affirmation avec des exemples de races bovines françaises. Cet article décrit plusieurs types de changements dans les objectifs d'amélioration génétique avec l'apparition de nouveaux enjeux et/ou agents impliqués en rapport avec le développement de stratégies pour donner de la valeur ajoutée à la race. Les différentes façons suivant lesquelles ces changements se sont produits sont abordées par la suite. Les situations analysées montrent des configurations dans lesquelles il est facile d'atteindre un consensus ainsi que des situations de conflits. Les cas étudiés soulignent l'importance de l'existence d'espaces où puissent s'exprimer les différents points de vue. Le rôle des associations des races est en effet essentiel mais demeure complexe puisque, dans certains cas, les objectifs de l'amélioration génétique sont fortement discutés. La question de l'orientation de la race devient ainsi la question clé quand des initiatives sont prises pour donner de la valeur ajoutée aux races locales. Les nouveaux choix pour ajouter de la valeur ont généralement des conséquences importantes dans la définition des objectifs d'amélioration génétique.

Mots-clés: *objectifs d'amélioration génétique, valorisation, races locales, bovins*

Resumen
Un modo de hacer que las razas locales sean más sostenibles consiste en promocionar sus productos a través de iniciativas individuales o colectivas. Estas iniciativas pueden generar nuevos puntos de vista sobre la raza y conllevar debates e incluso tensiones entre las partes interesadas. Ilustramos esta afirmación con ejemplos de las razas bovinas francesas. En este artículo, se describen varios tipos de cambios en los objetivos de mejora genética, habiendo aparecido nuevos retos y/o partes interesadas vinculados al desarrollo de estrategias de aportación de valor añadido a la raza. A continuación se explican las diversas formas en que se han producido estos cambios. Las situaciones analizadas muestran configuraciones en las que resulta fácil llegar a un consenso así como casos de conflicto. Los casos estudiados ponen de relieve la importancia de la existencia de escenarios en los que los distintos puntos de vista puedan ser expresados. Así, el papel de las asociaciones de las razas es esencial pero sigue siendo complejo dado que, en algunos casos, los objetivos de la mejora genética son fuertemente discutidos. La cuestión de la orientación de la raza pasa a ser la cuestión clave cuando se toman iniciativas de aportación de valor añadido

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a las razas locales. Las nuevas opciones de valor añadido tienen generalmente consecuencias importantes en la definición de los objetivos de mejora.

Palabras clave: *objetivos de mejora, valorización, razas locales, ganado bovino*

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Introduction

Animal breeding and the conservation of animal genetic resources are mainly managed at the scale of the populations, which are generally described in terms of breeds. Some of these breeds are raised all around the world, with a genetic management more or less organized at the international level (e.g. the Thoroughbred horse breed, the Holstein dairy cattle breed, the Meishan pig breed, etc.). Such breeds are highly specialized in one function (for the above breeds, horse races, dairy production and reproduction and maternal abilities, respectively). A much larger number of breeds, generally less specialized, are called "local breeds", "native breeds", "heritage breeds", "traditional breeds", "rare breeds", etc. The definition of these terms may depend on the point of view: for instance, according to FAO (2007a), at the world level, a local breed is a breed raised in a single country, whereas the word "local" generally refers to an area smaller than a whole country.

The present paper deals with local breeds, according to the definition provided by the French Ministry of Agriculture: "a local breed is a breed predominantly bound to a given territory, by its origin, location and farming system". To decide if a breed can be considered as local, some rules have been defined on the basis of the distribution of animals across administrative departmental districts (Order by the French Ministry of Agriculture, dated 26 July 2007). As an example, there are a total of 46 recognized cattle breeds in France, including 29 local breeds. According to their actual population size, breeders of these local breeds manage a selection programme (the main purpose is to improve genetic value of the animal population for characteristics considered of interest by the stakeholders) or a conservation programme (the main purpose is to maintain or develop the animal population number); in both cases, more or less simple methods to monitor the within-population genetic variability are implemented.

There are many reasons to maintain local breeds (see, e.g. FAO, 2007b; Gandini *et al.*, 2010) and the best way is to develop initiatives that make these breeds self-sustaining (e.g. Gandini and Oldenbroeck, 2007; Hiemstra, 2010). Among these initiatives, efforts are generally made to develop one or some market chain(s) allowing farmers to benefit from a substantial income from their animals (that we will denote as 'valorization' in the following). Many examples of valorizations of local breeds have been reported, from both developed (e.g. Verrier *et al.*, 2005) or developing (e.g. Mathias, Mundy and Köhler-Rollefson, 2010) countries. Such a valorization contributes generally (but not systematically) to the stabilization or the increase of the population size of the breed and the increase of the number of farmers using the breed (Verrier *et al.*, 2005; Quéméré, 2006; Lambert-Derkimba, 2007). However, this process can introduce new stakes concerning the future of the breed and the involvement of new stakeholders. Then, the question addressed in this paper is if valorization can question the genetic strategies developed for local breeds, as hypothesized by Audiot *et al.* (2005). More specifically, we will analyse the consequences of the valorization of local breeds on the definition of the breeding goals, considering both the breeding goals themselves and the process for their definition. This issue will be addressed through the cases of six French local cattle breeds that were the object of our former studies or studies by other authors (see references hereafter in the text).

The case studies

General information about the cattle breeds studied is shown in Table 1. Four breeds are dairy breeds. The last two used to be multi-purpose breeds (milk, beef and draught), but were specialized in beef production during the 1970s and the 1980s. Four breeds are raised in mountain areas, the farming system including transhumance, the other two being raised in the West of France. Among these six breeds, only the Aubrac breed accounts for more than 100 000 cows. The two breeds with the smallest actual population size, namely the Vosgienne and Bretonne Pie Noire breeds, are considered as rare breeds: their breeders' associations benefit from a public financial support for managing a conservation programme and their breeders benefit from the European subsidies for the *in situ* preservation of animal genetic resources.

The ways of valorizing local breeds are diverse (Table 1). They can be either collective actions or individual initiatives. Collective actions involve farmers grouped in cooperatives or associations, as well as companies in charge of processing the products. These actions often focus on labelled products such as geographical indications (community regulation no. 510-2006), namely Protected Designation of Origin (PDO) and Protected Geographical Indications (PGI), or "Label Rouge", an official label for a product of higher quality. Individual initiatives are

Table 1. General information about the breeds under study.

Type	Breed	Area	Total number of cows in 2010[1]	Programme[2]	Ways of valorization[3]
Dairy	Abondance	Northern Alps	50 000	S	PDO cheeses
	Bretonne Pie Noire	Southern Brittany	1400	C	Direct sale, organic food, etc.
	Tarentaise	Northern Alps	13 600	S	PDO cheeses
	Vosgienne	Vosges and Alsace	4000	C	Agri-tourism and PDO cheese
Beef[4]	Aubrac	Southern Massif Central	145 700	S	Exportation of crossbred calves for fattening; local "Label Rouge"
	Rouge des Prés	Maine and Anjou	43 800	S	PDO meat

[1]*Source*: "France Génétique Elevage" and "OS des races bovines en conservation".
[2]S = selection; C = conservation.
[3]PDO = protected designation of origin; "Label rouge" = official label for a product of higher quality.
[4]Up to the 1970s, the two beef breeds considered here were multi-purpose breeds, the cows being milked.

mainly based on direct sale, organic farming, or both, etc. Among the six breeds under study, the Bretonne Pie Noire breed is the only one to be valorized only by individual initiatives (Quéméré, 2006). Collective actions contribute to a small extent to valorize the Vosgienne breed. The other four breeds are mainly valorized by collective actions.

PDOs are of special importance for the valorization of local breeds and the specifications of animal products under PDO pay an increasing attention to the breed(s) allowed to be used for a given product (Lambert-Derkimba, Casabianca and Verrier, 2006). Among the six breeds under study, five are concerned by at least one PDO, the Bretonne Pie Noire breed being the only exception. The two beef breeds under study show singular and opposite figures. On the one hand, the Rouge des Prés breed is the only breed allowed to be used to produce the meat "Boeuf Maine-Anjou", the PDO project being an initiative of the breeders association (Noury, De Fontguyon and Sans, 2005). On the other hand, the Aubrac breed (in addition to the French Simmental breed) is allowed to produce milk for a PDO cheese called Laguiole but, currently, this possibility mainly refers to history (Béranger and Valadier, 2010) and is almost virtual: one can estimate that about 40 Aubrac cows are milked, which represents less than 1 percent of the milk production required for the production of the Laguiole cheese (Lambert-Derkimba, Casabianca and Verrier, 2006).

Let us consider in more detail the cases of the three dairy breeds under study concerned by a PDO, namely the Abondance, Tarentaise and Vosgienne breeds. It is possible to estimate the proportion of the production of a given PDO cheese because of a given breed, on the one hand, and the proportion of animals from a given breed used for a given PDO cheese, on the other hand (Lambert-Derkimba, Casabianca and Verrier, 2006). Such an approach requires knowledge about the racial composition of the stock devoted to a given PDO, about the productivity of animals according to their breed and about some technical parameters of the process (e.g. the quantity of milk required for producing 1 kg of maturated cheese). Table 2 shows the results of this approach for the three breeds considered in this paper to be valorized by a PDO cheese. The Tarentaise breed and the Beaufort cheese show atypical case of a tight connection between a local breed and a PDO product, the Beaufort cheese representing about half the use of the Tarentaise cows and this breed accounting for half the production of this cheese. This

Table 2. Cross-analysis of the contribution of three of the local breeds under study to the production of some PDO cheeses and of the contribution of these cheeses to the use of these breeds. Note that the name "Abondance" was simultaneously given to a cattle breed and a PDO cheese. From Lambert-Derkimba *et al.* (2006).

		PDO cheese				
		Abondance	Beaufort	Reblochon	Tomme des Bauges	Munster
Annual production (tonnes)[1]		2 008	4 800	15 133	815	7 403
Estimated proportion of the production due to a given breed[2]	Abondance	35%	50%	49%	30%	–
	Tarentaise	1%	50%	2%	20%	–
	Vosgienne	–	–	–	–	3%
Estimated proportion of animals from a given breed used for the cheese[3]	Abondance	3%	10%	26%	1%	–
	Tarentaise	1%	49%	5%	2%	–
	Vosgienne	–	–	–	–	6%

[1]Figures for year 2010 (Source: INAO).
[2]Figures for a given cheese may not sum up to 100%: in such a case, other breeds are allowed to be used.
[3]Figures for a given breed do not sum up to 100%, because each breed is used for other kinds of product.

connection is also revealed by the fact that several farmers simultaneously belong to the staff of the Tarentaise breeders association and to the staff of the inter-professional committee for the PDO Beaufort (Lambert-Derkimba, 2007). The Abondance breed is raised in an area which overlaps that of the Tarentaise breed, but its contribution is more balanced among a series of products and there are only a few cases of simultaneous participation to the staffs of the breeders association and an inter-professional PDO committee. Finally, there is a weak connection between the Vosgienne breed and the PDO cheese produced in the area where this breed is raised.

When the new stakeholders bring changes in the definition of breeding goals

Valorization may bring new stakes about the orientation of the breed characteristics and most of the time new stakeholders concerned by the future of the breed. It can be illustrated by the case of the Bretonne Pie Noire breed (Quéméré, 2006). This rare breed is raised in Brittany, the main French region for dairy production, with intensive farming systems. In a census performed in 1976, only 277 Bretonne Pie Noire cows were found, these cows being mainly raised by rather old and traditional farmers. The conservation programme started in 1977 on the basis of the results of the census. It mainly focused on the search for new bulls for artificial insemination and the management of the genetic variability. As the programme became known, new breeders were interested by the breed. Many of them were hobby breeders: in 2005, among a total of 338 breeders, there were 183 hobby breeders (Quéméré, 2006). Other new breeders were professional breeders wanting to switch from an intensive farming system to a more extensive one. The new breeders were interested in new types of valorization and choose the local breed to be a medium for those valorization dynamics: on farm processing and direct sale of dairy products, organic farming, using the cows as suckling cows for meat production, etc. Moreover, some institutional "breeders", such as a natural park or some associations choose the Bretonne Pie Noire breed for their activity, representing a total of 21 "breeders" in 2005 (Quéméré, 2006). One can wonder if the current dual-purpose of this breed, i.e. the use of the cows as dairy cows for on-farm processing or as suckling cows, will have consequences on the breed orientation. In other words, knowing that in this rare breed the selection pressure can only be weak, is there really room for selection towards a so large diversity of goals? Finally, the diversity of breeders represents a huge diversity of points of view about what the breed is and what it should be, even if a shared point of view is that the breed is well suited to less demanding and more autonomous farming systems.

The case of the Abondance breed is also illustrative. In a previous study (Lambert-Derkimba, 2007), we found several characteristics of the breeds that the stakeholders wanted to promote through the selection programme, according to their farming system. Some characteristics did not concern performances of production, but coat color, size of cows, aptitudes to walk in mountains pastures and, more generally, robustness. Especially, in mountainous areas, farmers looked for small cows, able to walk in high pastures and having good ability in sloping areas. On the contrary, farmers in plains looked for taller cows. Other characteristics concerned the performance of the animals, mainly the milk yield and the protein and/or fat contents. Farmers engaged in PDO rules of production looked for high protein content of the milk. For two PDOs, namely Beaufort and Tome des Bauges, farmers must also cope with the limit of milk yield (averaged at the herd level): this limit is equal to 5000 and 5500 kg per cow for the Beaufort and the Tome des Bauges, respectively. In such a case, farmers said that they put little emphasis on milk yield as a selection criterion for both bulls used for artificial insemination and dams of their new young cows. Accordingly, the analysis of the national database revealed that, the average estimated breeding value (EBV) for milk yield of Abondance cows raised in the area of a PDO implying a milk yield limit was significantly lower than the average EBV of Abondance cows raised in other areas (Lambert-Derkimba *et al.*, 2010). On the contrary, some farmers produce milk for industrial processors and with no limit on milk yield. Those farmers indicated that they put less emphasis on protein or fat content and they showed the highest average cows' EBV for milk yield (Lambert-Derkimba *et al.*, 2010). With such a high diversity of points of view among farmers, to define a breeding goal through a Total Merit Index (TMI) is a real challenge of the Abondance breeders association.

In the case of the Vosgienne breed too, there are different points of views on the breed orientation. Lauvie *et al.* (2011) identified a potential conflict between different development objectives: general milk quantity is an important criterion for a part of the breeders (selling milk to milk industry), while specific milk quality is important for breeders practicing on-farm cheese processing. This could be considered as a problem for a breed with a small population size as it is difficult to imagine several different selection programmes simultaneously.

When the evolution of the breeding goals results from a strong consensus

In the French Northern Alps, the tight connection between the Beaufort PDO cheese and the Tarentaise breed (see above) facilitated, among other factors, the definition of the breeding goals of the breed, especially the choice of the weights of the different traits in a TMI (Lambert-Derkimba, 2007). The breeders, mainly involved in the PDO production, have a clear point of view on what the breed has to become in the future: a mountainous breed, able to valorize a harsh environment areas and producing milk for high-quality cheese, with little emphasis on

milk yield. This is consistent with the specifications of the Beaufort PDO cheese, which imply specific farming practices and fix a higher limit to the average productivity of each herd (see above). Our analysis of the national dairy performances database confirmed that, as today, the Tarentaise breed can be considered as a specialized breed for such a farming system (Lambert-Derkimba *et al.*, 2010).

The case of the Aubrac breed is also interesting. Owing to the cessation of the use of animal power and the very low milk yield of the cows (cows must be milked with their calf, which start and end the process), the breeders oriented their farming system towards beef production only. Then, during the 1960s, the Aubrac breed was endangered by non-monitored cross-breeding with the Charolais beef breed, with no attention paid to maintain the pure breed stock (Béranger *et al.*, 1970). However, the F1 cows were not as adapted to the harsh environment of the Aubrac mountains as the pure Aubrac cows. As a consequence, during the late 1970s and the 1980s, farmers came back with the use of pure Aubrac cows and a new breeding programme for the Aubrac breed was developed (Calvani Abbo, 2005; Béranger and Valadier, 2010). Cross-breeding with the Charolais breed is still practised with about 65 percent of the Aubrac cows, to produce F1 calves whose destination was the Italian fattening industry. The strong maternal characteristics of the Aubrac (calving facilities, milk production and strong motherhood instinct) were developed by the breeders managing the pure breed. The Charolais breed transmits high growing and muscle development characteristics to the calves, allowing higher weight at suckling and higher performances during the fattening period. The Aubrac cows rapidly became valuable "*moules à veaux*" (cows were able to easily give birth and suckle crossbred calves despite their small size) and were able to be raised in the extensive farming systems of the Aubrac countryside and to valorize a harsh environment (Vissac, 2002). To valorize the female calves born from cross-breeding (only male are fattened in Italy), breeders built the label "Fleur d'Aubrac" (Certificate of Product Conformity) in 1991. To valorize older animals such as culled old cows, another label has been built in 1999: the label "Boeuf Fermier d'Aubrac" (Red Label). Those labels open the way of a better price for the meat and as a consequence, allow keeping breeders in isolated areas of Aubrac countryside. From the 1980s, the Aubrac breed is genetically oriented only for meat purpose and this consensus between stakeholders allowed saving the Aubrac breed in a period of strong decline of the population. However, the question of the conservation of milking abilities in a specific line of the breed still exists.

Conclusion

This paper illustrates the fact that valorization questions genetic strategies, especially the definition of breeding goals: new stakeholders have diverse interests concerning the breed evolution and interact with the breeding goals definition. Thanks to six French cattle breed cases, we can see several types of interactions and how breeders and association manage those situations. Arenas where the different points of views on the breed can be discussed are as a consequence of first importance. The example of the new organization for animal breeding in France shows that breeding organization can have as an official mission to be those places of debates. The French juridical framework for animal breeding ("Dispositif Génétique Français") considers the fact that breeding organization must associate not only with breeders but also with different stakeholders interested in the local breed management, including stakeholders from both the market chains and the corresponding territory. From a larger point of view, these places of debate are of first interest in decision-making processes for local breeds' management and allow the expression of the diversity of existing points of view. However, one should keep in mind that gathering a wide diversity of stakeholders and facilitating debates is not an assurance that a compromise will be found on the orientation of a breed. The alliances and political strategies influence the decision-making inside those management bodies which then become more complex. Moreover, at any time, a new valorization process could emerge and bring new point of views in the debates.

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Assessment of the meat quality of Italian Podolian and Greek Katerini cattle

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Summary
In order to satisfy the demands of the modern consumer for food of high quality, low in fat but rich in polyunsaturated fatty acids, farmers from the inner regions of both Italy and Greece in recent years have started to orient their activity to the rearing of autochthonous animal populations, as in the case of the bovine Podolian (Italy) and Katerini (Greece). As both of these populations (raised in two different countries, but under a similar free-range production system) were derived from *Bos primigenius*, it was considered interesting to compare their meat characteristics. For this target, eight animals were used, subdivided into two groups: Podolian group (reared in Italy and slaughtered at 18 months of age) and Katerini group (reared in Greece and slaughtered at 18 months of age). All animals were fed only on local pasture and they were slaughtered in licensed slaughterhouses in their country of birth and they were analysed in the laboratories of the University of Bari in Italy. The results show that the raw meat of Katerini bulls is less red, has higher moisture and is leaner. The fat of this meat is richer in C18:0 and ω3 fatty acids. These data seem to indicate that the meat produced by the breeds studied can satisfy the dietary demands of the modern consumer. As the Katerini breed is threatened with extinction, this study can offer a reason to the local authorities to make a possible future rescue programme, which necessarily passes through a chemical and nutritional characterization of its meat.

Keywords: *Katerini cattle, Podolian cattle, meat quality, fatty acid composition*

Résumé
Au cours des dernières années, les agriculteurs des régions internes de l'Italie et de la Grèce, pour satisfaire les demandes des consommateurs modernes en aliments de haute qualité, à faible teneur en matières grasses, mais riches d'acides gras polyinsaturés, ont commencé à orienter leurs activités en faveur de l'élevage de populations animales autochtones, comme les bovins Podolica (Italie) et Katerini (Grèce). Puisque ces deux populations (élevées dans deux pays différents mais dans un système de production en plein air semblable) proviennent du *Bos primigenius,* il a été jugé intéressant de comparer les caractéristiques de leur viande. On a utilisé à cette fin huit animaux subdivisés en deux groupes: le groupe de bovins Podolica (élevés en Italie et abattus à l'âge de 18 mois) et le groupe de bovins Katerini (élevés en Grèce et abattus à l'âge de 18 mois). Tous les animaux ont été nourris uniquement avec du pâturage local, abattus dans des abattoirs accrédités dans leur pays d'origine et analysés dans les laboratoires de l'Université de Bari en Italie. Les résultats ont révélé que la viande crue des taureaux Katerini est moins rouge, plus maigre et possède une teneur en eau plus élevée. La matière grasse de cette viande est plus riche en C18:0 et en acides gras ω3. Ces données semblent indiquer que la viande produite par les races étudiées peut satisfaire les demandes alimentaires des consommateurs modernes. Puisque la race Katerini est menacée d'extinction, cette étude peut donner aux autorités locales une justification pour la future mise en place d'un programme de sauvetage qui passe forcément par la caractérisation chimique et nutritionnelle de sa viande.

Mots-clés: *bovins Katerini, bovins Podolica, qualité, de la viande, composition des acides gras*

Resumen
Con el fin de satisfacer la demanda de los consumidores actuales de alimentos de alta calidad y bajos en grasa pero ricos en ácidos grasos poliinsaturados, agricultores de zonas interiores de Italia y Grecia han comenzado en los últimos años a dirigir su actividad a la cría de poblaciones animales autóctonas, como es el caso de las razas bovinas Podolian en Italia y Katerini en Grecia. Dado que ambas poblaciones (criadas en dos países diferentes pero bajo un sistema similar de producción extensivo) derivan de *Bos primigenius*, se consideró interesante comparar las características de sus carnes. Con este objetivo, se utilizaron ocho ejemplares, divididos en dos grupos: grupo Podolian (criados en Italia y sacrificados a los 18 meses de edad) y grupo Katerini (criados en Grecia y sacrificados a los 18 meses de edad). Todos los individuos se alimentaron exclusivamente con pastos locales y fueron sacrificados en mataderos autorizados de su país de nacimiento. Los análisis se realizaron en los laboratorios de la Universidad de Bari en Italia. Los resultados revelan que la carne cruda de la raza Katerini es menos roja, tiene mayor humedad y es menos grasa. La grasa de esta carne es más rica en ácidos grasos C18:0 y ω3. Estos datos parecen indicar que la carne producida por las razas estudiadas puede satisfacer las demandas alimentarias de los consumidores modernos. Ya que la raza Katerini se encuentra en peligro de extinción, este

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estudio puede ofrecer un argumento a las autoridades locales para desarrollar un posible programa de rescate que necesariamente pasaría por la caracterización química y nutricional de su carne.

Palabras clave: *ganado Katerini, ganado Podolian, calidad de carne, composición de ácidos grasos*

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Introduction

The socio-economic changes related to new trends towards local and typical productions, receive increasing interest from the consumers, as natural, healthy and tasty products that are produced in environmentally friendly production systems, provide new opportunities for the sustainable development of local animal breeds (Ligda, Papadopoulos and Georgoudis, 2002). Their special quality is defined by the uniqueness of the resources used, the natural vegetation "consumed", the production methods employed and the local gastronomy.

The new demands of the modern consumer for high-quality food, poor in saturated fats, but rich in polyunsaturated fatty acids because of their beneficial effects on human health provide a new framework for livestock farming (Borsotelli and Berra, 1994; Vonghia *et al.*, 1999). Following these trends, farmers from the regions of Thessalia in Greece and Apulia in Italy have considered rearing autochthonous animals, as in the case of the bovine Podolian (Italy) and Katerini (Greece). Both these populations derive from the *Bos primigenius* or Uro, the first bovine for which there were findings and its domestication seems to have taken place in the 400 B.C. in the Middle East. There are two theories about the origin of these two breeds. According to the first, they derived from cattle that came to southern Europe in 452 B.C. following Huns who, on their way from Mongolia, passed through the Ukrainian steppe, which is considered to be their birthplace. However, according to another theory, in Crete in Greece existed a long-horned cattle which can be identified as *Bos primigenius*. Recent assessments indicate that there are 23 000 heads of Podolian bovine in south Italy, registered in the Herdbook (ANABIC, 2007) and only 217 of the Katerini breed (MRDF, 2008). The Podolian cattle are spread throughout an area that mainly covers the inland territories of southern peninsular Italy (Abruzzo, Basilicata, Calabria, Molise and Apulia) (Marsico *et al.*, 2008a, 2008b). One of the outstanding characteristics of these cattle is their exceptional ability to adapt to particularly difficult environments, as well as their extraordinary capacity to utilize food resources that would not otherwise be used (ANABIC, 2007). The Podolian has been used in the past, mainly for their labour capacity and secondarily for meat and milk products. Its milk is ideal for producing the famous "caciocavallo" cheese (Tarricone *et al.*, 2009a, 2009b).

The Katerini cattle breed is of small size with average wither height of 125 and 113 cm for males and females, respectively. The head is large with long lyra-shaped horns. The neck is medium to short and strong. The basic colour is grey, but it ranges from black to brown. The average weight is 375 kg for males and 280 kg for females. The breed is characterized by a white ring around the nose. In general, the body conformation is of a strong draft animal of the Steppe type. The few remaining animals are raised in the region of Thessaly (central Greece) (Ligda, 2009).

However, owing to the rise and spread of agricultural mechanization, the selection of these two breeds was oriented mainly towards meat production, and to a lesser extent, towards dairy production, particularly in certain areas. As far as the reproductive aspect is concerned, age at first calving is rather advanced (about 3 years). This is primarily because of the breed's harsh habitat, especially owing to extreme heat of the summer months, with the amount of available food resources being decreased; thus, slower the growth rates of younger animals. Nevertheless, these types of cattle develop a long reproductive life, breeding for over 10 years with an average time span of 15 months between calvings. For the most part, calvings are spontaneous and are concentrated during the springtime. Calves suckle for at least 4 months (ANABIC, 2007). The calves are then slaughtered in order to be sold for meat at around 15–18 months with weights ranging around 300–350 kg (in Greece, the slaughtering weight is lower and around 250 kg).

Although, for the Podolian cattle, there is available literature (Braghieri *et al.*, 2007, 2009; Marsico *et al.*, 2007, 2008a, 2008b; Vicenti *et al.*, 2007; Ragni *et al.*, 2008; Tarricone *et al.*, 2009a, 2009b), for the Katerini cattle (Greece) the bibliography is very limited and it refers to the origins and the genetic characterization of animals (Georgoudis and Ligda, 2000; Ligda *et al.*, 2006; MRDF, 2008; Ligda, 2009). Therefore, we considered that it would be interesting to compare some meat quality parameters of the two breeds, Podolian and Katerini, for a possible future plan of rescuing the latter by ensuring the biochemical and nutritional characterization of its meat.

Materials and methods

Location of experiment and management system

This trial was carried out on two farms selected in Italy and Greece: the "Rago" farm in south Italy and the "Ark

Dimou" farm in central Greece. In both farms, the raised cattle are born and weaned on pastures in the same period. Both farms are focused on meat production. Animals are kept outdoors during the summer where they feed on pasture and only during the cold months of winter they are kept indoors and fed with forage gathered from pastures, when available.

For the analysis, four Italian Podolian and four Greek Katerini bulls were used, born from parents registered in the relevant herdbooks of each breed. All animals were raised under an extensive grazing system based on local pastures. When the animals reached the target slaughter age (18 months), they were slaughtered according to the European Union (EU) Regulations (European Parliament and Council, 2001).

Slaughter and sampling procedures

The animals were slaughtered in licensed slaughterhouses in their country of birth, when they reached the lower end of the typical endpoint age range (18 months) for the local market. The bulls were transported to a local public abattoir and kept in covered yards, deprived of feed but with free access to water. They were weighted immediately prior to slaughter.

After the fasting period, the steers were stunned using a captive bolt pistol and slaughtered according to standard commercial procedures. The carcasses were chilled at 10–12 °C for 12 h and 0–2 °C for 12 h. On every cold carcass of each animal, we recorded the weight and pH with a pH-meter (Eutech Instruments XS PH110) with a Hamilton Double Pored penetrating electrode. The carcasses were split along the spine into two halves. From each carcass forequarter, the 9–11th rib section of the *Longissimus dorsi* muscle was removed by a straight cut perpendicular to the vertebral axis, from the middle of each intercostal space of the vertebrae. The *Longissimus dorsi* was collected at 24 h post-mortem, frozen at 4 °C under vacuum until analyses were performed 3 days later.

Laboratory analysis

On the third day, all carcasses were transported to the laboratories of the University of Bari in Italy, where all laboratory analyses took place. The 10th rib cut was separated into fat, lean and bone in order to calculate the lean, fat and bone percentages. Samples of *Longissimus* muscle were sliced into 2.5 cm steaks for tenderness testing measurements. The rest of the *Longissimus* muscle was homogenized in a blender and stored for 1 h at 4 °C until subsequent analysis for moisture, fat, protein, ash and intramuscular fatty acid composition. Cooking loss was evaluated in the meat samples of similar shape, individually cooked at 180 °C until the internal temperature reached 75 °C (monitored with thermocouples introduced in the core). Cooking loss was expressed as the percentage loss related to the initial weight.

Meat colour was assessed by the L*,a*,b* system using a HunterLab colorimeter (Colorflex) to determine the colorimetric index of chromaticity. The colour of the fat-free surface of the *Longissimus* muscle was evaluated using the mean value of three colour determinations.

Moreover, Warner–Bratzler (WB) texture meat analysis was performed. Fresh *Longissimus* muscle samples (of 25.4 mm cross-section with fibres perpendicular to the direction of the blade) were used for measurement. Shear force was assessed in both raw and cooked meat (in triplicate) using a WB device, shearing until breaking the samples with a cutting speed of 200 mm/min. The shear force value reported for each steak was the average value for all the evaluated cores.

After grinding the samples, moisture content, protein and ash were determined according to ASPA methods (ASPA, 1980). Fat percentage was measured according to the Soxhlet method (Soxhlet, 1879). The data are expressed per 100 g muscle.

Fatty acid analyses

Samples of *Longissimus* muscle were minced carefully in a food processor. An adaptation of the Folch, Less and Stanley (1957) method was employed in the extraction of intramuscular lipids. Approximately 5 g of meat were homogenized with 5 ml of chloroform:methanol (2:1, v/v). Lipid extracts were converted to fatty acid methyl esters (FAME) as described (Morrison and Smith, 1964). Separation and quantification of FAME was carried out using a gas chromatograph (Shimadzu GC-17A with FID detector) equipped with a flame ionization detector and fitted with a PBX-70 capillary column (60 m, 0.25 internal diameter and 0.25 μm film thickness, SGE) and using a split/splitless injection system (split ratio of 1:30) and helium as a carrier gas at a flow rate of 1.5 ml/min.

The injection port and detector were maintained at 245 and 280 °C, respectively. Column oven temperature was programmed for 5 min at 135 °C, followed by an increase of 3 °C/min to 210 °C, and, finally, held at 210 °C for 20 min. Individual fatty acids were identified by comparing their retention times with those of a standard fatty acid mix Matreya.

Statistical analysis

Statistical treatments of the data were done by analysis of variance (ANOVA). Analysis of covariance was also performed, with breed type as the main effect, for data adjusted to a constant portion of hot carcass weight, fatness or muscle fat content for both breeds. The hypothesis test of two-tailed *t* test was used for the analysis of quantitative variables. All statistical analyses were carried out using SAS (SAS, 1999).

Results and discussion

Physical and chemical composition of Longissimus muscle

The results of the comparison of raw meat characteristics between the Italian Podolian cattle and the Greek Katerini are presented in Table 1. According to these, Podolian meat was redder (16.61 vs 12.88; $P < 0.01$), and the cooked Podolian meat was definitely more shear resistant (2.04 vs 1.65; $P < 0.05$). Concerning the other quality parameters, the observed differences were not statistically significant. Raw meat of Italian Podolian cattle (Table 2) had significantly ($p < 0.05$) lower moisture (73.69 percent vs 76.36 percent), and ($p < 0.01$) higher fat percentage (3.11 percent vs 0.71 percent). Furthermore, the meat presented less undetermined acids (0.57 percent vs 1.24 percent), fact that it was confirmed also after cooking, where Italian Podolians show a more fatty meat (3.27 percent vs 1.15 percent) and less rich in indeterminate acids.

Fatty acid composition of intramuscular fat from Longissimus muscle

Data referring to the fatty acid profile of intramuscular fat in Podolian and Katerini breed are presented in Table 3. It was found that the fat of raw meat of Greek Katerini cattle, compared with that of the Italian Podolian cattle, was characterized by higher percentage (at $p < 0.01$ and/or $p < 0.05$) of C15:0 (0.84 percent vs 0.32 percent), C18:0 (20.57 percent vs 15.71 percent), C15:1 (0.31 percent vs 0.17 percent), C17:1 (1.04 vs 0.74 percent), CLA (9Z,11E) (0.21 percent vs 0.09 percent), C18:3ω3 (2.23 percent vs 0.35 percent), EPA (0.50 percent vs 0.09 percent), C22:5ω3 (1.23 percent vs 0.34 percent) and of lower concentrations of C16:1ω7 (1.38 percent vs 2.18 percent), C18:1ω9c (22.32 percent vs 34.13 percent), monounsaturated fatty acids (MUFA) (28.32 percent vs 40.96 percent), unsaturated fatty acids (UFA) (44.49 percent vs 53.23 percent) and of a lower value in relationship UFA/saturated fatty acids (SFA) (0.99 vs 1.36).

Moreover, significant differences ($p < 0.01$ and/or $p < 0.05$) were observed in the concentration of some fatty acids of the extracted fat of the cooked meat (Table 3). Katerini cattle cooked meat is characterized by higher percentages of C15:0 (0.80 percent vs 0.33 percent), C18:0 (18.57 percent vs 15,66 percent), C17:1 (1.07 percent vs 0.79 percent), CLA (9Z,11E) (0.21 percent vs 0.09 percent), EPA (0.70 percent vs 0.05 percent) and lower concentrations of C18:1ω7 (1.79 percent vs 3.41 percent).

The observed differences in physico-chemical composition of meat may be attributed to the animal's genetic origin, but they can also be ascribed to the feeding system and, particularly, to the floristic composition of pastures and their quantity. Pastures' characteristics affect the animal's growth rate and fattening, and therefore, the percentage of carcass cuts, on their composition in lean, fat and bone, and finally, on the percentage content of water, protein and fat of meat (Matassino, Casentino and Girolami, 1985; French *et al.*, 2000; Baublits *et al.*, 2004). The feeding system, according to quantity and quality aspects, also has an impact on fatty acid composition and, particularly, on polyunsaturated fraction, and the structure of cell membranes that seems to depend on the quantity of meat's fat (Cerrato, 2000; Gambacorta *et al.*, 2005).

Table 1. Physical parameters of Podolians and Katerinis meat.

	Katerini	Podolian	SEM	effect
pH 24	5.56	5.51	0.215	ns
L* (lightness)	39.35	36.52	1.77	ns
a* (redness)	12.88	16.61	0.942	**
b* (yellowness)	11.54	12.61	0.649	ns
Raw WBS				
Shear force (kg/cm^2)	2.48	2.17	0.571	ns
Shear resistance (cm)	2.65	2.58	0.698	ns
Cooked WBS				
Shear force (kg/cm^2)	5.55	7.36	2.373	ns
Shear resistance (cm)	1.65	2.04	0.15	*
Cooking loss (%)	22.4	22.06	7.848	ns

SEM, standard error of means; ns, $p > 0.05$.
*$p < 0.05$; **$p < 0.01$.

Conclusions

The results obtained, based on our experimental conditions, show that the raw meat of Greek Katerini cattle compared with the Italian Podolian cattle is less red, has higher moisture and is leaner. This trend was also confirmed after it was cooked, and it also presented lower shear resistance. In addition, the intramuscular fat

Table 2. Chemical composition % of raw and cooked meat.

	Raw				Cooked			
	Katerini	Podolian	SEM	effect	Katerini	Podolian	SEM	effect
Moisture	76.36	73.69	1.06	*	73.98	69.26	3.4	ns
Proteins	20.42	21.47	0.805	ns	22.1	25.7	3.087	ns
Fats	0.71	3.11	0.411	**	1.15	3.27	0.757	**
Ashes	1.25	1.16	0.094	ns	1.35	1.27	0.205	ns
Undetermined acid	1.24	0.57	0.241	**	1.40	0.50	0.341	**

SEM, standard error of means; ns, $p > 0.05$; *$p < 0.05$; **$p < 0.01$.

Table 3. Fatty acid composition.

Acids	Raw				Cooked			
	Katerini	Podolian	SEM	effect	Katerini	Podolian	SEM	effect
C14:0	2.89	1.86	0.880	ns	2.77	1.78	0.670	ns
C15:0	0.84	0.32	0.170	**	0.80	0.33	0.100	**
C16:0	20.61	20.17	2.070	ns	22.00	20.07	1.620	ns
C17:0	0.60	0.55	0.080	ns	0.64	0.57	0.050	ns
C18:0	20.57	15.71	2.330	*	18.57	15.66	1.370	*
C20:0	0.59	0.49	0.080	ns	0.61	0.44	0.120	ns
C14:1	0.20	0.12	0.040	*	0.18	0.12	0.010	**
C15:1	0.31	0.17	0.040	**	0.28	0.20	0.040	*
C16:1ω7	1.38	2.18	0.280	**	1.72	2.06	0.310	ns
C17:1	1.04	0.74	0.090	**	1.07	0.79	0.060	**
C18:1ω7	2.31	3.17	1.410	ns	1.79	3.41	0.760	*
C18:1ω9t	0.38	0.45	0.080	ns	0.38	0.50	0.040	**
C18:1ω9c	22.32	34.13	2.440	**	24.81	34.50	2.190	**
C18:2ω6t	0.34	0.14	0.240	ns	0.35	0.14	0.180	ns
C18:2ω6c	7.50	8.47	2.930	ns	7.50	8.47	2.710	ns
CLA(9Z,11E)	0.21	0.09	0.050	*	0.21	0.09	0.050	*
CLA(10E,12Z)	0.08	0.18	0.070	ns	0.08	0.18	0.070	ns
C18:3ω3	2.23	0.35	0.470	**	2.23	0.35	0.200	**
C18:3ω6	0.16	0.02	0.120	ns	0.18	0.04	0.100	ns
C20:2ω6	0.07	0.06	0.060	ns	0.07	0.04	0.070	ns
C20:3ω3	3.73	1.78	1.450	ns	2.46	1.35	0.730	ns
C20:3ω6	0.69	0.43	0.320	ns	0.45	0.37	0.260	ns
C20:4ω3	0.12	0.11	0.070	ns	0.18	0.07	0.070	ns
C20:4ω6	0.02	0.00	0.030	ns	0.03	0.00	0.040	ns
EPA	0.50	0.09	0.040	**	0.70	0.05	0.190	**
C22:5ω3	1.23	0.34	0.440	*	0.87	0.20	0.110	**
C22:5ω6	0.19	0.20	0.080	ns	0.16	0.11	0.080	ns
Other acids	9.36	7.68	2.945	ns	8.67	8.33	1.005	ns
SFA	46.24	39.09	5.035	ns	45.37	38.85	2.403	**
MUFA	28.32	40.96	3.241	**	30.22	41.59	2.352	**
PUFA	16.16	12.26	5.569	ns	15.81	11.22	3.946	ns
ω3	6.92	2.68	2.232	*	6.33	2.02	1.094	**
ω6	9.25	9.59	3.316	ns	9.47	9.21	2.874	ns
UFA	44.49	53.23	4.930	*	46.02	52.82	2.65	*
ω6/ω3	1.35	3.66	0.286	**	1.45	4.61	0.315	**
SFA/PUFA	3.24	3.40	1.133	ns	3.18	3.54	0.974	ns
UFA/SFA	0.99	1.36	0.208	*	1.02	1.36	0.112	**
A.I.	0.75	0.52	0.194	ns	0.73	0.52	0.129	ns
T.I.	1.97	1.40	0.390	ns	1.84	1.41	0.185	*

SEM, standard error of means; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; T.I., thrombogenicity index; A.I., atherogenicity index; ns, $p > 0.05$; *$p < 0.05$; **$p < 0.01$.

of Katerini is richer in ω3 fatty acids and in C18:0, a trend that is confirmed after it is cooked.

The above results indicate that the meat of Greek Katerini cattle can satisfy the dietary needs of the modern consumer. They also support previous work concerning the need to develop initiatives aimed at increasing the viability of raising local cattle by promoting them on the basis of their quality products (Ligda, 2009). Towards this objective, local and collective efforts, including all stakeholders, should be developed aiming at the certification of the specific quality meat of Katerini cattle. Further research is needed, not only on a larger sampling of animals but also on the animals' finishing system in order to fully investigate the meat quality characteristics of these local cattle populations in order to establish successful development schemes.

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Producción de carne bovina de calidad diferenciada en el marco de un programa de conservación de la raza Serrana de Teruel

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Resumen

La Serrana de Teruel es una raza bovina en peligro de extinción, criada tradicionalmente en áreas montañosas del Sur de Aragón (España). Con objeto de recuperar la raza, se realizó la caracterización morfológica, zootécnica y genética de la población existente. La raza presentó un grado medio-alto de armonía y homogeneidad, siendo la mayoría de individuos de perfil recto, eumétricos y sublongilíneos, aunque de menor tamaño al observado en otras razas filogenéticamente próximas. Los estudios de biodiversidad mostraron niveles altos de variabilidad genética y bajos de consanguinidad, a pesar del censo reducido (240 individuos en 2010), y proporcionaron las bases para llevar a cabo un programa sostenible de conservación. Para garantizar su mantenimiento a largo plazo, los bancos de germoplasma mantienen 6400 dosis de semen y 74 embriones. Paralelamente, se analizó la viabilidad comercial de la raza, a través del estudio de la calidad de canal y carne de las categorías comerciales de ternero, añojo y cebón (castrados con 9 meses), con edades a sacrificio de 12, 22 y 22 meses y pesos vivos de 470, 720 y 660 kg, respectivamente. Finalmente, se realizó un análisis prospectivo, según la opinión de expertos, de una nueva carne de vacuno con denominación de calidad, llamada 'Serrana de Teruel'. Estos trabajos muestran la posibilidad de realizar una producción alternativa, tipo cebón, susceptible de acogerse a distintivos de calidad diferenciada, que podrían suponer un incentivo para la explotación de la Serrana de Teruel frente a otras razas, lo que favorecería su conservación a medio plazo.

Palabras clave: *raza autóctona, caracterización, valor añadido, castración*

Summary

Serrana de Teruel is an endangered cattle breed raised traditionally in the mountainous areas of Southern Aragon (Spain). With the aim of recovering the breed, a characterization was carried out to determine the morphology, husbandry and genetic values of the Serrana de Teruel breed. Individuals showed a medium to high degree of homogeneity and harmony, most of the animals being of straight profile, and eumetrical and sublongilineal individuals, although smaller in size than other phylogenetically proximate breeds. Biodiversity studies showed good diversity values despite the breed's low effective population size (240 individuals in 2010). These studies provided the basis for a sustainable programme of genetic conservation. In order to guarantee long-term maintenance, germplasm banks contain 6400 doses of semen and 74 embryos. Concurrently, the commercial viability of the breed was studied by means of an analysis of carcass and meat quality from three commercial categories – yearling, bull and steer (castrated at 9 months old) – with ages at slaughter of 12, 22 and 22 months and live weights of 470, 720 and 660 kg,, respectively. Good performances and high-quality products with no commercial constraints in the beef market were obtained. Finally, a prospective study for a new beef quality product labelled 'Serrana de Teruel' was performed, according to the opinions of experts. These studies provide the standard requirements for the alternative production of a labelled beef product that might create an incentive for the production of the Serrana de Teruel breed among other breeds, and thus favour the conservation of the breed in the medium term.

Keywords: *local breed, characterization, added value, castration*

Résumé

La Serrana de Teruel est une race bovine rustique élevée dans les régions montagneuses du sud de l'Aragon (Espagne) qui est en danger d'extinction. Afin de récupérer cette race on a réalisé la caractérisation morphologique, génétique et zootechnique de la population existante. La race présente un degré moyen-élevé d'harmonie et d'uniformité, la plupart des animaux étant de profil droit, eumétrique et sublongiligne, bien que plus petit en taille que les autres races proches. Des études sur la biodiversité ont montré des niveaux élevés de diversité génétique et un faible niveau de consanguinité, malgré les effectifs limités d'animaux (240 individus en 2010), en fournissant les bases du programme de conservation. Afin de garantir le maintien à long terme, a été créée une banque de matériel génétique contenant 6400 doses de semence et 74 embryons. En parallèle, on a confirmé la viabilité commerciale de la race à travers l'étude de la qualité de la carcasse et de la viande pour les catégories commerciales de veau, taurillon et bouvillons (castrés à 9 mois), avec des âges à l'abattage de 12, 22 et 22 mois, et 470, 720 et 660 kg de poids vif, respectivement. Enfin, nous avons mené une analyse prospective, à

dires d'experts, pour un nouveau label de qualité du bœuf appelé 'Serrana de Teruel'. Ces travaux montrent la possibilité d'une production alternative, comme bœuf, susceptible de bénéficier d'une certification de qualité, ce qui pourrait créer une incitation pour l'exploitation de la Serrana de Teruel parmi les autres races, et ainsi favoriser sa préservation à long terme.

Mots-clés: *race locale, caractérisation, valeur ajoutée, castration*

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Introducción

La raza Serrana de Teruel procede del *Bos taurus primigenius,* y constituye una variante de las razas bovinas que se desarrollaron en las serranías del Sistema Central Español (Aparicio-Sánchez, 1944). Tanto por su ubicación, en áreas montañosas del Sur de Aragón (Figura 1), como por su sistema extensivo de explotación, puede considerarse representativa de la primitiva agrupación Serrana. Se trata de una población muy rústica, adaptada a las duras condiciones de montaña seca, y que fue utilizada tanto para la producción de carne y piel como para el trabajo rural, e incluso en festejos taurinos. En la segunda mitad de siglo XX, la raza fue cruzada con otras más selectas, presentando una evolución censal claramente regresiva, que hizo que la Serrana de Teruel fuera considerada como raza en peligro de extinción (BOE, 2009a; FAO, 2011).

En el año 2000 se iniciaron las labores de recuperación y caracterización con 60 individuos, procedentes de diversas explotaciones del área geográfica de influencia de la raza, que respondían al estándar racial de la primitiva agrupación Serrana. A partir de estos individuos se constituyó el núcleo de conservación *in situ* (Diputación Provincial de Teruel, Cedrillas, Teruel; Figura 2), y se creó la Asociación de Ganaderos de Raza Serrana de Teruel (ASERNA; 7 explotaciones). Periódicamente, del núcleo de conservación *in situ* se seleccionaban individuos desde un punto de vista morfológico y de ascendencia racial documentada, y se trasladaban al núcleo de conservación *ex situ* (Diputación General de Aragón, Movera, Zaragoza). Con objeto de establecer un programa sostenible de caracterización y preservación de esta población bovina, se ha realizado la caracterización morfológica, zootécnica y genética de estos individuos, se ha estudiado su potencial productivo y se ha llevado a cabo un análisis prospectivo de la cadena de valor de la carne de Serrana de Teruel.

Se resumen a continuación los resultados más relevantes obtenidos en los estudios citados.

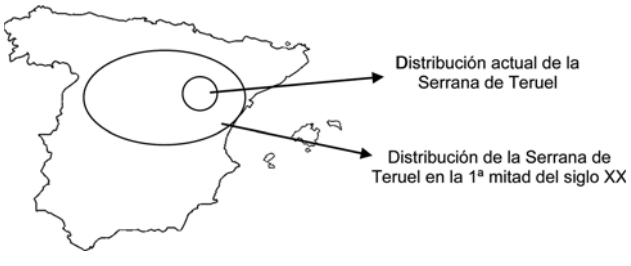

Figura 1. La raza Serrana de Teruel, localizada anteriormente en el Sistema Central Español, se ubica en la actualidad en la comarca de Gúdar-Javalambre (Teruel, Sur de Aragón).

Estudio poblacional, zootécnico y morfo-estructural de la raza

Como punto de partida para la conservación y mejora de la raza, fue necesario estudiar la estructura poblacional y las características zootécnicas y morfo-estructurales de la población Serrana de Teruel, sobre los núcleos de conservación *in situ* (172 animales) y *ex situ* (42 animales) (Vijil et al., 2009a). El núcleo *in situ* (Teruel) se mantuvo en un sistema extensivo de montaña seca, similar al manejo tradicional de estos animales; por su parte, el núcleo *ex situ* (Zaragoza) permaneció estabulado, aprovechando en primavera y otoño praderas polifitas.

En el año 2009, el 80,3% de las hembras tenía una edad inferior a 6 años (sólo el 4,8% superaba los 15), porcentaje que ascendía al 98% en el caso de los machos, como consecuencia de la exigencia contenida en el plan de conservación, que pretende mantener el suficiente número de reproductores como para, en primer lugar, aplicar criterios estrictos de selección morfo-estructural sobre su descendencia destinada a la reposición; y en segundo lugar, evitar un nivel de consanguinidad que pudiera

Figura 2. Núcleo de conservación *in situ* (Finca de Castelfrío, Teruel) de la raza Serrana de Teruel.

comprometer la supervivencia de la raza. El plan de conservación contempla el mantenimiento de todos los sujetos que presenten las características fanerópticas y morfo-estructurales de la raza y sin alteraciones genéticas que impidan o dificulten su reproducción, hasta alcanzar un mínimo de 2 partos, en el caso de las hembras, y 2 años en el caso de los machos. En consonancia con la distribución etaria, el 60,4% de las hembras eran nulíparas, el 11,1% primíparas y el 28,5% multíparas, siendo destacable que sólo 8 de las hembras tenían documentados 6 o más partos.

En cuanto a las características reproductivas de la raza, el primer parto se registró de media a los 33,0 ± 9,2 meses, con un intervalo entre los sucesivos partos de 14,8 ± 5,0 meses, sin variaciones significativas entre los órdenes respectivos ni entre los dos núcleos poblacionales existentes. En el núcleo de conservación *in situ* dichos partos se concentraron en primavera (56,7%), no así en el núcleo *ex situ*, en el que la distribución fue más regular, con valores similares en primavera, verano e invierno (33,3%, 31,0% y 28,6%, respectivamente). Esa misma disparidad se mantuvo en la distribución mensual, con máximos en mayo (29,9%, núcleo *in situ*) y febrero–marzo (35,7%, núcleo *ex situ*).

En los machos (núcleo *ex situ*, n = 9), la circunferencia escrotal experimentó un rápido crecimiento, pasando de 20,0 ± 1,8 a 39,0 ± 2,2 cm entre los 6 y 36 meses de edad, y estableciendo una correlación significativa ($p < 0,05$) tanto con la edad ($r = 0,79$) como con el peso vivo de los animales ($r = 0,83$). La edad media de obtención de eyaculados aptos para la elaboración de dosis seminales fue de 20,4 ± 3,3 meses. Los eyaculados obtenidos (n = 90) presentaron de media un volumen de 5,28 ml, 882×10^6 espermatozoides/ml, 9,8% formas anormales y 85% espermatozoides vivos. Con respecto a las hembras (núcleo *ex situ)*, se determinaron semanalmente los niveles plasmáticos de progesterona (Radioinmunoanálisis, Coat-a-Count Progesterona, DPC®) sobre un total de 19 novillas y 14 vacas, lo que permitió establecer que la pubertad en las novillas se inicia a los 14,3 ± 1,8 meses de edad, y la actividad ovárica se reinicia a los 53,9 ± 15,4 días post-parto.

El peso medio al nacimiento de los terneros (núcleo *ex situ*, n = 42) fue de 37,9 kg. Los pesos de los terneros, alimentados exclusivamente con leche materna, ascendieron a 59,3 y 83,8 kg a los 30 y 60 días de edad, sin diferencias significativas en función del sexo, y con una correlación significativa ($p < 0,05$) con el peso al parto ($r = 0,83$), el número de parto ($r = 0,79$) y la edad ($r = 0,74$) de la madre. Se registró una producción lechera (mediante la doble pesada del ternero antes y después de la tetada) en el período parto–60 días de 6,4 kg/día (3,5% grasa, 3,7% proteína). Los crecimientos diarios de los terneros oscilaron de 0,738 a 0,762 kg, independientemente del sexo de la cría o el período considerado.

Con el fin de establecer las bases del estándar racial de la Serrana de Teruel, se estudiaron en 50 hembras y 3 machos adultos un total de 35 caracteres fanerópticos y morfológicos y, en las hembras, 15 medidas y 11 índices zoométricos (Vijil et al., 2009b). De acuerdo con los resultados obtenidos, la raza está integrada mayoritariamente por animales de perfil recto, eumétricos y sublongilíneos; de capa castaña (aunque con presencia de individuos negros y chorreados); cuernos de tamaño medio/grande en forma de gancho; presencia de orla; papada continua que sobrepasa las axilas; relativamente cerca de tierra; gran desarrollo torácico y línea dorso-lumbar recta y descendente desde la grupa. En conjunto, los animales estudiados presentaron un grado de homogeneidad y armonía medio–alto. Así mismo, resultan de menor formato corporal que otras razas próximas, probablemente como mecanismo adaptativo al difícil medio en que se explotan y la ausencia, hasta ese momento, de un modelo organizado de mejora. Estos estudios permitieron la inclusión de la raza Serrana de Teruel en el Catálogo Oficial de Razas de Ganado de España (BOE, 2007), así como la elaboración y aprobación del estándar racial y la reglamentación específica del Libro Genealógico de la raza (BOA, 2011), en colaboración con la Asociación de Ganaderos de Raza Serrana de Teruel (ASERNA).

Programa de criopreservación de semen y embriones

A lo largo del desarrollo de los proyectos se constituyó el Banco de Germoplasma de la raza, a partir de los individuos del núcleo *ex situ,* y con estricta sujeción a los imperativos legales exigidos. La obtención de dicho material fue más compleja de lo habitual, dado el carácter temperamental de la raza (Serrana de Teruel) y la falta de habituación a los manejos requeridos. El Banco de Semen contaba en septiembre de 2010 con un total de 6395 dosis, obtenidas de 8 sementales mediante electro-eyaculación o vagina artificial.

Por su parte, sobre un total de 15 hembras seleccionadas desde un punto de vista morfológico y de ascendencia racial documentada, se realizó un tratamiento de superovulación y recogida de embriones. La valoración de los embriones se efectuó mediante observación con lupa estereoscópica y aplicando los criterios de la Sociedad Internacional de Trasplante de Embriones (IETS) para determinar su estado de desarrollo, calidad y preparación para su congelación. Se congelaron los embriones considerados plenamente viables, 84 en total, procedentes de 12 hembras y 5 machos.

En el mes de noviembre de 2009 se llevó a cabo la transferencia de 10 de los embriones congelados de la raza Serrana de Teruel, con el fin de comprobar su viabilidad después de la congelación, y por ende, para aumentar el efectivo vivo de la población. Para ello, se utilizó un lote de 10 novillas de la raza Parda de Montaña de las que se disponía en el CITA de Aragón, como hembras receptoras de los embriones. Previamente a la realización de la

transferencia, se comprobó el estado de carnes, la función reproductiva (ciclicidad y ausencia de procesos patológicos) y la situación sanitaria de las novillas. A cada receptora (n = 10) se le trasplantó un embrión de calidad 1 (confirmada dicha calidad también tras la post-congelación) en estadío de mórula (n = 7), blastocisto temprano (n = 2) ó blastocisto expandido (n = 1), en el cuerno uterino ipsilateral al ovario que presentaba un cuerpo lúteo, mediante transferencia no quirúrgica a través del cérvix, previa anestesia epidural con Clorhidrato de lidocaína (Xilocaína Ovejero, León). La fertilidad se determinó por ecografía transrectal 5 semanas después de la transferencia de embriones, y se confirmaron cuatro gestaciones que finalizaron con éxito.

Diversidad genética y relaciones con otras razas

Con el fin de conocer la variabilidad genética de la raza Serrana de Teruel, se analizaron 30 microsatélites estandarizados internacionalmente en 142 individuos. Además se estudiaron otras poblaciones del mismo tronco (Avileña-Negra Ibérica, Serrana Negra, Pajuna y Albera), así como Pirenaica y Parda de Montaña, estableciéndose las relaciones genéticas entre ellas (Sanz et al., 2011).

Todos los microsatélites estudiados en la población de Serrana de Teruel resultaron polimórficos, detectándose un total de 198 alelos. El análisis del equilibrio genético Hardy–Weinberg mostró que todos los *loci* estaban en equilibrio excepto el INRA35, probablemente por la presencia de alelos nulos no detectables. La población Serrana de Teruel analizada presentó una elevada variabilidad con valores altos de heterocigosidad esperada y observada (He = 0,68 y Ho = 0,67) y una baja consanguinidad (F_{IS} = 0,039).

Se analizó la estructura de las poblaciones estudiadas mediante el programa STRUCTURE, utilizando el modelo de mezcla de poblaciones con frecuencias alélicas correlacionadas entre poblaciones. Se testó la presencia de un número de poblaciones (k) comprendido entre k = 1 y k = 8. En base a las probabilidades de cada uno, se eligió k = 6 como el número adecuado de poblaciones (Figura 3). Para k = 6 se apreció la cercanía genética de la Serrana de Teruel con la Serrana Negra; asimismo, en los individuos de Serrana de Teruel se observó una gran heterogeneidad con una clara influencia de Parda de Montaña.

En el análisis de la estructura de la Serrana de Teruel se detectaron claramente dos subpoblaciones (valor más probable de k = 2, programa STRUCTURE): la subpoblación 1, más numerosa y de procedencia variada con influencia de Parda de Montaña; y la subpoblación 2, más homogénea y formada por individuos procedentes del núcleo de conservación *ex situ* (seleccionados desde un punto de vista morfológico y de ascendencia racial documentada). El porcentaje de animales correctamente asignados a la Serrana de Teruel para q ≥ 0,8 fue de 47,5%, apreciándose una clara influencia de la raza Parda de Montaña en los individuos mezclados.

Este es el primer estudio genético de la raza Serrana de Teruel, del que se puede destacar que la población se diferenció genéticamente del resto de las razas incluidas en el estudio, aunque el censo de animales que pueden ser considerados con mayor grado de pureza de la población es bajo. Tanto el análisis de estructura como el estudio de distancias genéticas entre razas mostraron cercanía genética entre dicha población y razas de montaña, coincidiendo con los datos históricos disponibles; estos cruces han podido contribuir a la elevada variabilidad genética observada en la población Serrana de Teruel. Esta información deberá tenerse en cuenta a la hora de establecer una programación de cruzamientos que pueda contribuir de forma efectiva a potenciar la diversidad genética de la raza y evitar elevados niveles de consanguinidad.

Potencial productivo de carne de calidad diferenciada

Para evaluar el potencial productivo de la raza, como base para la obtención de productos susceptibles de acogerse a distintivos de calidad diferenciados, se utilizaron 20 terneros machos de raza Serrana de Teruel, adquiridos a la ASERNA y trasladados al CITA de Aragón. Se estudió la calidad de la canal y de la carne de las categorías

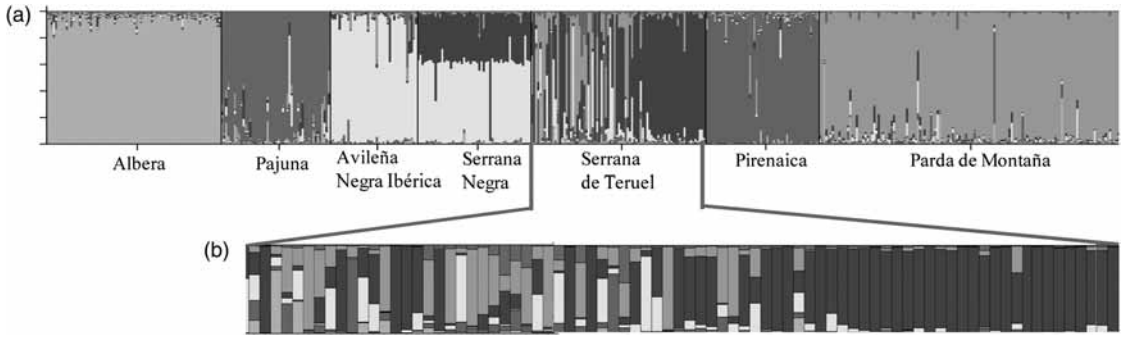

Figura 3. Estructura genética de poblaciones (a) y asignación de individuos de Serrana de Teruel (b).

comerciales de ternero, añojo y cebón (BOE, 2009b), con edades a sacrificio de 12, 22 y 22 meses (Figura 4) y pesos vivos de 470, 720 y 660 kg, respectivamente (Sanz et al., 2010; Albertí et al., 2011). Los terneros se sometieron a un cebo convencional con pienso y paja a voluntad desde su destete (4,7 meses, 148 kg) hasta alcanzar la edad objetivo al sacrificio, excepto entre los 15 y 20 meses de edad, en que añojos y cebones recibieron ensilado de cebada a voluntad y un suplemento de 3 kg concentrado/animal/día. La castración quirúrgica en los terneros destinados a la producción de cebón se realizó a los 9 meses de edad.

Se registró el peso semanal de los terneros, así como el espesor de la grasa dorsal medida mediante ultrasonidos (Aloka SSD-900, 7,5 MHz) sobre la 13ª costilla de los animales al inicio y al final de las distintas fases de cebo. Después del sacrificio, se registró el peso de las canales calientes. Tras 24 horas de oreo a 4°C, se realizó la clasificación subjetiva de las canales (Consejo de la Unión Europea, 2006), registrando su grado de conformación (escala 1–18) y engrasamiento (escala 1–15). Se midió el pH en el músculo a la altura de la 10ª costilla y el color de la grasa subcutánea. Se realizó el despiece de la media canal izquierda, y se determinó la composición comercial de las categorías extra, 1ª, 2ª y 3ª (% carne). A continuación, se estudió la composición tisular de carne comercializable, grasa de recorte y hueso (% sobre la canal). A continuación, se registró la evolución del color de la carne hasta los 15 días con un espectrocolorímetro Minolta CM2600d en carne envasada en film permeable al oxígeno y mantenida en oscuridad a <4°C. Se calculó el tono, el croma y la estimación del contenido en pigmentos carotenoides en la grasa (SUM) (Prache & Theriez, 1999). La capacidad de retención de agua (CRA) se midió por pérdidas de goteo en un filete de 100 g. Para estudiar la dureza de la carne se envasaron al vacío tres muestras del músculo *Longissimus dorsi* (5ª a 11ª costilla) de 3,5 cm de espesor y se maduraron durante 1, 7 y 14 días. Se midió la textura sobre dichas muestras cocidas, con un Instron modelo 5543 dotado de una célula Warner–Bratzler. Finalmente, se realizó una valoración de la calidad sensorial de la carne madurada a 1, 7 y 14 días, con un panel entrenado de 9 personas, valorando los atributos en una escala de 10 puntos. Las variables se analizaron mediante el paquete estadístico SAS (análisis de la varianza, PROC GLM). En el caso de los datos de evolución de color y esfuerzo máximo se aplicó un análisis de varianza de medidas repetidas (PROC MIXED).

Figura 4. Ejemplares de las categorías comerciales de ternero (12 meses), añojo (22 meses) y cebón (22 meses) de la raza Serrana de Teruel.

Durante el primer año de vida, la ganancia de peso de los terneros fue de 1,5 kg/día; el segundo año, fue superior en añojos que en cebones (1,1 vs. 0,9 kg/día), como consecuencia de la castración. Las canales de los animales enteros presentaron mayores valores en rendimiento y conformación, e inferior grado de engrasamiento que las procedentes del lote de cebones (Tabla 1), confirmando que la castración favoreció la deposición de grasa subcutánea.

En la Figura 5 se muestra la diferente pauta de deposición de grasa dorsal observada en cebones y añojos. Hasta el momento de la castración ambos lotes presentaron una evolución similar en dicha reserva grasa. Posteriormente, los cebones depositaron mayor cantidad de grasa dorsal que los animales enteros. Durante el periodo final de acabado (2 meses), ambas categorías depositaron una cantidad similar de grasa, sin embargo, los añojos no compensaron el menor engrasamiento alcanzado en la fase de cebo con ensilado (entre los 15 y 20 meses de edad), y por tanto, los cebones presentaron mayores reservas de grasa dorsal en el momento del sacrificio.

Tabla 1. Peso, clasificación y medidas morfométricas de las canales de los tipos comerciales ternero, añojo y cebón (edad a sacrificio de 12, 22 y 22 meses respectivamente; cebón castrado a los 9 meses de edad), estudiados en la raza Serrana de Teruel.

	Ternero	*Añojo*	*Cebón*	*EE*	*Sign.*
Peso vivo sacrificio (kg)	471,3^{c}	720,3^{a}	660,6^{b}	18,7	***
Peso canal fría (kg)	277,4^{c}	425,7^{a}	365,2^{b}	10,1	***
Rendimiento canal (%)	58,9^{a}	59,1^{a}	55,3^{b}	0,4	***
Conformación (1–18)	10,3^{a}	9,7^{a}	8,3^{b}	0,4	**
Engrasamiento (1–15)	5,0^{b}	5,7^{b}	8,0^{a}	0,3	***
Longitud canal (cm)	121,7^{b}	140,6^{a}	137,7^{a}	1,2	***
Anchura canal (cm)	58,6^{b}	68,2^{a}	67,4^{a}	0,6	***
Profundidad interna pecho (cm)	32,7^{b}	38,6^{a}	39,3^{a}	0,9	***
Longitud pierna (cm)	78,6^{b}	89,4^{a}	88,0^{a}	0,9	***
Anchura pierna (cm)	27,3^{c}	31,5^{a}	29,8^{b}	0,4	***
Perímetro pierna (cm)	114,8^{c}	129,8^{a}	122,8^{b}	1,2	***
Profundidad pierna (cm)	42,9^{b}	47,7^{a}	46,0^{a}	0,6	***
Índice de compacidad	2,13^{c}	3,03^{a}	2,64^{b}	0,1	***

Dentro de cada parámetro, distinta letra entre tipos comerciales indica diferencias significativas ($P < 0.05$). EE = error estándar.

Como era de esperar, las medidas objetivas de conformación de la canal se incrementaron con la edad de los animales (Tabla 1). La castración afectó de forma significativa a la anchura y perímetro de la pierna, presentando los cebones inferiores valores a los animales añojos. El mejor índice de compacidad de la canal se observó en la categoría de añojo, seguida de la categoría cebón, y por último, la de ternero.

En la Tabla 2 se muestra el despiece comercial y la composición tisular de las canales en los tres tipos comerciales estudiados. Los terneros de 12 meses presentaron mayor proporción de piezas de las categorías extra (solomillo) y primera a la observada en los animales enteros de 22 meses (añojo). En este sentido, la castración aumentó la proporción de carne extra recogida en los animales cebones, respecto de los añojos. Con relación a la composición tisular, las categorías ternero y añojo

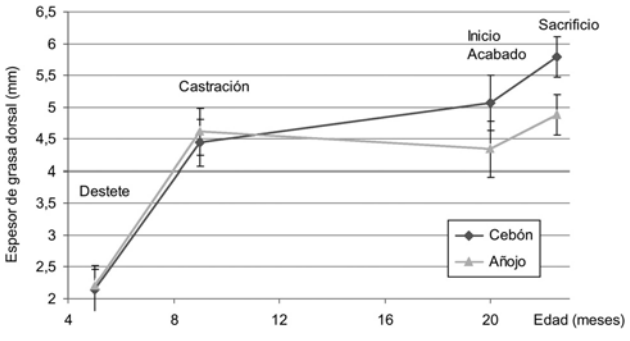

Figura 5. Evolución del espesor de la grasa dorsal (13ª costilla) en animales enteros (añojos) y castrados con 9 meses de edad (cebones).

Tabla 2. Despiece comercial y composición tisular (%) de las canales de los 3 tipos comerciales ternero, añojo y cebón (edad a sacrificio de 12, 22 y 22 meses; cebón castrado a los 9 meses de edad), estudiados en la raza Serrana de Teruel.

	Ternero	*Añojo*	*Cebón*	*EE*	*Sign.*
Extra (solomillo)	3,1^{a}	2,8^{b}	3,1^{a}	0,07	*
Primera[1]	63,4^{a}	61,4^{b}	60,9^{b}	0,4	**
Segunda[2]	7,2	7,1	7,3	0,1	NS
Tercera[3]	26,4^{b}	28,8^{a}	28,8^{a}	0,5	**
Carne	74,4^{a}	75,8^{a}	71,4^{b}	0,7	**
Grasa	5,5^{b}	5,1^{b}	8,4^{a}	0,4	***
Hueso	20,1	19,1	20,3	0,5	NS

Dentro de cada parámetro, distinta letra entre tipos comerciales indica diferencias significativas ($P < 0,05$). EE = error estándar.
[1]Lomo + Babilla + Tapa + Contra + Cadera + Rabillo + Redondo + Aguja + Espalda + Pez
[2]Morcillos + Llana + Aleta + Brazuelo
[3]Falda + Diafragma + Filete de rellenar + Pecho + Pescuezo + Costillar + Trapillos + Recortes

ofrecieron un porcentaje superior de carne respecto a la categoría cebón, que de nuevo mostró el porcentaje más elevado de grasa observado en el ensayo. De forma global en los tres tipos comerciales estudiados en la raza Serrana de Teruel, las canales presentaron un elevado porcentaje de hueso, superior al registrado en otras razas rústicas españolas, una proporción de grasa baja y un porcentaje de carne alto, intermedio a los valores obtenidos en el estudio de Albertí et al. (2001), para las razas rústicas y razas cárnicas españolas.

Con relación a la calidad instrumental observada en la carne de la Serrana de Teruel (Albertí et al., 2011), el pH a las 24 horas del sacrificio fue de 5,6 de media, sin diferencias entre las tres categorías comerciales, y evidenció que los animales que no habían sufrido estrés previo al sacrificio. La capacidad de retención de agua fue del 3,2% de agua exudada a los 5 días y tampoco varió entre lotes. La grasa subcutánea de los terneros (12 meses) fue más luminosa y blanca que la de añojos y cebones (22 meses), debido probablemente al acumulo de pigmentos procedentes de la dieta recibida (concentrado y dieta mixta con silo de cebada, para terneros y añojos/cebones, respectivamente) más que a un efecto de la edad de los animales. En la evolución del color de la carne envasada en film permeable al oxígeno se apreció que la carne de ternero fue la más pálida, ya que tuvo menor croma y mayor claridad y tono que la de las otras categorías. La carne de añojo (22 meses) fue roja, determinada por su menor claridad y menor tono, mientras que el cebón (22 meses) presentó una carne con un rojo más vivo debido a su mayor croma. Se deduce del ensayo que su vida útil, envasada y cubierta en film, estaría entre 5 y 8 días.

En la Figura 6 se muestra la evolución de la dureza instrumental de la carne de las tres categorías comerciales estudiadas. En el caso del ternero y del añojo, esta dureza disminuyó con el tiempo de maduración, mientras que,

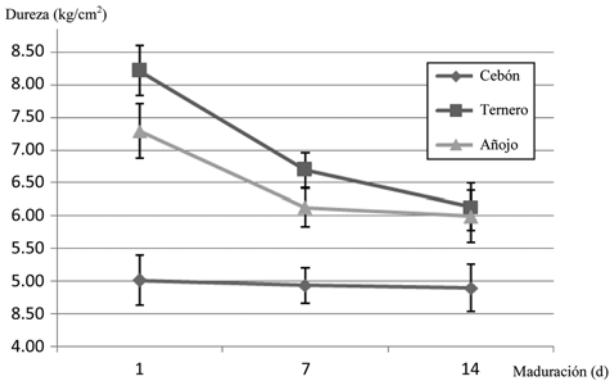

Figura 6. Evolución de la dureza instrumental de la carne de las tres categorías estudiadas.

sorprendentemente, la carne de cebón fue la menos dura en los tres tiempos estudiados (1, 7 y 14 días), y permaneció estable. Comparada con otros bóvidos, la dureza a 7 días de la carne de añojo fue inferior a la obtenida en la raza Serrana Negra – 7,2 y 7,7 kg/cm^2, para pienso comercial y natural (Asenjo, 1999) – aunque superior a la observada por Sañudo et al. (2004) en otras razas rústicas españolas (3,07, 2,33 y 1,92 kg/cm^2, para 1, 7 y 21 días de maduración).

También se detectó un efecto significativo del tiempo de maduración (1, 7 y 14 días) sobre la calidad sensorial de la carne. Las notas de terneza y aceptación global aumentaron con el tiempo, y disminuyó la puntuación de fibrosidad, no afectando a las notas de olor o flavor de la carne. La carne de añojo fue la mejor valorada por su mayor terneza, jugosidad, aceptación global y menor fibrosidad; la carne de cebón fue la peor valorada por su menor terneza, jugosidad, aceptación global, mayor fibrosidad, olor a vacuno y a rancio; y la carne de ternero presentó valores intermedios entre las dos carnes anteriores. Cabe destacar que la valoración sensorial de los atributos ligados a la textura de estas carnes (terneza y fibrosidad) dio resultados totalmente dispares a los obtenidos en la valoración instrumental realizada con el equipo Instron. Quizá los pocos efectivos de la raza puedan estar condicionando de alguna manera los incoherentes resultados obtenidos y por ello, para confirmar los resultados, se evidencia la necesidad de continuar con los estudios de calidad de carne iniciados en la raza.

Con el fin de promocionar la raza en su zona de influencia, se realizó una degustación de 1500 pinchos de carne de Serrana de Teruel, coincidiendo con la celebración de una fiesta popular en Teruel. Se ofreció a 750 personas carne procedente de una canal de cebón, asada durante 12 horas. De los 150 cuestionarios realizados, se desprende que el producto promocionado tendría muy buena aceptación por parte del consumidor turolense, que concedió una nota de 8,3 sobre 10 en apreciación global de la carne (Diario de Teruel, 2010).

De estos resultados se puede concluir que la raza Serrana de Teruel se encuadraría dentro del grupo de razas rústicas bovinas españolas. Esta raza produjo una carne de color rojo, que envasada en film se conservó hasta los 8 días, y que precisó un tiempo de maduración largo. Se confirmaría la viabilidad de las categorías comerciales estudiadas, que podrían acogerse a un distintivo de calidad diferenciada, dada la buena aceptación de las mismas por parte del consumidor.

Prospección de la cadena de valor de la carne y el mercado actual

Desde una perspectiva empresarial, la diferenciación del producto mediante una marca de calidad constituye una de las estrategias básicas de marketing. Desde la perspectiva del consumidor, la presencia de una marca de calidad es una de las señales de calidad más importantes para evaluar la calidad de la carne en el momento de la compra. En este marco conceptual, se realizó un análisis prospectivo, según la opinión de expertos, de una nueva carne de vacuno con denominación de calidad, llamada 'Serrana de Teruel' (Bernués et al., 2011; Olaizola et al., 2011).

Dado el reducido censo de animales y las condiciones de trabajo, la información se recogió mediante el método Delphi, un proceso sistemático e iterativo encaminado hacia la obtención de opiniones anónimas de un grupo de expertos (Landeta, 2002). Se seleccionó un panel de 47 expertos del área geográfica de influencia de la raza (Teruel, Zaragoza y Valencia). Los expertos se agruparon en 4 tipos de operadores: (1) Producción (ganaderos), (2) Industria (mataderos, mayoristas y minoristas), (3) Consumo (restaurantes, críticos de cocina y asociaciones de consumidores), y (4) Administración.

Para medir las opiniones se utilizó la escala de Likert (de 1, 'totalmente en desacuerdo', a 5, 'totalmente de acuerdo') y se realizaron dos rondas de cuestionarios, siendo 38 finalmente los expertos que respondieron en las dos rondas (7 producción, 8 industria, 17 consumo, 6 administración). Para el análisis de la información obtenida se calcularon indicadores estadísticos descriptivos como la mediana, la media ponderada según el grado de conocimiento manifestado por cada experto y la desviación típica.

El cuestionario utilizado recogía información sobre (i) condicionantes del sistema de producción, (ii) atributos de calidad de la carne de vacuno, (iii) atributos de calidad de la carne valorados por los consumidores, y (iv) mejores estrategias de marketing. De las opiniones del grupo de expertos se extrae que los factores más importantes a tener en cuenta en la creación de un producto cárnico nuevo son (i) el uso de pastos como factor de producción, (ii) la maduración de la carne y la alimentación que recibe el animal, (iii) la confianza en el carnicero, y (iv) el establecimiento de una denominación de calidad como estrategia de marketing, respectivamente.

Sin embargo, uno de los problemas frecuentemente mencionados para explicar la falta de confianza de los

consumidores en los productos cárnicos es la divergencia entre las distintas formas de entender la calidad entre diversos actores u operadores de la cadena (Wandel & Bugge, 1997), lo que conduce a fallos en la trasmisión de información entre éstos y los consumidores (Corcoran et al., 2001). Este trabajo se centró también en describir diferencias significativas entre las opiniones de los diversos operadores, que se analizaron con la prueba no paramétrica de Kruskal–Wallis, en cada una de las dos rondas del cuestionario.

Los diversos operadores mostraron opiniones claramente diferentes en relación con la conveniencia de reducir los costes de producción mediante una mayor extensificación, considerado importante por productores y administración, pero menos por la restauración y el consumo, y sobre todo por los operadores de la industria (Figura 7). La dificultad de acceso a infraestructuras sólo es percibida como importante por los productores. Como factores que influyen en la calidad de la carne, existen diferencias para el periodo de cebo y la conformación de la canal, siendo valorados como muy importantes por los productores. La castración de los animales está valorada por la administración, producción e industria, pero es poco importante para el consumo. Lo contrario ocurre con el manejo de los animales en el matadero, sobre el que los consumidores muestran mayor preocupación. Las opiniones de los atributos más valorados por los consumidores difieren en el tema de la certificación de calidad, menos importante para la industria y la administración, y en la existencia de una alimentación animal sin transgénicos, más valorado por productores y sobre todo restauradores y consumidores. Con respecto a las estrategias de marketing para hacer frente a los problemas del sector, la diferenciación mediante una marca de calidad es globalmente el factor más importante, sin embargo, no es así percibido por los operadores intermediarios de la cadena (mataderos, mayoristas y minoristas).

Del estudio se desprende la importancia de todos estos aspectos, que deberán tenerse en cuenta para mejorar la comunicación entre los diferentes eslabones de la cadena de valor de la carne, a la hora de crear una nueva marca de carne de vacuno de calidad diferenciada.

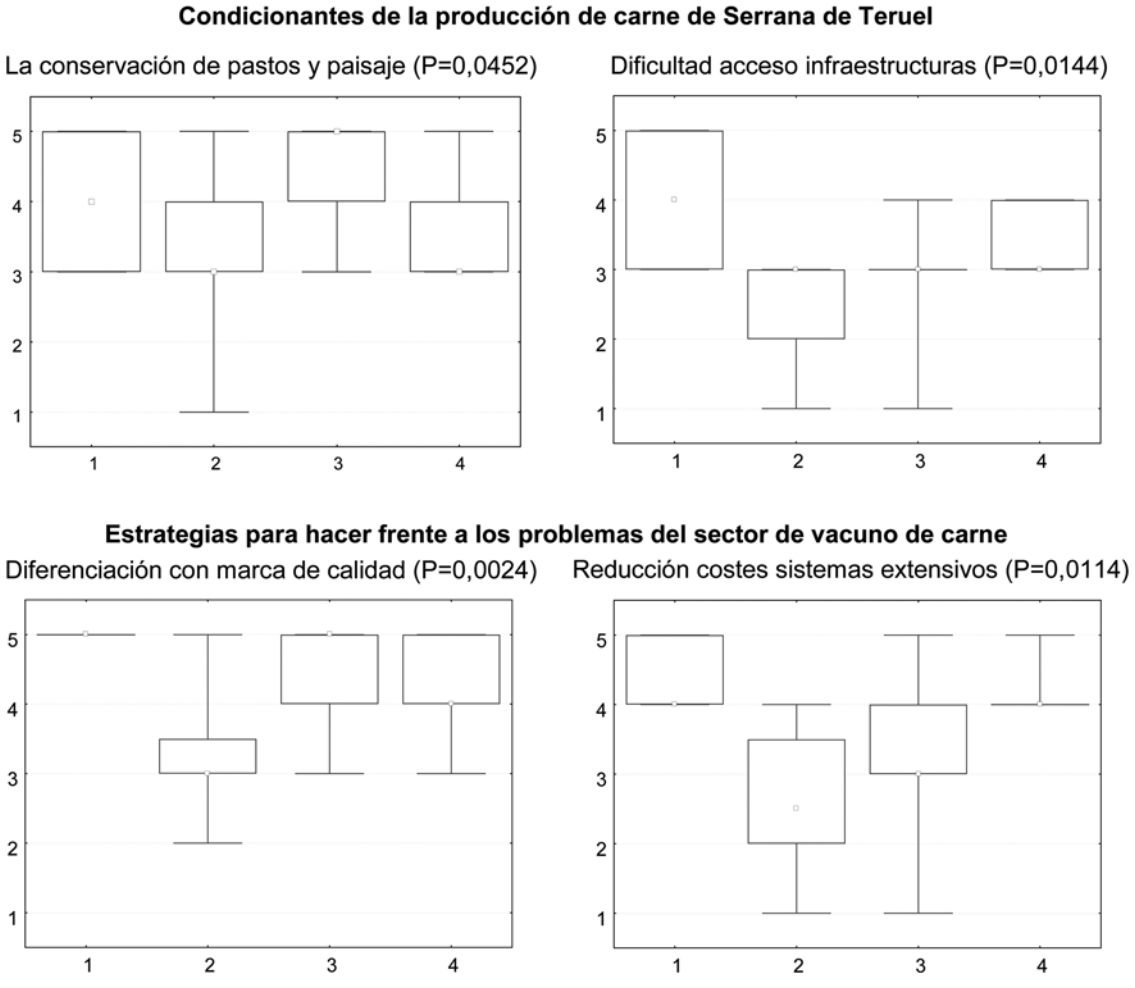

Figura 7. Diferencias de opinión entre operadores sobre las estrategias para hacer frente a los problemas del sector de vacuno de carne y los condicionantes de la producción de carne de Serrana de Teruel (mediana, 25%–75%, min–max). Eje X: 1 = Producción (ganaderos), 2 = Industria (mataderos, mayoristas y minoristas), 3 = Consumo (restaurantes, críticos gastronómicos y asoc. de consumidores), 4 = Administración. Eje Y: 1 = Muy en desacuerdo, 2 = En desacuerdo, 3 = Neutral, 4 = De acuerdo, 5 = Muy de acuerdo.

Consideraciones finales

La evolución del censo de 60 a 240 individuos en los últimos 10 años muestra el interés en la recuperación de la raza, tanto por parte de las autoridades como de los ganaderos. Se cuenta además con el material genético criopreservado a lo largo de los proyectos desarrollados. Sin embargo, será necesario llevar a cabo el plan sostenible de conservación desarrollado, teniendo en cuenta las características morfológicas y genéticas registradas. Se ha comprobado la viabilidad de diversos productos comerciales, que permitirían realizar una producción alternativa, tipo cebón, susceptible de acogerse a distintivos de calidad diferenciada, que podrían suponer un incentivo para la explotación de la Serrana de Teruel frente a otras razas, lo que favorecería su conservación a medio plazo.

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Adding value to local breeds with particular reference to sheep and goats

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Summary
About 82 percent of the total known sheep breeds are local breeds, and for goats, the respective figure is 86 percent. From the scientific perspective, as local breeds are unique genetic resources, they are valuable. However, the relative value assigned to local breeds differs between interest groups. Using several strategies to improve the relative value of local breeds will strengthen the prospects of their sustainable use. In this context, marketing is perhaps the most powerful tool. Marketing strategies include identification and promotion of traditional meat, milk and wool products from sheep and goats linked to local breeds, highlighting the quality and culture associated with these products and facilitating access of farmers to commercial markets. Other important strategies relate to: promotion of local breeds as the best suited for use in landscape management, silvopastoral systems and organic farming; exploitation of unique characteristics of local breeds in agritourism (food, non-food products, souvenirs and recreation) and for educational purposes; sustainable use of local breeds in breeding schemes; educating people about the value and importance of local breeds; introduction of legislative measures; finally, research can serve as a very powerful tool to add value to local breeds by creating new knowledge and providing scientific evidence on particular biological characteristics.

Keywords: *Sheep, goats, local breeds, relative value*

Résumé
Environ 82 pour cent du nombre total de races ovines connues sont des races locales et pour les chèvres, le chiffre correspondant est de 86 pour cent. D'un point de vue scientifique et étant donné que les races locales constituent une ressource génétique unique, les races locales ont une grande valeur. Cependant, la valeur relative assignée aux races locales diffère selon les groupes d'intérêt. L'emploi de diverses stratégies visant à améliorer la valeur relative des races locales consolidera les perspectives de leur utilisation durable. Dans ce contexte, la promotion commerciale est peut-être l'outil le plus puissant. Les stratégies commerciales incluent l'identification et la promotion de la viande et des produits laitiers et lainiers traditionnels, des ovins et caprins, liés aux races locales, en mettant l'accent sur la qualité et la culture associées à ces produits et en facilitant l'accès des éleveurs aux marchés. D'autres stratégies importantes se rapportent à: la promotion des races locales comme étant les plus appropriées pour l'aménagement des paysages, les systèmes sylvopastoraux et l'élevage biologique; l'exploitation des caractéristiques uniques des races locales en tourisme rural (gastronomie, produits non alimentaires, souvenirs, loisirs) et à des fins éducatifs; l'utilisation durable des races locales dans les programmes de sélection; l'instruction de la population sur la valeur et l'importance des races locales; l'introduction de législations; et finalement, la recherche peut servir comme un outil très puissant pour donner de la valeur ajoutée aux races locales par le biais de la génération de nouvelles connaissances et en apportant des preuves scientifiques qui supportent la spécificité des caractéristiques biologiques.

Mots-clés: *Ovins, caprins, races locales, valeur relative*

Resumen
Alrededor del 82 por ciento del total de razas ovinas conocidas son razas locales, siendo el dato correspondiente para las cabras del 86 por ciento. Desde la perspectiva científica y dado que constituyen un recurso genético único, las razas locales son muy valiosas. No obstante, el valor relativo asignado a las razas locales difiere según los grupos de interés. El empleo de diversas estrategias para mejorar el valor relativo de las razas locales fortalecerá las perspectivas de su uso sostenible. En este contexto, la promoción comercial es tal vez la herramienta más poderosa. Las estrategias comerciales incluyen la identificación y promoción de los productos cárnicos, lácteos y laneros tradicionales, de las ovejas y cabras, vinculados a las razas locales, destacando la calidad y la cultura asociadas a estos productos y facilitando el acceso de los ganaderos a los mercados. Otras estrategias importantes están relacionadas con: el fomento de las razas locales como las más adecuadas para la ordenación del paisaje, los sistemas silvopastorales y la ganadería ecológica; la explotación de las características únicas de las razas locales en el turismo rural (gastronomía, productos no alimentarios, recuerdos, ocio) y con fines educativos; el uso sostenible de las razas locales en los esquemas de mejora; la educación de la población sobre el valor e importancia de las razas locales; la introducción de medidas legislativas; y finalmente, la investigación puede servir como una herramienta muy potente para dar valor añadido a las razas locales mediante la generación de nuevos conocimientos y proporcionando pruebas científicas que respalden la particularidad de las características biológicas.

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Palabras clave: *Ovejas, cabras, razas locales, valor relativo*

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Introduction

According to the definition given by Food and Agriculture Organization of the United Nations (FAO), local breeds are those found in only one country (FAO, 2007a). In the present work, the term "local breeds" will not be used in this strict sense, but would rather indicate to large extent local indigenous and locally adapted breeds. It is worth noting that the overwhelming majority of local breeds are indigenous breeds. The importance of local sheep and goat breeds is indicated, among other things, by their uniqueness as genetic resources and by their large numbers compared with the total number of known breeds for each species. The proportion of local breeds to the total number of breeds reaches 82.4 and 86.3 percent for sheep and goats, respectively. The need of conservation and sustainable use of farm animal biodiversity is stressed by the Interlaken Declaration on Animal Genetic Resources (FAO, 2007b). Unfortunately, it seems that the value of local breeds is not well understood by the general public and by policy-makers. Moreover, local breeds are usually neglected by those considered as the most significant and powerful stakeholders of the livestock production sector (e.g. breeders). From the scientific perspective, local breeds constitute the major component of farm animal biodiversity and are characterized by their excellent adaptation to specific environmental conditions. Furthermore, local breeds are linked to traditional products of special qualities and to several practices that are part of cultural heritage. Therefore, every effort to add value to local breeds is worthwhile and will improve the prospects of their conservation through sustainable use.

The several strategies available to increase the value of local breeds can be arbitrarily grouped into three categories:

1. Linking local breeds with
    - 1.1 Traditional products
    - 1.2 Tourism/agritourism
2. Promoting use of local breeds in specific farming systems:
    - 2.1 Organic production
    - 2.2 Conservation grazing/silvopastoral systems
    - 2.3 Small low-input farms and hobby farms
3. General strategies:
    - 3.1 Marketing
    - 3.2 Legislation
    - 3.3 Organization of stakeholders
    - 3.4 Raising public awareness.

Needless to say, that generally, strategies are interrelated and overlapping, particularly those of the last category and the two others. In addition, these strategies apply to other species besides sheep and goats. It must be also mentioned, that a very powerful means, not actually a strategy but a tool, for adding value to local breeds is research. In the following part, each strategy is briefly described and, in most cases, is illustrated by examples related to local sheep and goat breeds.

Strategies to add value to local breeds

Linking local breeds to specific traditional products

This is a widely applied and effective way that increases the value of local breeds. The process implies labelling of traditional products according to national or international appellation systems. At the European Union (EU) level, the labels used for traditional food products including meat and milk products from sheep and goats, are the PDO (Protected Designation of Origin), PGI (Protected Geographical Indication) and TSG (Traditional Specialty Guaranteed). Some EU member states have their own appellation system, which runs in parallel with the EU system (e.g. Appellation d'origin controlee system in France). The significant contribution of local breeds to PDO/PGI products in 17 European countries was highlighted in a review paper by Zjalic *et al*. (2010). In this regard, it is of interest to note that in Mediterranean countries a larger number of local breeds are found compared with Northern European countries and this fact is reflected in the number and proportion of registered animal products from local breeds in the two regions, i.e. 207 of a total of 251 (82 percent) in the southern countries, 42 of a total of 77 (54 percent) in the northern countries (Table 1).

Furthermore, it is worth noting that EC Regulation 510/2006 does not exclude unprocessed wool products from EU labelling and this opportunity should be exploited.

Official and recognized labelling adds value to the product, to the producer and to the specific breed(s) of farm animal linked to the product. It is also a form of guarantee for the consumer. The complete list of products protected by EU labels is available at: ec.europa.eu/agriculture/quality/door/list.html

There are numerous examples of which only a few could be mentioned here. Besides some well-known cases of protected sheep milk cheeses from local breeds, like the Roquefort from Lacaune sheep in France, the Queso Manchego from Manchega in Spain, the Pecorino Siciliano from Comisana sheep in Italy, additional examples are, lamb meat from the Manx Loaghtan sheep, a primitive local breed on the Isle of Man in the

Table 1. Geographic indication animal products from local breeds in 17 states.[1]

State	Cow cheese	Sheep cheese	Goat cheese	Mixed cheese	Beef	Lamb and mutton	Pork[2]	Total
Northern	11	5	6		4	9	7	42
Mediterranean	15	18	15	36	30	24	69	207
Total	26	23	21	36	34	33	76	249

[1]Adapted from Zjalic *et al.* (2010).
[2]Fresh pork and products.

UK. This PDO product is less fatty, darker and with better taste and flavour than meat from commercial breeds. Following the PDO award, there has been an upward trend for the small sheep breed population. Also, the Corderex lamb from Extrermadura, Spain, with a PGI label and coming from the homonymous native breed which is considered as part of the local ecosystem. Another case is the Palmero (PDO) cheese from La Palma Canary Island, Spain, which is produced from goat milk of the local Palmera goat and enjoys good reputation and price, despite the low volume of production.

Linking local breeds with tourism/agritourism

The concept that local breeds are an integral part and contribute to the maintenance of the rural environment is worthwhile promoting in the case of tourism and agritourism programmes. For instance, local breeds were reintroduced in certain areas of Serbia and Montenegro to improve attractiveness to tourists, while in the Netherlands there are many farms keeping local breeds for recreation and country fairs (FAO, 2007a). In Hungary, the local sheep breed Racka is important for small-scale farms and tourism in rural areas (Ratky *et al*., 2011). Also important is to link local breeds to specific food (preferably dairy and meat delicacies) and non-food (wool, leather) products and souvenirs. Local sheep breeds of Austria, exploiting mountain pastures, besides their very good quality meat, produce wool with special qualities and colours, and are used in traditional clothing (www.oengene.at/index.php). In all cases, the products should contain the elements of tradition and specialty.

Promoting use of local breeds in organic production

Organic systems of animal production are largely based on forages and have been associated with sustainability of resources, welfare of animals and product quality. In The State of the World's Animal Genetic Resources (FAO, 2007a), it is stated that the expansion of organic production potentially promotes the keeping of well-adapted local livestock breeds. Local breeds are genetically adapted to their environment, are more resistant to local parasites and diseases, more resilient to climatic stress, and utilize low-quality feed compared with commercial breeds (Van Diepen McLean and Frost, 2007). Therefore, local breeds are the obvious choice of organic livestock production. Moreover, the use of local breeds in such systems gives higher economic benefits to the producers, at least under the support scheme of the EU (Frost, Morgan and Moakes, 2009; Mena *et al*., 2009).

It is quite interesting that a number of products registered with quality EU labels are produced either by conventional or by organic methods, although the organic part constitutes a small proportion of the total volume of production. Organic Roquefort, Pecorina Romana and Idiazabal cheeses are some of many examples. They have the advantage of being promoted both as organic and as registered quality products adding extra value to the products and the breeds involved.

Conservation grazing/silvopastoral systems

Grazing is an efficient tool for the sustainable management and conservation of forests and natural pastures. local breeds provide the best solution when it comes to utilization of farm animals for conservation grazing purposes in forests and rangelands of various forms (grasslands, shrublands, wetlands, etc.), especially in hills and mountains, as well as in marginal areas. Conservation grazing of hill and mountain pastures by local breeds is a routine practice in some countries, and in the case of sheep, purebred females of these breeds constitute the basis of systematic two- and three-way cross-breeding schemes aiming at meat production. The United Kingdom, where the sheep industry is stratified according to specific environments (hills, uplands and lowlands), is the best example of such successful schemes. Hard sheep, mostly of the local Scottish Blackface and the Welsh Mountain breeds, are kept as pure-breds in the hills and mountains of the country, exploiting and conserving these difficult environments. Older ewes not required to produce replacement stock are transferred into upland areas and crossed to longwool breeds (e.g. Border Leicester) to give first cross ram lambs that are fattened, and ewe lambs that are transferred into lowlands to be crossed to a terminal sire breed (Texel, Suffolk) to produce slaughter lambs (Simm, 1998; Hybu Cig Cymru, 2009).

Grazing is also considered an efficient fuel break management method, while at the same time it contributes to diversification of low-diversity forest areas (RCC, 2006). A good example comes from Andalusia, Spain. Scientists of various disciplines, together with farmers keeping the local breeds Raza Segurena (sheep) and

Cabra Malaguena (goat), participate in a network that was formed with the support of the local government. About 7 500 sheep and goats guided by shepherds graze a mountainous area of 910 ha clearing fuel breaks. For the service they provide, farmers get paid €34–€70/ha/year according to several criteria. It was estimated that the cost of this fuel break clearing method is about 23 percent of alternative methods (Ruiz-Mirazo, Robles and González-Rebollar, 2009). This is an efficient tool for adding value to local breeds and is financially supported by the EU through agri-environmental measures of the Common Agricultural Policy (CAP). The question regarding who has to pay for the valuable environmental service local breeds provide by grazing rangelands and forests, always arises. If there is a demand on the part of the society to enjoy the environmental benefits forests and rangelands offer, then it is rational to assume that the society has to bear at least part of the cost. In this regard, the relevant CAP measures are in the right direction.

Concerning silvopastoral systems, they combine forest tree cultivation with low-input livestock production based on grazing. They fulfil the concept of sustainability and are friendly to the environment. Though there are similarities from the management point of view with forest conservation grazing systems, a major difference is that silvopastures are man made, whereas forests to a large extent are natural. In any case, local breeds fit very well within silvopastoral systems and such systems may actually contribute to the conservation of local breeds at risk (Rigueiro-Rodriguez *et al.*, 2008).

Small-scale farms and hobby farms

Many of the existing livestock breeds have survived thanks to smallholders and hobby farms. Smallholder production is much closer to agro-ecological farming practices, contributes to biodiversity conservation and is characterized by a diversity of products. There is nowadays increasing support for small-scale farms as an alternative to commercial large-scale farming operations that have been blamed for farm animal biodiversity loss (Report of the Pew Commission on Industrial Farm Animal Production 2008; Van't Hooft, 2009). In the Netherlands, the number of small-scale and hobby livestock farms is on the increase and many of them keep rare local breeds (Country Report in FAO, 2007a).

Several Organizations and Networks encourage and provide support for small-scale, low-input production from local breeds (ELBARN, Heifer Project, World Initiative of Sustainable Pastoralism, etc.), and it is anticipated that this kind of efforts will be intensified in the near future to the benefit of local breeds through utilization. In a recent report by the Small Scale Farming Organisation (www.smallscale-farming.org/), the qualities and advantages of using local breeds in small-scale livestock farming, and the role of this type of farming in climate change and food security, are highlighted.

Marketing

Marketing is the most powerful strategy to add value to local breeds. Finding or creating markets for meat, milk and wool products from local sheep and goat breeds substantially improves the prospects of their sustainable utilization. Marketing strategies include identification of special characteristics of local breeds associated with their products, highlighting the quality characteristics and cultural aspects linked to traditional products from local breeds, facilitating access of local breed farmers to commercial markets, using special approved labelling, conducting market research for identification of likely users, informing consumers through promotion campaigns about the unique distinctive quality characteristics of products, attempting to change current market attitudes towards product differentiation instead of standardized products and a number of other actions that contribute to better marketing prospects.

Many organizations promote the marketing of products from local breeds at the national, regional and international level. Breeders associations and societies play an important multifunctional role in the conservation, development and promotion of local breeds. Apart from keeping the necessary records in herd books, they provide information on the special characteristics of the breed and its products, they promote the marketing of products in various ways including, whenever this is justified, the registration and official labelling of traditional products, they participate in farm animal fairs, etc. At the European level, besides a number of breed societies, associations, networks, foundations, etc. operating within countries, the SAVE foundation and SAVE Network (www.save-foundation.net) in cooperation with the European Ark Network (www.arca-net.info), the Agrobiodiversity Net (www.agrobiodiversity.net) and the European Livestock Breeds Ark and Rescue Net (ELBARN, www.elbarn.net) have decided to introduce a special label "… as a trademark for small scale, extensive production from local breeds and plant varieties…". The procedures for awarding this label will be much simpler than when applying for the three EU trademarks (PDO, PGI and TSG), but conditions will be strict and more meaningful in terms of production requirements for the voluntary certification of the relevant products. At the global level, of particular interest is the initiative by the Slow Food Organization (www.slowfood.com) to link a product to a specific breed.

Legislation

Legislation is a political strategy that can be used to support local farm animal breeds either directly (subsidies) or indirectly (via several administrative measures). Through agri-environmental measures and headage payments for local breeds in danger of being lost to farming, the CAP of the EU is an example of this type of strategy. It is also true that some provisions of existing EU legislation do not favour genetic diversity, as it is the EU carcass classification system of lambs which is based on

conformation and fat class and does not make any distinction between commercial and local breeds, operating, therefore, against the latter. For the sheep and goat sector, the European Parliament has called on the European Commission "to introduce an additional payment for farmers in mountain regions and other areas facing particular difficulties who are engaged in farming with rare traditional and regional breeds of sheep and goat in order to maintain biodiversity in agriculture and to preserve sheep in sensitive areas" (EC, 2008). It remains to be seen whether such measures will be included in the new CAP (2014-2020) considering that there is much debate going on around the CAP reform.

Organization of stakeholders

In a number of countries, breed societies are well established, especially in the cattle sector, and operate quite successfully. In many other countries, this useful strategic tool does not exist, and in these cases the establishment of breed societies would be a very important step towards conservation and utilization of local sheep and goat breeds, and should be encouraged and supported by state and private institutions within countries. In any case, it should be remembered that, according to the Global Plan of Action (FAO, 2007b), it is the responsibility of each country to establish national inventories of animal genetic resources and to contact periodic monitoring of relevant trends and associated risks.

At the regional level, cooperation between neighbouring countries leads to initiatives like the Nordic Genetic Resource Center (NORDGEN), which deals with plants, farm animals and forests. Within NORDGEN, the Farm Animal Division works on promoting "the genetic, economic, cultural, historical and social values of farm animal diversity. . ." (www.nordgen.org). At the European level, a number of organizations are actively involved in local breed conservation and utilization efforts, among which, as already mentioned, is the SAVE foundation which is linked to, and cooperates with a number of European NGOs operating towards the same directions. A product-oriented organization, ATELIER (http://atelier.laine.pagesperso-orange.fr), promotes European wool and wool products not necessarily from local breeds, although such breeds constitute an important part of its activities. At the international level, the Rare Breeds International organization (http://www.rarebreedsinternational.org/) is primarily concerned with conservation of rare (usually, but not always local) breeds, and the Slow Food Organization.

Raising public awareness

There is a real need to raise awareness about farm animal genetic resources, particularly about local breeds, among the general public, government officials and policy-makers. local breeds are living cultural heritage and for economic, biological, scientific, cultural and historical reasons (Maijala, 1987), it is necessary to conserve and utilize them in a sustainable way. In many countries, animal genetic resources are not considered a priority area and very little is being done with the consequence that "some breed populations and their unique characteristics may decline significantly, or be lost before their value is recognized. . ." (FAO, 2009). Public pressure is needed to change official attitudes when things follow this path. For raising public awareness, concerted actions are essential with the involvement of scientists, breed societies, farmers' associations, environmental groups and public media. To this end, science journalists may play an important role. Issues of tradition and culture, product quality, animal welfare, sustainability of resources, preservation of biodiversity, alternatives to mass production, etc. to which the general public is quite sensitive should be highlighted, and be associated with particular local sheep and goat breeds within the country.

Research

Farm animal research provides the insight for several important biological characteristics, and benefits from the genetic variability among the large number of breeds, most of which are local ones. At the same time, local breeds benefit from research results that reveal and identify some special biological characteristics of economic and scientific importance related to aspects of disease resistance, reproduction, longevity, adaptation to climate change, behaviour, quantity and quality of products, ability to utilize poor quality feed, etc. Certain networks and cooperative research projects on sheep and goat research have significantly contributed to the current scientific knowledge on these species. To name a few in the Euro-Mediterranean region, the ECONOGENE project (http://www.econogene.eu/default.asp) which addressed several aspects of sheep and goat genetic resources and rural development in marginal European agrosystems, the LowInputBreeds project (www.lowinputbreeds.org/project.html), aiming, among others, at improving organic and "low–input" sheep production systems, the HERITAGE sheep project (http://www.heritagesheep.eu/), the FAO/CIHEAM Network (http://www.iamz.ciheam.org) on sheep and goats.

Concerning results of research on local breeds, of a non-exhaustive list, only a few examples will be given. The Red Maasai sheep breed of Kenya, was shown to be resistant to parasitic diseases (Bishop and Morris, 2007) and this finding has provoked interest in this breed by countries with developed sheep industry (e.g. Australia). Resistance to many of the intestinal parasites and to foot rot was demonstrated for the Gulf Coastal local sheep of the Southeastern United States (Miller *et al.*, 1998). This, together with other properties like heat tolerance, these sheep possess, has led to the rediscovery of this breed by farmers in that region. Fat-tailed sheep breeds show

remarkable adaptation to the harsh environmental conditions found in dry areas, and with the ongoing climate change, these breeds may prove extremely valuable (Iniguez, 2008). Research on indigenous goat breeds of South Africa has indicated the potential of adding further value to these animals through the production of cashmere (Braun, 2000). Several studies of the Skopelos goat breed in Greece have revealed a number of good characteristics about this local breed, in 1998 a breed society was established and a genetic improvement project was initiated in 2003. Both the population and the number of farmers keeping Skopelos goats are on the increase. In Portugal, for the PDO Nisa cheese, superior cheese making yield and better quality characteristics were shown when milk from two local sheep breeds was used and compared with milk from a foreign breed (Martins *et al.*, 2009). In theory, this research finding adds value to milk from the local breeds, but in practice, it is not known whether this milk enjoys a higher price than milk from the foreign breed.

Conclusions

The majority of known sheep and goat breeds are local. These animals are genetically adapted to their environment and have special characteristics that differentiate them from commercial breeds. The special and, quite often, superior characteristics of local breeds over foreign breeds in their native environment provide the basis for promoting their use in several production systems that guarantee the sustainability of resources and the quality of products. Several strategies are available and may be used to improve the prospects of utilization of local sheep and goat breeds, thus adding real value to these animals and safeguarding their survival. Depending on the breed and the existing situation, combining appropriate strategies increases the probabilities of success.

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Comparing two local French pig breeds: diversity of challenges and linkage to their territories

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Summary
This paper compares the dynamics of two local pig breeds (the *Porc Blanc de l'Ouest* and the *Nustrale* pig breeds). Those breeds are bred in contrasting territories and we demonstrate by our comparative analysis the diversity of visible stakes in the link of breeds to territories. We distinguish three categories of dissimilarities between the two cases: the first is linked to biogeographic dimension of the territory, the second to the agro-economic dimension of the territory and the last to the sociocultural aspects of the territory. We develop in the discussion an invitation to pay more attention to anchorage dynamics of local breeds in their territories.

Keywords: *Local breeds, pig, territory, local development, France*

Résumé
Cet article compare les dynamiques de deux races porcines locales (les races porcines Porc Blanc de l'Ouest et Nustrale). Ces races sont élevées dans des territoires contrastés. Avec notre analyse comparative, nous montrons la diversité d'enjeux visibles dans le lien des races avec les territoires. Nous distinguons trois catégories de dissemblances entre les deux cas: la première est liée à la dimension biogéographique du territoire, la deuxième l'est à la dimension agro-économique du territoire et la dernière aux aspects socio culturels du territoire. Dans la discussion nous invitons à prêter plus d'attention aux dynamiques d'ancrage des races locales dans leurs territoires.

Mots-clés: *Races locales, porc, territoire, développement local, France*

Resumen
Este artículo compara las dinámicas de dos razas porcinas locales (las razas porcinas Porc Blanc de l'Ouest y Nustrale). Estas razas son criadas en territorios desiguales. Con nuestro análisis comparativo, mostramos la diversidad de desafíos visibles en el vínculo de las razas con los territorios. Distinguimos tres categorías de disimilitudes entre los dos casos: la primera está relacionada con la dimensión biogeográfica del territorio, la segunda lo está con la dimensión agro-económica del territorio y la última con los aspectos socio culturales del territorio. En la discusión se anima a prestar más atención a las dinámicas de arraigamiento de las razas locales en sus territorios.

Palabras clave: *Razas locales, cerdo, territorio, desarrollo local, Francia*

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Introduction

Local breeds are a part of agrobiodiversity. To go beyond the opinion that agricultural development is hostile to breed diversity (Hall and Ruane, 1993), some authors suggest that using local animal or vegetal genetic resources in local development initiatives can help maintain and valorize agrobiodiversity in a sustainable development perspective (Wood and Lenne, 1997; Rege and Gibson, 2003). Development initiatives involving local breeds are diverse (Audiot, 1995; Lauvie *et al.*, 2011): they concern local landscape maintenance, thanks to grazing (Tisdell, 2003; Yarwood and Evans, 2003), preservation or design of specific livestock farming systems based on local resources (BertagliaMormont and Trometter, 2005). Even for quality food products associated with local breeds, several types of development initiatives are observed (Audiot *et al.*, 2005; Lauvie, 2007; MathiasMundy & Köhler-Rollefson, 2010): Protected Designation of Origin (PDO) projects (Verrier *et al.*, 2005; Lambert-Derkimba, 2007; Lambert-Derkimba *et al.*, 2011), direct selling networks (Coutron-Gambotti *et al.*, 1999) and short food supply chains (Herold *et al.*, 2010), etc.

Local breeds' management and development are as a consequence in the heart of numerous stakes and strongly connected to other dynamics in their territory (from a social,

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economical and environmental point of view). As "local", we can consider those breeds as resources for local development dynamics. However, only a few references are available addressing this link between local breeds and territory dynamics (e.g. Lauvie, 2011). As we consider this link being of first importance to understand local breeds' development dynamics, our aim in this paper is, by using a compared analysis, to present two contrasted relationships of local breeds to territory and to make more explicit the diversity of visible stakes in this link of breeds to territories. As a consequence, we will show how important it is to consider local breed management in link with territorial questions. We compare the cases of two local pig breeds raised in France in much contrasted situations: the *Blanc de l'Ouest* pig breed and the *Nustrale* pig breed.

After having presented both situations according to identified questions, we will detail the results of the compared analysis and organize our discussion around the question of the territorial dimension of the breed management and development.

Materials and methods

In management and development projects of local breeds one of the main global stakes is to maintain the population size and the genetic variability of the breeds (Boichard, Maignel and Verrier, 1997; Caballero and Toro, 2000). Moreover, analyses of case studies reveal specific stakes linked to the anchorage of breeds in territories. Our aim is to discuss, by implementing a compared analysis, the categories of those stakes and to show the importance of taking into account the anchorage in a territory when dealing with local breeds' development.

In this paper, we use the term of territory to mention a stretch of area used and managed by human societies (as defined by Brunet, Ferras and Théry, 1992). As a consequence, we consider the territory with its both spatial and social dimensions.

We compared two local pig breeds in two contrasted territories: *Blanc de l'Ouest* pig breed (called PBO in this paper) localized in Brittany, France and *Nustrale* pig breed localized in Corsica, France.

The criteria used to choose the two breeds to compare are

- The pig species.
- The region: The aim is to compare cases in very contrasted context (geographic, agro-economic). Brittany is the first French region for intensive pig production, and there is only extensive pig production in Corsica.
- The food product development initiatives: very contrasted dynamics. There are market facilities in Corsica, with a PDO application in progress (Lambert-Derkimba *et al.*, 2008); there are commercial outlet difficulties in Brittany, with the failure of a collective initiative (Lauvie *et al.*, 2008).

We consider that a comparative analysis of two local breeds in the same country (same global and national public action frame), from the same specie (roughly same biological characteristics) but in contrasted territories would allow to bring out the characteristics linked to anchorage to territories and to discuss them.

The information on the two cases come from interviews and document analysis conducted during former studies for our Ph.D. Thesis (Lauvie, 2007; Lambert-Derkimba, 2007). This information is used to detail each case history. Then a comparative study of the two situations allows us to identify elements that showed strong contrasts. We make the hypothesis that those elements are indicative of the specificities of the situations in each territory. We then analyse those elements of contrast in order to feed the discussion on the stakes surrounding local breeds, their development and their anchorage in territories.

Results

The first part of the results is constituted by the detailed stories of both cases. The narrative technique was chosen to present our cases, as proposed for instance by Christian (1998) and used by Brives (2001) or Lauvie (2007). In this report, we will present a summary of each story. The second part of the results is constituted by the compared analysis itself.

The PBO case in Brittany

The PBO is a pig breed from the Western part of France (Brittany and the regions nearby). Since 1970s, the PBO has known a decreasing number of the animal population. The population was replaced with conventional and specialized breeds well implanted in the region and associated with intensive breeding systems. But in 1981, the Institut Technique du Porc (or ITP, the National Technical Institute for Pig Breeding) started a programme of genetic management of the rare pig breeds, including the PBO pig breed. ITP took a census of the breeders and identified the animals. By then, the breed became known as one of the local pig breed in France, recognized by the National Ministry of Agriculture. The ITP established breeding advices, based on scientific knowledge in genetics, to manage the genetic variability in the population.

Then, a breeders' association, which took the form of a union of the breeders, was created in 1994 to manage the breed. They became the official association in charge of the management of the breed, linked to the ITP who provides technical help for genetic management, and belonging to the LIGERAL (Local Pig Breeds Herd Book). As a consequence, regional organizations have given a support to the association. The Natural Park of the Armorique Region, for instance, supports the secretarial work of the association.

The association has also got a financial support from the local and regional authorities.

Several plans were established to find collective commercial outlets (for instance, a plan to work in partnership with a pork butcher). The plans failed but in parallel several breeders have organized individual ways of finding outlets: for instance, direct selling of cooked pork, farm inns offering meal with grilled suckling piglets. According to some breeders, the failure of the collective projects is mainly because of their location in a region where industrial pig production is dominant. They also underline their difficulties to slaughter as some public slaughter houses have closed (the industrial pig production works with private slaughter houses), and their difficulties to find commercial outlets. The breeders have to find their place in an environment where a conventional pig production is dominant.

Until the near period, breeders were in line with the genetic management requirements. The breeders are regarded as "good pupils" of genetic management as they mostly follow the mating prescriptions from the ITP. But for the last years, the assessment of the ITP (now called Ifip-Institut du porc-) has shown a decrease in the number of sows bred for reproduction. So, the population size of the PBO pig breed has decreased during the last years. Some of the breeders explain this phenomenon by the lack of structured marketing chain, which makes difficult sustainable production activities with this local breed.

The *Nustrale* case in Corsica

In Corsica, pig production was traditionally family based. Nowadays, pig farming system is based on the use of pasturelands a great part of the year. Animals are raised on several types of pasturelands with a very specific fattening period in chestnuts and acorns forest. The territory where the animals go to pasture is called "rughjoni". During the winter, pigs are slaughtered and processed into local products, culturally rooted in the Corsican gastronomy. Producers are realizing all the operations classically distributed along the supply chain: breeders are at the same time farrowers, fatteners, slaughterers, processors, ripeners and sellers. Such an activity is giving to the single farmer constraints of quantity of work but it allows gathering all the added value proceeding from each activity. This represents an "ecocultural" system (Commandeur and Casabianca, 2007) contrasting a lot with the conventional pig production nowadays in Europe and sharing some characteristics with Spanish and Italian local systems (Casabianca and Fallola, 1994).

After a long work involving many breeders and several generations of animals, Corsican Pig Breed Association has recently been recognized by the French CNAG (National Commission of Genetic Improvement). This recognition is at the same time the final step of the previous work for recognition and the first step of a new period: the management in routine of the genetic resource. In this perspective, managers of the local breed are stabilizing technical choices about its genetic (Casabianca *et al.*, 2000). The regional organization in charge of this management is the first professional one appearing in this sector giving real references. Today the main task of this sector is to improve the capacity of farmers to produce pure breed animals. But many difficulties for this production are linked to the lack of infrastructures in the farms, and also to the lack of technical knowledge of farmers about genetic management of the animal population within an official scheme.

The livestock farming system is very stable because of the large independency from the other producers, from input supply and from the final market as well. But it induces a strong individualism that could be considered as an obstacle to the collective organization of the sector. Anyway, thanks to the dynamics around the breed association, a regional syndicate was created to be an official applicant of a PDO for Corsican processed meat. In this new project, a code of practices defining rules of production has to be fixed. Within the application, low growth local breed is obviously mobilized to insure a strong link with the territory. In this situation, new stakes around the genetic resources appear because of the fundamental role of the breed within the PDO project. As the breed is included in the specification of the PDO production project, the production of pure bred animals becomes a real challenge for the farmers.

Comparative analysis

The second step in our analysis is the compared analysis. The aim of this compared analysis was to highlight the main points of contrast.

The first element of contrast is linked to the biogeographic dimension of the territory.

In the *Nustrale* case, animals are free raised in the main part of the year on large areas: even if farmers use feeding with external resources, animals make use of "rughjoni", that means rangeland attached to the farm (can reach several hectares of chestnut and oak forests, shrub areas, etc.). As a consequence, those systems are called extensive systems. On the contrary, in the PBO case, pigs are reared in diverse situations. Some farmers use small parks to breed their animals. There is no rangeland and those systems are closer from classical outdoors pig farming systems.

Concerning the location of the breeders, the geographical spreading of the PBO breeders in all the western part of France (three administrative regions) induces difficulties on the breeding animal's exchanges between farmers. In the Corsican area, a greater number of breeders are localized in a smaller geographical area. Even if geomorphological characteristics are restrictive, farmers can easily exchange breeding animals.

The second element of contrast is linked to the agro-economic dimension of the territory.

In the *Nustrale* case, the process of cured meat is based on local practices and know-how. The range of products and its seasonality is well identified and specific to this territory. On the contrary, products from PBO breed are based on individual strategies to valorize the meat. The range of products is very large and depends on farmers initiatives. There is no specific link to the territorial heritage according to the product.

Moreover, the food chain organizations are also very contrasted in the two studied cases. In Brittany, the PBO breeders can be considered as marginal in a context where intensive pig production is dominant. As a consequence, a large part of the services structures are privatized and PBO farmers have difficulties to find public slaughterhouses at a reasonable distance. On the contrary in Corsica, *Nustrale* pig breeders represent an important proportion of the pig breeders in the island. The local authorities support the breeders by financing collective tools (slaughterhouse, breeding animal centres, etc.).

The last point of strong contrast concerns sociocultural aspects. It deals with the involvement of several actors within the society in those projects. The involvement of regional public action and also the goodwill of the local breed and its products in the whole region are stronger in Corsica than in Brittany. There are in Corsica frequent mentions of the breed and the PDO project in the local press. There is each year a specific day organized for the breed promotion, and in general the breed is known by the various stakeholders in the territory. On the contrary, the local breed is not very well known in the Britanny area. There is few communication around the breed. The main engagement of regional public action is through the Regional Natural Park of *Armorique*, which promotes all the local breeds in different species. Other part of the promotion can be made by individual initiatives of breeders (agrotourism, pedagogic farms).

Discussion

Local breeds in their territories and development dynamics

The results of the compared analysis of these two cases show that local breeds can have very contrasted development dynamics, even in the same species and within the same national institutions context. This is linked to local specificities and we underline the importance of the anchorage process in a specific territory.

We think that other cases from other species and other countries should be studied in the same perspective to reinforce the idea of the necessity of taking into account local specificities in multiples dimensions, in situations with different biological constraints (different species) or different institutional and socio-economic constraints (different national contexts).

The link to territory in the development process of local breeds

The interest of this compared analysis is to show that local breeds from the same species can follow very contrasted dynamics. These dynamics can be comprehended only considering the breed in its territory with its multiple dimensions (biogeographic, agro-economic and sociocultural).

In the present work we considered local breeds with relatively small population size, while it is interesting to test whether this view is relevant for livestock breeds of larger population size, in particular when those populations show less anchorage to a specific territory, because of a wider extension with their growing population number.

The role of local breeds in designing innovate livestock farming systems

Local breeds are often presented as breeds that fit to local conditions, most of the time presented as population that fit to harsh environment and extensive systems (Denis, 1997; Verrier *et al.*, 2005). However, as illustrated in our compared analysis, there is a wide range of extensive systems, where the local breeds are used, from rangeland systems to free-range systems. In fact, local breeds can be considered as not efficient in intensive systems compared with mainstream breeds selected to maximize their production in such systems, but their adaptability to a wide diversity of alternative systems more or less distant from classical intensive systems is underlined. As a consequence, they represent important potential local resources to be used in the development of alternative systems.

In such a context, our comparison shows the importance to analyse the breeds and their development dynamics in link with their territory when designing those alternative systems with local breeds.

Indeed, in some cases the alternative systems are designed at the scale of the farm that develops alternative projects compared with the dominant situation of the territory (as we show in the case of PBO with diverse initiatives from the breeders at individual points of views). We can see such situations for other breeds with more or less success. In other cases, the alternative systems are designed at the scale of a whole territory and are defined as alternative to the global dominant model (as we showed with the *Nustrale* case).

At both scales, the designing processes of alternative systems are based on various elements of systems among which the local breed can be a key element.

The role of local breeds in sustainable development

When assessing the sustainability of such an alternative we could raise the question of the role local breed could play in reaching this sustainability. This question can be raised both at the individual or territorial scales:

– At the individual scale, the local breeds reflect questions about specific ability (from an animal production point of view) that give them adaptability to specific environment, allowing for instance valorization of local food resources, or adaptability to the process of a local product, etc. The local breed echoes also to questions of public image of the breed that can be of social importance for the breeder, but also of economic importance when a farmer valorize products from that breed.
– At the territorial scale, the local breed can be considered as a common good. It contributes to biodiversity management, heritage and collective management involving a diversity of stakeholders (Audiot, 1995; Guyard, 2006; Labatut, 2009). In particular for what concerns genetic management, there is a strong collective dimension of the management of those breeds.

All those stakes around local breeds are strongly participating to stakes of alternative systems designing in northern country, to meet sustainability requirement, but also to face growing uncertainty (global changes, etc.). Those stakes also strongly echo to stakes for southern country (adaptability to harsh environments, resources for uncertainty management, adding value to local resources, etc.) and north/south comparative studies could enrich the vision of local breeds management and development dynamics.

Conclusion

Thanks to a compared analysis we underline the complexity of local breeds' management dynamics and we show the importance of analysing it with a multistake and multidimensional point of view. We also emphasize the importance of considering this management from a territorial point of view.

The linkage between local breeds and territories has an essential role to play in future research on the compatibility of animal genetic resources management and local development for the sustainability of agriculture and food systems, making a link between local development stakes and wider global stakes of sustainability.

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Suitability of traditional and conventional pig breeds in organic and low-input production systems in Europe: Survey results and a review of literature

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Summary
For many years, there has been debate about the suitability of traditional and conventional pig breeds in low-input and organic production systems. This review compiles reproductive and finishing performance of traditional and conventional breeds in low-input and organic production systems in Europe, based on literature studies and farm surveys until 2010. In comparison with traditional breeds, conventional breeds wean many piglets, have efficient and fast growth and lean carcasses. They thrive well in North West European climatic conditions with temperate summers and mild winters. Optimal housing may be indoors with outdoor runs, because this provides a controlled environment in which large litters are more easily managed. The lean meat of conventional breeds is suitable for the commodity organic pork market. Traditional breeds comprise a group of prolific breeds with good finishing performance (e.g. Saddlebacks, Pulawska) and breeds kept for special meat production (e.g. Ibérico, Cinta Senese). The prolific and leaner traditional breeds are suitable for commodity organic pork production, especially when crossed with conventional white boar breeds to give some extra leanness to the carcass. Special meat breeds are unsuitable for commodity organic pork production owing to their low fertility and high carcass fatness, but extra added value is obtained by their specific meat and fat quality.

Keywords: *pig, organic, breed, performance*

Résumé
Pendant longtemps, il a été débattu de la pertinence des races porcines traditionnelles et conventionnelles dans les systèmes de production biologique et dans ceux à faible apport d'intrants. Cette synthèse compile des données de performances reproductives et en finition de races traditionnelles et conventionnelles dans des systèmes de production biologique et à faible apport d'intrants en Europe, sur la base d'études bibliographiques et d'enquêtes d'exploitation réalisées jusqu'à 2010. Par rapport aux races traditionnelles, les races conventionnelles sèvrent un grand nombre de porcelets, ont une croissance efficiente et rapide et des carcasses maigres. Ces races prospèrent bien dans les conditions climatiques du nord-ouest de l'Europe avec des étés tempérés et des hivers doux. Le logement dans des bâtiments avec parcours en plein air peut être le logement optimal puisque celui-ci offre un environnement contrôlé qui rend plus facile la conduite des grandes portées. La viande maigre des races conventionnelles convient au marché de la viande de porc biologique. Les races traditionnelles comprennent un groupe de races prolifiques avec de bonnes performances en finition (par exemple, Saddleback, Pulawska) et des races élevées pour la production de viande spéciale (par exemple, Ibérico, Cinta Senese). Les races traditionnelles prolifiques plus maigres sont appropriées pour la production de viande de porc biologique, notamment lorsqu'elles sont croisées avec des verrats de races conventionnelles blanches dans le but d'avoir des carcasses encore plus maigres. Les races à viande spéciale ne conviennent pas à la production de viande de porc biologique à cause de leur faible fertilité et du fait d'avoir des carcasses très grasses. La spécificité de leur viande et la qualité de leur gras apportent cependant de la valeur ajoutée supplémentaire.

Mots-clés: *porc, biologique, race, performances*

Resumen
Durante muchos años se ha debatido sobre la idoneidad de las razas porcinas tradicionales y convencionales en los sistemas de producción ecológica y en aquéllos con bajo nivel de insumos. Esta revisión recopila datos de rendimientos reproductivos y de acabado de razas tradicionales y convencionales en sistemas de producción ecológica y con bajo nivel de insumos en Europa, en base a estudios bibliográficos y encuestas ganaderas realizados hasta 2010. En comparación con las razas tradicionales, las razas convencionales destetan muchos lechones, crecen de forma rápida y eficiente y tienen unas canales magras. Estas razas prosperan bien en las condiciones climáticas del noroeste europeo con veranos templados e inviernos suaves. El alojamiento en naves con parques exteriores puede ser el alojamiento óptimo puesto que proporciona un ambiente controlado en el que el manejo de grandes camadas resulta más fácil. La carne magra de las razas convencionales es apropiada para el mercado de carne de cerdo ecológica. Las razas tradicionales comprenden un grupo de razas prolíficas con buenos rendimientos en el acabado (por ejemplo, Saddleback, Pulawska) y razas criadas para la producción de carne especial (por ejemplo, Ibérico, Cinta Senese). Las razas tradicionales prolíficas más magras son adecuadas para la producción de carne de cerdo ecológica, sobre todo cuando son cruzadas con verracos de razas convencionales blancas con el fin de obtener canales aún más magras. Las razas de carne especial no son apropiadas para la producción de carne de cerdo

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ecológica debido a su baja fertilidad y al elevado contenido en grasa de sus canales. No obstante, el carácter específico de su carne y la calidad de su grasa aportan un valor añadido extra.

Palabras clave: *cerdo, ecológico, raza, rendimientos*

Submitted 23 November 2011; accepted 23 August 2012

Introduction

The organic and low-input farming sector is rapidly developing in the EU. Utilized agricultural areas have increased by 6.5 percent per year on average in the period between 2000 and 2008 (EU, 2010). The number of organic pigs increased from 0.39 to 0.81 million heads from 2002 to 2007, which amounts to an average annual increase of 15.5 percent (EU, 2010). Despite this rapid growth, only 0.5 percent of the EU pig herd is raised organically. Based on the number of certified organic pigs produced in 2007, Germany is the largest producer with almost 0.2 million heads, followed by Denmark (0.08 million), France (0.07 million), Austria (0.07 million), Greece (0.06 million), The Netherlands (0.06 million) and Great Britain (0.05 million) (EU, 2010).

In comparison with intensive pig production systems, low-input systems are characterized by smaller herd size, more space per animal, lower capital investment, often outdoor management, provision of bedding, greater labour requirement and focus on animal welfare. Organic pig production systems are similar to low-input systems, but additionally operate according to EU regulations on organic livestock farming (834/2007), which prescribe low stocking densities and access to outdoor runs, restrict the level of non-organic feeds and prohibit the use of genetically modified feeds.

Owing to the national histories of organic pork production, diverse climatic conditions and national organic farming regulations, large variation exists in organic housing and management conditions between European countries (Edwards, 2011; Früh, 2011). For example in Germany, The Netherlands and Sweden, the housing for organic pork production is mostly indoors with access to concrete outdoor runs. In Great Britain and Denmark, organic production stages are outside with individual paddocks with huts (Larsen and Jørgensen, 2002). In Southern Europe (Italy, Spain), most of the organic pig herds are outdoors and are situated in hills and mountains. Both traditional and conventional pig breeds are used in low-input and organic production systems. Traditional breeds such as Saddleback, Large Black and Mangalitza are often used on smaller scale organic farms, both as purebred stock and as crosses with conventional sire line breeds such as Duroc and Piétrain. Conventional breeds typically include crosses of Landrace, Large White and Duroc, and specialized genetic lines developed by breeding companies (Martins *et al.*, 2002).

For many years, there has been debate about the suitability of traditional and conventional breeds in low-input and organic production systems (DEFRA, 2002; Brandt *et al.*, 2010). Traditional breeds are recommended by the Soil Association (2011) to retain genetic diversity. Moreover, these breeds are presumed to have characteristics that make them well adapted to lower input, free-range and organic systems (Chambers, 2005). However, traditional breeds may be less prolific, grow slowly and have excess carcass fat at heavy slaughter weights (Blair, 2007; Kelly *et al.*, 2007). On the other hand, conventional breeds or specialized genetic lines have high prolificacy, efficient feed conversion, high growth rates and carcass leanness. However, these breeds are selected in conventional, confined environments and therefore may not be sufficiently adapted to a production environment that is characterized by more space and freedom of movement for the animals, use of diets with more fibrous feedstuffs and lower protein quality, restricted use of antibiotics and a higher influence of (possibly adverse) weather conditions (DEFRA, 2002; Kelly *et al.*, 2007).

This review compiles reproductive and finishing performance of traditional and conventional breeds in low-input and organic production systems in various European countries, based on literature studies and farm surveys. This information will increase insight into the suitability of traditional versus conventional breeds for these production systems. Additionally, performance evaluation of traditional breeds may help in assessing the conservation value of these breeds and may reveal breed characteristics that can be used to increase economic value and consequently self-sustainability of the breeds (Pugliese *et al.*, 2003).

Suitability of breeds is closely linked to both environment, e.g. climatic conditions, and market requirements, e.g. specialized cured meat production or commodity pork production (Martins *et al.*, 2002; Uremović *et al.*, 2003; Blair, 2007). Therefore, breed comparisons will be made for three macroclimatic regions, i.e. North West Europe, Eastern Europe, and Southern Europe, while market requirements will be taken into account when evaluating breed suitability.

Materials and methods

Literature

Between June 2010 and July 2011, an online literature scan was performed in order to find data on reproductive and finishing performance of traditional and conventional

breeds in organic and low-input pig production systems. Online sources that were used included the Scopus database (www.scopus.com), the Organic Eprints archive (www.orgprints.org), Google (www.google.com) and Google scholar (scholar.google.com). All references containing the terms 'organic', 'pig', 'breed', 'genotype', 'line', 'low input', 'farm', 'performance', 'modern', 'conventional', 'traditional', 'local', 'native', 'reproduction', 'finishing', 'fattening' in the title or abstract were collected. Search results included both peer-reviewed and non-peer-reviewed scientific publications, conference proceedings, reports from research projects, unpublished reports from relevant pig breeding projects, information on websites and book chapters. Literature sources originated from three macroclimatic regions: North West Europe, including the countries Great Britain, Germany, Denmark, and Sweden; Eastern Europe including Hungary, Poland, Austria, Croatia and Bulgaria; and Southern Europe including Italy and Spain. For reproductive and finishing performance of traditional breeds, in total 32 literature sources were used. These included 12 sources from North West Europe, 12 sources from Eastern Europe and 8 sources from Southern Europe. For reproductive and finishing performance of conventional breeds, in total 21 literature sources were used. These included 13 sources from North West Europe, 5 sources from Eastern Europe, and 3 sources from Southern Europe.

Survey data

For various European countries, relevant contact persons from breeding organizations, universities and research institutes were approached and were sent forms requesting information on the performance of traditional or conventional pig breeds in organic or low-input production systems between 2006 and 2010. Requested information included farm name and location, period of data collection, sow breed and terminal boar breed. The following sow reproductive performance parameters were requested: number of sows per farm, number of litters per sow per year, farrowing rate, total number piglets born per litter, number of liveborn piglets per litter, mortality until weaning and duration of lactation period. Finishing performance parameters that were requested included: number of finishing pigs per farm, start and end weight of the finishing period, daily weight gain, feed conversion ratio, mortality until slaughter, backfat thickness and lean meat percentage. If known, information was also provided on the feeding regime of the finisher pigs.

The survey included the following countries and respective organizations: Denmark: Aarhus University, Faculty of Agricultural Sciences, DJF; Germany: University of Kassel, Faculty of Organic Agricultural Sciences, Department of Animal Nutrition and Animal Health; Great Britain: BPEX (British Pig Executive); Italy: ANAS (Italian Association of Pig Breeders); The Netherlands: TOPIGS Breeding Company; Austria: BEP Bioschwein project no. 100188 BMLFUW*LE.1.3.2/0134-II/1/2006; Poland: POLSUS (Polish Association of Pig Breeders and Producers); Spain: TOPIGS Ibérica; Sweden: Quality Genetics, Swedish University of Agricultural Sciences; Hungary: National Association of Mangalitza Breeders; France: IFIP (French Institute for Pig and Pork Industry).

For reproductive and finishing performance of traditional breeds, surveys were used from North West Europe (West France, Mid France), Eastern Europe (Hungary, Poland) and Southern Europe (South West France, South France, Corsica, Italy, Spain). For reproductive and finishing performance of conventional breeds, surveys were used from North West Europe (Great Britain, Denmark, The Netherlands, Sweden, Germany).

Breed definitions

Traditional breeds were defined as breeds that were bred by farmers for many decades, before the drastic reduction of breed variety caused by the rise of industrial agriculture (Sustainable table, 2011). In the current review, traditional breeds included British Saddleback, German Saddleback, Angeln Saddleback, Swabian-Hall, Large Black, Middle White, German Saddleback, Basque, Bayeux, Gascon, Limousin, Nustrale, Porc Blanc de l'Ouest, Danish Black Spotted, Mangalitza, Turopolje, Black Slavonian, Pulawska, Zlotnicka, East Balkan Swine, Mora Romagnola, Sarda, Casertana, Nero Siciliano, Cinta Senese, Calabrese, Majorcan Black Pig and Ibérica.

Conventional pig breeds were defined as contemporary breeds that were developed, mostly based on local Landrace and/or Large White populations, to maximize production in large-scale confinement operations (Frick and Dening, 2008). In this review, these breeds include purebred stock and crosses of Large White, Duroc, Landrace, Nero di Parma and German Edelschwein, and genetic lines which have been bred by breeding companies, including Camborough 12 (PIC, Great Britain), TOPIGS commercial cross (TOPIGS, The Netherlands), BHZP commercial cross (Bundeshybridzuchtprogramm, Germany).

Breed averages

Breed averages were calculated for the following reproductive and finishing traits: number of liveborn piglets per litter, preweaning mortality (%), number of weaned piglets per litter, average daily gain (g/day), feed conversion ratio and carcass lean meat (%). These breed averages are reported in Figures 1–6 of the Results section and were obtained by averaging values of respective traits of single literature references or surveys that are reported in Tables 1–4 of the Results section. If only one reference was available for a certain breed, this reference was used to represent a breed average.

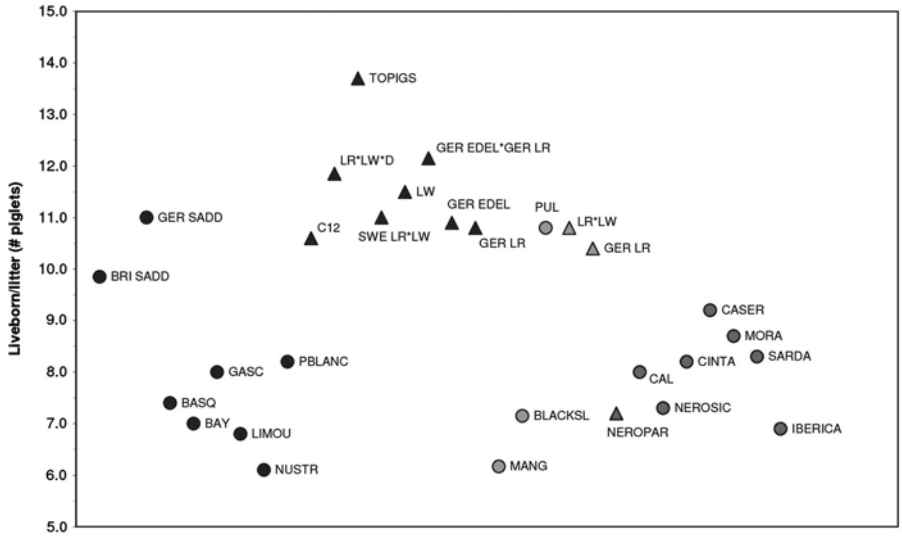

Figure 1. Average number of liveborn piglets for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 1 and 2. GER SADD: German Saddleback; BRI SADD: British Saddleback; PBLANC: Porc Blanc de l'Ouest; BAY: Bayeux; LIMOU: Limousin; TOPIGS: TOPIGS commercial cross; GER EDEL: German Edelschwein; LR: Landrace; LW: Large White; D: Duroc; GER LR: German Landrace; SWE LR: Swedish Landrace; C12: Camborough 12; PUL: Pulawska; BLACKSL: Black Slavonian; MANG: Mangalitza; GASC: Gascon; BASQ: Basque; NUSTR: Nustrale; CASER: Casertana; MORA: Mora Romagnola; SARDA: Sarda; CINTA: Cinta Senese; CAL: Calabrese; NEROSIC: Nero Siciliano; NEROPAR: Nero di Parma; IBERICA: Ibérica.

Results

Reproductive and finishing performance data of individual literature studies and farm surveys of traditional and conventional breeds are shown in Tables 1 and 3 (traditional breeds) and Tables 2 and 4 (conventional breeds). Data are grouped according to macroclimatic region (North West Europe, Eastern Europe, Southern Europe). Data from Tables 1–4 were averaged per breed within each of the three macroclimatic regions and shown for various reproductive and finishing traits in Figures 1–6.

Reproductive performance of traditional and conventional breeds in organic and low-input pig production systems

For traditional breeds, the number of sows included in the various references ranged from 10 to 1404 animals

Figure 2. Average preweaning mortality for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of the three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 1 and 2. GER SADD: German Saddleback; BRI SADD: British Saddleback; PBLANC: Porc Blanc de l'Ouest; BAY: Bayeux; LIMOU: Limousin; TOPIGS: TOPIGS commercial cross; GER EDEL: German Edelschwein; LR: Landrace; LW: Large White; D: Duroc; GER LR: German Landrace; SWE LR: Swedish Landrace; C12: Camborough 12; PUL: Pulawska; BLACKSL: Black Slavonian; MANG: Mangalitza; GASC: Gascon; BASQ: Basque; NUSTR: Nustrale; CASER: Casertana; MORA: Mora Romagnola; SARDA: Sarda; CINTA: Cinta Senese; CAL: Calabrese; IBERICA: Ibérica.

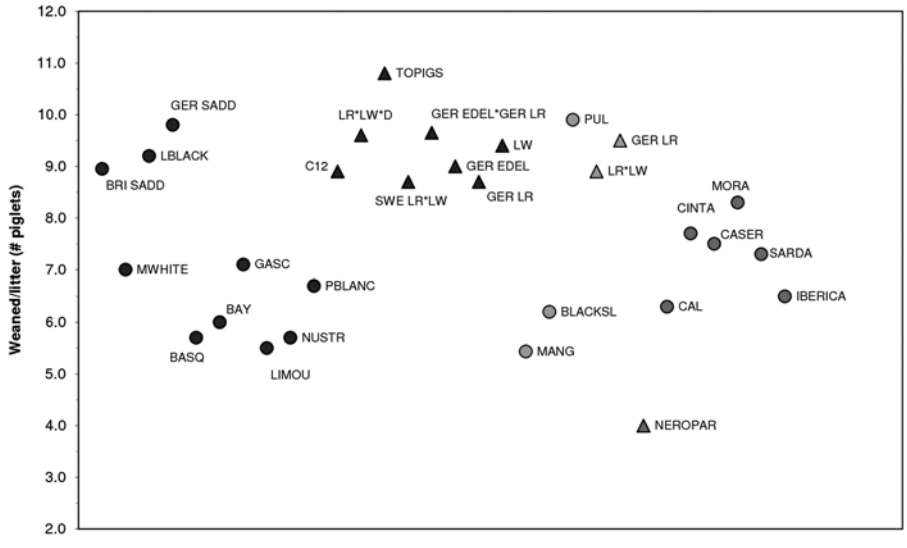

Figure 3. Average number of weaned piglets for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 1 and 2. GER SADD: German Saddleback; LBLACK: Large Black; BRI SADD: British Saddleback; MWHITE: Middle White; PBLANC: Porc Blanc de l'Ouest; BAY: Bayeux; LIMOU: Limousin; TOPIGS: TOPIGS commercial cross; GER EDEL: German Edelschwein; LR: Landrace; LW: Large White; D: Duroc; GER LR: German Landrace; SWE LR: Swedish Landrace; C12: Camborough 12; PUL: Pulawska; BLACKSL: Black Slavonian; MANG: Mangalitza; GASC: Gascon; BASQ: Basque; NUSTR: Nustrale; CASER: Casertana; MORA: Mora Romagnola; SARDA: Sarda; CINTA: Cinta Senese; CAL: Calabrese; NEROPAR: Nero di Parma; IBERICA: Ibérica.

(Table 1). For conventional breeds, the number of sows ranged from 15 to 2877 animals (Table 2).

In North West Europe, the number of liveborn piglets per litter ranged from 6.8 to 11.0 for traditional breeds, and from 10.6 to 13.7 piglets for conventional breeds (Tables 1 and 2). Figure 1 shows that the French traditional breeds have the lowest litter sizes, whereas the German Saddleback has a litter size within the same range as the conventional breeds. In Eastern Europe, the highest litter sizes were found for the traditional Polish Pulawska breed (10.8 piglets) and the conventional Austrian Large White × Landrace cross (11.8 piglets) (Tables 1 and 2). The traditional Croatian Black Slavonian and Hungarian Mangalitza breeds have the lowest litter sizes (5.9–7.4 piglets).

In Southern Europe, litter size ranged from 6.1 piglets (Nustrale) to 9.2 piglets (Casertana).

Preweaning mortality shows a large variation within all macroclimatic regions, especially for the traditional breeds

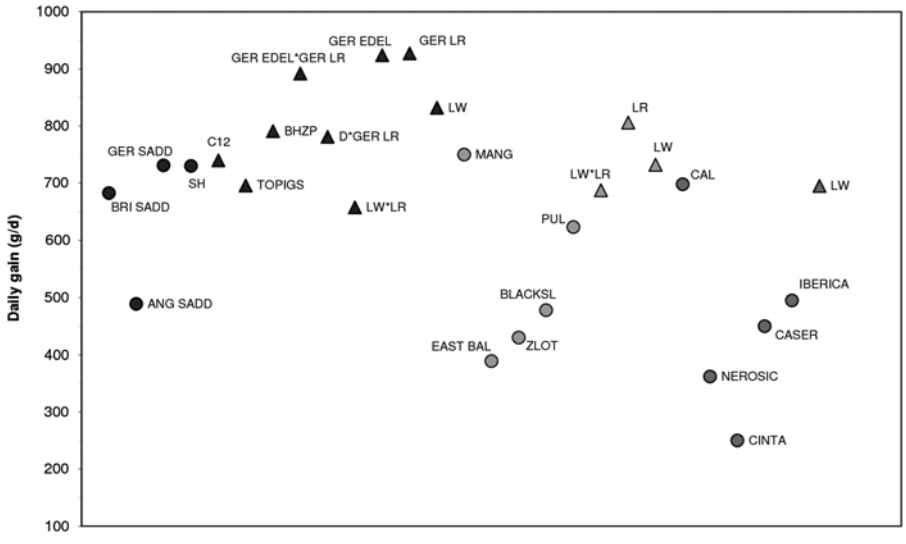

Figure 4. Average daily gain (g/day) for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 3 and 4. ANG SADD: Angeln Saddleback; BRI SADD: British Saddleback; GER SADD: German Saddleback; SH: Swabian-Hall; C12: Camborough 12; TOPIGS: TOPIGS commercial cross; BHZP: Bundeshybridzuchtprogramm; D: Duroc; LR: Landrace; LW: Large White; GER EDEL: German Edelschwein; GER LR: German Landrace; MANG: Mangalitza; PUL: Pulawska; BLACKSL: Black Slavonian; ZLOT: Zlotnicka; EAST BAL: East Balkan Swine; CAL: Calabrese; CINTA: Cinta Senese; NEROSIC: Nero Siciliano; CASER: Casertana; IBERICA: Ibérica.

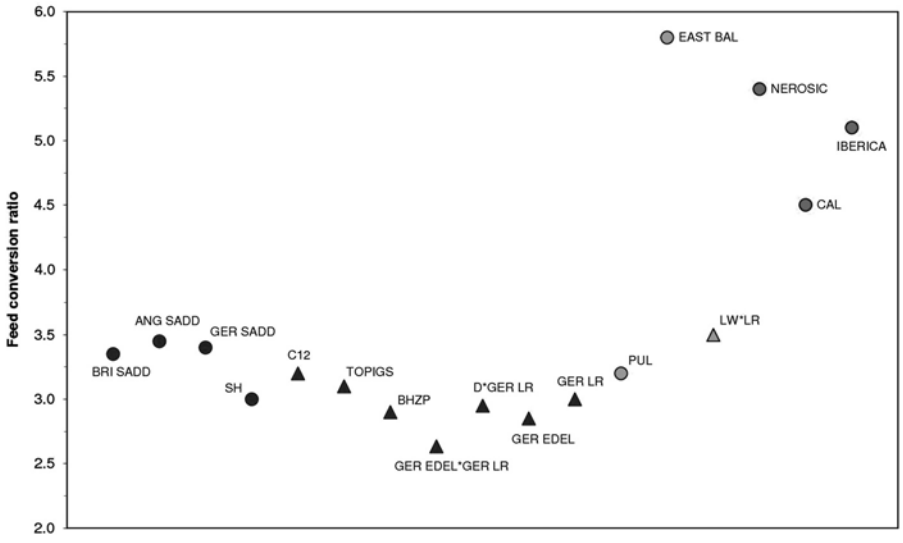

Figure 5. Average feed conversion ratio for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 3 and 4. BRI SADD: British Saddleback; ANG SADD: Angeln Saddleback; GER SADD: German Saddleback; SH: Swabian-Hall; C12: Camborough 12; TOPIGS: TOPIGS commercial cross; BHZP: Bundeshybridzuchtprogramm; GER EDEL: German Edelschwein; GER LR: German Landrace; D: Duroc; LR: Landrace; PUL: Pulawska; LW: Large White; EAST BAL: East Balkan Swine; NEROSIC: Nero Siciliano; CAL: Calabrese; IBERICA: Ibérica.

(Tables 1 and 2; Figure 2). In North West Europe for example, the British Saddleback breed has an average preweaning mortality of around 10 percent (Figure 2), whereas the French Limousin breed has a mortality of 19 percent (Figure 2). All conventional North Western European breeds have preweaning mortalities above 16 percent, except for the Landrace, Large White and Duroc crosses used in Great Britain (12.9 percent; Table 2). In Eastern Europe, preweaning mortality was lowest for the traditional Pulawska (8.0 percent) and conventional German Landrace (8.7 percent) and highest for the Swedish Landrace × Large White cross (18.4 percent; Table 2). In Southern Europe, mortality ranged between 4.4 percent (Mora Romagnola) and 23.0 percent (Basque) (Table 1; Figure 2).

In North West Europe, the traditional breeds German and British Saddleback and Large Black show similar numbers of weaned piglets (9–10 piglets) as the conventional breeds (Figure 3). In Eastern Europe, the traditional Mangalitza and Black Slavonian have the lowest number

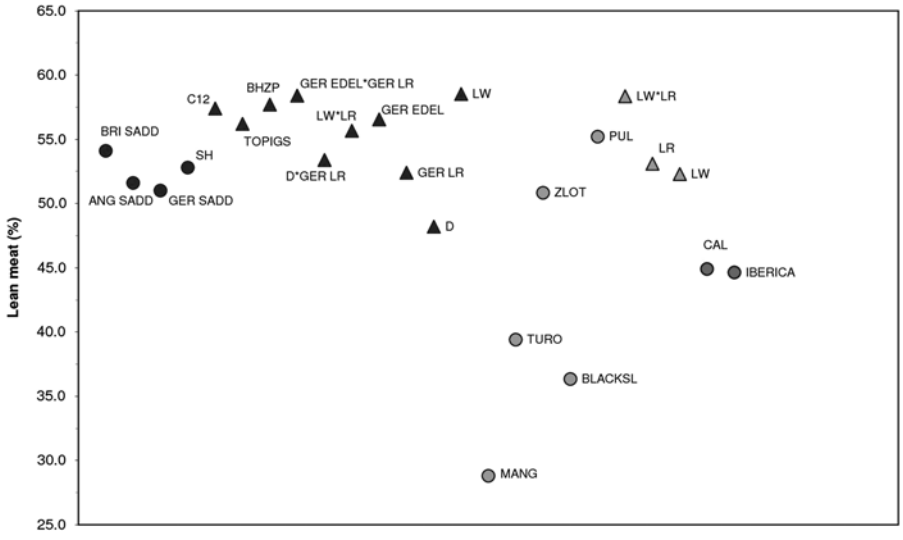

Figure 6. Average lean meat percentage for traditional (•) and conventional (▲) pig breeds kept in organic or low-input pig production systems. Data are pooled averages from literature and survey data for each of three European macroclimatic regions (blue: North West Europe; green: Eastern Europe; red: Southern Europe), as listed in Tables 3 and 4. BRI SADD: British Saddleback; ANG SADD: Angeln Saddleback; GER SADD: German Saddleback; SH: Swabian-Hall; C12: Camborough 12; TOPIGS: TOPIGS commercial cross; BHZP: Bundeshybridzuchtprogramm; GER EDEL: German Edelschwein; GER LR: German Landrace; LW: Large White; LR: Landrace; D: Duroc; PUL: Pulawska; ZLOT: Zlotnicka; TURO: Turopolje; BLACKSL: Black Slavonian; MANG: Mangalitza; CAL: Calabrese; IBERICA: Ibérica.

Table 1. Reproductive performance of traditional pig breeds reared in organic and low-input systems, arranged by macroclimatic zone, breed and country.

Sow Breed	Boar breed	Country[a]	Year	No. sows	Liveborn/ litter	Preweaning mortality %[b]	Weaned/ litter	Litters/ year	Reference
North West Europe									
British Saddleback	British Saddleback	GBR	1972–1975				9.2		Alderson (2007)
British Saddleback	Duroc	GBR	1999–2002	20	10.4	12.5	9.1	1.8	DEFRA (2002)
British Saddleback	Large White, Landrace	GBR	2005	200	9.3	8.5	8.5	1.8	CIWF (2005)
British Saddleback	British Saddleback	GBR	2008	14			9.0	2.2	Laverstoke farm (2009)
Large Black	Large Black	GBR	1972–1975				9.2		Alderson (2007)
Middle White	Middle White	GBR	2008	23			7.0	2.2	Laverstoke farm (2009)
German Saddleback	German Saddleback	DEU	2007	34	11.0	10.9	9.8	1.7	Ehlich (2007)
Bayeux	Bayeux	FRA	2003–2008	177	7.0	14.3	6.0		IFIP (2008)
Limousin	Limousin	FRA	2003–2008	127	6.8	19.1	5.5		IFIP (2008)
Porc Blanc de l'Ouest	Porc Blanc de l'Ouest	FRA	2003–2008	97	8.2	18.3	6.7		IFIP (2008)
Danish Black Spotted	Danish Black Spotted, Duroc	DNK	2008	10			8.2		Kongsted *et al.* (2008)
Eastern Europe									
Mangalitza (Blonde)	Mangalitza (Blonde)	HUN	2003	1404	6.0	10.0	5.4	1.7	MOE (2003)
Mangalitza (Swallow-bellied)	Mangalitza (Swallow-bellied)	HUN	2003	242	5.9	10.2	5.3	1.8	MOE (2003)
Mangalitza (Red)	Mangalitza (Red)	HUN	2003	394	6.6	15.1	5.6	1.7	MOE (2003)
Mangalitza	Mangalitza	AUT	2010	38			6.3	2.0	Prevost (2010)
Turopolje	Turopolje	AUT	2010	164			6.5	2.5	Prevost (2010)
Black Slavonian	Black Slavonian	HRV	2000		6.9	15.9	5.8		Uremović *et al.* (2000)
Black Slavonian	Black Slavonian	HRV	2003	60	7.4	10.8	6.6	1.8	Uremović *et al.* (2003)
Pulawska	Pulawska	POL	2006–2009	909	10.8	8.0	9.9	1.8	POLSUS survey (2009)
Southern Europe									
Basque	Basque	FRA	2003–2008	517	7.4	23.0	5.7		IFIP (2008)
Gascon	Gascon	FRA	2003–2008	938	8.0	11.3	7.1		IFIP (2008)
Nustrale	Nustrale	FRA	2003–2008	306	6.1	6.6	5.7		IFIP (2008)
Mora Romagnola	Mora Romagnola	ITA	2006–2009	191	8.7	4.4	8.3	1.3	ANAS survey (2010)
Sarda	Sarda	ITA	2007–2009	32	8.3	11.8	7.3	1.2	ANAS survey (2010)
Casertana	Casertana	ITA	2006–2009	84	9.2	18.1	7.5	1.3	ANAS survey (2010)
Nero Siciliano	Nero Siciliano	ITA	2006–2009	276	7.3			1.1	ANAS survey (2010)
Cinta Senese	Cinta Senese	ITA	2006–2009	991	8.2	6.4	7.7	1.3	ANAS survey (2010)
Calabrese	Calabrese	ITA	2006–2009	168	8.0	20.8	6.3	1.3	ANAS survey (2010)
Ibérica	Ibérico, Duroc	ESP	2009–2010	311	6.9	6.2	6.5	2.2	TOPIGS Ibérica survey (2010)

[a]Official alpha-3 country codes of the ISO 3166-1 encoding list.
[b]Excluding stillborn piglets.

Table 2. Reproductive performance of conventional pig breeds reared in organic and low-input systems, arranged by macroclimatic zone, breed and country.

Sow Breed	Boar breed	Country[a]	Year	No. sows	Liveborn/ litter	Preweaning mortality %[b]	Weaned/ litter	Litters/ year	Reference
North West Europe									
Camborough 12[c]	Duroc	GBR	1999–2002	20	10.6	20.8	8.4		DEFRA (2002)
Landrace, Large White, Duroc crosses	Meatline boars	GBR	2009	777	10.9	12.9	9.5	2.2	BPEX (2009)
Landrace, Large White, Duroc crosses	Duroc, Landrace, Yorkshire	DNK	2008		12.8	24.2	9.7		Aarhus University survey[f] (2008)
TOPIGS commercial cross[d]	Piétrain	NLD	2010	170	13.7	20.4	10.9	2.1	TOPIGS survey (2010)
Swedish Landrace × Large White	Hampshire	SWE	2008	40	11.0	20.9	8.7		Wallenbeck, Rydhmer and Thodberg (2008)
Large White	Large White	SWE	2009	2877	11.5	18.3	9.4	2.2	Quality Genetics survey (2009)
German Edelschwein × German Landrace[e]		DEU	2006	69	11.9	20.2	9.5		Haus Düsse (2006)
German Landrace × German Edelschwein	Duroc, Hampshire-Duroc, Hampshire-Piétrain, Piétrain	DEU	2007	103	12.4	21.0	9.8	1.9	Sundrum (2007)
German Edelschwein	Piétrain, Duroc	DEU	2007	36	10.9	17.4	9.0	2.0	Sundrum (2007)
German Landrace	Duroc, Hampshire-Duroc, Landrace, Piétrain	DEU	2007	47	10.8	19.4	8.7	2.0	Sundrum (2007)
Eastern Europe									
Swedish Landrace × Large White		HRV	2003	55	9.8	18.4	8.0	1.8	Uremović *et al.* (2003)
German Landrace		HRV	2003	15	10.4	8.7	9.5	2.1	Uremović *et al.* (2003)
Large White × Landrace	Piétrain	AUT	2009	23	11.8	16.9	9.8	2.0	Leeb, Bernard and Winckler (2010)
Southern Europe									
Nero di Parma	Nero di Parma	ITA	2002–2006	120	7.2		4.0		Sabbioni *et al.* (2007)

[a]Official alpha-3 country codes of the ISO 3166-1 encoding list.
[b]Excluding stillborn piglets.
[c]PIC (Landrace × Large White) × Duroc cross.
[d]Landrace × Large White cross.
[e]Westhybrid.
[f]The survey included 15 farms, but the number of sows was unknown.

Table 3. Finishing performance of traditional pig breeds, reared in organic and low-input systems, arranged by macroclimatic zone, breed and country.

Sow breed	Boar breed	Country[a]	Year	Feed	No. pigs	Daily gain (g/day)	FCR[b]	Lean meat (%)	Back fat (mm)	Reference
North West Europe										
British Saddleback	Duroc	GBR	1999–2002	Organic *ad lib*[c]	144	740	3.3	54.1	14.3	DEFRA (2002)
British Saddleback	Large White, Landrace	GBR	2005	Concentrate/grass silage		625	3.4			CIWF (2005)
German Saddleback	German Saddleback	DEU	1995–1996		43	731	3.4	51.0		Ehlich (2007)
Angeln Saddleback	Piétrain	DEU	2003	Cereals, grain legumes[d]	10	489		50.7		Weissmann, Biedermann and Klitzing (2005)
Angeln Saddleback	Angeln Saddleback	DEU	2004–2006	Organic *ad lib*[c]	58		3.6	48.2		Brandt *et al.* (2010)
Angeln Saddleback	Piétrain	DEU	2004–2006	Organic *ad lib*[c]	62		3.3	55.9		Brandt *et al.* (2010)
Swabian-Hall	Swabian-Hall	DEU	2004–2006	Organic *ad lib*[c]	30		3.3	51.5		Brandt *et al.* (2010)
Swabian-Hall	Piétrain	DEU	2004–2006	Organic *ad lib*[c]	29		3.0	57.0		Brandt *et al.* (2010)
Swabian-Hall	Swabian-Hall	DEU	2005	Organic *ad lib*[c]	26	744	2.9	47.4		Werner, Brandt and Quanz (2007)
Swabian-Hall	Piétrain	DEU	2005	Organic *ad lib*[c]	28	716	2.8	55.3		Werner, Brandt and Quanz (2007)
Eastern Europe										
Zlotnicka	Zlotnicka	POL	1997–1999		423	412		49.3	19.0	Szulc *et al.* (2006)
Zlotnicka	Polish Large White	POL	1997–1999		36	479		51.5	16.0	Szulc *et al.* (2006)
Zlotnicka	Hampshire	POL	1997–1999		31	399		51.7	16.0	Szulc *et al.* (2006)
Pulawska	Pulawska	POL	2006- 2009			623	3.2	55.2	12.9	POLSUS survey (2009)
East Balkan Swine	East Balkan Swine	BGR	1992–1993			389	5.8			Ivanova-Peneva and Stoykov (2005)
Black Slavonian	Black Slavonian	HRV	1988	Pasture, grain suppl				28.6		Petričević, Kralik and Petrović (1988)
Black Slavonian	Black Slavonian	HRV	1988	Pasture, grain suppl				28.5		Kralik, Petričević and Levaković (1988)
Black Slavonian	Black Slavonian	HRV	2000	Pasture, grain suppl		478		42.9		Uremović *et al.* (2000)
Black Slavonian	Black Slavonian	HRV	2001	Pasture, grain suppl				32.4		Kralik and Petričević (2001)
Black Slavonian	Black Slavonian	HRV	2005	Pasture, grain suppl				41.0		Senčić *et al.* (2005)
Black Slavonian	Swedish Landrace	HRV	2005	Pasture, grain suppl				44.6		Senčić *et al.* (2005)
Turopolje	Turopolje	HRV	2003	Acorns, pasture				39.4		Dikić *et al.* (2003)
Mangalitza	Mangalitza	HUN	2001	Farm feeds, green fodder				28.8		Kralik and Petričević (2001)
Mangalitza	Mangalitza	HUN	2010	Farm feeds, green fodder		750				GEH (2010)
Southern Europe										
Mora Romagnola	Mora Romagnola	ITA	2007						52.1	Lo Fiego *et al.* (2007)
Casertana	Casertana	ITA	2006	Formulated[e]	32	450			44.9	Pietrolà *et al.* (2006)
Nero Siciliano	Nero Siciliano	ITA	2003	Natural pastures	41	200			40.3	Pugliese *et al.* (2003)
Nero Siciliano	Nero Siciliano	ITA	2005	Pelleted complete	10	540	5.4		39.3	Liotta *et al.* (2005)
Nero Siciliano	Nero Siciliano	ITA	2007	Acorns	12	346				Zumbo *et al.* (2007)
Cinta Senese	Cinta Senese	ITA	2002	Pasture + food suppl	16	250			64.7	Franci *et al.* (2003)

Continued

Table 3. Continued

Sow breed	Boar breed	Country[a]	Year	Feed	No. pigs	Daily gain (g/day)	FCR[b]	Lean meat (%)	Back fat (mm)	Reference
Calabrese	Calabrese	ITA	2005	Proteinaceous crops	36	698	4.5	44.9	35.3	Rossi *et al.* (2007)
Majorcan Black Pig	Majorcan Black Pig	ESP	2007	Pasture, cereals[f]	66				72.1	Gonzalez *et al.* (2007)
Ibérica	Duroc	ESP	2009–2010	Acorns, herbs, cereals	5713	495	5.1	44.6	62.5	TOPIGS Ibérica survey (2010)

[a]Official alpha-3 country codes of the ISO 3166-1 encoding list.
[b]Feed conversion ratio.
[c]Feed: Organic standard (EC Regulation 1804/1999).
[d]Supplied in the form of coarse meal.
[e]Two diets differing in energy content, supplied on a basis of 9 percent of metabolic weight.
[f]Also included were legume seeds, figs, almonds, acorns and several Mediterranean shrubs.

of weaned piglets (5–6 piglets), whereas the traditional Pulawska and the conventional German Landrace and Large White × Landrace cross have the highest number of weaned piglets (9–10 piglets) (Figure 3). In Southern Europe, the number of weaned piglets ranged between 4.0 (Nero di Parma) and 8.3 (Mora Romagnola) (Table 1; Figure 3).

Finishing performance of traditional and conventional breeds in organic and low-input pig production systems

For traditional breeds, the number of pigs included in the various references ranged from 10 to 5713 animals (Table 3). For conventional breeds, the number of pigs ranged from 10 to 940 animals (Table 4).

In North West Europe, daily gains of traditional breeds ranged between 489 and 744 g/day, whereas for conventional breeds this range was 518 and 975 g/day (Tables 3 and 4). Growth rates of the traditional German and British Saddleback and Swabian-Hall were comparable to growth rates of conventional commercial genetic lines, such as the Camborough 12 and TOPIGS commercial cross (Figure 4). The conventional breeds German Edelschwein, Landrace and a cross between them achieved the highest growth rates of around 900 g/day. In Eastern Europe, the lowest growth rates were found for the traditional East Balkan Swine, Zlotnicka and Black Slavonian breeds (400–500 g/day), and the highest growth rate for the conventional Landrace breed (800 g/day). In Southern Europe, growth rates varied from 250 g/day for the traditional Italian Cinta Senese, to 700 g/day for the conventional Large White and traditional Italian Calabrese breeds.

In North West Europe, the lowest feed conversion ratios were achieved by conventional breeds (German Edelschwein × Landrace: 2.5–2.7) and the highest by traditional breeds (Angeln Saddleback: 3.3–3.6). In Eastern and Southern Europe, data on feed conversion ratios were limited. The Polish Pulawska breed had the lowest feed conversion ratio (3.2), whereas the Bulgarian East Balkan Swine had the highest (5.8).

Traditional breeds in North West Europe have lean meat percentages in the same range (50–55 percent) as conventional breeds (48–60 percent), but the majority of conventional breeds have lean meat percentages above 55 percent. In Eastern Europe, there is a large variation within the traditional breeds in lean meat percentage. The Hungarian Mangalitza achieved 28.8 percent, whereas the Pulawska breed achieved 55.2 percent. Conventional breeds had the highest lean meat percentages, with the Large White × Landrace cross achieving 57.7–59.9 percent (Table 4; Figure 6). Lean meat percentages of the Southern European Calabrese and Ibérica breeds were around 45 percent.

Table 4. Finishing performance of conventional pig breeds, reared in organic and low-input systems, arranged by macroclimatic zone, breed and country.

Sow breed	Boar breed	Country[a]	Year	Feed	No. pigs	Daily gain (g/day)	FCR[b]	Lean meat (%)	Back fat (mm)	Reference
North West Europe										
Camborough 12[c]	Duroc	GBR	1999–2002	Organic *ad lib*	144	740	3.2	57.4	11.4	DEFRA (2002)
TOPIGS commercial cross[d]	Piétrain	NLD	2008	Organic	2128	696	3.1	56.2	16.9	TOPIGS survey (2008)
BHZP commercial cross[e]	BHZP commercial cross[e]	DEU	2004–2006	Organic *ad lib*	67		3.1	58.2		Brandt *et al.* (2010)
BHZP commercial cross[e]	BHZP commercial cross[e]	DEU	2005	Organic *ad lib*	26	791	2.7	57.2		Werner, Brandt and Quanz (2007)
German Edelschwein × German Landrace[f]		DEU	2000	Grains, concentrate[g]	25	822		59.5	23	Haus Düsse (2000)
German Edelschwein × German Landrace[f]	Piétrain	DEU	2000	Organic	338	831	2.5	60.6	14.4	Haus Düsse (2000)
German Edelschwein × German Landrace	Piétrain	DEU	2007	Organic *ad lib*	24	951	2.7	57.5		Lapp *et al.* (2009)
German Edelschwein × German Landrace	Duroc	DEU	2007	Organic *ad lib*	24	964	2.7	56.0		Lapp *et al.* (2009)
Duroc × German Landrace	Hampshire × Piétrain	DEU	2002–2003	Concentrates, crops	100	748		55.6		Farke and Sundrum (2005)
Duroc × German Landrace	Piétrain	DEU	2002–2003	Concentrates, crops	60	748		55.1		Farke and Sundrum (2005)
Duroc × German Landrace	Piétrain	DEU	2003	Organic	20	490		52.5		Weissmann, Biedermann and Klitzing (2005)
Duroc × German Landrace	Piétrain	DEU	2003	Organic	20			50.6		Farke and Sundrum (2005)
Duroc × German Landrace	German Edelschwein	DEU	2007	Organic *ad lib*	28	975	2.8	54.4		Lapp *et al.* (2009)
Duroc × German Landrace	Duroc	DEU	2007	Organic *ad lib*	17	944	3.1	52.1		Lapp *et al.* (2009)
Large White × German Landrace	Piétrain	DEU	2002–2003	Concentrates, crops	40	697		54.7		Farke and Sundrum (2005)
Large White × German Landrace	Piétrain	DEU	2003	Organic	10	518		52.7		Weissmann, Biedermann and Klitzing (2005)
German Edelschwein	German Edelschwein	DEU	2000	Organic	127	924	2.6	55.3	21	Haus Düsse (2000)
German Edelschwein	Piétrain	DEU	2004–2006	Organic *ad lib*	44		3.1	57.8		Brandt *et al.* (2010)
German Landrace	German Landrace	DEU	2000	Organic	198	927	2.7	54.4	22.4	Haus Düsse (2000)
German Landrace	Duroc	DEU	2003	Organic	10			47.5		Farke and Sundrum (2005)
German Landrace	Duroc	DEU	2004–2006	Organic *ad lib*	65		3.3	55.3		Brandt *et al.* (2010)
Duroc	Duroc	DEU	2003	Organic	10			48.2		Farke and Sundrum (2005)
Large White × Landrace	Duroc	DNK	2002–2003	Organic *ad lib*	50	758		59.6	16.5	Oksbjerg *et al.* (2005); Strudsholm and Hermansen (2005)
Large White	Duroc, Swedish Landrace	SWE	2001–2002	Organic *ad lib*	79	832		58.6	13.5	Heyer, Andersson and Lundström (2006)
Eastern Europe										
Large White × Landrace	Piétrain	AUT	2000	Organic *ad lib*	15	641		57.7		Laister and Konrad (2005)
Large White × Landrace	Piétrain	AUT	2009	Organic	940	734	3.5	59.0		Leeb, Bernard and Winckler (2010)
Landrace	Duroc	AUT	2000	Organic *ad lib*	16	806		53.1		Laister and Konrad (2005)

Continued

Table 4. Continued

Sow breed	Boar breed	Country[a]	Year	Feed	No. pigs	Daily gain (g/day)	FCR[b]	Lean meat (%)	Back fat (mm)	Reference
Large White	Large White	AUT	2000	Organic *ad lib*	16	732		52.3		Laister and Konrad (2005)
Southern Europe										
Large White	Large White	ITA	2006	Formulated[h]	18	695			20.3	Pietrolà *et al.* (2006)
Landrace × Large White	Duroc	ESP	2005	Pasture[i], concentrate[j]	64				26.4	Latorre *et al.* (2009)
Landrace × Large White	Piétrain	ESP	2005	Pasture[i], concentrate[j]	64				27.6	Latorre *et al.* (2009)

[a]Official alpha-3 country codes of the ISO 3166-1 encoding list.
[b]Feed conversion ratio.
[c]PIC (Landrace × Large White) × Duroc cross.
[d]Landrace × Large White cross.
[e]Bundeshybridzuchtprogramm.
[f]Westhybrid.
[g]Barley, wheat and a protein concentrate in the form of a formulated diet.
[h]Two diets differing in energy content, supplied on a basis of 9 percent of metabolic weight.
[i]Free availability of grass, shrubs, trees and a limited amount of acorns.
[j]Formulated, pelleted barley–corn–wheat–soybean meal concentrate.

Discussion

The objective of this review was to compare the suitability of traditional and conventional pig breeds in low-input and organic production systems in Europe, based on reproductive and finishing performance derived from literature studies and farm surveys. Reproductive and finishing performance are indicative for the economic sustainability of a production system (Egerszegi *et al.*, 2003), albeit their usefulness for evaluating breed suitability also depends on market requirements (Martins *et al.*, 2002). For example, for commodity organic pork production in The Netherlands, the carcass-value marketing system is based on high lean meat percentages, whereas for dry-cured meat production fat quality and quantity are important. Therefore, when discussing the suitability of traditional versus conventional breeds, distinction will be made between production for commodity pork production and specialized cured meat production. In this review, the breed performance is compared within macroclimatic regions, because the suitability of a breed is strongly related to environment and local climatic conditions (Blair, 2007).

For evaluation of breed performance, data of individual literature studies and surveys were pooled and averaged per breed within a macroclimatic region. Statistical meta-analysis could not be used to evaluate differences in breed performance or potential genotype–environment interactions, because for many breeds, performance data were of different years and available only from a limited number of literature sources.

Pig farming conditions

In North West Europe, organic and low-input pig production in countries such as Germany, Sweden, Denmark and The Netherlands is characterized by the use of mainly conventional breeds in indoor housing systems with outdoor runs (Wallenbeck, Rydhmer and Thodberg, 2008; Edwards, 2011; Früh, 2011). In Great Britain, sows live in paddocks and just before farrowing the sow is moved to a farrowing paddock with individual huts (Edwards, 2011). Finishing pigs are also kept in paddocks for most of the time and some farms have deep straw yards for the last 2–4 weeks before slaughter. Small farms (less than 20 sows) with direct sales usually have a wide range of traditional breeds, including Large Black, Middle White and Gloucester Old Spots (Martins *et al.*, 2002). Larger herds of over 50 sows have sales through key wholesale outlets, mainly supplying multiple retailers (Martins *et al.*, 2002). On these farms, mainly conventional breeds such as Large White, Duroc and Landrace crosses or commercial hybrids from breeding companies are used. Feeding on North West European organic farms is according to EU organic regulations.

In Eastern European countries such as Hungary, Croatia and Poland, pigs in organic and low-input systems are kept under extensive conditions in large pens or on pasture. They feed on natural resources of pasture and oak woodland supplemented

with mixtures of cereals and green fodder (Egerszegi *et al.*, 2003; Karolyi, Luković and Salajpal, 2007). Breeds used are mainly traditional, local breeds.

In Southern Europe, there are different rearing systems according to geographical location. In Italy, most of the organic pig herds are outdoors and situated in hills and mountains (Edwards, 2011). Farrowing and weaning are about 95 percent outdoors in huts. Fattening is about 60 percent outdoors, with the rest indoors with an outdoor run (Edwards, 2011). Animals are fed on locally available nutrients such as grass, crops, acorns, herbs, sometimes supplemented with cereals or concentrates. Organic feeds are allowed to contain a maximum of 5 percent of conventional components. Around 50 percent conventional breeds (Large White, Landrace and Duroc) and 50 percent traditional breeds (Nero Siciliano and Cinta Senese) are used (Früh, 2011). In Spain, performance data were available of the Iberian pig and the Majorcan Black pig. Data on Iberian pigs included reproductive and finishing performance under free-range conditions. In the fattening period (i.e. 'montanera'), pigs are fed on acorns and grass in Mediterranean forest (Daza *et al.*, 2008). Majorcan Black pigs are reared similarly in extensive conditions (Gonzalez *et al.*, 2007).

Reproductive performance

The majority of data on reproductive performance of conventional breeds comes from North West Europe. In Eastern and Southern Europe, reproductive performance data of conventional breeds in organic and low-input production systems were scarcely available, because of the predominant use of traditional breeds in these regions.

In North West Europe, conventional breeds have relatively high reproductive performance compared with traditional breeds. The relatively large litter sizes at birth and high numbers of weaned piglets of conventional breeds are due to years of selection pressure on this trait in the breeding goal of conventional breeding programmes (Wallenbeck, Gustafson and Rydhmer, 2009). Preweaning mortality is relatively high (>16 percent) for conventional breeds compared with traditional breeds. Various factors explain these high mortality rates.

First, the high litter sizes at birth in conventional breeds are considered as a risk factor for stillbirth and mortality of liveborn piglets (Bille *et al.*, 1974; Zaleski and Hacker, 1993). Problems with mortality related to high litter sizes are even exacerbated in low-input and organic production systems compared with conventional systems, owing to the structurally higher litter sizes in these environments (Leenhouwers *et al.*, 2011). In large litters, the farrowing process may be prolonged, which may lead to a larger proportion of piglets suffering from oxygen stress during birth. This may lead to stillbirth and reduced vitality of liveborn piglets (Zaleski and Hacker, 1993). Additionally, both absolute birth weight and within-litter uniformity in birth weight decrease with increasing litter size. Light piglets at birth have a higher risk of mortality owing to starvation or crushing, especially in litters with low birth weight uniformity (English and Smith, 1975; Canario *et al.*, 2010).

Secondly, both piglet vitality and maternal behavioral characteristics have often been neglected in conventional breeds, because of the confined, controlled farrowing and lactation environments which are aimed at prevention of mortality, e.g. the use of heating areas for piglets and the use of farrowing crates that prevent mortality owing to crushing (DEFRA, 2002). Indeed, preweaning mortality rates are substantially lower in indoor systems compared with outdoor systems (Sabbioni *et al.*, 2007; Wallenbeck, Gustafson and Rydhmer, 2009; Leenhouwers *et al.*, 2011). In organic and low-input systems, good maternal abilities and high piglet vitality are obviously crucial for piglet survival, because sows are housed loose in the farrowing pen, which makes piglets more at risk to be crushed by the sow (Honeyman and Roush, 2002; Wallenbeck, Gustafson and Rydhmer, 2009) and less possibilities of herdsmen to supervise and care for piglets in a group-housed and outdoor lactation environment (Wallenbeck, Gustafson and Rydhmer, 2009).

Thirdly, in organic and low-input systems, lactation feeds of lower protein quality and higher roughage content are used. Conventional sows may be less adapted to these diets (Kelly *et al.*, 2007), which may lead to problems with milk production and consequently mortality of liveborn piglets owing to starvation.

For traditional breeds, there was high between-breed variation in reproductive performance. In Great Britain and Germany, some prolific traditional breeds, such as German and British Saddlebacks, wean similar numbers of piglets (9–10) as conventional breeds, e.g. Landrace × Large White × Duroc crosses and German Edelschwein × Landrace crosses. British Saddlebacks originally are a hybrid cross of Essex and Wessex Saddleback breeds. Especially the Wessex was noted for its high prolificacy (Alderson, 2007). Saddlebacks often are mated with white conventional breeds to produce blue crossbred sows for outdoor systems and were selected by major breeding companies as one of the parents of commercial hybrid breeding sows (e.g. Camborough) because of their grazing ability, temperament, maternal qualities and the level of fatness which serves as a buffer against outdoor conditions (Alderson, 2007).

In Eastern Europe, the Polish Pulawska breed actually weans more piglets per litter than the Landrace and Landrace × Large White crosses used in this region. Pulawska is an indigenous breed from Eastern Poland and originally was a cross between primitive local pigs and Berkshire boars. Later on, English Large White has been used to upgrade the Pulawska breed. Pulawska has a spotted coat pattern and its utilization is between a meat and fat-meat pig (Elbarn, 2010). Traditional breeds used for special meat production, for example French

breeds such as Nustrale, Basque and Gascon, the Hungarian Mangalitza, the Spanish Iberian pig and the local Italian breeds Mora Romagnola and Cinta Senese, typically have low reproductive performance because these breeds are generally unimproved in fertility traits (Egerszegi *et al.*, 2003).

Finishing performance

In general, conventional breeds such as German Edelschwein and German Landrace grew faster and more efficiently than traditional breeds. However, some traditional breeds such as German and British Saddleback and Swabian-Hall achieved similar growth rates than commercial hybrids developed by breeding companies. Additionally, carcasses of the majority of conventional breeds were leaner than carcasses of traditional breeds. These results confirm the effects of genetic selection in conventional breeds on daily gain, feed conversion ratio and lean meat percentage (Blair, 2007; Brandt *et al.*, 2010). In contrast, in traditional breeds such as Ibérica, focus has been more on meat quality characteristics (e.g. drip loss, marbling, colour and structure). Extra added value is obtained through specific nutritional and taste characteristics of special meat products such as hams, salamis and other cured products. In this way, the low reproductive and finishing performance of these breeds is offset by price premiums of the pigs produced.

General suitability of breeds

Taken together, the suitability of traditional versus conventional breeds for low-input and organic production systems depends on finding a balance between productivity, suitability to outdoor conditions and market suitability (Compendium of Animal Health & Welfare in Organic Farming, 2000). The traits important for a good outdoor sow are: prolificacy, good maternal instincts, good fat reserves to provide both protection against weather and energy reserves for an active outdoor life, and independence combined with ease of handling (Blair, 2007).

Results from this review show that conventional breeds wean many piglets, have efficient and fast growth and lean carcasses. These conventional breeds may thrive well in North West European climatic conditions where summers are warm, but not hot, and winters are cool instead of cold. Optimal housing may be indoors with outdoor runs, as currently predominantly used in countries such as Denmark, Germany, Sweden and The Netherlands. This provides a more controlled environment in which large litters are more easily managed and in combination with balanced formulated feeds, high lean growth rates can be sustained. The relatively lean meat of conventional breeds is suitable for sales through key wholesale outlets serving the commodity organic pork market. Together with the use of conventional breeds in organic and low-input systems, a suitable breeding strategy should be chosen to provide farmers with adequate replacement gilts. For the Dutch organic pig sector, Leenhouwers *et al.* (2011) proposed a two-breed rotation system where animals from conventional Yorkshire and Landrace sow lines with the highest genetic merit for desirable traits (e.g. mothering ability, piglet vitality, sow longevity) for organic pig production are selected. Conventional breeds may be less suitable in more free-range extensive environments as found in Eastern and Southern Europe, where large litter sizes pose a risk for piglet mortality. Also the climatic conditions in these regions may be unfavourable. In cold winters, their lack of carcass fat gives them poor protection against cold and in hot summers their white skin pigment makes them sensitive for sunburn.

Traditional breeds roughly fall into two categories: (1) a group of prolific breeds with good finishing performance such as Saddlebacks and Pulawska and (2) breeds kept for special meat production (e.g. Ibérico, Cinta Senese). The prolific and leaner traditional breeds belonging to the first group are suitable for commodity organic pork production, especially when crossed with conventional white boar breeds (e.g. Large White, Landrace or Duroc) to give some extra leanness to the carcass. Special meat breeds are unsuitable for commodity organic pork production because of their low fertility and high carcass fatness, but extra added value is obtained by their specific meat and fat quality. Moreover, their black skin pigment makes them well adapted to be reared outdoors in hot climates as found in Southern European regions.

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