Spanish Journal of Agricultural Research
14(1), e0601, 12 pages (2016)
eISSN: 2171-9292
http://dx.doi.org/10.5424/sjar/2016141-7681
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)

RESEARCH ARTICLE

OPEN ACCESS

The "Criollo Negro de la Costa Ecuatoriana" pigs: effect of sex and rearing system on performance, carcass and meat traits

Martín A. González[1], Franklin R. Peláez[1], Andrés L. Martínez[2], Carmen Avilés[2] and Francisco Peña[2]

[1] Universidad Técnica Estatal de Quevedo. Dept. Control de Calidad, Quevedo. Ecuador. [2] Universidad de Córdoba. Dept. Producción Animal. Ctra. Madrid-Cádiz Km. 396-a. 14071 Córdoba, Spain.

Abstract

The objective of this study was to evaluate the effect of rearing system (confinement, C *vs* semi-confinement, SC) and sex (barrows *vs* females) on growth performance, carcass traits and meat quality of "Criollo negro de la costa ecuatoriana" pigs. A total of 32 pigs, 16 barrows and 16 gilts were used. The average daily gain (0.30 kg/day *vs* 0.22 kg/day), slaughter weight (51.4 kg *vs* 43.1 kg), morphometric parameters and weights for the most valuable meat cuts were higher in C pigs than in SC pigs, whereas hot and cold carcass yields were higher in SC pigs than in C pigs. The loin and sirloin percentages from C pigs were lower and higher compared with those SC pigs, respectively. Carcass of C pigs showed higher percentage of fat and lower percentage of lean and bone that SC pigs. The rearing system had scarce effects on meat quality traits and mineral composition. Meat from C pigs showed lower scores for color, brightness, and unctuousness, and higher for metallist taste, juiciness and persistence of flavor than SC pigs. Few sensory attributes of cooking chops were affected by sex. Metallist taste was higher in barrows, while brightness and lard flavor were higher in females. It can be concluded that the rearing system had a significant effect on most of the productive and carcass traits, whereas its effect was limited on the meat traits. Sex had little influence on most of the traits studied.

Additional key words: autochthonous pig breeds; Ecuadorian pigs; carcass quality; growth performance; meat quality; rearing conditions.

Abbreviations used: BEC (Black Ecuadorian Creole = Criollo negro de la costa ecuatoriana); C (confinement); LT (*Longissimus thoracis* muscle); SC (semi-confinement).

Citation: González, M. A.; Peláez, F. R.; Martínez, A. L.; Avilés, C.; Peña, F. (2016). The "Criollo Negro de la Costa Ecuatoriana" pigs: effect of sex and rearing system on performance, carcass and meat traits. Spanish Journal of Agricultural Research, Volume 14, Issue 1, e0601. http://dx.doi.org/10.5424/sjar/2016141-7681.

Received: 18 Mar 2015. **Accepted:** 28 Jan 2016.

Funding: Universidad Técnica Estatal de Quevedo (Ecuador).

Competing interests: The authors have declared that no competing interests exist.

Correspondence should be addressed to Carmen Avilés: v92avrac@uco.es

Introduction

In Ecuador, the census of Creole pigs, of which 57%, 35% and 8% are located in the mountain, coastal and eastern regions, respectively, has declined in recent years (INEI, 2012) by the introduction of improved pig breeds. The 3-5% of these pigs, called "Criollo negro de la costa ecuatoriana" (BEC), show similar phenotypic characteristics to the Ibérica Negra Lampiña breed. This pig population is known for its hardiness and adaptation to a harsh environment and is characterized by an early sexual maturity, a low prolificacy, reduced growth and carcass performances, small mature size (40 and 35 kg for barrows and females, respectively), dark coloration with predominance of black color, sparse and short hair black slate, long narrow snout, fragile body, narrow chest, poor body conformation and higher hind limb than forelimb (Benítez & Sánchez, 2001; Santos Ricalde *et al*., 2011). Given its low nutritional needs and the ability to utilize fibrous feeds, these animals can enhance unconventional food resources and have an important place in alternative breeding systems. Furthermore, the absence of genetic selection with respect to lean content may be associated with good meat quality (Renaudeau *et al*., 2005; Renaudeau & Mourot, 2007). Most of its production is done under extensive management in small herd size (Benítez & Sánchez, 2001), and according to historical data, these animals were fed with local resources, domestic by-products and residues from industrial plantations. This system, called "traspatio", is an alternative to the sustainability socio-economic and cultural, both the rural population and those living in the suburbs of large cities. However, this management leads to high carcass fatness. In order to valorize the local breed pigs, it would be possible to adapt feeding strategies for the Creole pigs that can be established in order to increase the carcass and meat quality. An improvement in pig productivity could improve the livelihoods of the resource-poor rural farmers and reduce the tendency toward gradual substitution of the Creole pig by high lean genotype pigs with a possible extinction of this local breed in a medium term.

Very few studies are published evaluating the growth, carcass and meat quality of BEC pigs, indicating a lack of technical information which could be used by the producers to improve the system and processes. Therefore, the aim of this research was to investigate the effects of production system, traditional farming or semi-confinement (SC) and conventional indoor rearing or confinement (C), and sex on growth performance and carcass and meat traits of "Criollo negro de la costa ecuatoriana" pigs as a part of a project that it is trying to guarantee the existence of this endangered pig genotype.

Material and methods

Animals and management

A total of 32 BEC pigs (16 barrows and 16 females, representing the offspring of 8 boars) were used for the trial. Animals were purchased in twelve farms located in the Ecuadorian coast and transferred to the swine farm "El Paraiso" (Los Rios province, coast of Ecuador). The area has a tropical climate with an average temperature of 25° C, an annual rainfall of 2400 mm and relative humidity of 82%. On arrival, all the pigs were identified, weighed, dewormed with Ivomec-Merial (0.08% ivermectin), housed in groups and offered a conventional diet for 15 days (period of adaptation). Males were castrated (under surgical anaesthesia with standard post-surgery treatment performed by a veterinarian). Then, 8 barrows and 8 females were randomly allocated to one of two treatments: traditional farming system and conventional indoor rearing system. The distribution of piglets in both rearing systems occurred at a weight of 18-22 kg and at an age of 165 days, approximately. All animals were manually fed twice a day (morning and afternoon) and water was provided *ad libitum,* and they received the same commercial diet, consisting of products of the area (16% crude protein, 6.2% ether extract, 8% crude fiber, 2.3% ash, 3200 kcal digestible energy/kg) *ad libitum* and 80% for C and SC groups, respectively. In C system, pigs were housed in individual pens (1 × 1.5 m) with feed and water bowls. In the SC system, pigs were also housed in individual pens of 1 × 1.5 m over night with concrete floor, feed and water bowls, and they were kept individually in a paddock of about 625 m^2/animal during the day where they consumed banana (in an amount of about 275 g/day/pig, increasing 40 g every 5 days), roots, leaves and tubers of papaya, cassava, oranges, and insects, worms, etc. Individual body weight and feed consumption were recorded at 0, 15, 30, 45, 60, 75 and 90 days of experiment and these data were used to calculate average daily gain and feed conversion ratio. The study was carried out in accordance with Ecuadorian national recommendations for animal handling including animal welfare.

Slaughtering, sampling and carcass measurements

At the end of the trial (90 days), pigs were weighed in the experimental farm and transported to a commercial slaughterhouse. At the abattoir, animals were resting for 12 h with full access to water but not to feed. Then, pigs were electrically stunned, exsanguinated, scalded, skinned and eviscerated according to standard commercial procedures. The slaughter was performed, in compliance with ethical guidelines for animal care, in two different days in which both sexes and rearing systems were adequately represented. The slaughter weight, empty body weight (was calculated by deducting the weight of digesta) and hot carcass weight was recorded. In addition, the pH was measured at 45 min (pH_{45}) and at 24 h (pH_{24}) *postmortem*, in the left *Longissimus thoracis* muscle (LT) at the caudal end over 12^{th} rib, at right angles to the sagittal plane surface, using pH-meter with temperature compensation (Lutron mod. 212; pH Electronica, Buenos Aires, Argentina) equipped with a glass electrode (previously calibrated with pH 4.01 and 7.00 standard buffers equilibrated at 25ºC) enclosed with an unbreakable stainless steel knife, to facilitate the measurements in a muscle, and thermometer.

Carcasses were chilled at 4°C for 24 h, and cold carcass weight was recorded. The hot and cold carcass weights were used to calculate carcass yields. Then, the head was removed and the carcasses were split along midline. Several morphometric variables were measured using a vernier caliper or a flexible tape on the hanging right half of the carcass at 24 h *postmortem* following the method described by Peinado *et al*. (2004) and Fisher *et al*. (2003). These measurements were: backfat thickness (at the level of the 12^{th} rib, taken 1/4, 2/4 and 3/4 the length ventrally over the LT and perpendicular to the skin), carcass length (from the middle of the cranial edge of the first rib to the ischiopubic symphysis), shoulder length (from the middle of the dorsal edge of the scapula to the internal halfway of the facies articularis carpea), hand length (from the end of the olecranon to the distal point of the trotters), ham length (from the isquiopubic symphysis to the internal halfway point of the calcaneus), hind foot length (from the middle of the dorsal edge of the tarsus to the distal extreme of the trotters), maximum perimeter of the shoulder (at its widest, in the area of maximum amplitude), maximum perimeter of the ham (in the area of maximum amplitude, near the base of the tail) and wrist perimeters (at the narrowest point, in the middle of the metacarpus and metatarsus regions).

Afterwards, the left sides of the carcasses were quartered, according to Ecuadorian methods (Santos Ricalde *et al*., 2011), into five joints: fore limb (shoulder with front foot: means that portion of the fore limb which is separated by a straight cut at the wrist (carpal) joint), top loins (1^{th}-6^{th} thoracic vertebrae), loins (7^{th}-11^{th} thoracic vertebrae), tenderloins (12^{th}- thoracic vertebrae to last lumbar vertebra) and legs (hams with hind foot: portion of the leg which is separated by a straight cut passing through the hock (tarsal) joint). The different joints were weighed using calibrated scales sensitive to 1 g (GRAM DSN-30; BD COM, Zafra, Badajoz, Spain). Proportions of these joints based on the cold carcass were also determined. All the joints were dissected into skin, fat, muscle and bone. The cross sectional area of the LT on the 7^{th} rib was measured with a transparent cellulose acetate grid divided into l-cm squares. Then, a portion of the LT including the 7^{th} to the 11^{th} ribs was taken for later determinations.

Laboratorial analyses

The analysis of mineral composition was evaluated according to Galián *et al*. (2007). Briefly, approximately 1 g of meat (LT) was used for the process of obtaining ashes in a furnace oven (Model HK-11; Herotec, Ahlen, Germany). The ashes were dissolved with 2 mL of 65% nitric acid and 5 mL of 37% hydrochloric acid fuming on a hot plate and the volume was made up to 50 mL with distilled deionized water (obtained from the device Milli-Q Gradient A10, Molsheim, France). After that, the samples were analyzed for the determination of minerals in a plasma absorption spectrometer (Model Optima 200DV; Perkin-Elmer, Waltham, MA, USA). The minerals analyzed were: calcium, magnesium, iron, copper, zinc, phosphorus, manganese, potassium and sodium. The results obtained for each mineral were expressed in mg/100 g of raw meat, after application of the corresponding dilution factors. In this study, two replicates for each meat sample were performed.

Water holding capacity was determined only 1 day *postmortem*. Drip loss was measured following the method of Honikel (1998) on cubic pieces of 1.5 cm thick, free of external fat and connective tissue. The samples were weighed, hung by a nylon cord and put on top, inside a container which was closed after filling to avoid evaporation, ensuring the meat had no contact with the container walls. This container was placed in a chamber at 4 °C during 24 h and then reweighed. Drip loss was calculated as the difference in weight of the meat sample (after superficially wiping dry), before and after the hanging × 100, divided by initial sample weight yields. In order to assess water-holding capacity from cooked meat and to carry out the sensory analysis, a portion of the LT of the left half of each carcass was extracted and vacuum packed. The pieces were stored at 4ºC during 24 h. Then, two 1.5-cm thick steaks were obtained from each portion. Cooking loss was expressed as percentage weight loss of the initial weight. The cooking procedure was as follow: all the vacuum packed steaks were thawed previously to each session. They were reserved in a cooler at 4ºC during 24 h and, 2 h before the analysis the steaks were taken out the cooler until they achieve an internal temperature of 15-17ºC. Next, the meat samples, packed in nylon/polyethylene vacuum bags, were heated by immersion at 80ºC until they reached an internal temperature of 72ºC in a water bath (JP Selecta, Barcelona, Spain) with controlled temperature, followed by cooling in cold tap water for 40 min. Internal temperature of the cooked muscle was monitored by an iron/constantan thermocouple wire connected to a thermometer (Hanna Instruments, USA) and inserted into the geometric center of the sample. Before slice they were weighted to determine cooking losses. Subsequently, the pork samples were sliced (cubes of approximately 1.3 × 1.3 × 1.3 cm) taking care to avoid an excess content of fat or connective tissue. The cubes were placed in covered glass containers in a circulating water bath (approximately 60ºC) to equilibrate their temperature and immediately after were served on glass plates at room temperature (20–23ºC).

In order to evaluate the influence of sex and rearing system on the sensory characteristics, cooked slices of LT from 32 BEC pigs were assessed by a trained panel, using a quantitative–descriptive analysis method for 11 different attributes. Sensory quality of cooked meat samples was evaluated by 5 panelists (females, student and staff members from Quevedo University, Ecuador) previously trained for meat sensory evaluation. Training of panelists (Pillsbury, 1992) was performed with pork samples for 2 weeks. All sessions were done in a five booth sensory panel room at 22ºC equipped with white fluorescent lighting (220–230 V, 35 W). Rearing systems and sex were represented in all sessions in a balanced design with a randomized serving order within session. Panelists were asked to evaluate tenderness, color, brightness, lard flavor, pork odor, pork flavor, sweet taste, metallist taste, unctuousness, juiciness and persistence of flavor. The sensorial evaluations were performed according to Meilgaard *et al*. (2006), and each attribute was quantified using an unstructured 10 cm line, ranging from the lowest intensity of each trait (left side) to the highest (right side).

Statistical analysis

SAS 9.1 (SAS Inst. Inc., Cary, NC, USA) was used in all the statistical analyses. Data on carcass traits and carcass composition were analyzed using the GLM procedure with the rearing system, sex and their interaction as fixed effects. Data on sensory traits were analysed using the MIXED procedure. The mean score for each sample and attribute was used in the analyses. The statistical model included rearing system, sex and their interaction as fixed effects, and panelist`s sessions as random effect. Fisher's least significant difference test was used to compare least squares means. Relationships between variables were investigated by Pearson's correlation analysis. Statistical significance was declared at $p<0.05$.

Results

Growth performance

All pigs started the experiment and were slaughtered at a similar age. The live weight at the start (about 165 days of age) and end of the experimental period (90 days later) averaged 23.7 kg and 47.3 kg, respectively (Fig. 1). The total weight gain (kg) was 28.07, 27.78, 20.08 and 19.75 kg for barrows and females C, and barrows and females SC, respectively (data not shown). As expected, weight at slaughter was higher in C pigs than in SC pigs, whereas differences between barrows and females were not found (Table 1).

Average daily gain increased from 0.19 kg/day at start of trial (0-15 days on fattening) to 0.35 kg/day at end (75-90 days on fattening), and a significant effect ($p<0.05$) of rearing system and sex on growth was recorded. The C pigs and barrows grew faster than SC pigs and females, respectively. The daily feed intake

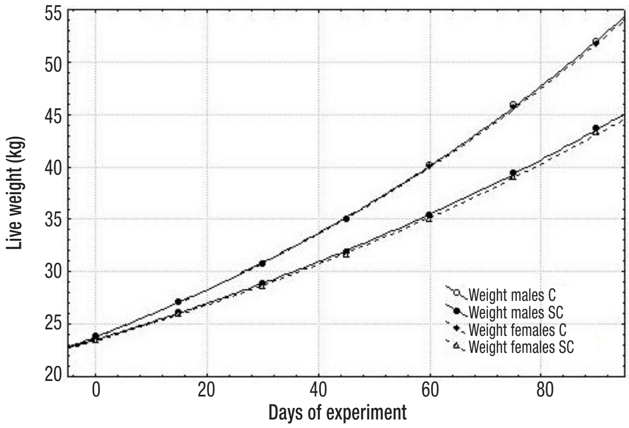

Figure 1. Growth of "Criollo negro de la costa ecuatoriana" pigs under two rearing systems (SC: semi-confinement; C: confinement).

in the groups SC and C during the study period increased gradually from 0.64 (0.47 and 0.275 kg of commercial diet and banana, respectively) and 0.6 kg/day in the first week to 2.8 (1.8 and 1.0 kg of commercial diet and banana, respectively) and 2.3 kg/day in the last week, respectively. Average feed conversion ratio during the experimental period was 4.99, and rearing system showed a clear influence ($p<0.05$) on this variable (4.54 *vs* 3.72 for C and SC, respectively). Sex had no significant effects ($p>0.05$) on this trait.

Carcass traits

The effects of rearing system and sex on slaughter weight, hot and cold carcass weights, dressing-out percentages, backfat thickness, rib eye area and carcass measurements are shown in Table 1. As expected, the C pigs, with higher slaughter weights ($p<0.001$), produced heavier carcasses ($p<0.001$), but carcass yields were lower ($p<0.001$) to those found in SC pigs (73.5% *vs* 74.9%). No significant ($p>0.05$) effect of sex was observed for any of the carcass traits studied.

Average backfat thickness and rib eye area in the current work ranged between 1.99 and 2.23 cm, and 7.40 and 8.71 cm^2, respectively. Both variables were significantly affected by the rearing system (higher in C pigs than in SC pigs, $p<0.01$) and sex (higher in barrows than in females, $p< 0.05$).

The mean values of the measurements taken in the carcass ranged between 66.9 cm and 12.1 cm for carcass length and wrist perimeter fore foot, respectively. With regard to morphometric parameters, rearing system influenced ($p<0.05$) most of the measures of length and perimeter of the carcass. However, sex affected ($p<0.05$) only the leg length, ham length and maximum perimeter ham.

Table 1. Effect of rearing system (SYS)[1] and sex[2] on slaughter weight, empty body weight, hot and cold carcass weights, dressing-out percentages, backfat thickness (at 12th rib), loin area and morphometric parameters from carcasses of "Criollo negro de la costa ecuatoriana" pigs.

	System C		System SC		SEM[3] (n=8)	Significance[4]		
	B	F	B	F		SYS	SEX	Interaction
Slaughter weight (kg)	51.41[a]	51.32[a]	43.21[b]	42.97[b]	0.397	***	ns	ns
Empty body weight (kg)	49.78[a]	50.18[a]	41.87[b]	41.83[b]	0.323	***	ns	ns
Hot carcass weight (kg)	38.00[a]	37.74[a]	32.48[b]	32.05[b]	0.513	***	ns	ns
Cold carcass weight (kg)	37.21[a]	37.00[a]	31.82[b]	31.41[b]	0.502	***	ns	ns
Dressing-out[5] (%)	73.20[b]	73.05[b]	74.33[a]	74.13[a]	0.141	***	ns	ns
Dressing-out[6] (%)	71.69[b]	71.62[b]	72.82[a]	72.64[a]	0.127	***	ns	ns
Dressing-out[7] (%)	76.35[ab]	75.22[a]	77.58[b]	76.64[ab]	0.152	***	ns	ns
Dressing-out[8] (%)	74.48[ab]	73.74[b]	76.01[a]	75.09[ab]	0.148	***	ns	ns
Backfat thickness[9] (cm)	2.13[b]	2.23[a]	1.99[c]	2.12[b]	0.018	**	*	ns
Loin area (cm^2)	8.71[a]	8.28[b]	7.55[c]	7.40[c]	0.112	***	*	ns
Carcass length (cm)	67.33	67.01	66.77	66.29	0.213	ns	ns	ns
Hand length (cm)	50.67[a]	50.51[a]	47.14[b]	47.78[b]	0.315	***	ns	ns
Shoulder length (cm)	35.23[a]	34.96[a]	33.00[b]	33.16[b]	0.366	***	ns	ns
Wrist perimeter fore foot (cm)	12.15	12.03	11.99	12.07	0.105	ns	ns	ns
Leg length (cm)	53.78[a]	52.31[a]	50.90[b]	50.55[b]	0.483	***	*	ns
Ham length (cm)	37.48[a]	37.09[a]	35.86[b]	35.13[b]	0.272	***	*	ns
Max. perimeter ham (cm)	53.40[a]	53.00[a]	51.31[b]	51.55[b]	0.680	***	*	ns
Wrist length limb foot (cm)	16.27[a]	16.12[a]	15.11[b]	15.36[b]	0.098	***	ns	ns
Wrist perimeter hind foot (cm)	13.81[a]	13.76[a]	11.99[b]	12.45[b]	0.242	***	ns	ns

[1] System C: confinement; System SC: semi-confinement. [2] B: barrows; F: females. [3] SEM: standard error of the mean. [4] ns: not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$. [5] Hot carcass weight × 100/slaughter weight. [6] Cold carcass weight × 100/slaughter weight. [7] Hot carcass weight × 100/empty body weight. [8] Cold carcass weight × 100/empty body weight. [9] BF: average backfat thickness measured at three points. [a-c] Means in the same row with a common superscript letter do not differ significantly ($p>0.05$).

The carcass cut weights and percentages respect to cold carcass weight, and the effects of rearing system and sex are presented in Table 2. The sirloin was the heaviest carcass cut (3.9 kg), and the top loin (2.0 kg) the lightest. These cuts represented from 22.7% to 11.5%, respectively. The study of the meat cuts reveals differences because of the rearing system and of the sex. The C pigs produced heavier heads ($p<0.001$), top loin ($p<0.05$), sirloin ($p<0.05$) and hams ($p<0.01$). Head and sirloin percentages were higher in SC pigs, whereas the percentage of the loin was lower. Likewise, the sum of the most valuable primal cuts was similar in both systems. Sex had significant effect ($p<0.05$) on sirloin percentage, greater in barrows.

The effect of rearing system and sex on tissue composition of commercial cuts are given in Table 3. The average content of skin, fat, lean and bone and was 6.2%, 38.9%, 46.1% and 8.8%, respectively; values that indicate its propensity to fatness, especially considering the low weight at slaughter. The proportion of fat in the carcass was lower ($p<0.001$), whereas the proportions of skin, lean and bone ($p<0.01$) and fat/lean and lean/bone ratios ($p<0.001$) were higher in the SC pigs than in the C pigs (data not shown), in accordance to the higher backfat percentage observed in their carcasses (Pugliese *et al.*, 2003). Also, sex significantly affected all traits studied. Barrows had significantly lower skin and fat proportions ($p<0.01$), and higher lean ($p<0.01$) and bone ($p<0.001$) proportions when compared with females (data not shown). The skin content of cuts ranged from 4.96% (loin) to 8.57% (top loin), the fat content between 29.9% (ham) and 48.0% (loin), the muscle between 38.4% (loin) and 58.2% (ham), and bone between 6.8% (ham) and 14.5% (top loin). The leaner primal cut was the ham and the loin had the highest fat content. The rearing system significantly ($p<0.05$) affected the tissue composition of most of the pieces, while there was a slight effect of sex, except on loin and sirloin.

Meat quality parameters

Animals from all groups showed similar values (data not shown) of pH_{45} (6.23 to 6.24), pH_{24h} (5.34 to 5.45) and for water holding capacity (2.7 to 3.4%

Table 2. Effect of rearing system (SYS)[1] and sex[2] on carcass cuts of "Criollo negro de la costa ecuatoriana" pigs.

	System C		System SC		SEM[3] (n=8)	Significance[4]		
	B	F	B	F		SYS	SEX	Interaction
Head (kg)	3.88	3.87	3.89	3.87	0.008	ns	ns	ns
Weight from left half carcass (kg)								
Shoulder	3.10^a	3.09^a	2.68^b	2.66^b	0.032	ns	*	ns
Top loin	2.15^a	2.13^a	1.83^b	1.77^b	0.026	*	*	ns
Loin	3.41^a	3.39^a	3.10^b	2.94^c	0.036	*	*	ns
Sirloin	4.48^a	4.45^a	3.48^b	3.25^b	0.077	*	ns	ns
Ham	3.53^a	3.50^a	3.02^b	2.97^b	0.039	**	ns	ns
Proportion of carcass (%)								
Head	10.42^a	10.47^a	12.24^b	12.44^b	0.125	***	ns	ns
Shoulder	16.68	16.70	16.83	16.93	0.036	ns	ns	ns
Top loin	11.55	11.51	11.50	11.52	0.046	ns	ns	ns
Loin	18.32^b	18.30^b	18.76^a	18.70^a	0.034	**	ns	ns
Sirloin	24.06^a	24.05^a	21.91^b	20.72^c	0.265	***	*	*
Ham	18.95	18.94	18.89	18.90	0.028	ns	ns	ns

[1] System C: confinement; System SC: semi-confinement. [2] B: barrows; F: females. [3] SEM: standard error of the mean. [4] ns: not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$. [a-c] Means in the same row with a common superscript letter do not differ significantly ($p>0.05$).

and 25.6 to 28.7% for drip and cooking loss, respectively).

Table 4 shows the mineral composition of the LT in BEC pigs. Sex had a significant influence on the ash content of meat. Females of the SC group had an ash content (1.69%) well above that in the other three groups (1.21, 1.30 and 1.04%, respectively). Average values of the mineral composition of the meat were 232.1, 340.6, 7.1, 58.6, 23.8, 0.23, 2.34, 1.58 and 0.033 mg/100 g for P, K, Ca, Na, Mg, Cu, Fe, Zn and Mn, respectively.

The rearing system had a little influence on the meat mineral levels. The sex had an effect on the levels of the minerals P, Na, Cu and Fe ($p>0.001$) and Mg ($p>0.05$). The barrows showed higher levels of P and Mg and lower of Na, Cu and Fe than the female pigs. Sex differences in the Fe content, essential ingredient of the myoglobin and hemoglobin, did not translate into differences in meat color (Table 5).

The average ratings for the sensory attributes of each rearing system and for sex are given Table 5. Based on these results, the meat of the animals studied can be defined as moderately tender, with little brightness and color, with high odor and pork flavor, little unctuous on the palate, juicy and moderate to high persistence of flavor. The evaluation by the sensory panel of the pork loins did not show large differences in tenderness, color homogeneity, lard flavor, pork flavor and sweet taste. However, significant differences ($p<0.05$) were obtained for the remaining attributes studied between rearing systems. Metallic taste, juiciness and persistence of flavor were higher ($p<0.05$) for meat from C pigs (rating 0.77, 5.6 and 6.5, respectively) than SC pigs (rating 0.5, 5.0 and 6.0, respectively), while meat color (4.1 *vs* 5.0), brightness (4.4 *vs* 4.8) and unctuousness (4.0 *vs* 4.8) were lower. In contrast to rearing system, few differences in sensory attributes were observed between sex: metallic taste (higher in barrows: 0.7 *vs* 0.5, $p<0.01$) and brightness (higher in females: 4.4 *vs* 5.1, $p<0.01$).

Discussion

Growth performance

Average daily gain was lower in our study than that recorded by Fortina *et al.* (2005), Renaudeau & Mourot (2007) and Galián *et al*. (2009) in others autochthonous pig breeds, so that the Creole BEC, reared indoors or outdoors, needs longer to reach the same weights than these breeds. During the growing period, average daily gain tends to increase although these results were not in agreement with those provided by Latorre *et al*. (2008). As in the current experiment, a higher growth for barrows compared to females has been well documented in previous studies (Latorre *et al.,* 2008; Serrano *et al*., 2008). Nevertheless, these results contrast with those of Renaudeau & Mourot (2007) in Creole pigs, who indicated that daily gain was not affected by sex. The C pigs grew significantly more than SC pigs, in accordance with informations of Daza *et al*. (2006). These differences have

Table 3. Effect of rearing system (SYS)[1] and sex[2] on skin, fat, lean muscle and bone percentages in the primal cuts from "Criollo negro de la costa ecuatoriana" pigs.

%	System C		System SC		SEM[3] (n=8)	Significance[4]		
	B	F	B	F		SYS	SEX	Interaction
SHOULDER								
Skin	5.30[b]	5.36[b]	5.86[a]	5.94[a]	0.034	***	ns	ns
Fat	35.71[a]	34.91[a]	33.36[b]	34.30[b]	0.037	***	ns	ns
Lean	52.80	52.62	52.97	51.93	0.145	ns	ns	ns
Bone	7.18[b]	7.28[b]	7.81[a]	7.87[a]	0.048	***	ns	ns
TOP LOIN								
Skin	7.84[c]	8.01[c]	8.99[b]	9.46[a]	0.088	***	ns	ns
Fat	38.41[a]	38.66[a]	36.60[b]	35.87[c]	0.162	***	ns	*
Lean	40.03	39.33	39.62	39.45	0.083	ns	ns	ns
Bone	13.89[b]	14.06[b]	14.76[a]	15.23[a]	0.065	***	ns	ns
LOIN								
Skin	4.79[b]	4.81[b]	5.25[a]	4.99[b]	0.028	***	**	*
Fat	50.25[a]	50.52[a]	46.81[b]	44.54[c]	0.318	***	**	**
Lean	36.81[c]	36.42[c]	38.80[b]	41.42[a]	0.310	***	**	*
Bone	8.21[b]	8.24[b]	9.15[a]	8.92[a]	0.059	***	ns	ns
SIRLOIN								
Skin	6.31[c]	6.37[c]	7.93[b]	8.62[a]	0.124	***	**	**
Fat	44.64[a]	45.06[a]	41.52[b]	37.61[c]	0.693	***	**	**
Lean	41.82[b]	41.31[b]	41.12[b]	43.64[a]	0.252	**	*	*
Bone	7.26[c]	7.29[c]	9.47[b]	10.13[a]	0.140	***	**	*
HAM								
Skin	4.80[c]	4.85[c]	5.17[b]	5.57[a]	0.024	***	**	*
Fat	32.01[a]	31.76[a]	28.54[b]	27.48[c]	0.279	***	**	ns
Lean	56.75[b]	56.83[b]	59.34[a]	59.92[a]	0.182	***	ns	ns
Bone	6.50[b]	6.58[b]	7.02[a]	7.09[a]	0.035	***	ns	ns

[1] System C: confinement; System SC: semi-confinement. [2] B: barrows; F: females. [3] SEM: standard error of the mean. [4] ns: not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$. [a-b] Means in the same row with a common superscript letter do not differ significantly ($p>0.05$).

been related to the higher energy requirements for physical exercise and thermoregulation in SC pigs (Pugliese *et al.*, 2003), among others.

In our study, feed conversion ratio was slightly higher than that recorded (4.2) by Fortina *et al.* (2005) in Casertana and Mora Romagnola breeds reared indoors, fed using diets formulated for commercial hybrid pigs and slaughtered at<60 kg of live weight. The differences between rearing systems (4.54 *vs* 3.72 for C and SC, respectively) could be attributed to differences in digestibility of diets and given that part of the diet of the SC pigs could not be controlled. In agreement with Peinado *et al.* (2012) in crossbred pigs (Landrace × Large White dams × Duroc sires), sex had no significant influence on feed conversion ratio. However, Renaudeau & Mourot (2007) and Serrano *et al.* (2008) noted in Creole and Iberian × Duroc pigs, respectively, that barrows had a higher feed conversion ratio than gilts.

Carcass traits

This low body weight observed is not unusual or surprising if you consider studying Benitez & Sanchez (2001), where it is mentioned that the average slaughter weight of pigs reared in "traspatio" system in countries such as Ecuador was 45 kg. In common practice barrows and females of BEC pigs are usually slaughtered approximately at the same age, as was done in the present study. The poor dressing-out percentages are indicative of the low degree of muscularity from slightly fatness carcasses. The lowest carcass performance can be attributed to the weight/age at slaughter and the level of nutrition (Tartari *et al.*, 1993) among other factors. The average carcass yields are lower than those recorded in other rustic pig breeds (77.6-83%) (Renaudeau & Mourot, 2007; Santos Ricalde *et al.,* 2011; Franco *et al.,* 2014). These results could be related with differences in slaughter weight since differences in the degree of fat are very light. In agreement with previous studies, in the current experiment the dressing percentage is similar in barrows than in females.

It should be noted that the carcass yields was significantly lower in the C pigs than those found in SC pigs (73.5% *vs* 74.9%), in agreement with the results obtained by Galián *et al*. (2009) who found higher carcass yield values in Chato Murciano pigs reared outdoors (74.2 *vs* 73.1% and 72.7 *vs* 71.7%, for hot and cold carcass yield values, respectively). However, Daza *et al*. (2006) in Iberian pigs found that the pigs fed in confinement had a carcass yield significantly higher than those fed extensively with acorns and grass. The higher crude fiber consumption in pigs fed extensively could be the cause of reduced carcass yield in these animals.

The values obtained for backfat thickness showed that the animals under this study were leaner because of their low weight and age at slaughter. However, if the levels of the fat thickness relate to slaughter weight, these values are considered to be high, and caused to a large extent by the rusticity of the breed. In the current experiment, the average values for backfat thickness were lower than those reported by Franci *et al.* (2005) and Poto *et al.* (2007) in several breeds (3.6-8.9 cm). These results are in disagreement with previous reports, which demonstrated that autochthonous pigs are characterised by stronger fatty deposition than commercial pigs (Wojtysiak & Poltowicz, 2014). However, these

Table 4. Effect of rearing system (SYS)[1] and sex[2] on the mineral composition of the *Longissimus thoracis* muscle from “Criollo negro de la costa ecuatoriana” pigs.

	System C		System SC		SEM[3]	Significance[4]		
	B	F	B	F	(n=8)	SYS	SEX	Interaction
Ash percentage	1.21	1.30	1.04	1.69	0.063	ns	***	*
P (mg/100 g RM)	240.62^{a}	223.23^{b}	242.31^{a}	222.37^{b}	2.871	ns	***	ns
K (mg/100 g RM)	352.58^{a}	329.05^{b}	323.51^{b}	357.31^{a}	10.211	ns	ns	ns
Ca (mg/100 g RM)	6.46^{b}	6.86^{ab}	7.08^{a}	7.90^{a}	0.121	*	ns	ns
Na (mg/100 g RM)	57.02^{b}	60.17^{a}	56.52^{b}	60.58^{a}	0.236	ns	***	ns
Mg (mg/100 g RM)	26.44^{a}	20.70^{b}	22.28^{ab}	25.76^{a}	0.325	ns	*	*
Cu (mg/100 g RM)	0.18^{b}	0.27^{a}	0.20^{b}	0.26^{a}	0.012	ns	***	ns
Fe (mg/100 g RM)	2.21^{b}	2.50^{a}	2.22^{b}	2.44^{a}	0.011	ns	***	ns
Zn (mg/100 g RM)	1.42^{b}	1.60^{b}	2.08^{a}	1.24^{b}	0.031	ns	ns	*
Mn (mg/100 g RM)	0.033	0.032	0.034	0.033	0.002	ns	ns	ns

[1] System C: confinement; System SC: semi-confinement. [2] B: barrows; F: females. [3] SEM: standard error of the mean. [4] ns: not significant; * $p<0.05$; ** $p<0.01$; *** $p<0.001$. RM: raw material. [a-b] Means in the same row with a common superscript letter do not differ significantly ($p>0.05$).

Table 5. Effects of rearing system (SYS)[1] and sex[2] on sensory evaluation of the cooked *Longissimus thoracis* muscle from “Criollo negro de la costa ecuatoriana” pigs.

	System C		System SC		SEM[3]	Significance[4]		
	B	F	B	F	(n=8)	SYS	SEX	Interaction
Tenderness	5.52	5.96	5.52	5.43	0.123	ns	ns	ns
Meat colour	3.93^{b}	4.31^{b}	5.02^{a}	5.24^{a}	0.101	*	ns	ns
Brightness	3.60^{c}	5.00^{b}	4.30^{b}	6.11^{a}	0.095	*	**	*
Lard flavour	5.09^{a}	5.24^{a}	4.20^{b}	5.01^{a}	0.132	*	*	ns
Pork odour	7.39^{b}	7.63^{b}	8.16^{a}	7.72^{b}	0.187	ns	ns	ns
Pork flavour	7.23	7.88	7.27	7.92	0.115	ns	ns	ns
Sweet taste	0.84^{a}	0.89^{a}	0.73^{ab}	0.64^{b}	0.085	*	ns	ns
Metallic taste	0.87^{a}	0.67^{b}	0.61^{b}	0.49^{c}	0.062	*	**	ns
Unctuousness	3.87^{b}	3.89^{b}	4.69^{a}	4.81^{a}	0.075	*	ns	ns
Juiciness	5.52^{a}	5.69^{a}	4.77^{b}	4.96^{b}	0.081	*	ns	ns
Persistence of flavour	7.09^{a}	6.59^{a}	5.91^{b}	5.75^{b}	0.102	*	ns	ns

[1] System C: confinement; System SC: semi-confinement. [2] B: barrows; F: females. [3] SEM: standard error of the mean. [4] ns: not significant; * $p<0.05$; ** $p<0.01$. [a-b] Means in the same row with a common superscript letter do not differ significantly ($p>0.05$).

comparisons are hard because of differences in the experimental designs as the dorsal thickness has a strong relation to slaughter weight and diet composition. Thus, Aro & Akinjokun (2012) recorded backfat thickness values between 1.2 and 2.8 in Large White × Duroc pigs fed cassava peel and slaughtered at 68-70 kg liveweight. There were significant differences between the two systems for backfat, which is similar to found by Pugliese *et al*. (2003) and Daza *et al*. (2006) in Nero Siciliano and Iberian pigs, respectively. Backfat thickness was higher in females than barrows, in agreement with Renaudeau & Mourot (2007), Latorre *et al*. (2008) and Aro & Akinjokun (2012). The low weight and age of the animals at slaughter could be the main causes of the lack of differences between sexes. Nevertheless, our results disagree with Renaudeau *et al*. (2005) in Creole pigs, who indicated that the barrows deposit more fat than females mainly at lumbar level. The rib eye area was lower than that recorded in most of the literature consulted due to lower slaughter weight and even with respect to the results obtained by Wojtysiak & Połtowicz (2014) on Pulawska pigs slaughtered at 30 kg body weight. The absence of an improvement program and the poor quality of feed provided to the animals could be the main causes of poor muscle development, and consequently the low values of the rib eye area.

The conformation of the carcass is an aspect of interest in the meat industry. Such confirmation may be assessed by subjective variables and through objective measurements. The mean values from carcass measurements were lower than those found by De Jesús-López (2008) in Spanish autochthonous breeds (Celta). However, the values were higher than those recorded by Ramos (2008) in Peruvian Creole pigs, which is in consonance on the differences in body weight between the two populations (51.4 kg *vs* 35.4±5.1 kg). The carcass measurements are related to the genetic biotype and slaughter weight, resulting in a low score of carcass conformation. With regard to morphometric parameters, rearing system effects were significant in most of the lengths and perimeters of the carcass, in agreement with Galián *et al.* (2009) in Chato Murciano breed. However, Pugliese *et al*. (2003) found no significant differences for all carcass measurements, except for body length, between indoors and outdoors pigs. These differences were mainly caused by the carcass weight of both groups. No significant differences were observed between sex, except for leg length, ham length and maximum perimeter ham, in agreement with Franco *et al*. (2014) in Celta pig crossbred with Duroc and Landrace genotypes.

The comparisons with the results obtained by other authors both local breeds and commercial breeds are hard because of differences in the carcass cutting between studies. Also, differences in regional quartering methods might explain these differences. The study of the most valuable meat cuts reveals some differences because of the rearing system. These results are consistent with the research of Daza *et al*. (2006) and Galián *et al*. (2009). In contrast, authors like Galián *et al*. (2008), in Chato Murciano pigs, reported higher weights on the carcass cuts from pigs reared outdoor. These discrepancies between studies could be attributed to the availability and quality of the feeding system in both indoor and outdoor system. Primal cut yield, except sirloin percentage, was not affected by sex confirming the results of Peinado *et al.* (2012) and Franco *et al*. (2014) in crossbreed pig (LD × LW dams × Duroc sires) and Celta pig crossbred, respectively. Ayuso *et al*. (2014) reported that the pieces obtained from Iberian pigs showed similar weights and yields in both sexes, with the exception of the forelegs (heavier in barrows). Conversely, Serrano *et al*. (2008) found that primal cut yield was lower for barrows than for females.

The proportion of fat in the carcass was lower, whereas the proportions of skin, lean and bone and fat/lean and lean/bone ratios were higher in the SC pigs than in the C pigs, in accordance to the higher backfat percentage observed in their carcasses (Pugliese *et al.*, 2003). Carcass from gilts were leaner than barrows with lower percentage of intermuscular fat in the loin, sirloin and ham, while the fat contents in the shoulder and top loin were similar in both sexes which agree with Serrano *et al*. (2008) in Iberian pigs.

In several cuts of the carcass, the system × sex interaction was significant. Males reared in the SC system accumulated more fat than females, while in the C system differences between barrows and gilts were not found. Most foraging capacity by barrows might be the main cause of these differences. Something similar, though in the opposite direction was observed for lean content.

Meat quality parameters

Average pH values and the pH fall in the first 24 hours *postmortem* (0.9) revealed an acceptable *postmortem* glycolysis and could be associated to an appropriate pre-slaughter handling. The differences in pH_{45} (6.2) and pH_{24} (5.3) values obtained in our study with those recorded by Ramos (2008) in Peruvian Creole pigs (6.9 and 5.7, respectively) could be attributed to the period of fasting, stress at slaughtering and the age of the animals. The no significant influence of sex on the pH was in line with the results recorded by other authors (Renaudeau & Mourot, 2007; Franco *et al*., 2014). However, Serrano *et al*. (2008) found that initial and ultimate pH were higher for barrows than for females. These discrepancies could be related to stress factors and differences in the glycolytic potential between sexes (Larzul *et al*., 1997).

The water holding capacity values obtained in our study for can be considered as normal, and were similar to those recorded by Tejerina *et al*. (2012) in Iberian pigs free-range or confinement rearing, Franco *et al*. (2014) in Celta pig crossbred, and Franci *et al*. (2005) in Cinta Sinese breed, although higher than those recorded by Galián *et al*. (2008) in Chato Murciano breed. In the literature on meat quality in different livestock species, is widely known the strong relationship between pH and water holding capacity. Our data did not show such differences in pH_{24} in any of the two different rearing systems, which could explain the lack of differences in the variables drip and cooked losses. These results are in accordance to Tejerina *et al*. (2012), but contrary to Rosenvold & Andersen (2003), Pugliese *et al*. (2004), Franci *et al*. (2005) and Galian *et al*. (2008). There were no differences in water holding capacity between sexes, in accordance to Pugliese *et al*. (2004).

Average ash content of meat samples (1.3%) was slightly higher than reported by Mienkowska-Stepniewska *et al*. (2007) in five pig breeds (1.1%), although well below that recorded by Aro & Akinjokun (2012) in Large White × Duroc pigs (3-4%). When we compare the values of mineral composition of meat with the reference values provided by other authors (Muñoz & Ledesma, 2002) referred to the mineral composition of the pig LT, note that the levels of P, K, Mg, Fe and Cu are high whereas Ca, Na and Zn are within the normal values, which agrees with Galián *et al.* (2007) and Poto *et al.* (2007) in Chato Murciano breed. The Cu content could be related to the rearing system ("traspatio" involving more physical exercise that in in-door system) and muscle oxidative metabolism of this breed, in line with that indicated by Poto *et al*. (2007) in Chato Murciano pig and its crosses. The mean values obtained in elements like K, Cu, Fe and Zn were similar to those obtained by other authors, who found values of 330-349 mg/100 g for K (Poto *et al.*, 2007), 0.2 mg/100 g for Cu or 2.3 mg/100 g for Fe and 1.4 to 2.5-2.7 mg/100 g for Zn (Guang-Zhi *et al.*, 2008). The values for P, Ca and Mg appeared at a higher quantity than in results obtained by Muñoz & Ledesma (2002), Galián *et al.* (2007) and Poto *et al*. (2007). The average values of Mn were 0.033 mg/100 g, level similar than those found by McCance & Widdowson's (1991), although lower than those recorded by Ramos (2008) in Peruvian Creole pigs (0.008 mg/100 g). Galián *et al.* (2007) and Poto *et al*. (2007) in Chato Murciano breed only found traces of manganese. Due to the limited information about Mn values in pork meat, we cannot discuss this item further. However, comparisons must be made with caution given the large variations found among breeds (Guang-Zhi *et al*., 2008) and feed regimes (Mienkowska-Stepniewska *et al*., 2007). Guang-Zhi *et al.* (2008) found significant differences between mineral elements in LT in five pig breeds (three local and two imported breeds). On the whole, local breeds had higher Na, Ca, Fe, Cu and Zn levels and lower K level than that in the imported breeds; while, no significant differences were found among the five breeds for Mn levels.

The rearing system had a slight effect on the levels of the mineral content of the meat. The pigs reared outdoors (SC system) showed higher levels of Ca. In previous studies (Galián *et al.*, 2007, 2008, 2009; Poto *et al.*, 2007), the pigs reared indoors showed higher levels of Fe, Cu and Zn, and lower levels of Mg, P and K than the pigs reared outdoors. The differences between the results of our study and the aforementioned works can be partially explained by factors such as weight at slaughter, genotype and physical exercise, among other.

The differences in the sensory analysis could be due to the characteristics of the rearing system, exercise and/or physical variables, but not be ascribed to a pH difference as no significant differences in pH were found between the different systems and sex. It is widely accepted that the tenderness is the most important factor affecting overall meat acceptability. The tenderness was positively correlated with cooking loss (0.475), not reaching statistical significance other correlations with *postmortem* meat instrumental traits. Nam *et al*. (2009) reported that tenderness score was correlated with L^* and drip loss, and negatively correlated with pH_{45}. Also, cooking loss was positively correlated with brightness (0.482), while showed negative correlations with taste attributes as sweetness (-0.408) and metallicness (-0.383), which agrees with Nam *et al*. (2009). As the above authors reported, these results suggest that panelists do not prefer pork in terms of taste which has high cooking losses and is perceived as tough meat. So, it may be natural that taste acceptance decreases as cooking losses increase.

In summary, Creole is a breed of slow growth and with a clear tendency to fatness. The rearing system significantly influences the growth and quality of the carcass and meat, while the influence of sex was light.

Acknowledgements

We thank the Animal Production Science personnel at the Veterinary Faculty of Cordoba (Spain) for their assistance.

References

Aro SO, Akinjokun OM, 2012. Meat and carcass characteristics of growing pigs fed microbially enhanced cassava peel diets. Arch Zootec 61 (235): 407-414. http://dx.doi.org/10.4321/S0004-05922012000300009

Ayuso D, González A, Hernández F, Peña F, Izquierdo M, 2014. Effect of sex and final fattening on ultrasound and carcass traits in Iberian pigs. Meat Sci 96: 562-567. http://dx.doi.org/10.1016/j.meatsci.2013.08.018

Benítez OW, Sánchez DM, 2001. Los cerdos criollos en América Latina. Los cerdos locales en los sistemas tradicionales de producción. Estudio FAO Producción y Sanidad Animal 13-35. FAO, Roma.

Daza A, Mateos A, López Carrasco C, Rey A, Ovejero I, López-Bote CJ, 2006. Effect of feeding system on the growth and carcass characteristics of Iberian pigs, and the use of ultrasound to estimate yields of joints. Meat Sci 72 (1): 1-8. http://dx.doi.org/10.1016/j.meatsci.2005.04.031

De Jesús-López MC, 2008. Caracterización productiva de cerdos del tronco Celta. Universidad de Santiago de Compostela, Spain.

Fisher AV, Green DM, Whittemore CT, Wood JD, Schofield CP, 2003. Growth of carcass components and its relation with conformation in pigs of three types. Meat Sci 65 (1): 639-650. http://dx.doi.org/10.1016/S0309-1740(02)00266-8

Fortina R, Barbera S, Lussiana C, Mimosi A, Tassone S, Rossi A, Zanardi E, 2005. Performances and meat quality of two Italian pig breeds fed diets for commercial hybrids. Meat Sci 71 (4): 713-718. http://dx.doi.org/10.1016/j.meatsci.2005.05.016

Franci O, Bozzi R, Pugliese C, Acciaioli A, Campodoni G, Gandini G, 2005. Performance of Cinta Senese pigs and their crosses with Large White. 1 Muscle and subcutaneous fat characteristics. Meat Sci 69 (3): 545-550. http://dx.doi.org/10.1016/j.meatsci.2004.10.005

Franco D, Vazquez JA, Lorenzo JM, 2014. Growth performance, carcass and meat quality of the Celta pig crossbred with Duroc and Landrance genotypes. Meat Sci 96 (1): 195-202. http://dx.doi.org/10.1016/j.meatsci.2013.06.024

Galián M, Peinado B, Martínez C, Periago MJ, Ros G, Poto A, 2007. Comparative study of the characteristics of the carcass and the meat of the Chato Murciano pig and its cross with Iberian pig, reared indoors. Anim Sci J 78 (6): 659-667. http://dx.doi.org/10.1111/j.1740-0929.2007.00487.x

Galián M, Poto Á, Santaella M, Peinado B, 2008. Effects of the rearing system on the quality traits of the carcass, meat and fat of the Chato Murciano pig. Anim Sci J 79 (4): 487-497. http://dx.doi.org/10.1111/j.1740-0929.2008.00554.x

Galián M, Poto A, Peinado B, 2009. Carcass and meat quality traits of the Chato Murciano pig slaughtered at different weights. Livest Sci 124 (1-3): 314-320. http://dx.doi.org/10.1016/j.livsci.2009.02.012

Guang-Zhi R, Ming W, Zhen-Tian L, Xin-Jian L, Jun-Feng C, Qing-Qiang Y, 2008. Study on the correlations between mineral contents in musculus Longissimus dorsi and meat quality for five breeds of pigs. Am J Anim Vet Sci 3: 18-22. http://dx.doi.org/10.3844/ajavsp.2008.18.22

Honikel KO, 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci 49 (4): 447-457. http://dx.doi.org/10.1016/S0309-1740(98)00034-5

INEI, 2012. IV Censo Agropecuario del Ecuador. Instituto Nacional de Estadísticas e Informática en el Ecuador.

Larzul C, Lefaucheur L, Ecolan P, Gogué J, Talmant A, Sellier P, Le Roy P, Monin G, 1997. Phenotypic and genetic parameters for longissimus muscle fiber characteristics in relation to growth, carcass and meat quality traits in Large White pigs. J Anim Sci 75 (12): 3127-3137.

Latorre MA, Garcia-Belenguer E, Ariño L, 2008. The effects of sex and slaughter weight on growth performance and carcass traits of pigs intended for dry-cured ham from Teruel (Spain). J Anim Sci 86 (8): 1933-1942. http://dx.doi.org/10.2527/jas.2007-0764

Meilgaard MC, Carr BT, Civille GV, 2006. Sensory evaluation techniques, 4th edition. CRC Press.

Mienkowska-Stepniewska K, Kulisiewicz J, Batorska M, Rekiel A, Wiecek J, 2007. Mineral composition of loin meat in the Polish maternal and paternal breeds of pigs. Ann Warsaw Univ Life Sci 44: 33-39.

Muñoz M, Ledesma JA, 2002. Tablas de valor nutritivo de alimentos. Mc Graw Hill, Mexico.

Nam YJ, Choi YM, Lee SH, Choe JH, Jeong DW, Kim YY, Kim BC, 2009. Sensory evaluations of porcine longissimus dorsi muscle: Relationships with postmortem meat quality traits and muscle fiber characteristics. Meat Sci 83 (4): 731-736. http://dx.doi.org/10.1016/j.meatsci.2009.08.015

Peinado B, Poto A, Gil F, López G, 2004. Characteristics of the carcass and meat of the Chato Murciano pig. Livest Prod Sci 90 (2-3): 285-292. http://dx.doi.org/10.1016/j.livprodsci.2004.07.018

Peinado J, Serrano MP, Nieto M, Sánchez J, Medel P, Mateos GG, 2012. The effects of gender and castration of females on performance and carcass and meat quality of heavy pigs destined to the dry-cured industry. Meat Sci 90 (3): 715-720. http://dx.doi.org/10.1016/j.meatsci.2011.11.001

Pillsbury K, 1992. Accelerated training of sensory descriptive flavor analysis panelist. Food Technol 11: 114-118.

Poto A, Galián M, Peinado B, 2007. Chato Murciano pig and its crosses with Iberian and Large White pigs, reared outdoors. Comparative study of the carcass and meat characteristics. Livest Sci 111 (1-2): 96-103. http://dx.doi.org/10.1016/j.livsci.2006.12.005

Pugliese C, Madonia G, Chiofalo V, Margiotta S, Acciaioli A, Gandini G, 2003. Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors. 1. Growth and carcass composition. Meat Sci 65 (2): 825-831. http://dx.doi.org/10.1016/S0309-1740(02)00287-5

Pugliese C, Calagna G, Chiofalo V, Moretti VM, Margiotta S, Franci O, Gandini G, 2004. Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors: 2. Joints composition, meat and fat traits. Meat Sci 68 (4): 523-528. http://dx.doi.org/10.1016/j.meatsci.2004.02.020

Ramos D, 2008. Caracterización de la canal y la carne del cerdo criollo y de los productos cárnicos en el Departamento de Tumbes-Perú. Universidad de León, Spain.

Renaudeau D, Hilaire M, Mourot J, 2005. A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 150 days of age. Anim Res 54 (1): 43-54. http://dx.doi.org/10.1051/animres:2004042

Renaudeau D, Mourot J, 2007. A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 90 kg BW. Meat Sci 76 (1): 165-171. http://dx.doi.org/10.1016/j.meatsci.2006.10.024

Rosenvold K, Andersen HJ, 2003. Factors of significance for pork quality, a review. Meat Sci 69 (3): 219-237. http://dx.doi.org/10.1016/S0309-1740(02)00186-9

Royal Society of Chemistry, 1991. McCance, Widdowson's composition of foods, 5th ed. Cambridge, UK.

Santos Ricalde RH, Trejo Lizama W, Osorto Hernández W, 2011. Rendimiento de la canal y desarrollo de los órganos torácicos y abdominales de los 25 a los 45 kg en cerdos criollos pelones [Carcass yield and thoracic and abdominal viscera growth from 25 to 45 kg in creole hairless pigs]. Revista Científica, FCV-LUZ 20(5): 396-402.

Serrano MP, Valencia DG, Fuentetaja A, Lázaro R, Mateos GG, 2008. Effect of gender and castration of females and slaughter weight on performance and carcass and meat quality of Iberian pigs reared under intensive management systems. Meat Sci 80 (4): 1122-1128. http://dx.doi.org/10.1016/j.meatsci.2008.05.005

Tartari E, Benatti G, Lazzaroni C, 1993. Study of muscle hypertrophy in beef cattle: use of different nutritional levels in fattening bulls. Proc 10th Nat Cong, Scientific Association of Animal Production. Bologna (Italy).

Tejerina D, García-Torres S, Cava R, 2012. Water-holding capacity and instrumental texture properties of m. Longissimus dorsi and m. Serratus ventralis from Iberian pigs as affected by the production system. Livest Sci 148 (1-2): 46-51. http://dx.doi.org/10.1016/j.livsci.2012.05.005

Wojtysiak D, Połtowicz K, 2014. Carcass quality, physico-chemical parameters, muscle fibre traits and myosin heavy chain composition of m. longissimus lumborum from Puławska and Polish Large White pigs. Meat Sci 97 (4): 395-403. http://dx.doi.org/10.1016/j.meatsci.2014.03.006