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RESEARCH ARTICLE

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Foraging behaviour and performance of steers from two local breeds (Asturian Valley and Asturian Mountain) grazing in Cantabrian (N Spain) summer pastures

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Abstract

Steer meat production in northern Spain is deficient to attend market demand. This research aimed to compare the foraging behaviour and production of yearling steers from two local breeds differing in body weight (BW), Asturian Valley (AV, 372 kg) and Asturian Mountain (AM, 307 kg), grazing in summer pastures consisting of 70% grassland and 30% heathland. Bodyweight gains from a total of 42 steers were recorded during four grazing seasons (from June to October). In two years, in July and September, plant community selection and diet composition were estimated by direct observation and using faecal markers, respectively. Grazing time increased from July to September (488 *vs*. 557 min/day; $p<0.001$) as sward height in the grassland decreased. Although AV steers grazed proportionally for longer on herbaceous pastures than AM steers (81.3 *vs*. 73.3%; $p<0.05$), no differences between breeds were found in diet composition. AM steers showed greater mean daily BW gains than AV steers (252 *vs*. 133 g/day; $p<0.01$). From June to August, steers from both breeds gained BW (487 *vs*. 360 g/day for AM and AV, respectively; $p<0.01$), but thereafter BW gains decreased (120 *vs*. –12 g/day for AM and AV, respectively; $p<0.05$), because of reduced availability of grassland herbage. Yearling steers from AM breed seem to be better suited to mountain conditions than those from AV breed, probably because of their smaller body size and lower total nutrient requirements for maintenance.

Additional keywords: beef; body weight; grazing behaviour; mountain pasture; rustic breed.

Abbreviations used: ADF (acid detergent fibre); AM (Asturian Mountain cattle); AV (Asturian Valley cattle); BW (body weight); CP (crude protein); DM (dry matter); GLM (General Linear Model); LU (livestock unit); NDF (neutral detergent fibre); OM (organic matter); SEM (standard error of mean).

Authors' contributions: Conceived and designed the experiments: AM, KO and RC. Performed the experiments: ART, AM, VGP and KO. Collected the data: ART, VGP, RRG and RC. Analysed the data: ART, LMMF and RC. Contributed reagents/materials/analysis tools: LMMF. Wrote the paper: ART and RC. Critically revised the manuscript: LMMF, KO and RRG. Coordinated the research project: RC.

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Introduction

Steer meat is a product of high value for its quality and organoleptic characteristics (Vieira *et al*., 2007). However, its production in northern Spain is very low since beef production is mostly focused on veal category, so it is far from satisfying the market demands from trading companies, restaurants and consumers. A sustainable steer production could be feasible by taking advantage of the regional natural and semi-natural plant resources. In the mountainous areas of northern Spain (Cantabrian Range and Pyrenees), the traditional livestock management system involves a short-term transhumance or valley-mountain system, in which communal high mountain pastures are extensively utilized by livestock (mainly beef suckler cows and their calves) during summer, usually from May-June to September-October. This system offers advantages over more intensive ones because of reduced production costs and lower dependence on purchased feedstuffs, although there may be drawbacks at summer pastures such as inclement weather, lack of sanitary control (with risks of contagion of several infectious diseases), unwanted matings and casualties by predation (Liechti & Biber, 2016). In addition to the livestock production they sustain, mountain pastures are recognized for their great environmental value and high biodiversity. Most of these ecosystems are included in the 'Natura 2000' network of the European Union Habitats Directive, so their multifunctionality as providers of many ecosystem services should be acknowledged (Rodríguez-Ortega *et al*., 2014).

Asturian Valley (AV) and Asturian Mountain (AM) cattle are two local breeds from Asturias (N Spain) that are well adapted to extensive grazing systems at Cantabrian mountain pastures. The first one (with a current census in Asturias of approximately 201,400 animals) is devoted to meat production, having calves with excellent conformation, whereas AM breed (27,200 animals in Asturias) is listed as endangered and consists of smaller and more rustic animals (Cañón *et al*., 1994; Osoro *et al*., 1999). Both breeds have been studied to a large extent in terms of productive performance of suckler cows and calves under different pasture conditions (*e.g*. Osoro *et al*., 1999, 2000). However, little information is available on other animal types such as steers. If steer production from local breeds and utilization of summer pastures aimed at enhancing their biodiversity conservation has to be promoted, then a deeper knowledge on their grazing behaviour and productive potential is needed.

The aim of this work was to compare the foraging behaviour (plant community and diet selection) and the productive performance (body weight changes) of yearling steers from AV and AM breeds, grazing typical Cantabrian summer pastures consisting of 70% grassland and 30% heathland with broom scrublands.

Material and methods

Study site and experimental animals

The study was conducted during four years (2011-2014) at Cueva Palacios mountain research station, located in the natural park of Las Ubiñas-La Mesa, Quirós, south-central Asturias (43º03'N, 5º56'W), at 1600–1800 m above sea level. The experimental field comprised 36 ha composed of 70% herbaceous and 30% shrubland communities. The herbaceous pastures mostly consisted of mesophilous grasslands dominated by red fescue (*Festuca rubra* L., a fine-leaved grass), with a lower presence of other characteristic grasses such as *Agrostis capillaris* L. and *Nardus stricta* L. There were small areas of hygrophilous fens dominated by *Carex* spp., and calcareous rocky pastures with low plant cover. The shrublands mostly consisted of dwarf heathlands dominated by heather (*Calluna vulgaris* (L.) Hull), with bilberry (*Vaccinium myrtillus* L.) as the most abundant companion species. Other shrublands included broom (*Genista florida* L. subsp. *polygalaephylla* (Brot.) Cout.) formations on relatively deeper soils, in addition to small areas of furze (*Genista occidentalis* (Rouy) H. J. Coste) and barberry (*Berberis vulgaris* L. subsp. *cantabrica* Rivas Mart., T. E. Díaz, Fern. Prieto, Loidi & Penas) formations on calcareous soils.

A total of 42 yearling steers from the two Asturian local breeds were utilized (5, 6, 5 and 4 AV, and 6, 7, 5 and 4 AM in 2011, 2012, 2013 and 2014, respectively). All animals were born during winter-spring of the preceding year (from 2010 to 2013). As suckling calves, they spent the summer at the research station with their mothers, so they had previous experience on these summer pastures. Calves were weaned when returned to lowlands in October. When aged around one year, in January-February, they were castrated by surgical removal of the testicles. Previously, animals were sedated with 0.5 mL/100 kg of body weight (BW) of 2% xylazine and locally anesthetized with 60 mL/animal of lidocaine.

Experimental grazing season at summer pastures lasted from mid-June to late September or early October. Mean BW (± SE) at the start was 372 ± 7.9 kg for AV and 307 ± 11.2 kg for AM, with a mean age of 481 ± 7.7 days. At the experimental field, yearling steers grazed accompanied by other cattle in a herd of 19–24 cows (approximately three quarters of them suckling their calves) plus heifers. Applying the livestock unit (LU) coefficients of the European Union regulation (EC, 2009), managed stocking rate averaged over the four study years was 0.86 ± 0.054 LU/ha.

Before being moved to the mountain, animals were vaccinated against *Clostridium* spp. (Miloxan-Merial, Lyon, France), and drenched with deltametrine (Deltavex pour-on-S.P. Veterinaria, Tarragona, Spain). All procedures were carried out in accordance with European Union regulation on the protection of animals used for scientific purposes (EC, 2010).

Measurements on vegetation

Botanical composition of the main plant communities was sampled in late June of 2011, 2013 and 2014 recording 1000 vertical hits at 200 random loci in grasslands and 500 hits at 100 random loci in heathlands using a point quadrat (Grant, 1981).

The availability of preferred pasture was assessed by monthly measuring the sward height at 300–500 random sites in the grassland areas with a sward stick (Barthram, 1986).

Samples of the main plant components (*i.e.* herbage foliage from grassland, and current season's green shoots of heather and bilberry) were collected in July and September to assess their nutritive quality. Chemical determinations included organic matter (OM, no. 942.05) and nitrogen (N, no. 990.03) following the procedures of the Association of Official Analytical Chemists (AOAC, 2006). Crude protein (CP) was calculated as N×6.25. Neutral detergent fibre (NDF) was analysed according to the procedures described by Mertens (2002). Acid detergent fibre (ADF, no. 973.18) was analysed following the methods of AOAC (2006), and expressed inclusive of residual ash. Lignin (sa) was determined by solubilising cellulose with sulphuric acid (Robertson & Van Soest, 1981).

Foraging behaviour and performance of steers

Grazing behaviour (grazing time and plant community selection) was monitored in mid-July and mid-September of 2013 and 2014 by visual observations of the steers every 15 minutes during daylight hours (15 in July, 13 in September) in two consecutive days (Gary *et al*., 1970). The grazing activity of each individual at the different plant communities (grasslands, fens, rocky pastures, heathlands, broomfields, furze shrublands and barberry formations) was recorded.

The day after the visual recordings, individual grab samples of faeces were collected to estimate steers' diet composition using *n*-alkanes as faecal markers (Dove & Mayes, 1991). After being stored at –20ºC, faecal and plant (the same also used for nutritive quality analyses) samples were freeze-dried and milled to 1 mm before chemical analyses. *n*-Alkanes (from C_{21} to C_{36}) were extracted using the method described by Dove & Mayes (2006), and their concentrations quantified by gas chromatography, using a Perkin Helmer Clarus 580 equipped with a flame ionisation detector and an autosampler. Identification was performed by comparison of retention times of the samples components with the previously injected mixture of known *n*-alkanes. The response factors for the individual *n*-alkanes were calculated from peak areas and the known concentrations. The *n*-alkane concentrations were quantified relative to known amounts of the internal standards C_{22} (*n*-docosane) and C_{34} (*n*-tetratriacontane) added at the beginning of the extraction process.

Faecal *n*-alkane concentrations were corrected for their incomplete recovery in faeces using data from validation studies with cows (Ferreira *et al*., 2007). Diet composition (proportions of herbage, heather and bilberry) was estimated using an iterative least-squares procedure, which minimizes the discrepancies between the observed faecal concentrations of each *n*-alkane (C_{25}–C_{27} and C_{29}–C_{33}) and the estimated dietary proportions of plant components (Dove & Moore, 1995) using the Solver routine in Microsoft Excel. The other extracted alkanes were not used due to their low concentrations in both plant and faecal samples.

Steers were weighed at the beginning, middle (early August) and at the end of the grazing season. Daily BW changes were calculated for the different periods (*i.e.* from June to August, and from August to September-October) and for the whole grazing season.

Statistical analyses

Data on plant chemical composition (OM, CP, NDF, ADF and lignin) were analysed by a General Linear Model (GLM) procedure to examine differences among the plant components, season (July and September) and their interaction. Steers' individual data on grazing behaviour and diet composition were subjected to a GLM for repeated measures, including the fixed effects of breed, year, season (two repeated measures) and the full interactions. For non-grazed communities in one of the two seasons, that season with no variance was removed from the model to test the effects of breed, year and the interaction breed × year. Daily BW changes during the different periods (the two halves and the whole grazing season) were subjected to a GLM to examine the effects of breed, year and their interaction. Tukey's test was used for multiple comparisons among means. Correlations between BW changes (averaged for each breed) and mean sward height at each grazing period (the first and second half of the four grazing seasons; n=8) were checked with Pearson's correlation coefficient. All analyses were performed using Statistica 8.0 (StatSoft Inc., Tulsa, OK, USA).

Results

Available pastures and chemical composition

Grasslands presented a highly diverse botanical composition, with a total of 79 vascular species recorded. Although grasses predominated (54.6% cover on average, with red fescue as the most abundant), many other species were recorded, including other monocots

(9.3% cover) such as *Merendera montana* (L.) Lange and *Carex caryophyllea* Latourr., legumes (8.5% cover) such as *Trifolium repens* L., *Lotus corniculatus* L. and *Vicia pyrenaica* Pourr., and other dicots (25.4% cover) such as *Plantago media* L., *Plantago alpina* L. and *Pilosella officinarum* F. W. Schultz & Sch. Bip. to quote the most abundant ones. Heather dominated in heathlands with 44.8% mean cover, followed by bilberry (9.0%), with herbaceous species accounting for 31.6% cover (*Potentilla erecta* (L.) Raeusch. and *Succisa pratensis* Moench were the most abundant). Other shrub species such as *Chamaespartium sagittale* (L.) P. E. Gibbs and *Juniperus communis* L. subsp. *nana* (Willd.) Syme were sparsely found (3.9% cover in total).

The grassland sward height (means ± SE of four years) decreased from 14.4 ± 0.74 cm at the start to 3.3 ± 0.06 cm at the end of the grazing season. Averaged over time, mean sward heights were 7.8 ± 0.22 cm and 4.0 ± 0.20 cm during the first and second half of the grazing season, respectively, averaging 6.1 ± 0.11 cm during the whole grazing season.

Grassland herbage had greater CP (178 *vs*. 98 g/kg DM) and NDF contents (526 *vs*. 394 g/kg DM), and lower OM (930 *vs.* 962 g/kg DM) and lignin contents (34 *vs*. 141 g/kg DM) than shrubs, with ADF contents being greater in heather than in herbage and bilberry (319 *vs*. 239 g/kg DM; Table 1). Heather had greater OM and lignin contents, and lower CP contents than bilberry. Mean CP content in herbage increased from July to September, whereas it decreased in heather and bilberry (p<0.01 for component × season interaction; Table 1).

Foraging behaviour

Daily grazing time was similar for the two breeds and increased from July to September (from 488 to 557 min/day; SEM=11.2; p<0.001; Table 2). There were differences between years, with steers grazing for longer in 2013 than in 2014 (547 *vs*. 498 min/day; SEM=13.8; p<0.05). Grazing activity was concentrated from sunrise to midday (7:00–12:00 h) and again in the evening (18:00–21:00 h). Steers preferred to rest during the central hours of the day, especially from 13:00 to 15:00 h, although some differences between seasons were observed. The steers from both breeds showed more breaks in their grazing activity (both in the morning and in the afternoon) in July than in September (Fig. 1).

In general, AV steers grazed proportionally for longer times on herbaceous pastures (81.1% *vs*. 73.4%; SEM=1.98; p<0.05) and less on shrubby communities than AM steers (Table 2). The grazing time on herbaceous relative to shrub communities tended to decrease from July to September (from 80.1% to 74.4%; SEM=2.33; p=0.091). In addition, steers in 2014 tended to spend more proportional time grazing on herbaceous communities than those managed in 2013 (p=0.054), especially in the case of AM breed (p=0.085 for breed × year interaction). The dominant grasslands were more used by AV than AM steers (75.0% *vs*. 66.5%; SEM=2.02; p<0.05), whereas no differences between breeds were found in grazing time on other herbaceous communities with minor extension. In general, grazing time on both fens and rocky pastures decreased from July to September (from 3.5% and 5.8% to 1.2% and 2.4%, respectively; p<0.001), but with great differences between years (p<0.01 for year × season interaction).

Regarding shrubby communities, AM steers grazed for longer on heathlands than AV steers (21.5% *vs.* 12.5%; SEM=1.80; p<0.01; Table 2), especially during the morning meals (Fig. 1). For AV steers, grazing time on heathlands increased from July to September, but not for AM steers (p=0.055 for breed × season interaction). Heathlands were grazed proportionally for more time in 2014 than in 2013 (21.2% *vs*. 12.8%; SEM=1.90; p<0.01). There were no differences between breeds in the grazing time on broom scrublands, but it was longer in 2014 (6.6%) than in 2013 (3.6%; p<0.05). Noticeably, steers were not observed browsing the small-leaved shoots of brooms; instead, they were found only to graze below on the herbaceous or dwarf-shrub layer. Furze and barberry communities were

Table 1. Chemical composition (g/kg DM) of the main plant components (Pl) of mountain pastures sampled in two seasons (Ss), early (July) or late summer (September).

Chemical composition[1]	Herbage		Heather		Bilberry		SEM[2]	*p*-value		
	July	Sept.	July	Sept.	July	Sept.		Pl	Ss	Pl × Ss
OM	927	932	966	970	960	953	3.4	<0.001	0.684	0.173
CP	169	186	99	81	113	98	5.6	<0.001	0.254	0.009
NDF	521	532	433	383	414	347	29.3	<0.001	0.146	0.305
ADF	254	238	339	299	229	236	20.8	0.005	0.338	0.542
Lignin (sa)	35	32	203	176	90	96	11.7	<0.001	0.399	0.389

[1] OM: organic matter. CP: crude protein. NDF: neutral detergent fibre. ADF: acid detergent fibre.
[2] SEM: standard error of mean.

Table 2. Daily grazing times and percentages on different plant communities of summer pastures by yearling steers from two local breeds (AV: Asturian Valley; AM: Asturian Mountain; *n*=5 AV and 5 AM in 2013, *n*=4 AV and 4 AM in 2014).

	2013				2014				SEM[3]
	July		September		July		September		
	AV	AM	AV	AM	AV	AM	AV	AM	
Grazing time (min/day)	513	501	578	597	450	489	489	562	23.6
Grasslands[1] (%)	81.3	60.3	72.2	67.6	71.7	70.0	74.8	68.3	4.91
Fens (%)	4.6	3.6	0.6	0.0	2.0	3.8	1.5	2.9	1.26
Rocky pastures (%)	1.1	2.0	1.8	2.2	10.1	9.9	2.7	3.0	1.70
Total herbaceous (%)	87.0	65.9	74.5	69.8	83.9	83.7	79.0	74.2	4.91
Calluna heathlands (%)	10.1	33.5	19.4	21.9	7.2	11.8	13.4	18.8	3.78
Genista florida broomfields (%)	2.9	0.6	4.8	6.0	8.9	4.5	7.3	5.7	2.23
Other woody communities[2] (%)	0.0	0.0	1.3	2.3	0.0	0.0	0.4	1.2	1.06
Total shrublands (%)	13.0	34.1	25.5	30.2	16.1	16.3	21.0	25.8	4.91

Table 2. Continued.

	p-value[4]						
	Br	Ss	Yr	Br×Ss	Br×Yr	Ss×Yr	Br×Ss×Yr
Grazing time (min/day)	0.128	<0.001	0.019	0.139	0.179	0.267	0.958
Grasslands[1] (%)	0.010	0.980	0.769	0.435	0.150	0.825	0.165
Fens (%)	0.659	<0.001	0.691	0.991	0.223	0.008	0.672
Rocky pastures (%)	0.801	<0.001	0.005	0.971	0.816	<0.001	0.687
Total herbaceous (%)	0.016	0.091	0.054	0.374	0.085	0.653	0.122
Calluna heathlands (%)	0.003	0.279	0.005	0.055	0.144	0.127	0.040
Genista florida broomfields (%)	0.169	0.248	0.027	0.283	0.337	0.202	0.913
Other woody communities[2] (%)	0.361	-	0.346	-	0.928	-	-
Total shrublands (%)	0.016	0.091	0.054	0.374	0.085	0.653	0.122

[1]Include dominant mesophilous *Festuca-Agrostis* grasslands with interspersed patches of acidophilous *Nardus* grasslands and basophilous grasslands. [2]Include furze (*Genista occidentalis*) shrublands and barberry (*Berberis vulgaris*) formations on calcareous soils. [3]SEM: standard error of mean. Br (Breed), Ss (Season), Yr (Year).

only utilized in September with minimal grazing times (0.7% and 0.6%, respectively; Table 2).

Diet composition did not differ between breeds (Table 3). Steers selected greater percentages of herbage (80.0 ± 2.23%) than shrubs (15.5 ± 1.58% bilberry, 4.4 ± 0.89% heather). Herbage percentage in diet decreased from July to September (from 88.8% to 70.8%; SEM=2.84; $p<0.001$), whereas those of shrubs increased (bilberry from 9.7% to 21.5%; SEM=1.74; $p<0.001$; heather from 1.5% to 7.7%; SEM=1.46; $p<0.01$). There were no differences between years in dietary percentages of herbage or bilberry, while heather tended to account for greater percentages in 2014 than in 2013 (6.1% *vs.* 3.1%; SEM=1.11; $p=0.068$).

Animal performance

Overall, AM steers attained greater daily BW gains during the whole summer than AV steers (252 *vs.* 133 g/day; SEM=36.0; $p<0.05$), with greater overall gains observed in 2011 compared to 2012 and 2013 (319 *vs.* 112 g/day; SEM=50.4; $p<0.05$; Table 4). During the first half of the grazing season (from June to August) AM steers gained significantly more BW than AV steers (487 *vs.* 360 g/day; SEM=31.9; $p<0.01$). From August to October between-breed differences persisted, and AM steers continued to gain BW, whereas AV steers lost BW on average (120 *vs.* –12 g/day; SEM=45.5; $p<0.05$). There were differences across years in BW gains in both periods. From June to August greater gains were observed in 2012 and 2013 compared to 2011 (505 *vs.* 292 g/day; SEM=44.7; $p<0.01$), but thereafter the gains were greater in 2011 than in the following years (347 *vs.* –43 g/day; SEM=71.3; $p<0.001$). Thus, BW gains were reduced from the first to the second half of the grazing season except in 2011 (Table 4). No significant interactions between breed and year were detected in any period.

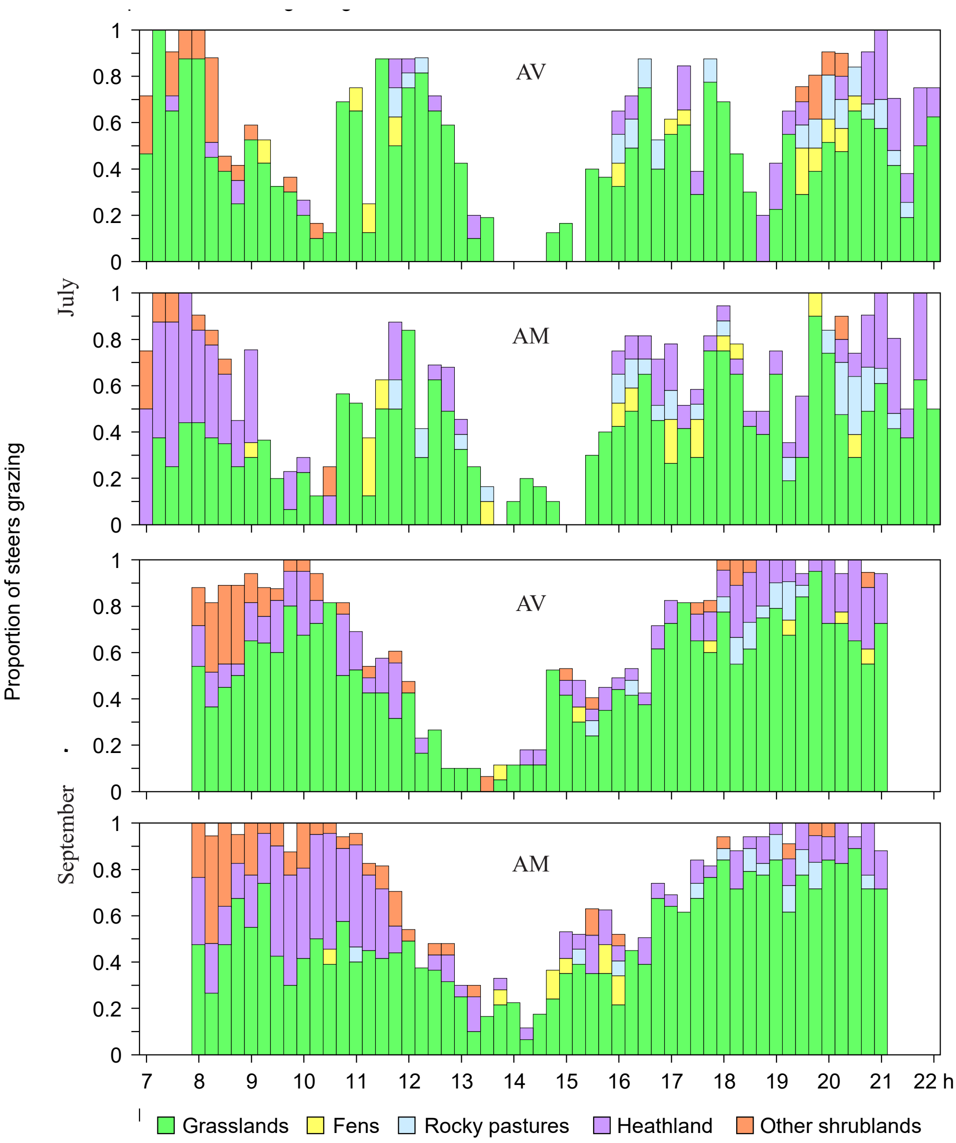

Figure 1. Diurnal variations in the grazing use of each plant community by yearling steers from two local breeds (AV: Asturian Valley; AM: Asturian Mountain) in Cantabrian summer pastures.

Correlation analyses showed significant (p<0.01) positive relationships between grassland mean sward height during a particular season and steers' mean BW gains for both breeds (r=0.838 for AV, r=0.877 for AM).

Discussion

Grazing behaviour and diet selection

No differences in total grazing time and diet selection were found between AV and AM steers in these summer pastures. In general, scarce differences in grazing behaviour have been observed between similar cattle breeds (*e.g*. Funston *et al*., 1991; Dumont *et al*., 2007; Fraser *et al*., 2009b). Some studies comparing breeds differing in mature body size, origin or aptitude did find differences in grazing activity or selected diet (*e.g*. Erlinger *et al*., 1990; Winder *et al*., 1996; Hessle *et al*., 2008). Much of the between-breed differences in foraging behaviour can be associated to differences in body size and related intake capacity, nutrient requirements and feeding efficiency for maintenance or growth (Rook *et al*., 2004; Dumont *et al*., 2007). In the current study AM steers grazed proportionally for longer time on heathlands and less on grasslands than AV steers. As heathlands generally occupied more rugged and steeper terrains than grasslands, the larger AV steers could be more constrained to move on and utilize those shrublands than the smaller AM steers, which are recognized to be more rustic and able to climb better than AV (Cañón *et al*., 1994; Osoro *et al*., 1999).

Table 3. Diet composition of yearling steers from two local breeds (AV: Asturian Valley; AM: Asturian Mountain) grazing on mountain pastures composed of 70% grasslands and 30% heathlands (*n*=5 AV and 5 AM in 2013, *n*=4 AV and 4 AM in 2014).

	2013				2014				SEM[1]	*p*-value[2]		
	July		September		July		September					
	AV	AM	AV	AM	AV	AM	AV	AM		Br	Ss	Yr
Herbage (%)	94.9	90.8	71.9	69.7	81.8	87.5	69.2	72.5	5.99	0.855	<0.001	0.272
Heather (%)	0.2	0.0	5.8	6.5	2.0	3.8	10.2	8.3	3.08	0.948	0.001	0.068
Bilberry (%)	4.9	9.2	22.3	23.8	16.2	8.7	20.7	19.2	3.66	0.752	<0.001	0.634

[1]SEM: standard error of mean. [2]All 2-way and 3-way interactions were non-significant (p>0.1) for all dependent variables. Br (Breed), Ss (Season), Yr (Year).

Thus, AM steers could favour a more homogeneous forage use of mountain pasture resources (Bailey *et al*., 1998).

Nevertheless, such differences in plant community selection were not reflected in differences in diet composition. It could be due to the fact that, when grazing on heathlands, especially at early summer (July), AM steers selected mostly herbaceous species growing among the dominant shrubs. Particularly in open heathland areas, steers could be selecting the narrow grassland strips as we did not record the particular plant items eaten at each feeding site, but the location. Open heathlands are much more utilized by cattle than close heathlands (Mandaluniz *et al*., 2011).

Steers preferentially selected grassland herbage against woody species of lower nutritive quality. Cattle are well known to graze preferentially on grasslands over heathlands (Gordon, 1989; Mandaluniz *et al*., 2011; Ferreira *et al*., 2013). In September, however, once grassland sward height was much shorter (3–4 cm), shrub percentage in diet increased, as previously observed in different studies with cows (Putman *et al*., 1987; Celaya *et al*., 2008). Bilberry was more selected than heather, similar to what was found by Grant *et al*. (1987) in Scottish heathlands. However, Sæther *et al*. (2006) observed low percentages of bilberry and similar to those of heather (around 2%) in cattle faeces by microhistological analyses, as most of the faecal fragments corresponded to herbaceous species (76% grasses, 8% sedges and 8% herbs).

On the other hand, the lack of observations of steers browsing on brooms agrees with previous findings on the cattle reluctance to consume this woody legume (Osoro *et al*., 2000). Broom formations have proliferated significantly over grassland and heathland areas since the small ruminants, mostly coming from transhumant herds, have disappeared for some decades in these mountains (González Díaz *et al*., 2019). Thus, the current replacement of sheep and goats by cattle may be ineffective to control broom encroachment, threatening the provision of quality pasture for livestock, the traditional pastoral landscape and its biodiversity. Nowadays, the removal of these shrublands has to be undertaken by costly mechanical clearings.

The diurnal grazing pattern shown by steers, with two main grazing periods in the morning and in the evening separated by a more or less marked break at noon, has been described in several studies with cattle foraging on mountain pastures (Funston *et al*., 1991; Aldezabal *et al*., 1999; Ferreira *et al*., 2013). Nevertheless, cattle show flexible circadian grazing

Table 4. Daily body weight (BW) changes of yearling steers from two local breeds (AV: Asturian Valley; AM: Asturian Mountain) grazing on mountain pastures composed of 70% grasslands and 30% heathlands.

	2011		2012		2013		2014		SEM[3]	*p*-value[4]	
	AV	AM	AV	AM	AV	AM	AV	AM		Br	Yr
n	5	6	6	7	5	5	4	4			
Initial BW (kg)	361	291	380	345	355	288	397	286	21.2	<0.001	0.099
BW change (g/day)											
Period 1[1]	278	307	454	562	419	584	288	497	70.6	0.007	0.003
Period 2[2]	333	360	-41	-2	-260	-80	-81	202	100.8	0.044	<0.001
Overall	305	333	101	131	22	195	104	349	79.6	0.022	0.011

[1]From mid June to early August. [2]From early August to September-October. [3]SEM: standard error of mean. [4]The interaction Br×Yr was non-significant (p>0.25) for all dependent variables. Br (Breed), Yr (Year).

patterns depending on environmental and pasture conditions, and may have between three and five grazing periods during a day depending on season (Erlinger *et al*., 1990; Linnane *et al*., 2001; Celaya *et al*., 2008). In the current study, the length of the meals increased from July to September, which resulted in longer daily grazing times late in the season, even though steers' activity was recorded for two hours less than in July (Fig. 1) according to the shortening of sunlight time. Similar results were obtained in heifers of traditional and commercial breeds grazing in Swedish semi-natural grasslands (Hessle *et al*., 2008). Regardless of some possible grazing activity at night (Linnane *et al*., 2001), the observed increase in daily grazing time from July to September would be mainly related to the reduced availability of preferred grassland herbage, thus forcing the steers to graze for longer in an attempt to compensate the reduced intake rate (Hodgson, 1990; Ferrer Cazcarra *et al*., 1995).

Steer performance

In spite of the lower growth potential, AM steers achieved greater BW gains than AV ones grazing on these summer pastures. Differences were observed in the two periods considered, *i.e*. regardless of the preferred herbage availability (mean grassland sward heights of 7.2–8.3 cm from June to August, and 3.7–4.6 cm thereafter). On the contrary, comparing the same animals when suckling their dams during the preceding year on the same summer pastures, AV calves showed greater BW gains than their AM counterparts (Román-Trufero *et al*., 2015). Thus, as yearlings, AV steers could not fully express their growth potential even with relatively high availabilities of palatable herbage of acceptable nutritive quality. Other factors like rugged terrain and increased energy costs could be affecting more AV steers compared to AM breed (Morris & Wilton, 1976).

With the exception of the first study year (2011), BW gains were reduced from the first to the second half of the grazing season. The nutritive quality of the main forages hardly changed, so the lowered performances from August onwards were primarily due to the reduced herbage availability, which limited intake. This is supported by the positive correlations found between grassland sward height and steers' BW gain for both breeds. The positive relationship between grassland sward height and cattle performance has been previously observed (*e.g*. Wright & Whyte, 1989; Morris *et al*., 1993; Realini *et al*., 1999). Even the exception of 2011 could be explained by the lowest sward height observed from June to August in that year (7.2 cm), reverted to be the highest from August to late September (4.6 cm) among the four study years, thereby implying a less severe restriction in herbage intake during the second half of the grazing season compared to the following years.

The lower performance of AV steers during the second half of the grazing season (with BW losses in three of the four years) indicates their worse suitability to graze short pastures than AM steers. This supports the hypothesis that smaller animal species, breeds or individuals can thrive better under conditions of scarce food availability because of their higher ability to graze on short swards and lower total energy demands (Morris & Wilton, 1976; Illius & Gordon, 1987; Wright *et al*., 1994). Previous studies in the same and nearby summer pastures as in the present study observed that AM cows had more favourable BW changes than AV cows when grazing on short grasslands with mean sward heights below 4 cm (Osoro *et al*., 1999). However, other studies in mountain pastures did not find significant differences between cattle breeds in animal performance, whereas pasture type had a great influence (Casasús *et al*., 2002; Fraser *et al*., 2009a). These contrasting results depend on the particular breeds (namely the extent of between-breed differences in adult body size) and the type of pasture studied.

Regardless of between-breed differences, steer productive performance in these summer pastures was relatively low compared to what can be achieved in lowland grasslands with milder climate (unpublished data). The great interannual variability observed reflects the dependence of this type of animal production on climatic factors that affect animal welfare and performance directly or indirectly through available pasture characteristics. However, it is noteworthy that the steers from the current study showed a compensatory growth once they returned to lowlands, achieving greater BW gains and similar final yields at slaughter compared to steers managed at lowlands (Román-Trufero *et al*., 2015).

In conclusion, summer pastures could be utilized to produce steers in a sustainable way, provided that their BW gains are not too much reduced late in the season due to the usual shortage of quality herbage. Yearling steers could be returned to lowlands a few weeks before (*e.g*. towards the beginning of September depending on weather and pasture conditions) to alleviate the slowdown of their growth. Yearling steers from AM breed showed a better ability to graze heterogeneous Cantabrian summer pastures than their AV counterparts as a result of their smaller body size and greater rusticity. Besides the higher performance, AM steers could favour a more homogeneous utilization of available pasture resources.

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References

Aldezabal A, Garin I, García-González R, 1999. Activity rhythms and the influence of some environmental variables on summer ungulate behaviour in Ordesa-Monte Perdido National Park. Pirineos 153-154: 145-157. https://doi.org/10.3989/pirineos.1999.v153-154.110

AOAC, 2006. Official methods of analysis, 18th ed. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Bailey DW, Dumont B, WallisDeVries MF, 1998. Utilization of heterogeneous grasslands by domestic herbivores: Theory to management. Ann Zootech 47: 321-333. https://doi.org/10.1051/animres:19980501

Barthram GT, 1986. Experimental techniques: the HFRO swardstick. In: The Hill Farming Research Organisation biennial report 1984-85. pp: 29-30. HFRO, Penicuik, UK.

Cañón J, Gutiérrez JP, Dunner S, Goyache F, Vallejo M, 1994. Herdbook analyses of the Asturiana beef cattle breeds. Genet Sel Evol 26: 65-75. https://doi.org/10.1186/1297-9686-26-1-65

Casasús I, Sanz A, Villalba D, Ferrer R, Revilla R, 2002. Factors affecting animal performance during the grazing season in a mountain cattle production system. J Anim Sci 80: 1638-1651. https://doi.org/10.2527/2002.8061638x

Celaya R, Benavides R, García U, Ferreira LMM, Ferre I, Martínez A, Ortega-Mora LM, Osoro K, 2008. Grazing behaviour and performance of lactating suckler cows, ewes and goats on partially improved heathlands. Animal 12: 1818-1831. https://doi.org/10.1017/S1751731108003224

Dove H, Mayes RW, 1991. The use of plant wax alkanes as markers substances in studies of the nutrition of herbivores: a review. Aust J Agric Res 42: 913-957. https://doi.org/10.1071/AR9910913

Dove H, Moore AD, 1995. Using a least-squares optimization procedure to estimate botanical composition based on the alkanes of plant cuticular wax. Aust J Agric Res 46: 1535-1544. https://doi.org/10.1071/AR9951535

Dove H, Mayes RW, 2006. Protocol for the analysis of *n*-alkanes and other plant-wax compounds and for their use as markers for quantifying the nutrient supply of large mammalian herbivores. Nat Protoc 1: 1680-1697. https://doi.org/10.1038/nprot.2006.225

Dumont B, Rook AJ, Coran C, Röver K, 2007. Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 2. Diet selection. Grass Forage Sci 62: 159-171. https://doi.org/10.1111/j.1365-2494.2007.00572.x

EC, 2009. Commission Regulation (EC) No 1200/2009 implementing Regulation (EC) No 1166/2008 of the European Parliament and of the Council on farm structure surveys and the survey on agricultural production methods, as regards livestock unit coefficients and definitions of the characteristics. 30 November 2009. Official Journal L 329: 15.12.2009, 1-28.

EC, 2010. Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes. 22 September 2010. Official Journal L 276: 20.10.2010, 33-79.

Erlinger LL, Tolleson DR, Brown CJ, 1990. Comparison of bite size, biting rate and grazing time of beef heifers from herds distinguished by mature size and rate of maturity. J Anim Sci 68: 3578-3587. https://doi.org/10.2527/1990.68113578x

Ferreira LMM, Garcia U, Rodrigues MAM, Celaya R, Dias-da-Silva A, Osoro K, 2007. The application of the *n*-alkane technique for estimating the composition of diets consumed by equines and cattle feeding on upland vegetation communities. Anim Feed Sci Technol 138: 47-60. https://doi.org/10.1016/j.anifeedsci.2006.11.007

Ferreira LMM, Celaya R, Benavides R, Jáuregui BM, García U, Santos AS, Rosa-García R, Rodrigues MAM, Osoro K, 2013. Foraging behaviour of domestic herbivore species grazing on heathlands associated with improved pasture areas. Livest Sci 155: 373-383. https://doi.org/10.1016/j.livsci.2013.05.007

Ferrer Cazcarra R, Petit M, D'Hour P, 1995. The effect of sward height on grazing behaviour and herbage intake of three sizes of Charolais cattle grazing cocksfoot (*Dactylis glomerata*) swards. Anim Sci 61: 511-518. https://doi.org/10.1017/S1357729800014089

Fraser MD, Davies DA, Vale JE, Nute GR, Hallett KG, Richardson RI, Wright IA, 2009a. Performance and meat quality of native and continental cross steers grazing improved upland pasture or semi-natural rough grazing. Livest Sci 123: 70-82. https://doi.org/10.1016/j.livsci.2008.10.008

Fraser MD, Theobald VJ, Griffiths JB, Morris SM, Moorby JM, 2009b. Comparative diet selection by cattle and sheep grazing two contrasting heathland communities. Agric Ecosyst Environ 129: 182-192. https://doi.org/10.1016/j.agee.2008.08.013

Funston RN, Kress DD, Havstad KM, Doornbos DE, 1991. Grazing behavior of rangeland beef cattle differing in biological type. J Anim Sci 69: 1435-1442. https://doi.org/10.2527/1991.6941435x

Gary LA, Sherritt GW, Hale EB, 1970. Behavior of Charolais cattle on pasture. J Anim Sci 30: 203-206. https://doi.org/10.2527/jas1970.302203x

González Díaz JA, Celaya R, Fernández García F, Osoro K, Rosa García R, 2019. Dynamics of rural landscapes in marginal areas of northern Spain: Past, present, and future. Land Degrad Dev 30: 141-150. https://doi.org/10.1002/ldr.3201

Gordon IJ, 1989. Vegetation community selection by ungulates on the isle of Rhum. II. Vegetation community selection. J Appl Ecol 26: 53-64. https://doi.org/10.2307/2403650

Grant SA, 1981. Sward components. In: Sward measurement handbook; Hodgson J, Baker RD, Davies A, Laidlaw AS, Leaver JD (eds). pp: 71-92. Br Grassl Soc, Hurley, UK.

Grant SA, Torvell L, Smith HK, Suckling DE, Forbes TDA, Hodgson J, 1987. Comparative studies of diet selection by sheep and cattle: blanket bog ant heather moor. J Ecol 75: 947-960. https://doi.org/10.2307/2260306

Hessle A, Rutter M, Wallin K, 2008. Effect of breed, season and pasture moisture gradient on foraging behaviour in cattle on semi-natural grasslands. Appl Anim Behav Sci 111: 108-119. https://doi.org/10.1016/j.applanim.2007.05.017

Hodgson J (ed), 1990. Grazing management: science into practice. John Wiley Longman, NY.

Illius AW, Gordon IJ, 1987. The allometry of food intake in grazing ruminants. J Anim Ecol 56: 989-999. https://doi.org/10.2307/4961

Liechti K, Biber JP, 2016. Pastoralism in Europe: characteristics and challenges of highland–lowland transhumance. Rev Sci Tech Int Off Epiz 35: 561-575. https://doi.org/10.20506/rst.35.2.2541

Linnane MI, Brereton AJ, Giller PS, 2001. Seasonal changes in circadian grazing patterns of Kerry cows (*Bos Taurus*) in semi-feral conditions in Killarney National Park, Co. Kerry, Ireland. Appl Anim Behav Sci 71: 277-292. https://doi.org/10.1016/S0168-1591(00)00188-X

Mandaluniz N, Aldezabal A, Oregui LM, 2011. Diet selection of beef cattle on Atlantic grassland-heathland mosaic: Are heathers more preferred than expected? Livest Sci 138: 49-55. https://doi.org/10.1016/j.livsci.2010.12.002

Mertens DR, 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. J AOAC Int 85: 1217-1240.

Morris CA, Wilton W, 1976. Influence of body size on the biological efficiency of cows: A review. Can J Anim Sci 56: 613-647. https://doi.org/10.4141/cjas76-076

Morris ST, Hirschberg SW, Michel A, Parker WJ, McCutcheon SN, 1993. Herbage intake and liveweight gain of bulls and steers continuously stocked at fixed sward heights during autumn and spring. Grass Forage Sci 48: 109-117. https://doi.org/10.1111/j.1365-2494.1993.tb01843.x

Osoro K, Fernández-Prieto E, Celaya R, Noval G, Alonso L, Castro P, 1999. Respuesta productiva de dos razas de ganado vacuno manejadas en dos cubiertas vegetales de montaña. ITEA-Inf Tecn Econ Agr 95A: 188-203.

Osoro K, Celaya R, Martínez A, Zorita E, 2000. Pastoreo de las comunidades vegetales de montaña por rumiantes domésticos: producción animal y dinámica vegetal. Pastos 30: 3-50.

Putman RJ, Pratt RM, Ekins JR, Edwards PJ, 1987. Food and feeding behaviour of cattle and ponies in the New Forest, Hampshire. J Appl Ecol 24: 369-380. https://doi.org/10.2307/2403881

Realini CE, Hodgson J, Morris ST, Purchas RW, 1999. Effect of sward surface height on herbage intake and performance of finishing beef cattle. N Z J Agric Res 42: 155-164. https://doi.org/10.1080/00288233.1999.9513365

Robertson JB, Van Soest PJ, 1981. The detergent system of analysis. In: The analysis of dietary fibre in food; James WPT, Theander O (eds). pp: 123-158. Marcel Dekker, NY.

Rodríguez-Ortega T, Oteros-Rozas E, Ripoll-Bosch R, Tichit M, Martín-López B, Bernués A, 2014. Applying the ecosystem services framework to pasture-based livestock farming systems in Europe. Animal 8: 1361-1372. https://doi.org/10.1017/S1751731114000421

Román-Trufero A, Celaya R, Martínez A, García-Prieto V, Osoro K, 2015. Rendimientos productivos de terneros cebones de razas asturianas bajo dos estrategias de manejo. XVI Jornadas sobre Producción Animal, Zaragoza (Spain), May 19-20. pp: 33-35.

Rook AJ, Dumont B, Isselstein J, Osoro K, WallisDeVries MF, Parente G, Mills J, 2004. Matching type of livestock to desired biodiversity outcomes in pastures – a review. Biol Conserv 119: 137-150. https://doi.org/10.1016/j.biocon.2003.11.010

Sæther NH, Sickel H, Norderhaug A, Sickel M, Vangen O, 2006. Plant and vegetation preferences for a high and moderate yielding Norwegian dairy cattle breed grazing semi-natural mountain pastures. Anim Res 55: 367-387. https://doi.org/10.1051/animres:2006033

Vieira C, Cerdeño A, Serrano E, Lavín P, Mantecón AR, 2007. Breed and ageing extent on carcass and meat quality of beef from adult steers (oxen). Livest Sci 107: 62-69. https://doi.org/10.1016/j.livsci.2006.09.004

Winder JA, Walker DA, Bailey CC, 1996. Effect of breed on botanical composition of cattle diets on Chihuahuan desert. J Range Manage 49: 209-214. https://doi.org/10.2307/4002880

Wright IA, Whyte TK, 1989. Effects of sward surface height on the performance of continuously stocked spring-calving beef cows and their calves. Grass Forage Sci 44: 259-266. https://doi.org/10.1111/j.1365-2494.1989.tb02163.x

Wright IA, Jones JR, Maxwell TJ, Russel AJF, Hunter EA, 1994. The effect of genotype × environment interactions on biological efficiency in beef cows. Anim Prod 58: 197-207. https://doi.org/10.1017/S1357729800042508