Feed sorting behavior and performance of Argentinian Creole, Braford and crossbred steers during the growing and fattening phases

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ABSTRACT

Local Latin American cattle breeds are considered highly adapted to grazing systems in harsh environments, but their potential in more intensified beef production systems, particularly when compared to imported breeds, is still a matter of debate. Argentinian Creole (CRA), Braford (BRA) and Creole x Braford (CXB) steers were evaluated in the growing (Experiment 1) and fattening phases (Experiment 2). In Experiment 1, 12 animals from each genetic group were allocated after weaning to four pens and fed a total mixed ration for 57 days. In Experiment 2, six 17-month old steers of each genetic group were allocated each to a single pen and fed a high concentrate diet for 55 days. Several traits associated with animal performance, feed intake and feed sorting were recorded. Experiment 1: CRA had lower daily weight gain than the other two groups (P<0.01) and also lower feed conversion ratio than BRA (P<0.01). BRA tended to sort against long particles (> 19 mm, BRA < CXB, P = 0.03) preferring short particles (4 - 8 mm, BRA > CRA = CXB, P = 0.06). Experiment 2: CRA had lower initial body weight (P < 0.01) and the difference with BRA was maintained at the end of the experiment (P<0.01). CRA had lower initial and final back fat thickness (P < 0.01) but initial and final rib eye area did not differ among groups. Feed sorting was similar among groups (P≥0.21). Considered overall, CRA steers performed poorly compared to BRA and CXB under unrestricted feeding in both experiments.

Keywords: Beef cattle, native breeds, crossbreeding, nutrition, growth, feed intake.

RESUMEN

Las razas autóctonas latinoamericanas se consideran muy adaptadas a sistemas pastoriles en ambientes adversos. Sin embargo, su real potencial de producción en sistemas más intensificados y en particular en comparación con razas exóticas introducidas es todavía tema de debate. Se evaluó el desempeño de los novillos Criollo Argentino (CRA), Braford (BRA) y Criollo x Braford (CXB) en las etapas de crecimiento y engorde intensivo (Experimento 1 y Experimento 2, respectivamente). En el Experimento 1, 12 animales de cada grupo genético se asignaron a cuatro corrales y se alimentaron con una ración totalmente mezclada durante 57 días. En el Experimento 2, seis novillos de 17 meses de edad de cada grupo genético se alojaron en corrales individuales y se alimentaron con una dieta concentrada durante 55 días. Se evaluó el comportamiento productivo y la selección de dieta. Experimento 1: CRA tuvo una ganancia diaria de peso más baja que los otros dos grupos (P <0.01) y su conversión (kg/kg) fue menor que BRA (P<0.01). Se observaron diferencias para seleccionar partículas largas (>19 mm, BRA<CXB, P=0.03) y una tendencia para seleccionar partículas cortas (4-8 mm, BRA>CRA y CXB, P=0.06). Experimento 2: el peso vivo inicial de CRA fue más bajo que en BRA y CXB (P<0.01) y la diferencia con BRA también fue significativa al final del experimento

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(P<0.01). CRA tuvo menor espesor de grasa dorsal (P<0.01). El área inicial y final del ojo de bife fue similar entre grupos en ambos experimentos. La clasificación de las partículas en alimento fue similar entre grupos (P≥0.21). Todos los resultados sugieren que CRA tuvo un desempeño productivo inferior a BRA y CXB en ambos experimentos.

Palabras clave: *bovinos para carne, razas autóctonas, cruzamientos, crecimiento, alimentación, consumo.*

INTRODUCTION

The advantage of imported versus locally adapted breeds for beef production in harsh environments has been a matter of debate for a long time, and it is still a controversial issue in Latin American countries. Among the breeds that have become popular among farmers from semi-arid regions in Argentina, the Argentinian Creole is the only recognized autochthonous breed, which originated from cattle brought to America by Spaniards in the XV century (Anderson *et al*., 2015). One of the breeds that have been introduced to improve beef production in semi-arid regions is Braford (a composite 5/8 Hereford -3/8 Brahman). In the semi-arid regions from the Northwestern area of Argentina, crosses between these breeds are also produced when Creole sires are mated with 15-month old Braford heifers to avoid calving problems in heifers (Anderson *et al*., 2015).

Together with the initiatives that aim for the conservation of genetic resources, there is also ongoing research to assess the potential contribution of local breeds to the improvement of beef production. A recent study has shown that Argentinian Creole cows have a higher ability to modify their grazing patterns throughout the year, adjusting their exploration strategy in response to seasonal changes in forage availability and nutritional value (Herrera Conegliano, 2018). Also, the Creole would be able to harvest forage with higher digestibility and protein content than a British breed (Angus) when grazing natural grasslands, particularly with low forage availability (Miñón *et al*., 1984 a; b).

Despite the potential advantages of the Creole in cow-calf operations under extensive production systems, studies conducted to characterize the productivity of grazing Creole steers showed that they had lower average daily weight gain and also produced lighter carcasses with less fat than British breeds and their crosses (Moralejo *et al*., 2003; Orellana *et al*., 2009). To the best of our knowledge, there are no experimental results evaluating Argentinian Creole steers in the post-weaning phase without restrictions in feed availability or in the fattening phase when fed a high-energy diet. Also, little is known about feed sorting strategies in Creole and their potential effects on beef productivity. Different adaptive strategies between Creole and Braford, which include feed sorting, could justify differences in productive performance in more intensified beef production systems. Therefore, the aim of this study was to evaluate feed intake, feed sorting behavior and productive performance of Creole, Braford and Creole x Braford steers fed high energy diets during the growing and fattening phases.

Composition	Growing	Fattening
Dry matter (%)	49.8	57.5
Crude protein (% DM)	14.0	14.0
Metabolizable energy (Mcal kg DM^{-1})	2.4	2.8
Ingredient composition (% DM)		
Corn silage	63.8	28.8
Grounded corn grain	17.5	34.3
Whole corn grain	-	23.0
Soybean meal	17.5	-
Sunflower meal	-	12.2
Urea	-	0.5
Mineral supplement^{A}	1.2	1.2
Particle size (% DM)		
Long (>19.0 mm)	6.1	2.5
Medium (8.0 ≤ x <19.0 mm)	50.8	46.2
Short (4 ≤ x < 8.0 mm)	13.1	17.0
Fine (< 4.0 mm)	30.0	34.3

Table 1. Chemical composition and particle size (%) of diets offered to Creole, Braford and Creole x Braford steers during the growing and fattening phases.

DM: dry matter; ^{A} Composition of mineral supplement: vit A: 105000UI, vit D3: 2100UI; Vit E: 140 UI; calcium: 26%; chloride: 8%; sodium: 5.10%; iron: 2156 ppm; Zinc: 1,856 ppm; magnesium: 1,512 ppm; copper: 420 ppm; monensin: 1,400 ppm; iodine: 20.7 ppm; selenium: 9.24 ppm; cobalt: 4.7ppm.

MATERIALS AND METHODS

The study was conducted at the Animal Research Institute of the Semiarid Chaco (“Instituto de Investigación Agropecuaria del Chaco Semiárido”, Leales, Tucumán, Argentina; 27.2º S, 65.3º W). The animals were handled in accordance with regulations for animal welfare of the National Institute for Agricultural Technology (INTA).

Experiment 1. Growing phase

Twelve steers of the following genetic groups: Braford (BRA), Creole (CRA) and Creole x Braford (CXB) were used in this experiment. Dams and calves grazed on native grasslands and implanted *Chloris gayana* pastures. After weaning, the calves were kept on *Chloris gayana* pastures. At the beginning of the experiment (mean age = 9.4 ± 0.64 mo.) the steers were randomly allocated to semi-covered pens equipped with feeders and waterers (4 pens of 64 m^2 for each genetic group with three steers/pens). After an adaptation period of 15 d to the new environment and diet (table 1), the steers were evaluated for an experimental period of 57 d.

Experiment 2. Fattening phase

Six steers of each genetic group (BRA, CRA and CXB) were selected at random from a group of grazing steers supplemented with grounded maize grain and soybean meal (50/50, at 1.2% live weight) when they were approximately 17 months of age. The steers were randomly allocated to single pens and they had an adaptation period, as described for Experiment 1. A high energy diet (table 1) was offered *ad libitum* for 55 d. To facilitate the expression of different feed sorting strategies among genetic groups, a mixed ration composed by whole and grounded maize grain, sunflower meal and a mineral supplement was top-dressed on whole crop maize silage (i.e., ration was not mixed).

Dry matter intake, body weight and ultrasound measurements

In both experiments, feed was delivered once daily (07.30 - 08.30 AM) on an *ad libitum* basis. Offered and refused feed was recorded daily in order to estimate feed intake. Feedstuffs were dried at 60ºC for 24 h.

In the last 15 days of each experiment, feed samples were collected every three days to analyze feed sorting. The amount of feed at 0 and 24 h post-delivery (offered and refused, respectively) was recorded and sampled in five different points of the feed bunk to ensure an accurate representation of the diet. Care was taken that each grab sample represented the top, middle, and bottom sections of the feed along the feed bunk. Concurrent with feed sampling, fecal samples from each steer were collected by grab sampling along the day. All samples were frozen at - 20ºC for subsequent analysis.

Live body weight (LW) was recorded every 21 days (08.30 - 09.30 AM) before feeding. Individual average daily gain (ADG) was estimated by linear regression. Feed conversion was estimated as the ratio between daily feed intake and ADG.

On days 0 and 57 of Experiment 1 and days 0 and 55 of Experiment 2, the steers were scanned with a Pie Medical Aquila ultrasound instrument (Esaote Vet, Maastricht, Netherlands) equipped with an 18-cm, 3.5MHz linear array transducer. The ultrasound rib eye area (ULMA) and subcutaneous back fat thickness (USFT) were measured on the *Longissimus thoracis* muscle between the 12th and 13th ribs.

Particle size analysis and sorting behavior

Feedstuffs collected at 0 and 24 h were thawed and particle size separation was performed with a three-screen separator to obtain four different fractions: a) long (> 19.0 mm), b) medium (8.0 ≤ x <19.0 mm), c) short (4 ≤ x < 8.0 mm) and d) fine (< 4.0 mm; Heinrichs, 2013). After separation, dry matter (DM) of each fraction was determined by oven-drying at 60 °C for 48 h. Particle size distribution (%) was calculated on a DM basis by dividing the weight of each dried fraction by the total weight of the dried sample. After drying, neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined for each food fraction offered in Experiment 2 in an Ankom 200 fiber extractor (Ankom Technologies, Fairport, NY, USA) according to Van Soest *et al*. (1991). Also, crude protein (CP) concentration was determined in samples with the combustion method in a Leco FP-2000 N analyzer (Leco Corp., St. Joseph, MI, USA).

Crude protein, NDF and ADF intake were calculated according to the actual intake of each fraction, as the difference between the amount of each fraction in the offered feed and that in the refused feed. Sorting behavior was calculated as the actual total dry matter intake (DMI) of each fraction size expressed as a percentage of the predicted DMI, where predicted intake of each fraction was equal to the product of DMI and fraction in the offered diet, also expressed on a DM basis. The three possible outcomes are: < 100%, = 100% and > 100%, which indicate selective refusals, no sorting and preferential consumption, respectively (Leonardi and Armentano, 2003).

Particle size and corn kernels in faeces

The particle size in faeces was determined following the procedure of Leiber *et al*. (2015) with modifications. Briefly, a 100 g sub-sample of thawed faeces were sieved through three vertically arranged wire-mesh screens (diameter = 20 cm) with pore sizes of 4.0 mm, 2.0 mm and 1.0 mm, respectively. The material retained in each screen was oven dried, and the percentage of each was calculated. The fractions evaluated in faeces were a) long particles (LPF, >4 mm); b) medium particles (MPF, 2.0 mm ≤ x <4.0 mm); c) short particles (SPF, 1.0 mm ≤ x < 2.0 mm), and d) fine particles (FPF, <1 mm). A second sub-sample of 50 g was dried at 60 °C for 48 h to determine dry matter of the original material.

In Experiment 2, a third sub-sample (250 g) was wet-sieved and grain particles retained on a 4.0-mm screen were collected. The corn grains retained in the screen were classified in two categories: whole kernels (no visible damage to the pericarp) and damaged kernels (pericarp damaged but kernel intact or kernel fractured into pieces; Beauchemin *et al*. 1994). Subsequently, the separated corn kernels were dried for 48 hours at 60°C. The percentages of both whole and damaged recovered grains were calculated considering the total dry matter in faeces.

Statistical analysis

All the data were analyzed in a completely randomized design including the genetic group as a fixed effect. The pen was the experimental unit, with n = 4 and n = 6 for growing and fattening phases, respectively. For individually recorded traits in Experiment 1, each steer in a pen was considered a sub-sample. Significant differences were found between diets by using α = 0.05; differences with 0.05 < α < 0.10 were considered suggestive. When ANOVA showed significant differences (P<0.05), Tukey multiple comparison tests were performed.

RESULTS

Experiment 1. Growing phase

Animal performance

No significant differences were detected in initial and final body weights (P = 0.51 and P = 0.15, respectively) among genetic groups in the growing phase (table 2). However, average daily gain was lower in CRA than in the other two groups (P<0.01). Total dry matter intake (kg DM d^{-1}; P<0.01) differed among the three genetic groups being the highest in CXB and the lowest in BRA. However, when feed intake was expressed as a percentage of live body weight, it was higher in CRA and CXB than in BRA (P<0.01). The feed conversion ratio was significantly higher (less efficient) in CRA when compared to BRA (P<0.01). Both initial and final rib eye area and initial fat thickness were not different between genetic groups. However, final fat thickness was higher in the crossbreds (CXB) than in CRA (P = 0.02), whereas BRA did not differ with the other two groups.

	CRA	BRA	CXB	SEM	P
		Growing phase			
LW Initial (kg)	157	168	166	7.1	0.51
LW Final (kg)	215	238	238	2.4	0.15
ADG (kg d-1)	1.05a	1.22b	1.27b	0.03	**0.03**
DMI (kg d-1)	5.86b	5.49a	6.30c	0.09	**< 0.01**
DMI (%LW)	3.15b	2.71a	3.11b	0.05	**< 0.01**
FC (kg kg-1)	5.59b	4.51a	4.98ab	0.18	**< 0.01**
ULMA initial (cm2)	27.1	27.9	25.8	1.6	0.63
ULMA Final (cm2)	36.8	39.0	36.4	1.6	0.48
USFT Initial (mm)	2.4	2.4	2.4	0.1	0.99
USFT Final (mm)	3.4a	4.0 ab	4.3b	0.2	**0.02**
		Fattening phase			
LW Initial (kg)	322a	358b	344b	6.3	**<0.01**
LW Final (kg)	392a	433b	417ab	8.44	**0.01**
ADG (kg d-1)	0.90	1.08	1.03	0.09	0.41
Intake (kg d-1)					
DMI	10.23a	10.85ab	11.20b	0.25	**0.04**
CP	1.51	1.59	1.59	0.04	0.36
NDF	4.38	4.62	4.64	0.13	0.36
ADF	2.27	2.41	4.41	0.07	0.31
DMI (%LW)	2.86	2.74	2.95	0.07	0.12
FC (kg kg-1)	11.85	10.43	11.43	1.17	0.67
ULMA initial (cm2)	51.06	51.74	46.92	2.37	0.32
ULMA Final (cm2)	57.56ab	62.82b	54.29a	2.60	**0.09**
USFT Initial (mm)	4.1a	4.9b	5.5c	0.2	**<0.01**
USFT Final (mm)	4.5a	7.8b	7.5b	0.6	**<0.01**

Table 2. Productive traits and feed intake of Creole (CRA), Braford (BRA) and Creole x Braford (CXB) steers during the growing and fattening phases.

LW: live weight; ADG: average daily gain; DMI: dry matter intake; NDF: neutral detergent fiber;
ADF: acid detergent fiber; CP: Crude Protein; FC: feed conversion; ULMA: ultrasound rib eye area; USFT: ultrasound subcutaneous fat thickness.
a,b,c Values within a row with different superscripts differ significantly (P < 0.05). SEM: standard error of the mean.

Sorting behavior and particle size in faeces

Variability among groups in sorting behavior during the growing phase was detected through the differential intake of particles of different sizes. In the case of medium, short, and fine particles, the intake of the three genetic groups (kg d^{-1}) was CXB > CRA > BRA (P<0.01) (table 3). In the case of long particles, the only significant difference was that between CXB and BRA (P<0.01). The three genetic groups tended to sort against long particles (< 100%), and differences were statistically significant for CXB and BRA (P = 0.03); also a trend was observed in the preferential consumption of short particles (BRA > CRA and CXB; P = 0.06). Considered together, the results of the sorting behavior index (%) in this phase suggest that BRA would have a comparatively higher intake of smaller particles than the other two groups.

The fecal excretion of LPF (% dry matter) in CRA was below the other two groups (P < 0.01) (table 4). For MPF, BRA had a lower value than either CRA or CXB (P = 0.06). When LPF and MPF are considered together, these fractions represent approximately 48.5%, 45.9% and 52.0% of DM in faeces of of CRA, BRA and CBX, respectively. No effect of the genetic groups was detected for the other two size classes (SPF and FPF) (table 4).

Experiment 2. Fattening phase

Animal performance

The initial body weight of CRA steers in this phase was below CXB and BRA steers (P<0.01); and because there were no significant differences in ADG, final body weight showed similar variation (P = 0.01); BRA was heavier than CRA, and CXB was similar to the other two genetic groups (table 2). Dry matter intake of CRA was significantly lower only when compared to CXB (P = 0.04). No significant differences were detected for initial ULMA (P = 0.32). However, final ULMA tended to be higher in BRA (P = 0.09). Crossbred steers had the highest initial USFT compared to purebreds at the beginning of the experiment (P<0.01) but at the end of the fattening period BRA and CXB had similar USFT that was around 70% higher than in CRA (P<0.01).

Sorting behavior and particle size in faeces

In this phase, daily feed intake (kg d^{-1}) discriminated by particle size showed variation only in the case of long particles, with CXB above the other two groups (P < 0.01). However, no statistically significant differences in sorting behaviour were detected as statistically significant across the four particle size classes (table 3).

As for the proportion of particle sizes in faeces, only LPF tended to differ among genetic groups, with CRA above BRA (P = 0.09; table 4). Although the presence of both whole and damaged corn kernels tended to be lower in BRA than in the other two groups of steers, the differences did not reach statistical significance (table 4).

DISCUSSION AND CONCLUSIONS

Braford breed and its crossbred with CRA showed better productive performance than CRA during the growing phase. The higher dry matter intake of CRA and CXB was not directly associated with higher ADG, particularly in the pure breed, resulting in CRA steers with a poorer feed conversion ratio than BRA. These findings were previously reported when Creole was compared with other British breeds such as Angus cattle raised in grazing systems (Moralejo *et al*., 2003). Neither lean tissue accretion estimated by rib eye area measurement nor subcutaneous back fat thickness differed between BRA and CRA. Therefore, these are not a feasible explanation for animal productive performance in the growing phase. However, differences in the amount of fat stored in other body sites, e.g. omental fat, cannot be ruled out as a potential explanation for differences in feed conversion.

This study found creole steers began their fattening phase at a similar age to other breeds, but with lower body weight and less fat cover. These characteristics are more obvious when

	CRA	BRA	CXB	SEM	P
		Growing phase			
Fractions^{A}		Dry matter intake (kg)^{B}			
Long	0.31^{ab}	0.24^{a}	0.38^{b}	0.03	**.01**
Medium	3.47^{b}	3.23^{a}	3.67^{c}	0.05	**<0.01**
Short	0.92^{b}	0.86^{a}	0.96^{c}	0.01	**0.01**
Fine	2.18^{b}	2.00^{a}	2.23^{c}	0.01	**<0.01**
		Sorting behavior (%)^{C}			
Long	76.18^{ab}	64.54^{a}	89.66^{b}	5.76	**0.03**
Medium	99.32	100.35	99.76	0.49	0.36
Short	102.31^{a}	104.19^{b}	101.50^{a}	0.70	**0.06**
Fine	105.50	105.24	102.46	0.99	0.10
		Fattening phase			
		Dry matter intake (kg)^{B}			
Long	0.35^{a}	0.30^{a}	0.44^{b}	0.01	**0.01**
Medium	4.48	5.24	5.15	0.20	0.34
Short	2.02	2.12	2.02	0.04	0.23
Fine	3.99	4.16	4.21	0.13	0.46
		Sorting behavior (%)^{C}			
Long	102.99	101.70	105.81	4.42	0.80
Medium	96.05	95.93	97.46	1.87	0.80
Short	103.78	105.56	105.56	1.31	0.21
Fine	102.95	102.63	102.63	2.14	0.90

Table 3. Feed sorting behavior of Creole, Braford and Creole x Braford (CXB) steers during the growing and fattening phases.

[A] Long: >19.0 mm; Medium: 8.0 ≤ x <19.0 mm; Short: 4 ≤ x < 8.0 mm; Fine:< 4.0 mm.

[B] Dry matter intake measured during feed sample collection.

[C] 100% = no sorting; < 100% = selective refusal; > 100% = preferential consumption.

[a,b] Values within a row with different superscripts differ significantly (P<0.05). SEM: standard error of the mean.

	CRA	BRA	CXB	SEM	P
		Growing phase Dry matter (%)			
Fraction^{A}					
LPF	6.79^{a}	11.70^{b}	13.50^{b}	0.86	**< 0.01**
MPF	41.87^{b}	34.21^{a}	38.46^{b}	1.92	**0.06**
SPF	1.76	1.34	1.49	0.46	0.46
FPF	49.57	52.75	47.00	1.89	0.15
		Fattening phase Dry matter (%)			
LPF	26.33^{b}	19.41^{a}	23.92^{ab}	2.11	**0.09**
MPF	32.23	36.84	34.35	1.57	0.15
SPF	2.87	3.02	2.55	0.34	0.62
FPF	38.57	40.73	39.18	2.72	0.34
		Corn kernels (% DM)			
Whole (%)	14.38	11.60	15.15	2.32	0.53
Damaged (%)	3.44	2.76	3.25	0.61	0.71

Table 4. Particle fractions and corn kernels detected in faeces of Creole (CRA), Braford (BRA) and Creole x Braford (CXB) steers during the growing and fattening phases.

[A] LPF: Long, >4 mm; MPF: Medium, 2.0 mm ≤ x <4.0 mm; SPF: Small, 1.0 mm ≤ x < 2.0 mm; FPF: Fine, <1 mm.

[a,b] Values within a row with different superscripts differ significantly (P < 0.05). SEM: standard error of the mean.

steers come from grazing systems (Moralejo *et al*., 2003). In their fattening phase, the three genotypes had similar performance, unlike the results obtained in the growing phase when animals should have been more efficient due to the contribution to weight gain of lean tissue growth. The results in the fattening phase did not agree with those found under grazing conditions with supplementation, where Creole steers gained only ~300 g per day in the last 30 d of fattening (Moralejo *et al*., 2003). The initial differences in body weight and fat thickness, generated during a short period on pastures before starting the fattening phase, were maintained until the end of the experiment, despite the three genetic groups having similar ADG and FC in the fattening phase. This indicates a high-concentrate diet would be essential to counterbalance the lower productivity of CRA, but it was not enough to obtain a carcass from Creole steers with the same fat cover at the same age as the other genetic groups.

When cattle were fed with a total mixed ration, BRA tended to select for shorter feed particles than CRA, which may lead to differences in nutrient intake or ruminal fermentation. The quality of feed particles of different sizes was not analyzed in the growing phase, but small and fine fractions are supposed to have better quality than long and medium size fractions because they were composed mostly by grounded corn grain and soybean meal. Regardless of the nutritional value, particles < 8 mm length in feed have high relative surface area, which promotes rapid fermentation by ruminal bacteria (Leonardi *et al*., 2005; Clauss and Hummel, 2017).

The genetic groups did not show any differences in sorting behavior in the fattening phase, which is consistent with similar CP, NDF and ADF intakes as well as ADG. A possible explanation is that the top dressing of concentrate on whole-plant maize silage forces the animal to eat concentrate first. However, when the animal reaches silage at the bottom of the feed bunk, it sorts for silage to balance its diet. In this study, the refused feed was sampled 24 h after delivery; therefore, the sorting behavior that took place during the first hours after feed delivery could have passed undetected. DeVries and Von Keyserlingk (2009) observed that when feed is delivered as a top-dressing, concentrate is preferentially consumed during the period right after feed delivery, while in the last hours before a new delivery, forage is preferred. Therefore, when a high amount of concentrate was offered on top of the ration, slight feed sorting differences observed in the growing phase between genetic groups could have gone unnoticed.

Faecal particle size is an indicator of both degradation and passage rate in the rumen (Rustas *et al*., 2010) and is also related to DMI (Okine and Mathisson,1991). The proportion of particles of > 2.0 mm in cattle faeces increases linearly as DMI increases, while particles > 1 mm decreases (Okine and Mathisson,1991). CRA steers which showed the lower percentage of retained LPF (long particles) had an intermedium DMI during the growing phase, while both BRA and CXB had a similar proportion of LPF particles but differed in feed intake. Conversely, in the fattening phase, BRA showed a lower percentage of LPF in the fattening phase, but DMI was similar to the other two genotypes. The sum of fractions longer than 2 mm in faeces, i.e., LPF plus MPF (table 4), showed that in both phases studied, BRA had a lower proportion of this fraction than CRA, while particles in CXB behaved variably depending on the phase considered. These results indicate better particle reduction throughout the gastrointestinal tract in BRA when animals were mostly fed with a grain-based diet. In addition, DMI differences between genetic groups did not drive differences in particle size in faeces and other digestive processes, which may differ between genetic groups, and could be involved in particle size reduction in gastrointestinal tract and nutrients utilization.

Free-ranging Creole cattle could have developed grazing and browsing strategies to cope with a restrictive environment, but they do not provide a comparative advantage under more intensive conditions. Creole steers reared under intensive conditions or those reared under grazing systems and fattened in a feedlot have a poorer performance than other foreign breeds such as Braford.

Although a consistent advantage due to heterosis in crossbred steers was not noticed, they did outperform Creole in several traits. In this case, the relative performance of crossbred versus purebred steers is biased due to potential maternal effects, given that the reciprocal cross was not evaluated. Future experiments should include crossbred steers sired by Braford bulls in order to confirm the combining ability and ultimately the convenience of this particular cross between Creole and Braford.

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REFERENCES

ANDERSON, D. M.; ESTELL, R. E.; GONZALEZ, A. L.; CIBILS, A. F.; TORELL, L. A. 2015. Criollo cattle: Heritage genetics for arid landscapes. Rangelands. 37: 62-67. doi. 10.1016/j.rala.2015.01.006

BEAUCHEMIN, K.A.; MCALLISTER, T.A.; DONG, Y.; FARR, B.I.; CHENG, K.J. 1994. Effects of mastication on digestion of whole cereal grains by cattle. J. Anim. Sci. 72: 36-246. doi. 10.2527/1994.721236x

CLAUSS, M.; HUMMEL, J. 2017. Physiological adaptations of ruminants and their potential relevance for production systems. Rev. Bras. Zootec. 46: 606-613. doi. 10.1590/s1806-92902017000700008

DEVRIES, T.J.; VON KEYSERLINGK, M.A.G. 2009. Feeding method affects the feeding behavior of growing dairy heifers. J. Dairy Sci. 92: 1161-1168. doi. 10.3168/jds.2008-1314

HEINRICHS, J. 2013. The Penn State Particle Separator. (Available at https://extension.psu .edu/penn-state-particle-separator#section-1 verified: 3 July 2018).

HERRERA CONEGLIANO, O.A. 2018. Comportamiento en pastoreo del ganado bovino Criollo Argentino y Aberdeen Angus ecotipo riojano, en pastizales naturales del Chaco Árido. Tesis Magister en Producción Animal. Facultad de Ciencias Agrarias, Universidad Nacional de Mar del Plata, Balcarce, Argentina. 79 p.

LEIBER, F.; IVEMEYER, S.; PERLER, E.; KRENMAYR, I.; MAYER, P.; WALKENHORST, M. 2015. Determination of feces particle proportions as a tool for the evaluation of the influence of feeding strategies on fiber digestion in dairy cows. J. Anim. Plant Sci. 25: 153-159.

LEONARDI, C.; ARMENTANO, L.E. 2003. Effect of quantity, quality, and length of alfalfa hay on selective consumption by dairy cows. J. Dairy Sci. 86: 557-564.

LEONARDI, C.; GIANNICO, F.; ARMENTANO, L.E. 2005. Effect of water addition on selective consumption (sorting) of dry diets by dairy cattle. J. Dairy Sci. 88: 1043-1049.

MIÑÓN, D.P.; CAUHEPÉ, M.A.; LORENZO, M.S.; COLOMBO, I.; BRIZUELA, M.A.; MIQUEL, M.C. 1984a. Análisis comparativo de las dietas de dos razas vacunas en un pastizal de la depresión del Salado (Buenos Aires). I-Composición botánica del alimento. Rev. Arg. Prod. Anim. 4: 789-801.

MIÑÓN, D.P.; CAUHEPÉ, M.A.; LORENZO, M.S.; COLOMBO, I.; BRIZUELA, M.A.; MIQUEL, M.C. 1984b. Análisis comparativo de las dietas de dos razas vacunas en un pastizal de la depresión del Salado (Buenos Aires). II-Composición química del alimento. Rev. Arg. Prod. Anim. 4: 803-814.

MORALEJO, R.; PEÑA BLANCO, F.; GARCÍA MARTÍNEZ, A.; MARTOS PEINADO, J.; ACERO DE LA CRUZ, R.; DOMENECH GARCÍA, V. 2003. Evaluación productiva de terneros Aberdeen Angus y criollo argentino en dos sistemas de alimentación en el nordeste de la pampa argentina. Archiv. Zoot. 52: 327-337.

OKINE, E.K.; MATHISON, G.W. 1991. Effects of feed intake on particle distribution, passage of digesta, and extent of digestion in the gastrointestinal tract of cattle. J. Anim. Sci. 69: 3435-3445. doi. 10.2527/1991.6983435x

ORELLANA, C.; PEÑA BLANCO, F.; GARCÍA, A.; PEREA, J.; MARTOS, J.; DOMENECH, V.; ACERO DE LA CRUZ, R. 2009. Carcass characteristics, fatty acid composition, and meat quality of Criollo Argentino and Braford steers raised on forage in a semi-tropical region of Argentina. Meat Science 81: 57-64. doi.10.1016/j.meatsci.2008.06.015

RUSTAS, B.O.; NØRGAARD, P.; JALALI, A.R.; NADEAU, E. 2010. Effects of physical form and stage of maturity at harvest of whole-crop barley silage on intake, chewing activity, diet selection and faecal particle size of dairy steers. Anim 4: 67-75. doi. 10.1017/S1751731109990887

VAN SOEST, P.J.; ROBERTSON, J.B.; LEWIS, B.A. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci.74: 3583- 3597. doi. 10.3168/jds.S0022-0302(91)78551-2