**Text

Description automatically generated with low confidence Latin American Archives of Animal Production. 2021. 29 (3-4)**

**Preliminary analysis of growth, carcass and meat quality of Criollo  
Uruguayan steers compared to Hereford steers.**

Eileen Armstrong[[1]](#footnote-1) [g©](mailto:eileen.armstrong@gmail.com)Danilo Fila [-g](mailto:danilofila@gmail.com)  [©](https://orcid.org/0000-0003-4842-7428) Juan Carlos Boggio [El](mailto:jcbrepro@gmail.com) [Rafael](https://orcid.org/0000-0001-9748-001X)Aragunde [-](mailto:proyectoaragunde@gmail.com) [-](https://orcid.org/0000-0002-7746-4917) Felipe Saravia [- -](mailto:felipesaravia1414@gmail.com)

Agustín Isaurralde [E](mailto:agustin.isaurralde.7@gmail.com) Rody Artigas [-](mailto:rodyartigas@gmail.com)  [© Fernando](https://orcid.org/0000-0002-9173-5752)Vila [g](mailto:fervilahill@gmail.com) Santiago Luzardo[[2]](#footnote-2) [E](mailto:sluzardo@inia.org.uy) Gustavo Brito2 [E](mailto:gbrito@inia.org.uy)  [©](https://orcid.org/0000-0002-7029-1574) Gerardo Evia[[3]](#footnote-3) [E](mailto:gerardo.evia@probides.org.uy)

Gerardo Dattele[[4]](#footnote-4) [E](mailto:lodimm@yahoo.com.br)

Faculty of Veterinary Medicine, Universidad de la República, Montevideo, Uruguay

**Preliminary analysis of growth, carcass and meat quality traits in Uruguayan Creole Cattle steers in comparison  
with Hereford steers.**

**Abstract.** The Uruguayan Creole cattle (UCC) reserve herd consists of approximately 600 animals. UCC have shown high capability of adaptation to unfavorable environments. Thirty UCC steers were compared to 10 Hereford steers in growth performance, carcass and meat quality traits. All animals received the same sanitary and nutritional management (grazing in natural grasslands, without supplementation), from 6-9 months of age until the end of the trial. At 43 months of age a sample of 6 UCC and 6 Hereford steers was selected for carcass and meat evaluation. The increase in body weight (BW) was similar between the two breeds, but Hereford steers showed heavier BW (p < 0.05) at the beginning and at the end of the trial. Ultrasound measures of rib-eye area and fat thickness of UCC were larger (p < 0.05). Most of the carcass measures did not show significant differences, except pH which was lower in UCC (p < 0.05). Significant differences were observed in tissue composition of the 10th rib, showing higher muscle percentage and lower bone percentage in UCC (p < 0.05), while their Hereford counterparts showed a higher fat percentage (p = 0.05). No significant differences were observed between both breeds for meat quality traits. Hereford showed higher unsaturated fatty acids percentage (p < 0.05) while UCC exhibited higher levels of conjugated linoleic acid (p < 0.05). No differences in sensory traits were detected by the consumer taste panel. A larger sample is needed to obtain firm conclusions, but these results are promising and show a very good potential of UCC for beef production, in comparison with a highly selected meat breed.

**Key words:** Creole cattle; carcass quality; meat quality; beef production; genetic resources.

**Summary.** The Uruguayan Creole Cattle (BCU) reserve has approximately 600 individuals. These animals have demonstrated a high hardiness and ability to adapt to unfavorable environments. In this work, the growth and meat production capacity of Criollo steers (n = 30) was evaluated in comparison with Hereford steers (n = 10). All animals were raised in an extensive system (grazing on natural pasture, without supplementation), from 6-9 months (m) of age. At 43 months, a sample of 6 Criollo and 6 Hereford steers were selected for slaughter. The evolution of body weight was similar among genetic groups, although Hereford animals presented a live weight 18.5 % higher at the beginning of the experiment (p < 0.05) and 13.4 % higher at the end of the experiment (p < 0.05). In the ultrasound measurements, BCU presented greater beef eye area and dorsal fat thickness (p < 0.05). No significant differences were observed for most of the variables measured in the carcass, with the exception of pH which was lower in BCU (p < 0.05). In the dissection of the 10th rib BCU presented higher percentage of muscle and lower percentage of bone (p < 0.05), while Hereford presented higher percentage of visible fat (p = 0.05). Meat quality characteristics were similar between BCU and Hereford. Hereford presented a higher percentage of unsaturated fatty acids than Criollo, in which a higher percentage of conjugated linoleic acid was observed (p < 0.05). There were no significant differences at the consumer panel level. These results would indicate a very good potential of BCU for meat production, compared to a highly selected meat breed.

**Key words:** Uruguayan Criollo cattle; carcass quality; meat quality; meat production; genetic resources.

Received: 2020-10-30. Accepted: 2021-04-01.

Armstrong *et al*

**Introduction**

The genetic reserve of Uruguayan Creole Cattle (BCU) is located in the San Miguel National Park (Rocha Department; 33°41' South latitude, 53°27' West longitude) and currently has approximately 600 animals of various age and sex categories. The park has mountainous environments, native forest, wetlands and natural countryside. Within the park, the BCU reserve has about 800 hectares (ha), of which 350 ha are not very usable because they are mainly native forest and grasslands, leaving about 450 ha available for grazing.

Introduced to the country by Hernando Arias de Saavedra in 1611 and later through the Jesuit missions of Alto Uruguay, Criollo cattle have been adapted to our environment for four centuries. This foundational population spread throughout the country before the introduction of commercial breeds in the late 19th century. From that moment on, the BCU population began to decline and was considered an unproductive breed. In the 1940s and with 35 animals, the Criollo cattle reserve was created in San Miguel Park (Arredondo, 1958).

The BCU is recognized as a breed by the FAO ([http://www.fao.org/dad-is)](http://www.fao.org/dad-is) and is in the process of registration with the Rural Association of Uruguay. They are long and angular, medium-sized animals (420 kg for cows and 700 kg for bulls, on average), with a height at the withers of 120 cm and an average body length of 140 cm. They show marked sexual dimorphism and a great diversity of coats, with pigmented mucous membranes and hooves. Both sexes have lyre-shaped horns (Fernandez *et al*., 2001; Rodríguez *et al.*, 2001). Despite its small size, the BCU reserve has a high genetic diversity evaluated by microsatellites. The presence of uncommon mitochondrial haplotypes shared with Iberian breeds, in addition to others shared with other Criollo breeds, evidences its Iberian origin (Armstrong *et al.*, 2013; Ginja *et al.*, 2019). The animals in the reserve are not selected on the basis of any productive characteristic. Breeding is by natural mating, in the field, between December and March, and there are no records of paternity or birth dates at the time of the trial. Weaning takes place between 6 and 9 months of age.

There are very interesting experiences that show the high potential for meat production of other American Criollo breeds similar to the Uruguayan Criollo, such as the Criollo Argentino (Garriz *et al*., 2008; Holgado and Ortega, 2019). These studies emphasize their ability to adapt to unfavorable environments and to produce high quality meat. Until now, there were no studies at BCU on steer growth, carcass quality or meat quality.

This paper presents the results of an observational study to evaluate the meat production capacity of these animals under the environmental conditions in which the reserve is currently located. The hypothesis was that, under similar nutrition and management conditions, BCU would show production indexes similar to other common breeds in our environment. The objective of this study was to evaluate animal growth (average weight gain, steak eye area, backfat thickness) and to characterize aspects of carcass quality (length, yield, etc.) and meat quality (color, cut strength, fatty acid profile, among others) in the Longissimus dorsi muscle of Criollo steers compared to Hereford steers in the same environment.) and meat quality (color, cutting strength, fatty acid profile, among others) in the *Longissimus dorsi* muscle of Criollo steers compared to Hereford steers, in the same environment of the reserve, which presents seasonal forage restrictions. The data collected may be used in the future to generate a unique and marketable product.

**Materials and Methods**

**Animals and treatment.**

All the procedures performed with the animals from the beginning of the experiment until their transport to the refrigerator followed the protocols of the Comisión Honoraria de Experimentación Animal (CHEA) of the Universidad de la República del Uruguay ([www.chea.edu.uy)](http://www.chea.edu.uy). The procedures from the arrival of the animals at the commercial slaughterhouse were subject to the animal welfare protocols of the National Meat Institute (INAC) of Uruguay (Barros and Castro, 2004).

Within the facilities of the Army Park Service (SEPAE - San Miguel), 30 Criollo animals (6 to 9 months old) were placed together with 10 Hereford animals (8 to 9 months old), all castrated and weaned males, in the same paddock. Animals were randomly selected within their age group and by breed. The Hereford steers came from a field outside the San Miguel Park, with improved pastures that included ryegrass*(Lolium multiflorum*) and white clover*(Trifolium repens*), while the Criollos were born and always remained on

The reserve's native fields within the park, which have marked seasonal restrictions on food availability. During the trial, all animals received the same health and feeding management. Grazing was continuous, native field grazing, without supplementation, in a 30 hectare paddock (1.3 animals/hectare). The paddock had a vegetative layer of between 5 to 50 cm, depending on soil depth and time of year (lower in winter; higher in spring-summer), and a cover of between 80 to 100 %, mainly composed of herbaceous and shrubby plants of the *Poaceae(Gramineae*) and *Asteraceae (Compositae*) families. The most common species were the subshrub Baccharis trimera and the summer grasses *Paspalum plicatulum, Cynodon dactylon and Dichanthelium sabulorum* (Lezama and Rossado, 2012). Since San Miguel Park is part of the National System of Protected Areas, its environments cannot be modified with improved pastures. The average annual temperature in the area is 17.4 ºC and the average rainfall is 1,257 mm.

**Data collected** *in vivo***.**

Live weight and ultrasound parameters (area of eye of beef-AOB and thickness of dorsal fat-EG) of the animals were evaluated at the beginning of the trial and at 24, 36 and 43 months. For AOB, the cross-sectional area of the *Longissimus dorsi* muscle at the level of the 12th muscle was measured. intercostal space. EG was measured in the cross-section at the level of the 12th intercostal space, perpendicular to the external border of the fat and at the level of the fourth part of the distal end of the *Longissimus dorsi* muscle with respect to the spine. Both measurements were taken by ultrasound, using an Esaote MyLabOneVet portable ultrasound scanner with a SV3L11 Animal Sience 6-2 Mhz 180mm probe (Ferrario and Fernandez, 2007). This stage lasted from June 2016 to June 2019. The following calculations were performed on live weight measurements (in kg): total weight gain (final weight - initial weight), final weight corrected for initial weight (final weight/initial weight x 100), analysis of variance (ANOVA) using initial weight as a covariate, linear prediction of final weight intervals by breed, daily weight gain (total weight gain/1096 days of experiment) and analysis of variance of daily weight gain using initial weight as a covariate. The end of the trial was given by the moment when most of the steers reached an acceptable finishing grade for slaughtering, in order to avoid economic losses to the producers.

**Slaughter and** *post-mortem* **data collected.**

At the end of May 2019, six steers of each breed were selected for slaughter at a commercial slaughterhouse in the area, authorized for export to the European Union. The selection was made taking into account live weight and finishing grade by visual evaluation, according to the body condition scale validated by Vizcarra *et al.* (1986). The objective was to evaluate the carcass and meat quality parameters of the six heaviest and best finishing steers of each breed. These 12 animals were slaughtered on the same day (June 17, 2019) at a commercial slaughterhouse in the area, located 106 km away from the paddock where the steers were (10 km by country roads and 96 km by main national route). The total fasting time was approximately 15 hours. The animals departed in a truck suitable for transporting cattle at 5 PM, arriving at the slaughterhouse at 6:30 PM, remaining fasting until slaughter at 6 AM (approximate hours). The carcasses were placed in cold chambers at 4 ºC for 72 hours prior to measurements. At this stage, the pre-slaughter live weight, chilled carcass weight and morphometric measurements were recorded: carcass length, breast depth, leg length and leg circumference, according to Feed (2010). The data collected were used to calculate the carcass yield percentage (chilled carcass weight/live weight x 100) and the compactness index (chilled carcass weight/carcass length, in kg/cm). The pH of the carcass was measured 72 hours after maturation in a chamber at 4 ºC. For laboratory analysis, a sample of approximately 10 cm was extracted. The width of the Longissimus dorsi muscle of each animal (with subcutaneous fat, intermuscular and bone) between the 8th and the 8th and the 10th. The ribs were individually packed, labeled and frozen at -20 ºC until analysis.

**Data collected in laboratory.**

For the determination of the percentage of muscle, fat and bone, dissection of the tenth and tenth thighs was performed. rib (estimated recovery rate: 98 %) according to the methodology detailed by Feed (2010).

After 6 days of maturation (0-2 ºC), the instrumental color of the meat in each sample was determined using the CIELab system (L\*: lightness, a\*: green (-) to red (+) component; b\*: blue (-) to yellow (+) component) in triplicate (average of three readings per sample) and with an air exposure time (blooming) of 45 minutes. A colorimeter was used

[C) G6©](https://creativecommons.org/licenses/by-nc-sa/4.0/)

Minolta CR-400 (Konica Minolta Sensing Inc., Japan) using a C illuminant, a standard 2° observer and an aperture size of 8 mm. Samples were then weighed and cooked on grills (GRP100 The Next Grilleration, Spectrum Brands, Inc., Miami, FL) to an internal temperature of 71 °C according to the American Meat Science Association (AMSA, 2016) protocol. After firing and cooling, the samples were weighed again to determine the firing losses.

The shear force was then measured with a TA.XT Plus texturometer (Stable Micro Systems, Godalming, Surrey, UK) equipped with a Warner Bratzler shear (V-slot). From each cooked sample, 6 subsamples (1.27 cm diameter cylinders) were obtained parallel to the longitudinal orientation of the muscle fibers. The parameter recorded was the maximum shear strength of each sample. The 6 individual values of shear strength corresponding to each sample were averaged in order to obtain a single value per sample.

In a portion of the unripened sample (thawed at 4 ºC) the intramuscular fat content was determined gravimetrically. Lipid extraction was performed following the chloroform-methanol procedure according to the procedure of Bligh and Dyer (1959). The fatty acids were cold methylated with methanolic potash (IUPAC, 1987). A Konik HRGC 4000 B with a 100 m long capillary column (SP 2560, Supelco, Bellefonte, USA; 0.25 mm internal diameter, 0.20 m thick) was used for chromatographic analysis. The carrier gas used was nitrogen at a flow rate of 1 ml/min. The injection volume was 1 µl and the detector used was flame ionization detector (FID). The SupelcoTM 37 Component FAME Mix standard was used to identify the peaks, and the fatty acids were identified by comparison of their retention times with the standards (Supelco, Bellefonte, USA). The fatty acids were expressed as a percentage of the total fatty acids identified.

A consumer panel was conducted in which panelists rated tenderness, flavor and overall acceptability using an 8-point hedonic scale (1- I like it very much to 8-I dislike it very much). It was a panel of 50 participants, including students, teachers and officials of the Faculty of Veterinary Medicine (Montevideo, Uruguay), of both sexes (27% women, 23% men), of various ages (26 people between 18 and 29 years old, 13 people between 30 and 50 years old, and 11 people over 50 years old). Eighty-four percent of the panelists used to consume beef every week. Samples (fillets) 2.5 cm thick were wrapped in aluminum foil and cooked on grills (GRP100 The Next Grilleration, Spectrum Brands, Inc., Miami, FL) to an internal temperature of 71 ºC at the geometric center. After cooking, the subcutaneous fat was removed and each sample was cut into 2.5 cm x 1.5 cm x 1.5 cm cubes. obtaining 10 cubes per sample (animal). Each bucket was wrapped in aluminum foil, coded with a 3-digit number and kept warm in a heater to prevent it from cooling before being served to consumers. The order in which consumers tasted the samples was different for each of them. The cube of meat delivered to each consumer was of the same location on the steak, so as to reduce the effect of positional bias on consumers.

**Statistical analysis.**

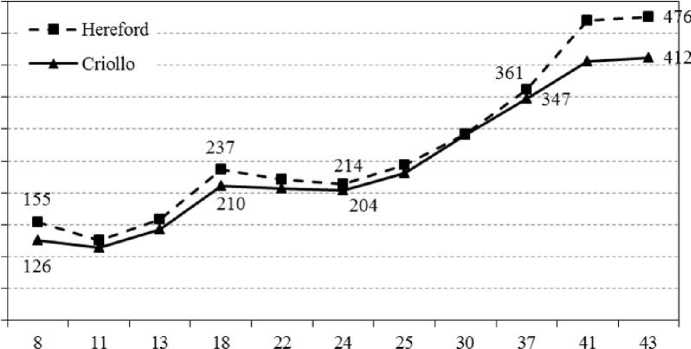
Excel, Statgraphics Centurion XV and STATA 16 (Stata Statistical Software: Release 16) were used for in vivo and carcass data. College Station, TX: StataCorp LLC). The data for each variable were discriminated according to breed and the means and variances of both groups were compared for each characteristic analyzed, using ANOVA and Kruskall-Wallis tests for live weights, total gain and gain per day, and Student's test for carcass measurements, in order to detect significant differences between breeds, always taking α=0.05 as the significance threshold.

Meat quality variables were analyzed using Statistical Analysis System (SAS) version 9.4 (SAS Institute, Cary, NC, USA) using a mixed model considering breed as a fixed effect and animal within breed as random, by the MIXED procedure. After performing the analysis of variance, LSMeans were calculated for breed comparisons at a significance level of α = 0.05, using the PDIFF option of LSMEANS, when F-tests were significant (p < 0.05).

**Results and Discussion**

The growth curve of Uruguayan Criollo steers and Hereford steers is shown in Figure 1. The median live weights for each breed and the comparison between the two groups are shown in Table 1. The evolution of body weight was relatively similar in both breed groups, the difference being significant at the beginning of the experiment and at the end (p < 0.05), where Hereford showed higher values, and not significant at intermediate points (p > 0.05). When using initial weight as a covariate in the analysis of variance, no significant differences were detected in the evolution of live weights (p = 0.203) or weight gain per day (p = 0.210).

In both groups, a decrease in body weight was observed after winter (June to August; at 11, 24 and 43 months) due to the temporary shortage of pasture. Hereford showed higher total and per day weight gain (p < 0.05) (Table 2), which was expected for a selected breed, although when corrected for final weight based on initial weight, there were no significant differences between breeds (p > 0.05). In the regression analysis for final weight, a superiority of 31 kg of weight was detected for Hereford compared to BCU, which was not significant (p = 0.203). In the linear prediction of final weight intervals by breed, BCU presented greater variation (BCU standard error = 23.31; Hereford standard error = 5.17), due to the combined effects of greater intra-breed variability in BCU as it is an unselected breed and the larger sample size.



**500**

**450**

**400**

**350**

**9 300 g 250 > 200**

**S 150**

**100**

**50  
0**

**Age (months)**

Figure 1. Evolution of live weight (median) of Uruguayan Criollo steers and Hereford steers. Weights were determined at the beginning of the experiment, at 18, 24, 36 and 43 months.

Table 1. Live weights (median ± standard error) of Uruguayan Criollo and Hereford steers at different times of the experiment.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Live weight (kg) | | | | |
| Initial | 18 months | 24 months | 36 months | Final |
| Creole | 126.0 ± 4.18 | 210.3 ± 6.39 | 203.5 ± 5.14 | 347.0 ± 6.99 | 412.0 ± 7.12 |
| Hereford | 154.6 ± 4.94 | 236.5 ± 6.61 | 214.0 ± 9.75 | 361.0 ± 11.81 | 476.0 ± 7.18 |
| p ANOVA | 0.003\* | 0.064 | 0.063 | 0.164 | 0.0001\* |
| p KW | 0.002\* | 0.047\* | 0.096 | 0.137 | 0.0013\* |

Initial: median live weight at the beginning of the trial (6-9 months of age); Final: median live weight at the end of the trial (43 months of age); p ANOVA: p-value of the analysis of variance between means; p K-W: p-value of the Kruskal-Wallis test of the comparison between medians; \*: values significantly different between both breeds (for α = 0.05).

Table 2. Corrected weights and total and daily gain (average ± standard deviation) for Uruguayan Criollo and Hereford steers.

|  |  |  |  |
| --- | --- | --- | --- |
|  | PF/PI | GT | kg/day |
| Creole | 338.1 ± 41.6 | 291.1 ± 23.1 | 0.272 |
| Hereford | 320.3 ± 37.0 | 327.5 ± 21.7 | 0.308 |
| p ANOVA | 0.350 | 0.002\* | 0.001\* |
| p KW | 0.351 | 0.004\* | 0.003\* |

PF/PI: correction of final weight by initial weight ((PF/PI) x 100, in kg.); GT: total gain (kg); kg/day: weight gain per day (grams); p ANOVA: p-value of the analysis of variance between means; p K-W: p-value of the Kruskal-Wallis test of the comparison between medians; \*: values significantlydifferent between both breeds (for α = 0.05).

The results for in vivo ultrasound measurements are shown in Table 3. Although only the initial and final results of the experiment are presented in this table, it is necessary to emphasize that higher AOB was detected in Criollos than in Hereford (p < 0.05) in all cases, except for AOB measured at 24 m of age (p ANOVA = 0.35; p Kruskal-Wallis = 0.18). The difference is highly significant and in the same direction when the data are corrected for live weight at the time of measurement (p < 0.01). The evolution of live weights and body condition of the animals visually evaluated seemed to indicate a priori a greater muscularity and better meat conformation in Hereford over BCU, however, objective measurements of AOB indicated the opposite, with BCU showing an AOB 13 cm2 greater than Hereford at the end of the trial. This is possibly a consequence of differences in body conformation (morphological assessment), with BCU having a conformation more similar to that of dairy cattle, similar to that observed in Criollo Argentino (Ferrando *et al.*, 2006; Garriz *et al*., 2008). Regarding dorsal fat thickness, no differences were detected in the ultrasonographic data (p > 0.05), although the differences are highly significant when corrected for live weight at the time of measurement (fat thickness (mm)/kg live weight; p < 0.05). These analyses show that the body condition evaluated by the usual scales for beef cattle is not the best indicator to use in the Uruguayan Criollo. The generation of a specific body condition scale for this breed, based on visual observation and ultrasound scans, would simplify the selection of animals for slaughter.

Table 3. Means for area of eye of beef (AOB) and backfat thickness (EG) and their correction for live weight at 12 and 43 years of age.

months of age for Uruguayan Criollo steers and Hereford steers.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Initial AOB | AOBPV | Final AOB | AOBPV | Final EG | EGPV |
| 12 months | 12 months | 43 months | 43 months | 43 months | 43 months |
| Creole | 13.1 ±2.9 | 10.7 ± 2.9 | 78.8 ± 7.8 | 19.3 ± 1.9 | 8.1 ±0.4 | 2.0± 1.3 |
| CV Creole (%) | 22.2 | 27.2 | 9.9 | 10.1 | 5.5 | 6.7 |
| Hereford | 10.7 ± 2.4 | 7.1 ± 1.5 | 65.6 ± 7.2 | 13.7 ± 1.6 | 8.0 ± 0.3 | 1.7 ± 0.1 |
| CV Hereford (%) | 22.8 | 20.4 | 11.0 | 11.3 | 4.1 | 6.0 |
| p ANOVA | 0.027\* | 0.0008\* | 0.009\* | 0.0000\* | 0.689 | 0.0001\* |
| p K-W | 0.024\* | 0.0005\* | 0.0017\* | 0.0006\* | 0.595 | 0.0009\* |

AOB: area of the eye of the steak (cm2); EG: back fat thickness (cm); AOBPV: correction for live weight at the time of data collection ((AOB/PV) x 100); EGPV: correction for live weight at the time of data collection ((EG/PV) x 100); CV: coefficient of variation; p ANOVA:

p-value of the analysis of variance between means; p K-W: p-value of the Kruskal-Wallis test of the comparison between medians; \*: values of the Kruskal-Wallis test of the comparison between medians; \*: values of the Kruskal-Wallis test of the comparison between medians.

significantly different between the two breeds (for α = 0.05).

The results of the parameters evaluated in the carcasses of the 12 animals slaughtered at slaughter (6 Criollos and 6 Hereford) are presented in Tables 4 and 5. There were no significant differences between the means for live weight at the end of the trial between groups (p > 0.05). Both groups suffered the nutritional restrictions typical of winter in animals subjected exclusively to grazing in natural pastures. The variables carcass weight, carcass length, leg length, leg circumference, carcass yield and compactness index showed no significant differences (p > 0.05). There were significant differences in the breast depth variable (p < 0.05), being almost 4 cm greater in Criollo. No significant differences in carcass yield were observed, in agreement with Garriz *et al.* (2008) who also found no significant differences between Argentine Criollo cattle and British beef breeds.

Table 4. Mean live weight at slaughter, chilled carcass weight, yield and compactness of Uruguayan Criollo and Hereford steers.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Live Weight (kg) | | Chilled Carcass Weight (kg) | | Yield (%) | | Compactness | |
| Hereford | Creole | Hereford | Creole | Hereford | Creole | Hereford | Creole |
| Media | 431.50 | 411.70 | 217.05 | 219.00 | 50.34 | 53.21 | 1.66 | 1.68 |
| DE | 21.82 | 18.90 | 11.50 | 10.91 | 3.47 | 1.73 | 0.10 | 0.10 |
| p value | 0.1230 |  | 0.7690 |  | 0.1060 | | 0.6980 |  |

SD: standard deviation. p-value: two-tailed p-value of the t-test.

Table 5. Average results for carcass length, chest depth, and leg length and girth of Uruguayan Criollo and Hereford steers.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Channel length (cm) | | Chest depth (cm) | | Leg length (cm) | | Leg circumference (cm) | |
| Hereford | Creole | Hereford | Creole | Hereford C | riollo | Hereford | Creole |
| Media | 130.50 | 130.10 | 63.25 | 66.70 | 80.16 | 81.20 | 102.42 | 99.83 |
| DE | 3.38 | 1.74 | 1.64 | 2.14 | 1.69 | 1.51 | 1.91 | 2.64 |
| p value | 0.7900 |  | 0.0110 | \* | 0.3050 |  | 0.0800 | |

SD: standard deviation. p-value: two-tailed p-value of the t-test. \*: values significantly different between both breeds (for α = 0.05).

The results of the dissection of the 10th. rib (Table 6) show that BCU had almost 9 % more muscle and 4 % less bone than Hereford (p < 0.05 in both cases), while Hereford had 4.5 % more visible fat (p = 0.05). This study shows a tendency of the Criollo towards higher meat production, with thinner and lighter bones, and less fat accumulation than the British breeds. This is consistent with what has been observed by other researchers in other Criollo breeds, especially in the Criollo Argentino, where at the same finishing weight, Criollo steers had a higher proportion of muscle and less bone than commercial breeds, although their external appearance is more "fleshy" (Ferrando *et al*., 2006; Garriz *et al*., 2008).

Table 6. Dissection of the 10th rib. Percentages of muscle, visible fat and bone in relation to the total weight of the cut in Uruguayan Criollo and Hereford steers.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | % Muscle |  | % Fat | Bone |
|  | Hereford Creole | Hereford | Creole | Hereford Creole |
| Media | 53.85 62.57 | 18.76 | 14.25 | 26.15 22.02 |
| DE | 4.33 2.90 | 4.49 | 2.08 | 3.23 1.95 |
| p value | 0.0022\* |  | 0.0496\* | 0.0229\* |

p-value: two-tailed p-value of the t-test. \*: values significantly different between both breeds (for α = 0.05). SD: standard deviation.

Instrumental measurements of meat quality (Table 7) showed no significant differences (p > 0.05) between breeds in cutting strength, cooking losses and color. The shear strength and color results are similar to those obtained by Realini *et al.* (2004) with 7 days of ripening and by Del Campo *et al.* (2008), both studies based on British beef breeds in Uruguay. A trend toward a higher percentage of intramuscular fat was observed in BCU (p < 0.10). Carcass pH values at 72 hours post-mortem did show significant differences, lower in Criollos (p < 0.05). It should be noted that the final pH values were high (pH > 5.8) in both breeds, which may be associated with stress conditions prior to slaughter during shipment, transport and/or handling in the holding pens at the slaughterhouse (Tarrant, 1989). The distance from the place where the animals were located to the slaughterhouse was not extensive (106 km), although the first 10 km were on country roads that are not in the same good condition as the national roads. Combined with the fasting time, these factors could explain the pH values detected. Lower pH levels in the transformation of muscle to meat affect meat quality (Wulf *et al*., 2002; Ferguson & Warner, 2008), which is somewhat reflected in the low meat lightness (L\*) values that were less than 35 in both breeds. Both groups of animals having been handled and transported in the same way and together, these pH differences could indicate a tendency in the Criollos towards a calmer temperament, which should be the subject of further studies.

Table 7. Least squares means for shear force, cooking losses, color and intramuscular fat percentage, measured at 6 days of maturation, and mean carcass pH measured 72 hours post-mortem, of Uruguayan Criollo and Hereford steers.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Creole | Hereford | p value |
| Shear force (kg) | 3.01 ± 0.15 | 3.15 ± 0.15 | 0.5215 |
| Cooking losses (%) | 18.7 ± 0.7 | 18.9 ± 0.7 | 0.8392 |
| L\* (units) | 34.4 ± 2.4 | 34.0 ± 2.3 | 0.7377 |
| a\* (units | 21.5 ± 1.0 | 19.0 ± 0.9 | 0.1064 |
| b\* (units) | 10.4 ± 0.6 | 9.8 ± 0.9 | 0.6173 |
| Intramuscular fat (%) | 3.94 ± 0.31 | 2.91 ± 0.37 | 0.0577 |
| pH 72 h | 5.91 ± 0.04 | 6.02 ± 0.04 | 0.0008\* |

L\*, a\*, b\*: color parameters measured prior to firing (brightness, red intensity and yellow intensity, respectively). p-value: p-value of the t-test. \*: values significantly different between both breeds (for α = 0.05).

The fatty acid profile (Table 8) shows 1.43 % more total polyunsaturated fatty acids (PUFA) in Hereford than in Criollo, the latter having 0.06 % more conjugated linoleic acid (p < 0.05 in both cases). These differences may be due to breed-specific metabolic factors, differences in ruminal microbiota, or differences in grazing behavior (Nogales *et al*., 2017; Spiegal *et al.*, 2017). Although they coexisted throughout the trial in the same farm, being a natural environment with a great variety of ecosystems and plant species, it is possible that there are differences at the level of diet selection, something that has been observed in other Criollo cattle (Spiegal *et al.*, 2017). The results obtained are consistent with the results reported by Brito *et al.* (2014) for pasture-fed animals, and by Nogales *et al*. (2017) in the Spanish Marismeña breed.

Table 8. Fatty acid profile in Uruguayan Criollo steers and Hereford steers

|  |  |  |  |
| --- | --- | --- | --- |
|  | Creole | Hereford | p value |
| C14:0 (myristic) | 3.30a± 0.17 | 2.69b ± 0.12 | 0.0157\* |
| C14:1 (myristoleic) | 0.50 ± 0.09 | 0.39 ± 0.03 | 0.3270 |
| C16:0 (palmitic) | 31.14 ± 0.37 | 30.95 ± 0.60 | 0.7978 |
| C16:1 (palmitoleic acid) | 3.60a ± 0.30 | 2.74b ± 0.16 | 0.0309\* |
| C18:0 (stearic) | 17.48 ± 0.81 | 19.17 ± 0.82 | 0.1743 |
| C18:1-n9 (oleic) | 38.45 ± 0.74 | 37.11 ± 1.01 | 0.3097 |
| C18:2-n6 (linoleic) | 2.00a ± 0.11 | 2.66b ± 0.26 | 0.0373\* |
| C20:0 (arachidic) | 0.16 ± 0.01 | 0.14 ± 0.01 | 0.2024 |
| C18:3-n6 (gamma-linolenic) | 0.12 ± 0.02 | 0.14 ± 0.01 | 0.3439 |
| C18:3-n3 (alpha-linolenic) | 0.77 ± 0.02 | 0.93 ± 0.07 | 0.0818 |
| CLA (CLA ac. conjugated linoleic acid) | 0.61a ± 0.02 | 0.55b ± 0.01 | 0.0312\* |
| C20:2-n6 (eicosadienoic) | 0.05 ± 0.005 | 0.05 ± 0.002 | 0.5634 |
| C20:3-n3 (eicosatrienoic) | 0.21 ± 0.008 | 0.23 ± 0.018 | 0.3324 |
| C20:3-n6 (dihomogamma-linolenic acid) | 0.12 ± 0.016 | 0.15 ± 0.031 | 0.0747 |
| C20:4-n6 (arachidonic) | 0.35b ± 0.049 | 0.52a ± 0.013 | 0.0181\* |
| C20:5-n3 (eicosapentaenoic) | 0.75b ± 0.051 | 1.00a ± 0.097 | 0.0416\* |
| C22:5-n3 (docosapentaenoic) | 0.34b ± 0.049 | 0.51a ± 0.052 | 0.0409\* |
| C22:6-n3 (docosahexaenoic acid) | 0.06 ± 0.010 | 0.07 ± 0.010 | 0.5628 |
| Saturated Fatty Acids (SFA) | 52.08 ± 0.97 | 52.96 ± 0.99 | 0.5399 |
| Monounsaturated Fatty Acids (MUFA) | 42.54 ± 0.98 | 40.23 ± 1.05 | 0.1396 |
| Polyunsaturated Fatty Acids (PUFA) | 5.38b ± 0.19 | 6.81a ± 0.43 | 0.0127\* |
| Fatty Acids - omega 6 series | 3.25b ± 0.10 | 4.08a ± 0.26 | 0.0142\* |
| Fatty Acids - omega 3 series | 2.13b ± 0.10 | 2.74a ± 0.19 | 0.0191\* |
| PUFA/SFA ratio | 0.10b ± 0.004 | 0.13a ± 0.009 | 0.0286\* |
| omega 6/omega 3 ratio | 1.54 ± 0.05 | 1.50 ± 0.06 | 0.6481 |

Percentage of each fatty acid within intramuscular fat ± standard deviation. \*: values significantly different between both breeds (for α = 0.05).

Finally, no significant differences were observed between breeds in terms of tenderness, acceptability and flavor in the judgments of a panel of untrained consumers (p > 0.05) (Table 9). These results would indicate a priori that the Uruguayan Criollo cattle breed would have a tendency towards the production of tender meat, with good color and flavor attributes, and with a good level of marbling, comparable to the meat of one of the most important beef breeds in the world, the Hereford.

Table 8. Fatty acid profile in Uruguayan Criollo steers and Hereford steers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Creole | Hereford | p value | DE |
| Tenderness | 3.09 | 2.96 | 0.5462 | 0.1784 |
| Taste | 3.18 | 3.21 | 0.8779 | 0.1634 |
| Overall acceptability | 3.15 | 3.10 | 0.7623 | 0.1455 |

p t-test value. SD: standard deviation. Hedonic scale (1- I like it very much; 2- I like it a lot; 3- I like it a lot; 4- I like it; 5- I dislike it; 6- I dislike it a lot; 7- I dislike it a lot; 8- I dislike it very much).

Although a larger sample size is required to obtain firm conclusions, these results would indicate that the Uruguayan Criollo cattle breed has a very good potential for the production of

189

high quality meat, with good carcass yields and very good attributes of color, flavor, tenderness and marbling, compared to a highly selected breed such as the Hereford.

**Conclusions**

In this exploratory study, similar performance was observed in the measured parameters related to beef production in Criollo steers compared to Hereford steers, a highly selected breed for beef. Without selection for any production traits, the BCU exhibits levels similar to a meat breed in terms of body weight gain, carcass yield and meat quality, including sensory evaluation. It presented a higher percentage of muscle and less of bone, in an environment of unimproved natural pastures with a marked seasonal shortage of forage, which is promising and opens the door to new lines of research to corroborate the primary data presented here. In order to allow a better evaluation of the animals, it would be important to generate a visual scale of body conformation specific for the Uruguayan Criollo, since the one commonly used in our environment is not consistent with what is observed in the ultrasound scans. As a perspective, it would be interesting to extend the study to include animals resulting from crosses between BCU and British breeds.

**Conflict of interest:** There is no conflict of interest on the part of the authors in relation to the data mentioned herein.

**Acknowledgments**

This research did not receive any specific grants from funding agencies in the public, commercial or non-profit sectors.

The authors would like to give special thanks to the personnel of the Servicio de Parques del Ejército (SEPAE) for their constant work and dedication; to the Frigorífico "Copayan S.A." for allowing access to their facilities and the extraction of meat samples; and to Dr. Carlos Garriz for providing his many years of experience and for his recommendations.

**Literature Cited**

American Meat Science Association (AMSA). 2016. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat, version 1.02. 2nd. edition. AMSA, Champaign, IL, USA.

Armstrong E., A. Iriarte, A. M. Martinez, M. Feijoo, J. L. Vega-Pla, J. V. Delgado, A. Postiglioni. 2013. Genetic diversity analysis of the Uruguayan Creole cattle breed using microsatellites and mtDNA markers. Gen. Mol. Res. 12 (2): 1119-1131. <https://doi.org/10.4238/2013>

Armstrong E., D. Fila, F. Saravia, J. Novo, R. Aragunde, A. Franca, G. Merola, G. Evia, S. Llambí. 2017. Evaluation of Uruguayan Criollo steers for beef production. First results. X Jornadas Técnicas Veterinarias, Montevideo, Uruguay.

Arredondo, H. 1955. Santa Teresa and San Miguel. The restoration of the fortresses. The formation of its parks. Revista de la Sociedad de Amigos de la Arqueología, Uruguay. Volume XIII. <http://www.monedasuruguay.com/bib/bib/s/sa> a13.pdf

Barros, A., L. Castro. 2004. Animal Welfare - Good Operational Practices. Technical Series No. 34, National Meat Institute (INAC), Uruguay. <https://www.inac.uy/innovaportal/file/2623/1/i> nac\_ba\_bpo.pdf

Bligh, E. G., W. J. Dyer. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology, 37(8), 911-917. <https://doi.org/10.1139/o59-099>

Brito, G, R. San Julián, A. La Manna, M. Del Campo, F. Montossi, G. Banchero, D. Chalking, J. M. Soares de Lima. 2014. Growth, carcass traits and palatability: Can the influence of the feeding regimes explain the variability found on those attributes in different Uruguayan genotypes? Meat Science 98(3) 533-538).

Del Campo M, G. Brito, J. M. Soares de Lima, D. Vaz Martinz, C. Sañudo, R. San Julián, P. Hernandez, F. Montossi. 2008. Effects of feeding strategies including different proportion of pasture and concentrate, on carcass and meat quality traits in Uruguayan steers. Meat Science 80 (2008) 753-760). <https://doi.org/10.1016/j.meatsci.2008.03.026>

Feed, O. 2010. Methodology for the evaluation of the qualitative characteristics of the carcass and meat. In: Introduction to the Science of Meat, Bianchi G., O. Feed O. Editorial Hemisferio Sur, Montevideo, Uruguay.

Ferguson, D. M. R. D. Warner. 2008. Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? Meat Science, 80 (1): 12-19.

<https://doi.org/10.1016/j.meatsci.2008.05.004>

Fernández G., M. Rodriguez, C. Silveira, C. Beard. 2001. Ethnic study of Uruguayan Criollo cattle: II. Analysis of the faneras. Arch. Zoot. 50: 119-124.

<https://www.redalyc.org/articulo.oa?id=49519016>

Ferrando, C., E. Paloma, P. Namur, D. Leguiza. 2006. Argentine Criollo and Aberdeen Angus cattle in the plains of La Rioja. Result of 11 years of evaluation in breeding systems. Series of publications of the Research Area of INTA EEA The Rioja, Argentina.

<https://doi.org/10.13140/RG.2.1.1883.1204>

Ferrario, J. D., M. A. Fernandez. 2007 Ultrasonic casing characteristics study: measuring is believing. Braford. 23(58):72-75. [http://www.produccion- animal.com.ar/informacion\_tecnica/ecografia\_ultr](http://www.produccion-animal.com.ar/informacion_tecnica/ecografia_ultr) sonido/67-medir.pdf

Ginja, C., L. T. da Gama, O. Cortés, I. Martin Burriel, J.L. Vega-Pla, *et al*. 2019. The genetic ancestry of American Creole cattle inferred from uniparental and autosomal genetic markers. Scientic Reports 9:11486. <https://doi.org//10.1038/s41598-019->

47636-0

Garriz, C. A., L. Vranic. 2008. Conformation and finishing in purebred steers and Criollo Argentino crosses. Argentine Journal of Animal Production. Vol. 28, pp: 177-233. [http://www.produccion- animal.com.ar/informacion\_tecnica/raza\_criolla/4](http://www.produccion-animal.com.ar/informacion_tecnica/raza_criolla/4) 8-conformacion.pdf

Holgado, F. D., M. F. Ortega. 2019. Productive characterization of the Argentine Criollo cattle: period 2006-2016. INTA Editions. Buenos Aires, Argentina. Pp: 26.

<https://inta.gob.ar/sites/default/files/inta_caract> erizacion\_productiva\_bovino\_2016\_2019.pdf

International Union of Pure and Applied Chemistry (IUPAC). 1987. Standard Method 2.301, Preparation of Fatty Acid Methyl Ester. In Standard Methods for Analysis of Oils, Fats and Derivatives. 7th. Edition, Blackwell, Oxford.

Lezama, F., A. Rossado. 2012. Effects of grazing on the structure of natural grasslands in San Miguel National Park and the Potrerillo de Santa Teresa biological station. Working Paper No. 48, PROBIDES.

<https://www.probides.org.uy/imagenes/ckfinder/> files/files/Documentos%20de%20Trabajo/DT48.pd f

Nogales, S., M. C. Bressan, J. V. Delgado, L. T. da Gama, C. Barba, M. E. Camacho. 2017. Fatty acid profile of feral cattle meat. Italian Journal of Animal Science 16 (1) 172-184.

<https://doi.org/10.1080/1828051X.2016.1263163>

Rodriguez M., G. Fernandez, C. Silveira, J. V. Delgado. 2001. Ethnic study of the Criollo cattle of Uruguay: I. Biometric Analysis. Arch. Zoot. 50: 113­118.

<https://www.redalyc.org/articulo.oa?id=49519016>

Realini, C. E., S. K. Duckett, G. W. Brito, M. Dalla Rizza, D. From MAttos. 2004. Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. Meat Science 66(3) 567-577). <https://doi.org/10.1016/S0309->

1740(03)00160-8

Spiegal, S. A., R. E. Estell, A. F. Cibils, D. K. James, R. Peinetti, D. M. Browning, K. B. Romig, A. L. González, A. J. Lyons, B. T. Bestelmeyer. 2019. Seasonal divergence of landscape use by heritage and conventional cattle on desert rangeland. Rangeland Ecology and Management. 72(4):590-601. <https://doi.org/10.1016/j.rama.2019.02.008>

Tarrant, V. P. 1989. Animal behavior and environment in the dark-cutting condition - A review. Irish Journal of Food Sciences and Technology, 13, 1-21. <https://www.jstor.org/stable/25580937>

Vizcarra, J. A., W. Ibañez, R. Orcasberro. 1986. Repeatability and reproducibility of two scales for estimating body condition in Hereford cows. Agronomic Research. N° 7: 45-47. <http://www.ainfo.inia.uy/digital/bitstream/item/> 5982/1/Inv.Agr.-1986-No.7.pdf

Wulf, D., R. Emnett, J. Leheska, S. Moeller. 2002. Relationships among glycolytic potential, dark­cutting (dark, firm, and dry) beef, and cooked beef palatability. Journal of Animal Science, 80, 1895­1903. <https://doi.org/10.2527/2002.8071895x>

1. Corresponding author: Eileen Armstrong, [eileen.armstrong@gmail.com](mailto:eileen.armstrong@gmail.com) [↑](#footnote-ref-1)
2. National Institute of Agricultural Research (INIA); [↑](#footnote-ref-2)
3. Program for the Sustainable Development of the Eastern Wetlands (PROBIDES); [↑](#footnote-ref-3)
4. Army Park Service (SEPAE). [↑](#footnote-ref-4)