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Preliminary observations on carcass traits and meat yield of five types of Brahman-influenced grass-fed bulls

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Abstract: Benefiting from interventions of the savanna ecosystem, breeders in Los Llanos of Apure State (Venezuela) are exploring the opportunity to improve cattle genetics by implementing crossbreeding programs. Fifty bulls (23 months of age) of five types of Brahman influence [Brahman (n = 10), F1 Angus x Brahman (F1-Angus; n = 10), F1 Chianina x Brahman (F1-Chianina; n = 10), F1 Romosinuano x Brahman (F1-Romosinuano; n = 10), and F1 Simmental x Brahman (F1-Simmental; n = 10)] were selected to be compared in carcass performance (linear measurements, quality and quantity indicators, Venezuelan and U.S. grades, and cutability) at a desirable conformation endpoint with a suitable market weight of 480 kg. An ANOVA-covariance was performed using the generalized linear model and frequency distribution of Venezuelan and U.S. grades by breed type were compared using the χ^2 test ($P < 0.05$). Shorter Brahman carcasses exhibited the most abundant finish, significantly different from the longer F1-Simmental and F1-Romosinuano counterparts. All carcasses fell into the A youngest maturity and were eligible for the USDA "Bullock" class designation; 62% reached the top Venezuelan quality grade, 96% graded U.S. Standard and 64% reached the U.S. yield grade 1, indicating superior cutability. Significant differences ($P < 0.05$) in yield of individual cuts (ribeye + strip loin, and cuts from the round) were detected between F1-Romosinuano and Brahman, F1-Angus, and F1-Chianina counterparts. F1-Chianina bulls had slight but significant ($P < 0.05$) advantages in yield of high-valued boneless cuts as compared to those of F1-Romosinuano and F1-Simmental counterparts. Conversely, F1-Romosinuano outperformed F1-Chianina in 1.73 % of medium-valued boneless cuts ($P < 0.05$). Under the sample selection criteria and harvest endpoint, slight changes in carcass performance can be expected from crossbreeding.

Keywords: Beef, Brahman, bull, carcass grading, crossbreeding, quality, yield.

Observaciones preliminares sobre las características de la canal y el rendimiento de carne de cinco tipos de toros alimentados con pasto influenciados por Brahman

Resumen: Con intervenciones del ecosistema sabana y aplicando un manejo adecuado de los pastos, ganaderos de Los Llanos del Estado Apure (Venezuela) estan explorando mejorar la genética del ganado con programas de cruzamiento. Cincuenta machos enteros (23 meses de edad) de cinco tipos raciales con influencia Brahman [Brahman puro (n = 10), F1 Angus x Brahman (F1-Angus; n = 10), F1 Chianina x Brahman (F1-Chianina; n = 10), F1 Romosinuano x Brahman (F1-Romosinuano; n = 10) y F1 Simmental x Brahman (F1-Simmental; n = 10)] se compararon en desempeño de la canal (mediciones lineales, indicadores de calidad y cantidad, categorías de clasificación y rendimiento carnicero) a un punto final de conformación deseable con un peso corporal aproximado de 480 kg. Se realizó un ANOVA-covarianza utilizando un modelo lineal generalizado y la distribución de frecuencias para las categorías en canal venezolana y americanas fue comparada por medio de una prueba de χ^2 ($P < 0.05$). Canales más cortas de Brahman puros exhibieron acabado más abundante, diferente ($P < 0.05$) de las contrapartes más largas F1-Simmental y F1-Romosinuano. Todas las canales cayeron en la madurez más joven (A) y fueron elegibles para la designación de clase "Bullock" del USDA; el 62% alcanzó el grado de calidad superior venezolano (categoría A), el 96% calificó en el grado de calidad Standard y el 64% alcanzó el grado máximo de rendimiento carnicero (grado 1 USDA). Los toretes F1-Chianina tuvieron ventajas leves pero significativas ($P < 0.05$) en rendimiento en cortes deshuesados de alto valor, en comparación con los de F1-Romosinuano y F1-

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Simmental. Por el contrario, F1-Romosinuano superó a F1-Chianina en 1.73% de cortes deshuesados de valor medio (P < 0.05). Bajo los criterios de selección de la muestra y el punto final de la cosecha, no se pueden esperar grandes cambios en el rendimiento carnicero a partir del cruzamiento.

Palabras clave: Carne bovina, Brahman, toros, clasificación de canales, cruzamiento, calidad y rendimiento.

Observações preliminares sobre características de carcaça e rendimento de carne de cinco tipos de touros alimentados com capim influenciados por Brahman

Resumo: Com o uso de tecnologias em um ecossistema de savana e aplicando um manejo adequado das pastagens, os criadores de Los Llanos do Estado de Apure (Venezuela) estão tentando melhorar a genética do gado através da utilização de programas de cruzamento. Cinquenta bovinos machos não castrados (23 meses de idade), de cinco cruzamentos com Brahman [Brahman puro (n = 10), F1 Angus x Brahman (F1-Angus; n = 10), F1 Chianina x Brahman (F1-Chianina; n = 10), F1 Romosinuano x Brahman (F1-Romosinuano; n = 10) e F1 Simental x Brahman (F1-Simental; n = 10)], foram comparados quanto às características (medidas lineares, indicadores de qualidade e quantidade e rendimento de desossa) y tipificacao de carcaça. Uma ANOVA-covariância usando um modelo linear generalizado. A distribuicão de frequência das categorías de canais venezuelanos e americanos de acordó com o tipo racial foi comparada por meio do tes χ^2 (P < 0.05). Carcaças de Brahman puros apresentaram maior cobertura de gordura do que carcaças de animais F1-Simmental e F1-Romosinuano (P < 0.05). Todas as carcaças foram com maturidade “A” (jovem / Bullock), sendo que 96% se qualificaram no grau de qualidade USDA “Standard” e 64% alcançaram o grau máximo de rendimento de desossa (grau 1). Pelo padrão venezuelano, 62% das carcaças alcançaram o grau de qualidade superior (categoria A). Diferenças significativas (P < 0.05) foram detectadas no rendimento de cortes individuais (filé de costela e contrafilé e cortes do coxão) entre carcaças de F1-Romosinuano e F1-Simental e F1-Angus e F1-Chianina. Carcaças de F1-Chianina apresentaram maiores rendimentos em cortes desossados de alto valor em comparação com F1-Romosinuano e F1-Simmental (P > 0.05). Carcaças de F1-Romosinuano tiveram 1.73 pontos percentuais a mais de rendimento em cortes desossados de valor intermediário, que carcaças de F1-Chianina (P < 0.05). Segundo os critérios de seleção da amostra e o ponto final de abate, não se podem esperar grandes mudanças na qualidade e rendimento das carcaças de diferentes cruzamentos.

Palavras-chave: Carne bovina, Brahman, touros, classificação de carcaça, cruzamento, qualidade, rendimento.

Introduction

Ranching under the harsh, tropical conditions forces the use of *Bos indicus* cattle, with greater adaptability than its *Bos taurus* counterparts (Huerta-Leidenz and Belk, 1996). Cattle production in neotropical savannas (Los Llanos) is challenged by four to six months of alternate extreme rains and droughts (Sarmiento *et al.*, 2004) and poor nutrition all year round (Lascano, 1991). However, in the southwestern state of Apure (Venezuela), a network of dikes has allowed flood control during the rainy season, while saving rainwater to be supplied to livestock during the severe drought (Sarmiento *et al.*, 2004; Smith *et al.*, 2006). Also, this hydraulic infrastructure has promoted the introduction and cultivation of invasive forage species, with better nutritional quality than the native savanna vegetation (Lascano, 1991). Benefitting from the ecosystem intervention and implementing adequate pasture management (e.g., fertilization, irrigation, and rotational grazing) progressive breeders have attempted to finish cattle in their ranches; a diversification strategy that is likely to become generalized in the future (Plasse, 1992; Plasse *et al.*, 1995). Poor production performances of *Bos indicus* types have raised local breeders’ interest in obtaining F1 offsprings as a terminal product to improve growth and carcass quality (Plasse, 1992; Plasse *et al.*, 1995). Besides the use of Continental and British breeds, researchers have tested the criollo Romosinuano, a heat-tolerant *Bos taurus* breed (Plasse *et al.*, 1995; Jerez-Timaure and Huerta-Leidenz, 2009; Riley *et al.*, 2012). The Venezuelan beef carcass grading systems (Decreto Presidencial No. 181, 1994; Decreto Presidencial No. 1896, 1997) have also been incentives for genetic-testing stories (Huerta-Leidenz and Jerez-Timaure, 1996; Rodriguez-Voigt *et al.*, 1997; Rodas-Gonzalez *et al.*, 2017). Carcass performance of non-castrated males is of major interest to the Venezuelan packer’s association (ASOFRIGO) because bulls and bullocks comprised 43.75% of the national harvest cattle presented for grading in 2019 (ASOFRIGO, unpublished data). If grass-fed young bulls with superior genetics and enhanced carcass performance could be directly sold to packers at premium prices, breeders operating in the region would get a higher return to their investments, thus increasing economic sustainability. Most of the literature comparing Brahman-influenced cattle and other breed types in carcass performance have used castrates under feedlot conditions (Crouse et al., 1989; Reverter et al., 2003; Schutt et al., 2009; Riley et al., 2012). To our knowledge, only Jerez-Timaure and Huerta-Leidenz (2009) and Huerta-Leidenz et al. (2020) have reported these genetic comparisons with grass-fed bulls in northern South America; and a similar approach was taken by Riera-Sigala et al. (2004) to assess breed type differences in growth performance and hot carcass weights. As a companion report to that of Riera-Sigala et al. (2004), the present work posits that it is feasible to finish young bulls in the same breeding operation on "Los Llanos" cultivated pastures and to improve carcass performance through crossbreeding. Hence, the main objective of this preliminary work was to explore differences in carcass traits and cutability of five types of Brahman-influenced young bulls fattened on pasture.

Materials and Methods

The trial was carried on in compliance with the criteria for animal care and welfare described in the Bioethics and Biosafety guide of the Fondo Nacional de Ciencia, Innovación y Tecnología (FONACIT, 2008).

Study area and ecosystem.

The exact location and the characteristics of the savanna ecosystem have been described in detail (Plasse et al., 1995; Riera-Sigala et al., 2004; Jerez-Timaure and Huerta-Leidenz, 2009). In brief, the trial was carried out in a privately-owned ranch located at the Southwestern isohyperthermic savannahs of Venezuela, 25 km away (south) from the Apure River. The area corresponds to a tropical dry forest with an annual mean temperature that varies between 22 and 29 °C. The average rainfall is approximately 1 400 mm / year, 60% of which occurs during June to August. The ranch has an approximate area of 25 000 ha (17 000 ha of well-drained savanna, and 8 000 ha are flooded in the rainy months). This area of extensive plains is mainly covered by savanna vegetation like *Leesia hexandra*, *Andropogum* sp, and *Paspalum plicatulum*.

Animal management and experimental procedures

Animal management from breeding up to harvesting had been described in detail (Riera-Sigala et al., 2004). Brahman cows were randomly selected from the herd and used to produce the straightbred and F1 offsprings by artificial insemination for a genetic improvement program based on directed crossbreeding (Plasse et al., 1995). *Bos taurus* sires were selected for growth characteristics that included direct and maternal effects. At a minimum, there were two direct and maternal effects. At a minimum, there were two sires per breed type. Seven straightbred Brahman (Brahman) bull calves were produced by AI of high-grade cows randomly selected from the ranch herd, using semen from sires selected in genetic programs carried out in Venezuelan ranches (Plasse et al., 1995); the other three sires were offsprings of registered Brahman cows. All dams used to produce F1-*Bos taurus* were high-grade Brahman cows. Calving dates were recorded to compute the chronological age of every calf. The calves were kept together with their mothers in native pastures until weaning, which was carried out at the approximate age of seven months. After weaning, animals were kept on cultivated grass until the next dry season when they were moved to good-quality lowland savanna. At the beginning of the rainy season, they were transferred to cultivated grass and alternated with good quality savanna (Plasse et al., 1995). The bull calves were subjected to a complete health program with an emphasis on disease prevention and parasite control. Additionally, they had full access to water and an adequate mineral mixture during their entire life. Upon reaching ca. 23 months of age with an approximate weight of 350 kg, a group of 91 bull calves, were randomly selected, classified by frame size and muscle thickness according to the guidelines of Decreto Presidencial No. 181 (1994), individually weighed and segregated by weight. Following the commercial criteria of the operation, the 10 heaviest bull calves from each of the five different breed types were chosen at the beginning of the dry season to be fattened on irrigated pastures. At the start of the trial, the resulting experimental group exhibited homogeneous frame sizes (mean scores tending to be described as “medium”) and muscle thicknesses (mean scores tending to be described as “slightly thick” (Riera-Sigala et al. 2004). Accordingly, the animal sample was constituted by five breed types as follows: Brahman (n = 10), F1 Angus x Brahman (F1-Angus; n = 10), F1 Chianina x Brahman (F1-Chianina; n = 10), F1 Romosinuano x Brahman (F1-Romosinuano; n = 10), and F1 Simmental x Brahman (F1-Simmental; n = 10). The selected 50 bull calves were introduced into the fattening module with pasture supplementation. The total experimental area was planted predominantly with tanner grass (*Brachiaria radicans*) and to a lesser extent with african star grass (*Cynodon nlemfuensis*), pará (*Brachiaria mutica*), and alemán (*Echinochloa polystachia*).

mutica), and alemán (*Echinochloa polystachia*). Paddocks were managed on a rotational schedule of 28 days with seven-day occupation and 21-day rest intervals resulting in a stocking rate of 2.4 animal units per ha. When needed, non-experimental, companion animals were introduced to adjust the target stocking rate. The supplement allotment of 4 kg/d.animal was available in mobile feed troughs. The ingredient composition and bromatological analysis of forage and supplements was reported by Riera-Sigala et al. (2004). A concise description of the bromatological analyses is shown in Table 1. Animal performance was monitored until reaching a desirable conformation at approximate, suitable market weight of 480 kg (Riera-Sigala et al., 2004).

Table 1. Bromatological analyses of forage and supplement offered to grazing bulls during the fattening phase.

Component	Forage	Supplement
DM (% fresh matter)	79.96	88.93
TDN (% DM)	63.31	68.90
CP (% DM)	6.19	14.03
NFE (g/100g DM)	47.19	48.77
EE (% DM)	1.06	3.65
CF (% DM)	34.10	13.95
Ash (%DM)	11.56	16.34
Calcium (% DM)	1.16	1.37
Phosphorus (% DM)	0.32	0.73

DM, dry matter; TDN, total digestible nutrients: CP, crude protein; NFE, Nitrogen-free extract, EE, ether extract; CF, crude fiber.

Cattle harvesting, carcass evaluation, and fabrication

Upon reaching the harvest endpoint, the cattle lots were progressively sent to a packing house located in the midwestern city of Barquisimeto, Lara State, approximately 500 km away from Hato Santa Luisa. A first group (n = 20) was sent for harvesting at 99 days of pasture fattening, the second group (n = 20) at 121 days, and the last group (n = 10) at 149 days. Harvesting, dressing procedures, and post-mortem inspection followed the standards of the Venezuelan Commission of Industrial Regulations (COVENIN, 1983). The carcass evaluation and fabrication protocols were described in detail elsewhere (Huerta-Leidenz et al., 2016; Rodas-González et al., 2017). It can be summarized as follows: The hot carcass weight and linear measurements (thoracic depth, thigh width, leg perimeter, length of pelvic limb, and carcass length) were taken at the harvest floor as described by Huerta-Leidenz et al. (1979). After 48 hours postmortem at 4 °C the chilled carcasses were evaluated for finish (1 = Extremely abundant, 2 = Abundant, 3 = Medium, 4 = Slight, 5 = Scarce) and adipose maturity (i.e., fat color, where, 1 = Ivory white, 2 = Creamy white, 3 = Light yellow, 4 = Intense yellow, 5 = Orange) according to Decreto Presidencial No. 1896 (1997), conformation profile score (1 = Very convex, 2 = Convex, 3 = Rectilinear, 4 = Concave, 5 = Very concave; Huerta-Leidenz et al., 1979). Additionally, chilled carcasses were evaluated according to the procedure stipulated for determining the USDA yield and quality grades with the ribeye area (REA), adjusted fat thickness at the 12th-rib (BACKFAT), percentage of kidney, pelvic, and heart fat (KPH), marbling scores, lean color and texture (lean maturity) and bone maturity scores (USDA, 2017).

After evaluation, the chilled carcasses were reduced to subprimal/retail cuts according to the Venezuelan commercial procedure (COVENIN, 1982) with the removal of excess subcutaneous fat, when present, leaving a maximum fat thickness cover of 0.64 cm on any cut. The typical butchering process for fabricating beef carcasses in Venezuela has been described anatomically (Montero et al., 2014). The muscle cuts from both carcass sides were individually weighed to determine their percentage yield to the whole chilled carcass, as well as the combined percentage of subprimal/retail cuts according to their market value in Venezuela (Huerta-Leidenz and Jerez-Timaure, 1996; Huerta-Leidenz et al., 2016). The co-products (amounts of clean bone and trimmed fat) were also computed as proportions (%) of the chilled carcass. Given that the chilled carcasses could not be weighed before fabrication, it was estimated by the sum of weights of all products (muscle cuts) and coproducts (trimmed fat, clean bone, connective tissues) derived from the fabrication. The international equivalences of Venezuelan commercial names for the beef cuts are given in Table 2.

Statistical analysis

All data were analyzed using the statistical program R (R Core Team, 2019). The Shapiro Wilk normality test (Shapiro and Wilk, 1965) was performed for each response variable. Natural logarithm ($y^*=\log(y)$) transformations were performed before the analysis when the variances were not homogeneous. The one-way analysis of variance-covariance was performed using the generalized linear model (GLM) which included breed type, as the independent variable. Final (harvest) weight was used as a covariate for adjusting carcass traits. Mean comparisons were performed by the Tukey's multiple range test (Steel and Torrie, 1992) with a significance level of 5%. Frequency distribution of Venezuelan and USDA (quality and yield grades) grades by breed type were compared using the chi-square option of R (R Core Team, 2019) with a a significance level of 5%.

Table 2. Myology and nomenclature of beef cuts in Venezuela and the United States (Huerta-Leidenz, 2013).

Myology	Cut nomenclature	
	United States	Venezuela
Psoas major and minor, a small portion of quadratus lumborum and iliacus.	Tenderloin	Lomito
Longissimus dorsi (thoracis and lumborum), longissimus costarum, intertransversales lumborum, trapezius and portion of serratus, rhomboideus and deltoideus.	Rib-eye roll and strip loin	Solomo de cuerito (Grueso y Delgado)
Bíceps femoris, proximal portion.	Top sirloin cap / rump steak / coulotte	Punta trasera
Gluteus superficialis, medius and profundus.	Center cut sirloin / top sirloin butt	Ganso
Semitendinosus	Eye of round	Muchacho redondo
Semimembranosus, abductor, recto internus and pectineus	Top (Inside) round	Pulpa negra
Bíceps femoris distal portion and a small portion of semimembranosus.	Bottom (Outside) round	Muchacho cuadrado
Rectus femoris, vastus lateralis, medialis, and intermedius.	Knuckle	Chocozuela
Tensor fasciae latae.	Tri-tip	Pollo
Gastrocnemius.	Heel of round	Lagarto de la Reina
Transversus abdominis, obliquus abdomis externi e interni, rectus abdominis, cutaneus, diaphragm.	Inside skirt, flank, flank steak, rose meat and shoulder rose, outside skirt and hanging tender.	Faldas
Intercostales externi and interni, levatores costarum, retractor costae, transversus thoracis, rectus thoracis, longissimus costarum, portions of longissimus dorsi, serratus dorsalis and scalenus.	Rib plate (short ribs+ back ribs + chuck short ribs)	Costilla
Digitorum longus, digitorum brevis, digitorum internus, digitorum externus, flexor carpi radialis, extensor carpi oblicuos.	Fore shank and hind shank	Lagarto anterior y posterior
Deltoideus, infraspinatus, triceps brachialis, teres minor and major, coracobrachialis.	Shoulder clod	Paleta
Pectoralis profundi and superficial, portions of brachiocephalicus and sternocefalicus.	Brisket	Pecho
Supraspinatus	Chuck (Mock) tender	Papelón
Latissimus dorsi, longissimus dorsi, multifidus dorsi, transversus espinalis, trapezius, and romboideus.	Chuck roll	Solomo abierto
Infraspinatus	Top blade	Unknown

Results

Effects of breed type on chronological age at harvesting and carcass traits

Means and standard error means (SEM) for bulls' chronological age, carcass traits, including grading performance, according to breed type, are shown in Tables 3 to 5. The chronological age at harvesting (ca. 27 months) did not differ (P > 0.10) among breed types (Table 3) and concurs with their non-significant differences in maturity indicators (Table 4). F1-Chianina carcasses were significantly deeper in thorax than Brahman which tended to exhibit lower values. Nevertheless, Brahman had legs with bigger perimeters, significantly different from F1-Angus and F1-Romosinuano (P < 0.05). The shortest carcasses were those from Brahman, significantly different from the longest ones of F1-Simmental. The distribution of Venezuelan and USDA carcass grades by breed type are depicted in Table 5. No significant differences in grade frequencies were detected (P > 0.05) among breed types.

Table 3. Chronological age at harvesting and hot carcass linear measurements according to breed type.

Variables [1]	Brahman (n =10)	F1-Angus (n =10)	F1- Chianina (n =10)	F1-Romosinuano (n =10)	F1-Simmental (n =10)	s.e.m.	P-value
Chronological age (months)	27.0	27.2	26.9	27.2	27.4	0.28	0.45
Thoracic depth (cm)	35.88^{a}	37.36^{ab}	39.80^{b}	37.21^{ab}	37.28^{ab}	1.29	0.05
Thigh width (cm)	56.90	55.50	56.78	55.61	55.77	0.82	0.24
Leg perimeter (cm)	118.12^{b}	114.41^{a}	117.04^{ab}	114.80^{b}	116.42^{ab}	1.14	0.01
Length of pelvic limb (cm)	72.05	69.50	72.07	69.82	71.56	1.29	0.14
Carcass length (cm)	125.42^{a}	128.70^{ab}	126.55^{ab}	128.11^{ab}	129.92^{b}	1.46	0.03

[1] Values are expressed as means; [a, b] Different letters following values in the same row indicate significant differences ($P < 0.05$).

Table 4. Carcass traits according to breed type

Variables [1]	Brahman (n =10)	F1-Angus (n =10)	F1-Chianina (n =10)	F1-Romosinuano (n =10)	F1-Simmental (n =10)	s.e.m.	P-value
Finish score [2]	2.81^{a}	3.84^{b}	3.72^{b}	3.90^{b}	3.82^{b}	0.02	< 0.01
Ribeye area, cm^{2}	72.51	71.87	73.78	70.90	69.48	5.50	0.82
Ribeye area / 45.4 kg ECCwt, cm^{2}	12.41	12.82	12.79	12.09	11.56	0.95	0.63
Adjusted back fat thickness, mm	1.91	1.50	1.12	1.41	1.30	0.03	0.09
KPH, %[3]	3.15^{b}	2.04^{a}	2.01^{a}	2.63^{ab}	2.56^{ab}	0.37	0.02
Conformation score [4]	2.82	3.02	3.01	3.18	3.40	0.02	0.41
Marbling [5]	5.78	4.96	4.80	5.21	5.01	0.03	0.52
Adipose maturity [6]	3.00	2.85	2.70	2.62	2.91	0.17	0.18
Skeletal maturity [7]	165.15	161.20	155.30	164.00	168.40	5.81	0.22
Lean maturity [7]	150.20	155.01	152.15	151.01	162.04	7.19	0.20

ECCwt refers to estimated chilled carcass weight.
[1]Values are expressed as means.
[2]Where 1 = Extremely abundant, 2 = Abundant, 3 = Medium 4 = Slight, 5 = Scarce.
[3]Proportion of kidney, pelvic, and heart fat.
[4] Where 1 = Very convex, 2 = Convex, 3 = Rectilinear, 4 = Concave, 5 = Very concave.
[5] Where 1 = Abundant, 2 = Moderate, 3 = Small, 4 = Slight, 5 = Traces, 6 = Practically devoid.
[6] Refers to fat color, where 1 = Ivory white, 2 = Creamy white, 3 = Light yellow, 4 = Intense yellow, 5 = Orange.
[7]Where carcasses within the 100–199 maturity range score represent the youngest group (100 is equal to A00 and 199 is equal to A99); 200–299: represent carcasses with intermediate, more advanced maturity (200 is equal to B00 and 299 is equal to B99).
[a,b] Different letters following values in the same row indicate significant differences ($P < 0.05$).

Table 5. Frequency distribution of carcass grades following the Venezuelan and USDA grading standards according to breed type

Carcass grade	Brahman n (%)	F1-Angus n (%)	F1- Chianina n (%)	F1-Romosinuano n (%)	F1-Simmental n (%)
Venezuelan grade [1]	(P-value = 0.72)				
A	7 (14)	5 (10)	7 (14)	5 (10)	7 (14)
B	3 (6)	5 (10)	3 (6)	5 (10)	3 (6)
USDA Quality grade [2]	(P-value = 0.08)				
“Bullock” Select	0 (0)	2 (4)	0 (0)	0 (0)	0 (0)
“Bullock” Standard	10 (20)	8 (16)	10 (20)	10 (20)	10 (20)
USDA Yield grade [3]	(P-value = 0.47)				
1	5 (10)	5 (10)	8 (16)	8(16)	6 (12)
2	5 (10)	4 (8)	2 (4)	2 (4)	4 (8)
4	0 (0)	1(2)	0 (0)	0 (0)	0 (0)

[1]A and B Venezuelan carcass grades correspond to the second- and third-quality categories, respectively .[2]Carcasses of young bulls with less than 30 months of age and (or) exhibiting an A physiological maturity are designated in the "Bullock" class; USDA Select and Standard quality grades correspond to the third and fourth quality, respectively for Bullocks. [3] USDA Yield grades (YG) are rated numerically, namely 1, 2, 3, 4, and 5; a YG 1 carcass is expected to have the highest proportion (>53.5%) of boneless, closely trimmed retail cuts, while a YG 5 carcass is expected to have the lowest proportion (< 44.3%) of boneless, closely-trimmed retail cuts.

Effect of breed type on estimated chilled carcass weight and fabrication yield

The estimated weight of the chilled carcass (ECCwt; Table 6) at a constant final body weight was affected by breed type (P = 0.01). Accordingly, F1-Angus carcasses yielded the lightest ECCwt, significantly different (P < 0.01) from those of Brahman, F1-Romosinuano, or F1-Simmental.

The ANOVA detected variation in the percentage yield of several individual cuts of the carcass (Table 6). F1-Romosinuano carcasses yielded the highest percentages of ribeye + strip loin, outperforming the F1-Chianina (P < 0.05) but F1-Romosinuano also yielded the lowest (P < 0.01) percentage of the eye of round, and showed similar trends regarding other cuts from the round [Top (inside) round, Bottom (outside) round, and Knuckle] as compared to Brahman, F1-Angus, and F1-Chianina counterparts.

Table 7 depicts the percentage means for the composite groups of closely-trimmed cuts classified by their commercial value. Breed type affected the percentages of high-valued boneless cuts (HVBC; P < 0.01), medium-valued boneless cuts (MVBC; P < 0.05) and low-valued cuts (LVC; P < 0.05). Nonetheless, yield (%) of total salable cuts (TSP) did no vary significantly among breed types. Mean comparisons indicate slight but significant advantages of the F1-Chianina bulls in yield of HVBC as compared to those of F1-Romosinuano and F1-Simmental counterparts. Conversely, F1-Romosinuano outperformed F1-Chianina in 1.73 percentage points of MVBC (P < 0.05).

Regarding co-products (Table 7), carcasses from Brahman yielded slightly higher proportions (P < 0.05) of trimmed fat than F1-Chianina and F1-Angus counterparts, while F1-Romosinuano and F1-Simmental showed intermediate values. Differences in percentage yield of clean bone among breed types did not reach statistical (P = 0.06) or practical significance.

Table 6. Estimated chilled carcass weight (ECCwt) and individual cut yield (%) according to breed type

Variable [1]	Brahman (n =10)	F1-Angus (n =10)	F1- Chianina (n =10)	F1-Romosinuano (n =10)	F1-Simmental (n =10)	s.e.m.	P-value
ECCwt (kg)	265.48^{a}	254.73^{b}	261.83^{ab}	266.33^{b}	264.89^{b}	3.51	0.01
Tenderloin	2.09	2.22	2.18	2.23	2.21	0.06	0.26
Ribeye and strip-loin	8.16^{ab}	8.05^{ab}	7.88^{a}	8.46^{b}	8.03^{ab}	0.17	0.03
Top sirloin cap	1.78	1.72	1.75	1.78	1.65	0.06	0.24
Top sirloin	2.93	2.99	3.07	2.88	3.02	0.10	0.43
Eye of round	1.95b	1.92^{b}	2.14^{c}	1.70^{a}	1.98b	0.05	< 0.01
Top (inside) round	6.97^{ab}	6.54^{a}	7.12^{b}	6.56^{a}	6.68^{ab}	0.13	< 0.01
Bottom (outside) round	3.57^{c}	3.40^{b}	3.58^{c}	3.15^{a}	3.27^{ab}	0.07	< 0.01
Knuckle	3.90^{ab}	3.91^{b}	4.02^{b}	3.67^{a}	3.78^{ab}	0.08	< 0.01
Tri-tip	0.93	0.98	1.01	0.90	1.01	0.04	0.07
Heel of round	1.45	1.54	1.54	1.46	1.45	0.05	0.11
Shoulder clod and top blade	8.50	8.80	8.75	8.88	8.64	0.15	0.20
Chuck tender	1.02	1.08	1.08	1.07	1.05	0.03	0.27
Chuck roll	14.91	14.87	14.50	16.08	15.19	0.16	0.06
Brisket	5.75	5.48	5.79	5.88	5.74	0.24	0.18
Skirts	2.82^{a}	3.30^{b}	2.93^{ab}	3.16^{ab}	3.04^{ab}	0.15	0.03
Rib plate	8.27	8.24	7.91	8.33	8.32	0.21	0.47
Fore shank	1.76	1.80	1.87	1.65	1.90	0.09	0.10
Hind shank	2.71	2.81	2.82	2.55	2.61	0.09	0.06

ECCwt was computed by the sum of weights of all products (muscle cuts) and coproducts (trimmed fat, clean bone, connective tissues) derived from the fabrication.1 Mean values of individual cuts are percentages based on the EECwt.
[a, b, c] Different letters following mean values within the same row indicate significant differences (P < 0.05).

Table 7. Yield of composite groups of closely-trimmed cuts, different in commercial value and total salable product (TSP) according to breed type

Variables [1]	Brahman (n =10)	F1-Angus (n =10)	F1- Chianina (n =10)	F1-Romosinuano (n =10)	F1-Simmental (n =10)	s.e.m.	P-value
High-valued boneless cuts, % [2]	33.77[ab]	33.31[ab]	34.32[b]	32.86a	33.09[a]	0.37	< 0.01
Medium-valued boneless cuts,% [3]	24.44[ab]	24.75[ab]	24.33[a]	26.06[b]	24.87[ab]	0.56	0.03
Low-valued cuts,% [4]	21.06[a]	21.91[b]	21.32[ab]	21.60[ab]	21.65[ab]	0.26	0.02
TSP,%5	79.30	79.99	79.98	80.52	79.63	0.54	0.22
Trimmed fat,(%)	6.85[b]	5.35[a]	5.23[a]	6.03[ab]	5.90[ab]	0.38	< 0.01
Total clean bone,%	13.22	13.98	13.94	13.09	13.94	0.40	0.06

[1]Percentage mean values were computed based on the estimated chilled carcass weight.
[2]Tenderloin + ribeye and strip-loin + Top sirloin + Eye of round + Top (inside) round + Bottom (outside) round + knuckle + Tri-tip + Heel of round.
[3] Shoulder clod and top blade + chuck tender + chuck roll.
[4]Brisket +Inside skirt, flank, skirts + rib plate + shanks.
[5] Total salable products consist of the sum of the high-, medium- and low-valued cuts.
[a, b] Different letters following values within the same row indicate significant differences (P < 0.05).

Discussion

The lack of differences among breed-types in chronological age at harvest was expected because neither of them differed (P > 0.05) in days of life or days on fattening, as reported by Riera-Sigala et al. (2004). According to the latter report, Brahman and F1-Romosinuano groups tended to remain longer on pasture to reach the endpoint (with mean values of 132.2 and 120.4 days, respectively) whereas F1-Continental types, Chianina and Simmental crossbreds, required shorter (P < 0.10) fattening periods (mean values of 110.6 and 113.6 days, respectively). Allegedly, the judgment of a desirable conformation in pasture-fattened bulls at these young ages and relatively light weights, responds more to a higher degree of muscling which could favor the earlier harvesting of the F1-Continental breed types, whose sires, of larger mature sizes, are generally described as later maturing, and more muscular (leaner) than other breed counterparts at the same weight (Byers et al., 1988).

The significance of the few differences found in carcass linear measurement is unclear. Lesser thoracic depths were also observed by Rodriguez-Voigt et al. (1997) in carcasses of Zebu-type steers when compared to those of dual-purpose types with a greater influence of dairy breeds. Huerta-Leidenz and Morón-Fuenmayor (1996) on characterizing a representative sample of harvest cattle of Venezuela (N = 1 112; 658 bulls) suggested that carcass linear measurements were poorly correlated with cutability (r = 0.09 to 0.13). However, Piedrahita et al. (2003) observed that shorter bull carcasses were associated with more desirable scores of conformation and finish. Although in our study there is no clear tendency to support the association of carcass length with conformation scores, it is worth noting that the carcasses with the most abundant finish (P < 0.01) were those of the shorter Brahman carcasses, significantly different from the longer F1-Simmental and F1-Romosinuano counterparts. A previous study (Jerez-Timaure and Huerta-Leidenz, 2009) in the same ranch had pointed out that Brahman bull carcasses tended to exhibit more abundant finish, thicker BACKFAT, and smaller REA as compared to four F1 B. taurus x Brahman crossbreds. Similarly, a more abundant finish of Brahman bull carcasses as compared to those of F1-Angus and F1-Simmenthal counterparts (P < 0.05) was observed by Huerta-Leidenz et al. (2020). Brahman carcasses also tended to exhibit thicker backfat (P = 0.09) and had the highest KPH percentage value, significantly different by approximately 1.1 percentage points from the F1-Angus and F1-Chianina. Also, Johnson et al. (1988) reported that Brahman bulls had a thicker BACKFAT than Continental-type bulls but thinner than the British-type counterparts. Thicker BACKFAT of British-type bulls as compared to their Brahman and dairy-type counterparts was also observed by Lopez (1977) in Texas. In Florida, Riley et al. (2012) reported thicker BACKFAT (2.6 vs. 1.5 mm), a higher KPH (0.92 vs. 0.76%) and larger REA (79.3 vs. 72.2 cm^2) in carcasses derived from grass-fed Brahman x Angus steers when compared to the Senepol (a heat-tolerant B. taurus) x Angus counterparts (P < 0.05). In our study, F1-Angus did not differ (P > 0.05) in these carcass traits from those of Romosinuano (a heat-tolerant B. taurus) x Brahman. All breed types reached either of the top two (A or B) Venezuelan quality grades eligible for bull carcasses. Because these bulls had a chronological age of less than 30 months and their carcasses fell into the A youngest maturity classification; they were, thus, eligible for the maturity classification; they were, thus, eligible for the "Bullock" class designation in the U.S. (USDA 2017). Except for two F1-Angus bullock carcasses that graded USDA Select, all others graded USDA Standard. USDA Yield grade 1 predominated in this bull sample, indicating superior cutability. Other studies with Brahman or Brahman crossbred bulls in their youngest A maturity, fattened to tropical or subtropical grass pastures, reported that their carcasses did not exceed "slight" marbling amount (Jerez-Timaure and Huerta-Leidenz 2009) or "practically devoid" of marbling (Chase et al. 2006), resulting in USDA Select or Standard grades. Also, in Venezuela, grass-fed F1 Senepol x Nelore bull carcasses of B maturity graded USDA Standard (Huerta-Leidenz et al., 2004). Likewise, in the report of Huerta-Leidenz et al. (2020), all grass-fed Brahman and F1 crosses were graded as Standard bullocks and reached either of the top two (1 or 2) USDA yield grades. In Mexico, even under feedlot tropical conditions, carcasses from Zebu straightbred and Dairy x Zebu crossbred young bulls did not surpass the "traces" amounts of marbling and thus, the USDA Standard grade (Vazquez-Mendoza et al., 2017) whereas all breedtypes reached the USDA yield grade 1, which agrees with our findings. In the work of Riley et al. (2012) under feedlot, subtropical conditions, Brahman and F1- Romosinuano steers graded with the least percentage of Choice carcasses and the greatest percentage of Standard carcasses (P < 0.01) while reaching USDA yield grade mean values of 2.9 and 2.7, respectively.

The significant differences in the estimated chilled carcass weight among the breedtypes were not expected because our previous report on the same cattle sample (Riera-Sigala et al. 2004) the unadjusted hot carcass weight did not differ among the breedtypes (P > 0.05). However, the weight of the hot carcasses from heaviest to lightest (Riera-Sigala et al., 2004) can be ranked in the same breed type order (i.e., F1-Romosinuano, Brahman, F1-Simmental, F1-Chianina, F1-Angus). However, in a previous trial, chilled carcasses derived from Romosinuano were significantly heavier than those from F1-Angus and F1-Chianina (Huerta-Leidenz et al. (2020).

Few studies have found significant differences between breeds or breed types for the percentage of expensive cuts of the carcass (Preston and Willis 1975). Huerta-Leidenz and Jerez-Timaure (1996) found that Continental-type bulls yielded a higher percentage (P < 0.05) of Venezuelan-styled HVBC as compared to Zebu and Dual purpose (Zebu x Dairy) types. Significantly lower HVBC yield of F1-Romosinuano compared to Brahman, F1-Limousin, and F1-Gelbvieh were also reported by Jerez-Timaure and Huerta-Leidenz (2009).

Regarding co-products, Huerta-Leidenz et al. (2020) also reported that Brahman bull carcasses tended to exhibit higher proportions of trimmed fat as compared to those from F1-Simmental (P = 0.08). However, significant differences in carcass yields of trimmed fat or clean bone among four Brahman-influenced breed types were detected by Jerez-Timaure and Huerta-Leidenz (2009). Notwithstanding, in an observational study with a larger number of Venezuelan cattle (all market classes) classified by apparent genotype (N = 844), Huerta-Leidenz and Jerez-Timaure (1996) found that Zebu-type carcasses yielded the highest percentage of trimmed fat, and the lowest proportion of bone; significantly different from the Continental type.

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Conclusions

Because of the very limited number of sires per breed and the relatively small progeny numbers, this experiment was not intended either to investigate progeny testing or to characterize these Brahman-influenced types. The preliminary results indicate that it is possible to fatten entire males grazing cultivated pastures with supplemental feed in ranches traditionally dedicated to breeding operations and to harvest them at relatively young ages or carcass maturities. The small differences detected among breed types in carcass performance indicators suggest that optimal harvest weight (or ages) of the larger genotypes, from a compositional standpoint, were not reached. Marketing schemes that restrict harvest weight and other characteristics tend to constrain potential improvement of efficiency. Except for some small advantages in leanness, no relevant changes in carcass performance can be expected from crossbreeding under the described conditions. The similarities among the breed type groups in chronological age at harvest, days on pasture, and most carcass performance indicators at the established harvest endpoint indicates that the initial selection of the heavier individuals from each group eliminated or reduced the natural variation, and hence, prevented the expression of genetic differences. The observations presented herein strongly suggest the convenience of repeating the experiment with larger sample size and make the comparisons at equal fatness endpoints.

Conflicts of interest. The authors declare no conflicts of interest.

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Literature Cited

Byers, F. M., H. R. Cross, and G. T. Schelling. 1988. Integrated nutrition, genetics, and growth management programs for lean beef production. In: Designing Foods: Animal product options in the marketplace. National Academy Press, Washington, DC. p. 283–291. doi:10.17226/1036.

Chase Jr., C.C., P. J. Chenoweth, R.E. Larsen, A. C. Hammond, T. A. Olson, R.L. West, and D.D. Johnson. 2001. Growth, puberty, and carcass characteristics of Brahman-, Senepol-, and Tuli-sired F1 Angus bulls. J. of Anim. Sci. 89: 2006–2015. doi:10.2527/2001.7982006x

COVENIN. 1982. Comisión Venezolana de Normas Industriales. Norma Venezolana 792-82. Carne de bovino. Definición e identificación de las piezas de una canal. Ministerio de Fomento. Fondonorma, Caracas, Venezuela. p 10.

COVENIN. 1983. Comisión Venezolana de Normas Industriales. Norma Venezolana 2072-83. Ganado bovino. Inspección Postmortem. Ministerio de Fomento. Fondonorma, Caracas, Venezuela. p 10.

Crouse, J. D., L. V. Cundiff, R. M. Koch, M. Koohmaraie, and S.C. Seideman. 1989. Comparisons of Bos indicus and Bos taurus inheritance for carcass beef characteristics and meat palatability. J. Anim. Sci. 67: 2661-2668. doi:10.2527/jas1989.67102661x

Decreto Presidencial No. 181. 1994. Gaceta Oficial de la República de Venezuela No 4737. p. 4. Caracas, Venezuela.

Decreto Presidencial No. 1896 (1997) Gaceta Oficial de la República de Venezuela No. 36.242. p 4. Caracas, Venezuela.

FONACIT. 2008. Código de Bioética y Bioseguridad. Ministerio del Poder Popular para Ciencia y Tecnología. 3a Edición. 63 pp.

Huerta-Leidenz, N. 2013. International nomenclature guide of beef cuts for the U.S.A. and other countries targeted by the U.S. Meat Export Federation. U.S.M.E.F. https://www.usmef.org/export-resources/intl-innovative-cuts/international-beef-cuts-nomenclature-guide/) (Accessed 23 December 2020).

Huerta-Leidenz N, E. Alvarado, L. Martínez, and E. Rincón. 1979. Conformación, acabado y características biométricas de la canal de diferentes clases de bovinos sacrificados en el Estado Zulia. Rev. Fac. Agron. (LUZ). 5: 522-536.

Huerta-Leidenz, N., and K. Belk. 1996. The Brahman cattle on the threshold of the XXI Century. Astro-Data, Maracaibo, Venezuela.

Huerta-Leidenz, N., and N. Jerez-Timaure. 1996. Discovering commercial value of Venezuelan beef. In: Ed. N Huerta-Leidenz and K Belk, editors, The Brahman cattle on the threshold of the XXI Century. Astro-Data, Maracaibo, Venezuela. p. 349-373.

Huerta-Leidenz, N., and O. Morón-Fuenmayor. 1996. Variation of certain traits measured in live cattle and their carcasses and correlations with yield of most valuable cuts. Rev. Científica FCV-LUZ. 6: 53-67.

Huerta-Leidenz, N., A. Rodas-González, and G.C. Smith. 2004. Effect of vacuum aging and influence of sire on palatability of beef longissimus from grass-fed F1 Senepol x Zebu bulls. Rev. Cientifica FCV-LUZ 14: 263-269.

Huerta-Leidenz, N., A. Rodas-González, A. Vidal, J. López-Nuñez, and O. Colina. 2016. Carcass cut-out value and eating quality of longissimus muscle from serially harvested savannah-raised Brahman–influenced cattle and water buffaloes in Venezuela. Animal Product. Sci. 56:2093-2104. doi.org/10.1071/AN14987.

Huerta-Leidenz, N., Ruiz-Flores A, Valerio-Hernandez, Jerez-Timaure N, and Rodas-Gonzalez A. 2020. Bullock carcass performance trends in Brahman and F1 crosses fattened on tropical pastures. Nacameh. 14(1): 16-30.

Jerez-Timaure, N., and N. Huerta-Leidenz. 2009. Effects of breed type and supplementation during grazing on carcass traits and meat quality of bulls fattened on improved savannah. Livestock Sci. 121:219-226. doi:10.1016/j.livsci.2008.06.015

Johnson, D. D., D. K. Lunt, J. W. Savell, and G.C. Smith. 1988. Factors affecting carcass characteristics and palatability of young bulls. J. Anim. Sci. 66: 2568-

-2577. doi:10.2527/jas1988.66102568x

Lascano, C. E. 1991. Harry Stobbs Memorial Lecture: Managing the grazing resource for animal production in tropical America. Trop. Grassl. 25: 66-72.

Lopez, A. L. 1977. Effects of age, breed and method of carcass suspension on Bullock beef palatability, carcass traits, histological measurements and certain age and yield predictors. Ph. D. Dissertation. Texas A&M University, College Station, Texas.

Montero, A., N. Huerta Leidenz, A. and Rodas González, L. Arenas de Moreno. 2014. Fabrication and variation of the cutout yield of beef carcasses in Venezuela: Anatomical description of the process and equivalency of cut nomenclature to North American counterparts. Nacameh 8:1-22.

Piedrahita, J., R. Quintanilla, C. Sañudo, J. L. Olleta, M. M. Campo, B. Panea, G. Renand, F. Turin, S. Jabet, K. Osoro, M.C. Olivan, G. Noval, P. Garcia, M. D. Garcia, M. A. Oliver, M. Gispert, X. Serra, M. Espejo, S. Garcias, M. Lopez, and M. Izquierdo. 2003. Carcass quality of 10 beef catlle breeds of the Southwest of Europe in their typical production systems. Livest. Prod. Sci. 82: 1-13. doi:10.1016/S0301-6226(03)00006-X

Plasse, D., 1992. Presente y futuro de la producción bovina en Venezuela. In: Ed. C. González-Stagnaro, editor, Ganadería mestiza de doble propósito. Universidad de Zulia Press, Maracaibo, Venezuela. pp. 1-24.

Plasse, D., H. Fossi, R. Hoogesteijn, O. Verde, C.M. Rodríguez, R. Rodríguez, and P. Bastidas. 1995. Growth of F1 Bos taurus × Bos indicus versus Bos indicus beef cattle in Venezuela. II. Initial, final, and carcass weight of bulls, and breeding weight of heifers. J. of Anim. Breed. Genet. 112: 133-145. doi:10.1111/j.1439-0388.1995.tb00548.x

Preston, T. R., and M. B. Willis. 1975. Intensive beef production. Pergamon Press Inc., New York, USA.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/ (Accessed 22 December 2019).

Reverter, A., D. J. Johnston, D. Perry, M. E. Goddard, and H. M. Burrow. 2003. Genetic and phenotypic characterization of animal, carcass, and meat quality traits from temperate and tropically adapted beef breeds. 2. Abattoir carcass traits. Aust. J. Agric. Res. 54: 119-134. doi: 10.1071/AR02086

Riera-Sigala T, A., Rodas-González, C. Rodríguez-Matos, J. F. Avellaneda, and N. Huerta-Leidenz. 2004. Growth traits and carcass weights of purebred Brahman and F1 Brahman x Bos taurus bulls raised and fattened semi-intensively on improved savannah. Arch. Latinoam. Prod. Anim. 12: 66–72.

Riley, D. G., C. C. Chase, S. W. Coleman, W. A. Phillips, M. F. Miller, J. C. Brooks, D. D. Johnson, and T. A. Olson. 2012. Genetic effects on carcass quantity, quality, and palatability traits in straight bred and crossbred Romosinuano steers. J. Anim. Sci. 90: 2159–2166. doi:10.2527/jas.2011-4471

Rodas González, A., N. Huerta-Leidenz, and N. Jerez-Timaure. 2017. Benchmarking Venezuelan quality grades for grass-fed cattle carcasses. Meat Muscle Biol. 1: 71-80. doi: 10.22175/mmb2017.04.0022

Rodríguez-Voigt, A., E. Noguera, H. Rodríguez, N. Huerta-Leidenz, O. Morón-Fuenmayor, and E. Rincón. 1997. Crossbreeding dual-purpose type cattle for beef production. Meat Sci. 47: 177-185. doi:10.1016/S0309-1740(97)00044-2

Sarmiento G, M. Pinillos, M. Pereira Da Silva, and D. Acevedo. 2004. Effects of soil water regime and grazing on vegetation diversity and production in a hyperseasonal savanna in the Apure´s Llanos, Venezuela. J. Trop. Ecol. 20: 2019-220. doi:10.1017/S0266467403001299

Schutt, K. M., H. M. Burrow, J. M. Thompson, and B. M. Bindon. 2009. Brahman and Brahman crossbred cattle grown on pasture and in feedlots in subtropical and temperate Australia. I. Carcass quality. Anim. Prod. Sci. 49: 426-438. doi:10.1071/EA08083

Shapiro, S., and M. Wilk. 1965. An analysis of variance test for normality (complete samples)', Biometrika. 52: 591-611.

Smith, J. K., E. J. Chacón-Moreno, R. H. G. Jongman, P. P. Wenting, and J. H. Loedeman. 2006. Effect of dike construction on water dynamics in the flooding savannahs of Venezuela. Earth Surf. Proc Land. 31: 81–96. doi:10.1002/esp.1235

Steel, D., and H. Torrie. 1992. Bioestadística: Principios y procedimientos 2nd ed. Mc. Graw Hill, Mexico DF, Mexico.

USDA. 2017. Official United States standards for grades of feeder cattle. Agric. Marketing Serv., United States Department of Agriculture, Washington, DC.

Vazquez-Mendoza, O. V., G. Aranda-Osorio, M. Huerta-Bravo, A. E. Kholif, M. M. Y. Elghandour, A. Z. M. Salem, and E. Maldonado-Simán. 2017. Carcass and meat properties of six genotypes of young bulls finished under feedlot tropical conditions of Mexico. Anim. Prod. Sci. 57: 1186–1192. doi:10.1071/AN141037