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A meta analysis on carcass and meat traits of feedlot steers from different genetic backgrounds in Brazil

Metanálise sobre características de carcaça e carne de novilhos confinados de diferentes origens genéticas no Brasil

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Abstract: The aim of the present study was to assess the carcass and meat characteristics of feedlot steers in Brazil according to genetic group through a systematic review and meta-analysis. An electronic article search was conducted at the Scielo and Google Scholar databases and data were grouped according to genetic predominance. The results were tested for heterogeneity and submitted to a normality test and F test and the means were compared by the Tukey test. Predominantly British steers were finished at a younger age, required longer confinement times and displayed lower hot carcass weights and smaller loin eye areas at slaughter. Muscle carcass percentages were higher in Continental and Synthetic steers compared to British and Zebu steers, while fat percentages were higher in British and Zebu steers compared to continental and synthetic breeds. Meat marbling was higher in British, continental and crossbreed steers compared to synthetic and zebu steers. A British steer origin allows for decreased slaughter age, although leading to reduced hot carcass weight, while a genetic Zebu predominance can produce high fat percentage carcasses.

Keywords: british, continental, subcutaneous fat.

Resumo: O objetivo do presente estudo foi avaliar as características da carcaça e da carne de novilhos confinados no Brasil de acordo com o grupo genético por meio de uma revisão sistemática e meta-análise. Foi realizada busca eletrônica de artigos nas bases de dados Scielo e Google Acadêmico e os dados foram agrupados de acordo com a predominância genética. Os resultados foram testados quanto à heterogeneidade e submetidos ao teste de normalidade e teste F e as médias comparadas pelo teste de Tukey. Novilhos predominantemente britânicos foram terminados em idade mais jovem, necessitaram de tempos de confinamento mais longos e apresentaram menores pesos de carcaça quente e menores áreas de olho de lombo no abate. Os percentuais de carcaça muscular foram maiores nos novilhos Continentais e Sintéticos em relação aos Britânicos e Zebu, enquanto os percentuais de gordura foram maiores nos Britânicos e Zebu em comparação aos continentais e sintéticos. O marmoreio da carne foi maior nos novilhos britânicos, continentais e mestiços em relação aos novilhos sintéticos e zebuínos. A origem do novilho britânico permite menor idade de

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abate, embora leve à redução do peso da carcaça quente, enquanto a predominância genética do zebu pode produzir carcaças com alto percentual de gordura.

Palavras-chave: britânico, continental, gordura subcutânea.

1. Introduction

Global concerns regarding food security have increased as population growth and consumption forecasts indicate that the world's food demands will be significantly higher in the coming decades [(1)]. Under this perspective, Brazil is considered one of the main beef producers in the coming years [(2)], with a responsibility towards increasing its production in a sustainable manner [(3)].

Due to the wide diversity of Brazilian production environments and management systems, national beef quality tends to be highly variable, which makes it difficult to systematize certain effects, such as genetics [(4)]. Even though research has committed to quantifying genetic carcass and meat effects in recent decades, few studies comparing the predominance of more than two genetic steer types (British, Continental, Zebu and their crosses) in the same search are available, due the requirement of many animals in order to ensure statistical assumptions. An alternative in this regard is the adoption of meta-analytical procedures, which can be applied alongside joint study analyses through the systematization of the results reported in multiple studies, allowing for increased precision, reduced costs and research time and increased analysis degrees of freedom [(5,6,7)].

Most of the cattle slaughtered in Brazil are of *Bos indicus* origin (over 80%), given the species tolerance to tropical climates and high ectoparasite resistance [(8)]. Despite advantages concerning this species production in tropical environments in intensive systems *i.e.*, under confinement, demands for animals with some degree of European blood have increased, whether for the development of defined genotypes, or for crosses to explore heterosis or synthetic breed development, due to market pressures for superior quality carcass and meat [(9)]. Therefore, certain features of interest to the beef industry, such as quantitative and physical carcass compositions, are economically important, as they affect cut yields and final consumer meat quality perceptions, having been widely evaluated in terms of genetic effects [(10)].

In this context, the aim of the present study is to evaluate carcass and meat characteristics in confined steers from different genetic origins in Brazil through a systematic review and meta-analysis, Our hypothesis is that, even in similar finishing systems, both in confinement and in scheduled slaughters to meet the consumer market, differences in carcass and meat characteristics of steers finished in Brazil can still be detected due to different genetic origins.

2. Material and methods

2.1 Systematic review

Two independent reviewers selected articles concerning the carcasses and meat of steers finished in feedlots through an electronic search conducted at the Scielo and Google Academic databases between June and December 2019.

The criterion for choosing the question applied in the article searches was decomposed according to the PICO tool [11], an acronym for "Patient, Intervention, Comparison and Outcomes". Pages in Portuguese with no year restriction were retrieved from the Google Scholar electronic platform. No language or year restrictions were applied to the Scielo electronic platform. The four PICO strategy components and the keyword elaboration employed in this research were applied to both platforms (Table 1).

Table 1 PICO strategy and keyword elaboration descriptions.

Acronym	Definition	Search protocol	Search strategy
P	Patient or problem	Beef cattle	beef cattle
I	Intervention	Different sexual conditions and different categories	steers OR cattle OR steers young
C	Control or comparison	Steers finished in confinement	confined steers OR finished in confinement
O	Outcomes	Quantitative and qualitative carcass and meat characteristics	carcass weight OR carcass yield OR tenderness of the meat OR muscle yield

A total of 380 articles were retrieved, 193 from the Google Scholar platform and 187 from the Scielo platform. The titles of each article were then read, eliminating duplicates. Each article's abstract was copied to Google Forms electronic forms for blind evaluation. Ten electronic forms were prepared and saved in a virtual Google Drive folder.

2.2 Article screening and selection

Ten evaluators were chosen during the screening stage and instructed to access the Google Drive electronic address that contained the 10 electronic forms, one specific for each reviewer according to electronic address access order. Each abstract appeared in two different forms and the evaluators classified the articles between "fit" and "unfit" to enter the database. "Fit" articles would have to: (1) originate from primary research (fieldwork); (2) address feedlot steer carcass and meat characteristics; (3) be developed in Brazil; (4) inform the breed or genetic predominance of the animals. If one of these criteria was not met, the article was classified as "unfit".

2.3 Database

A total 76 articles remained following the screening stage, which were then fully evaluated to construct the database, created in an Excel spreadsheet, in which each article treatment was considered a sampling unit (line) in the database. Information on the material and methods and results and discussion of the respective treatment were recorded for each sample unit. Subsequently, the data were classified according to the genetic predominance of the evaluated steers, namely British, Continental, Zebu, Synthetic or Crossed. Thirteen (13) variables were analyzed, comprising age at finishing, finishing period, body weight at slaughter, hot carcass weight, hot carcass yield, loin-eye area, subcutaneous fat thickness muscle percentage, bone percentage, fat percentage, meat coloring, meat marbling and meat shear strength.

2.4 Statistical analyses

Data were analyzed using the SAS 9.2 software. The consistency of inter-experiment results was quantified using Chi-square (Q) test heterogeneity measures and *I2* statistics (12), which quantifies heterogeneity meta-analysis impacts, with an independent criterion concerning number of studies and metric effects of each treatment (13). The I^2 statistics is calculated as:

$$I^2(\%)=\left(\frac{Q-(k-1)}{Q}\right)\times 100$$

where: *Q* is the heterogeneity statistic, and χ2 and k are the number of assays.

The *rstudent* statistic was used as an exclusion criterion for publications with an excess of observations with values above 2 and below -2 to identify articles presenting greater heteroscedasticity. The articles were also analyzed concerning methodological similarity, requiring the use of the same methodology as in meat analyses, as described by Pacheco (14). A total of 22 publications were removed from the analysis following this procedure, with 52 articles remaining and comprising the data matrix.

Data normality was tested by the Kolmogorov-Smirnov test and homogeneity of variances was assessed by the Levene and Brow-Forsythe tests. The mixed model procedure applied using the PROC MIXED command was used for normally distributed variables, due to the nature of the repeated data measures, sequentially in time (articles). The data were then submitted to an analysis of variance by the F test and significant means were compared by the Tukey test at a significance level of 5%. Finishing period, slaughter body weight, muscle percentage, bone percentage and shear force did not meet normality and residue homogeneity assumptions and were analyzed by the GLIMMIX procedure available in the SAS v. 9.2 software through the PROC GLIMMIX command. GLIMMIX is used to fit statistical models to data presenting inconsistent correlations or variability and in cases in which responses are not necessarily normally distributed (15).

The mathematical model used for the analysis of variance was:

$$Y_{ijklm} = \mu + n_i + breed_j + Sex_k + Concentrate_l + object_m + e_{ijklm}$$

Considering Y_{ijklm}, as dependent variables; μ as the the means of all observations, n_i as the effect of the article sample number, $breed_j$ as the effect of genetic predominance, $Concentrate_l$ as the effect of concentrate diet percentage, Sex_k as the effect of sexual condition, $object_m$ as the effect of the study object and e_{ijklm} as the random error associated with each observation, NID (0, σ2).

3. Results

Steers finished in Brazilian feedlots show differences in age at slaughter and finishing period without differing in body weight at slaughter as a function of genetic predominance (Table 2). British steers are slaughtered at a similar age to continental steers and younger than Zebu, synthetic and crossbred steers. The reduced slaughter age of British steers implies in a longer confinement period than steers of Continental, Zebu, and Synthetic origin. Predominantly Synthetic steers require less confinement times than crossbred steers. Slaughter weight was not influenced by genetic predominance in Brazilian research.

Table 2 Age and initial and final weight of feedlot steers according to genetic group.

	Age (months)	Finishing period (days)	Weight at slaughter (kg)
British	15.4 ± 1.2b	165.1 ± 11.5a	396.8 ± 22.5
Continental	18.8 ± 1.2ab	122.4 ± 10.1bc	444.3 ± 14.4
Zebu	21.1 ± 1.0a	128.2 ± 6.5bc	451.2 ± 10.6
Synthetic	20.1 ± 1.2a	117.4 ± 5.6c	458.3 ± 17.5
Crossed	20.1 ± 0.8a	141.4 ± 5.1ab	444.9 ± 10.6
P value	0.0036	0.0013	0.1525

The quantitative characteristics associated to slaughter and carcass cooling of the animals evaluated in the present study differed between the different genetic groups (Table 3). Hot carcass weights were lower in steers of British origin when compared to Zebu, Synthetic and crossbred steers, not differing from predominantly Continental steers. Hot carcass yields were similar among British, Continental, Zebu, Synthetic and crossbreeds. Concerning quantitative evaluations of the *longissimus dorsi* muscle, the loin-eye area of carcasses of Continental, Zebu, Synthetic and crossbred steers were similar to each other and superior to those of British origin. No genetic predominance influence was identified concerning subcutaneous fat thickness.

Table 3 Quantitative and qualitative feedlot steer carcass characteristics according to genetic group

	HCW, kg	HCY, %	REA, cm^2	SFT, mm
British	213.4 ± 11.8b	54.1 ± 1,2	56.6 ± 3.6b	4.8 ± 0.6
Continental	232.6 ± 18.3ab	53.1 ± 1.8	68.1 ± 4.8a	4.5 ± 0.9
Zebu	253.1 ± 7.3a	56.1 ± 0.5	64.3 ± 1.9a	5.1 ± 0.4
Synthetic	251.3 ± 8.9a	55.0 ± 0.9	70.9 ± 2.6a	4.3 ± 0.5
Crossed	250.9 ± 5.6a	56.0 ± 0.6	66.4 ± 1.6a	4.3 ± 0.3
P value	0.0174	0.2324	0.0116	0.2600

PCQ = Hot carcass weight; HCY = Hot carcass yield; REA = ribeye area; SFT = Subcutaneous fat thickness

Carcass muscle and fat percentages are affected by genetic predominance (Table 4), where Continental and Synthetic genetic steers confer higher muscle carcass percentages than British, Zebu andCrossbreeds, with the latter being similar to each other. Fat percentages were higher in British and Zebu steers compared to Continental and synthetic breeds.

Crossbred steers do not differ with regard to fat percentage in relation to the other analyzed groups. Bone percentages are not affected by genetic predominance.

Table 4 Physical carcass composition of feedlot steers according to genetic group.

	Muscle, %	Fat, %	Bone, %
British	61.5 ± 0.9b	23.1 ± 1.0a	15.1 ± 0.3
Continental	66.9 ± 1.5a	19.5 ± 1.4b	14.9 ± 0.4
Zebu	61.5 ± 1.3b	24.4 ± 1.2a	15.8 ± 0.4
Synthetic	68.4 ± 2.5a	16.9 ± 2.4b	15.3 ± 0.7
Crossed	63.6 ± 0.7b	22.1 ± 0.8ab	15.0 ± 0.2
P value	0.0024	0.0104	0.2127

Meat color and shear force were not influenced by genetic predominance (Table 5). Meat marbling in animals of British, Continental, and crossbreeds did not differ from each other but were superior to animals of Zebu and Synthetic origin.

Table 5 Meat traits from feedlot steers according to genetic group.

	Coloring, points	Marbling, points	Shear force, kgf/cm^3
British	3.69 ± 0.18	6.37 ± 0.50a	5.62 ± 0.40
Continental	3.85 ± 0.18	6.57 ± 0.65a	4.79 ± 0.68
Zebu	3.49 ± 0.26	4.70 ± 0.73b	5.49 ± 0.51
Synthetic	4.35 ± 0.61	3.02 ± 0.98b	4.53 ± 0.25
Crossed	3.93 ± 0.09	6.20 ± 0.36a	5.84 ± 0.33
P value	0.3777	0.0148	0.2712

4. Discussion

The precocity of European breeds, mainly in animals of defined British breeds, in relation to genotypes that contain Zebu blood is noted in this meta-analysis concerning age at slaughter and hot carcass weight. A predominantly British genetic background leads to decreased slaughter age compared to Zebu, Synthetic and Crossbreed animals, with no difference compared to Continental ones. On the other hand, these animals require more confinement times than Continental, Zebu and synthetic animals, explained by the low age at which British steers are confined in Brazil. Fernandes [(16)], report that precocity is one of the most commercially desired traits, as it is inversely correlated with meat tenderness. The authors also indicate that this influences the meatpacking industry and livestock breeders' associations encourage producers to sacrifice animals when they are young, with prizes and bonuses given to breeders who produce precocious animals. Mazzucco [(17)], report that smaller adult sizes, earlier maturation and lighter carcasses are characteristic of British breeds, although presenting more fat and lower lean muscle mass percentages than Continental breeds and their crosses. Owens [(18)] define physiological maturity as the weight at which body protein mass reaches its maximum, a situation in which protein addition declines to practically zero, which has been verified when the animals present around 36 % empty body weight fat.

The similarities observed for slaughter weights and subcutaneous fat thickness among different genetic steer predominances are probably due to studies carried out in slaughters scheduled to meet the consumer market, not exploring the full weight and fat gain deposition potential in steers, which may also be influenced by age and finishing period. However, although slaughter weights were similar, hot carcass weights were lower in British steers compared to the other groups evaluated in this meta-analysis, possibly as a response to their low slaughter age. This highlights the paradox that many production systems face when seeking greater herd precocity, but compromise carcass weight as a response to distinct selection process characteristics and respective breed aptitudes. As animals of Continental origin were selected seeking weight gains and high body weights at maturity, thus requiring greater musculature, British breeds, due to their greater precocity, have been subjected to an intense selection process to reduce slaughter age and obtain high meat quality [19]; [20]. These features are also manifested in Synthetic breeds and in crossed genotypes and are widely employed in a complementary manner in crossings [20,21] .

The smaller area of the *longissimus* muscle in animals with a British genetic predominance may also be associated with their lower age at slaughter. The precocity of British animals concerning fat deposition associated with good nutritional levels in the finishing phase allow for faster body fat deposition, determining slaughter at younger ages [22]. When working with energy supplementation in pastures cultivated in winter and summer, Vaz [23] verified that the dietary energy supply of supplemented animals determined different tissue gain compositions, with correlations between dietary energy levels and muscle development and subcutaneous fat deposition noted.

The results reported herein also indicate the potential for subcutaneous fat deposition in cattle of Zebu origin when submitted to better quality diets or even in crosses with animals of Continental origin as a strategy to increase slaughter weight without compromising fat carcass coverage [24]. Carcasses with low subcutaneous fat coverage may present muscle shortening during the carcass cooling phase and compromised meat tenderization [25]. Research involving molecular Zebu cattle analyses with regard to carcass and meat traits has increased in the last decade [26]. Genomic regions on chromosomes 1, 2, 5, 6, 7, 8, 10, 13, 14 and 26, which together explain 12.96% of the total additive genetic fat variance (subcutaneous fat thickness), associated with the rib eye area and marbling, have been identified in Nellore cattle [27], allowing for significant advances in genetic Zebu cattle carcass and meat quality improvement.

The higher muscle percentages detected in Continental and Synthetic steer carcasses compared to Zebu and British steers reflect the high weight gain capacity of these groups. This is desired in feedlots, due to higher potential for adding value per housed animal. On the other hand, larger and, consequently, older, animals require greater slaughter weights to present the fat coverage desired by slaughterhouses. [28]. This propensity is reflected in the carcass fat percentage of steers with Continental and Synthetic genetic backgrounds employed in Brazilian research, noted as lower than that of Zebu and British animals. Kause [29] verified that bovines of Continental origin demonstrate negative genetic correlations between conformation and fat deposition. Pritchard [30] report that carcass fat content is reduced in genetic selection programs aimed at increasing carcass weights, mainly in Continental breeds, due to increased growth rates.

The similarities in meat color and shear strength detected in the present meta-analysis can be partly explained by selected studies derived from feedlot finishing systems. This indicates that the genetic meat quality effect can be reduced when animals are submitted to better nutritional levels, and even go unnoticed by consumers. European breeds, especially those involving some degree of British blood, are more likely to exhibit a higher degree of meat marbling [31, 32]. Marbling is appreciated by consumers due to its effect on meat juiciness, tenderness, palatability, and polyunsaturated fatty acid levels, which represent relevant consumer sensory and qualitative characteristics [33, 34]. The literature indicates only slight marbling degree differences between the defined breeds and their crosses, when of *Bos taurus taurus* origin [35], which are accentuated when comparing defined and *Bos taurus indicus* cross breeds [36], or *Bos taurus indicus vs Bos taurus taurus* [17]. When associating the effect of marbling degree on meat tenderness and shear force in animals of *Bos taurus indicus* and *Bos taurus taurus* backgrounds, Wheeler [37] verified that increased marbling in Zebu cattle was more important than in animals of European origin, as a strategy to increase meat tenderness and reduce shear force.

Tenderness, which can be evaluated by shear force, is considered the most important meat quality [38] and is constantly estimated indirectly by subcutaneous fat thickness and muscularity [39]. However, even with differences in hot carcass weight and subcutaneous fat thickness, these were not enough in our study to imprint meat shear force differences between the evaluated genetic groups. The effect of breed on meat quality is a rather conflicting approach in the literature and comprises multiple factors. Based on a review of 10 available studies on beef tenderness in cattle, Berry [40] reported tenderness as assessed by the panel of evaluators to present a median heritability estimate of 0.23, suggesting that, after accounting for systematic environmental effect differences (*e.g.,* contemporary group, gender, age), 23% of the remaining intra-breed tenderness variability was due to additive genetic differences [41]. When comparing dairy and beef genotypes, Coleman [39] did not detect any effect of breed on steer meat tenderness and shear force, suggesting that effects such as age, degree of carcass finishing and meat marbling may better explain qualitative meat characteristic variations or similarities than genetic variations. Nassu [42], verified that genetic group had a smaller effect on sensorial meat characteristics than the combined effect between production system, sex, and genetic group. In a meta-analysis concerning beef cow meat tenderness, Pacheco [14] reported that the genetic effect and heterotype explain 24.79% of tenderness variations, with the remainder being explained by other factors, such as age, marbling, finishing period and the search itself.

5. Conclusion

A British genetic steer predominance confers greater slaughter precocity but reduces meat production in carcass equivalents. Greater muscularity as a result of Continental breed selection, as well as in Synthetic breeds, determines lower fat carcass levels. When subjected to intensive production systems such as confinement systems, Zebu cattle can produce quality carcasses, although further research and greater selection are required to lead to a marbling degree similar to that observed in predominantly European steers.

Conflicts of interest

The authors declare no conflicts of interest.

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