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Mixed factor analysis of the influences of beef cattle production characteristics on carcass traits

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ABSTRACT - This study aimed to investigate whether the beef cattle production system enhances the commercial value of beef carcasses. We assessed which characteristics of the production system most significantly influence the carcass grade and consequently the value generated, using a database from a commercial property analyzed through mixed factor analysis. The dataset included information on 3,612 cattle slaughtered commercially from a property in Mato Grosso do Sul in 2019. Qualitative explanatory variables considered were breed, sex, type of finishing, slaughterhouse, fat finishing, and dentition. Quantitative variables included live weight, hot carcass weight, carcass yield, value, amount paid, and payment according to carcass grade protocols. The carcass grade protocols in Mato Grosso do Sul, which are based on carcass classification criteria such as precocity, fat finishing, breed, sex, and slaughterhouse, were also examined. The analysis revealed that the absolute and cumulative percentages of variance explained by the factors were 65.27%, indicating that a significant portion of the total variance was explained by the model. The statistical model effectively represented the production system, decision-making regarding finishing methods, and slaughterhouse choices in relation to potential bonuses based on carcass classification, animal characteristics, and herd characteristics. Key productive characteristics influencing carcass remuneration included weight, sex, and type of finishing, all of which were closely linked to the production system employed.

Keywords: carcass grade, cattle production system, PCA, payment bonus protocols, type of finishing

1. Introduction

Brazil is a leading producer of beef cattle, predominantly focused on commodity-type production. However, the evolving demands in livestock activities reflect a shift toward adding value to meat products, such as premium cuts with high-quality standards (Viegas et al., 2015). Producers who can direct their meat production to niche or international markets can better position their products for commercialization (Flores et al., 2018). In response to these market shifts, carcass grade protocols have emerged, designed to identify animals with the potential to produce high-quality meat cuts (Gomes et al., 2019).

Globally, producers are typically compensated based on body weight (kg), carcass weight, and carcass qualities attributes (Peel et al., 2024). In Brazil, however, slaughterhouses typically base payments on hot carcass weight (kg), with carcass dressing percentage used as an important indicator of slaughter efficiency and yield (Costa et al., 2002). This system emphasizes quantity over carcass and meat cut quality.

The Brazilian standard form of negotiation is by carcass weight, where the price is expressed per arroba, a unit representing the weight of the bovine carcass (bone-in meat, excluding by-products). In Brazil, economic productivity indicators are also measured using arrobas. For instance, cattle with a live weight of 500 kg, producing a carcass of 250 kg, result in a 50% yield (250 kg/500 kg). These 250 kg of carcass equate to 16.7 arrobas; therefore, compensation is primarily based on carcass weight, which is converted to arrobas. If the negotiated price with the slaughterhouse is R$ 156.00 per arroba, the payment for the cattle would be R$ 2,600.

In payment systems based on carcass weight, carcasses are cleaned and weighed at the end of the slaughter line, and the weight is converted into arrobas (15 kg each). This conversion determines the payment amount for the cattle. With increasing demand for high-quality products and added value, differentiated remuneration systems are gaining traction in Brazilian livestock. To increase the return for Brazilian producers who strive to produce meat with quality attributes, carcass grading systems are increasingly necessary to allow this greater quality to be evaluated in the slaughtering process and properly recognized.

Carcass grade programs are developed by breeders' associations, participating slaughterhouses, and/or government agencies to enhance the value of beef production. Generally, these programs use three main criteria: maturity, carcass weight, and fat finish. Some programs also include a fourth criterion, namely, the percentage of the batch meeting the program criteria. Carcasses evaluated at slaughter that meet program criteria receive a base value based on weight, plus an additional bonus (Gomes et al., 2019).

In Mato Grosso do Sul, a major livestock region in Brazil, grade protocols reward carcasses meeting specific standards such as degree of finish and precocity — which refers to the animal's ability to reach adequate fat deposition and slaughter weight at an early age — with higher margins at slaughter and during commercialization (Flores et al., 2018). These protocols stem from both public and private initiatives aimed at incentivizing livestock farmers to add value to negotiations between producers and the meatpacking industry (Gomes et al., 2019).

The precocious prize protocol rewards animals with only milk teeth, two permanent teeth, or a maximum of four permanent teeth, with carcasses weighing at least 225 kg for males and 180 kg for females, and with low to uniform fat finishing — corresponding to 3 to 6 mm of subcutaneous fat, classified as fatness score 2 or 3 on a 1-to-5 scale (Gomes et al., 2019; Amaral et al., 2021). The Angus Certification benefits animals with at least 50% Angus genetics, young age, a minimum subcutaneous fat thickness of 3 mm, classified as "median" (score 3) on a 1-to-5 scale, while excluding animals with horns or Zebu characteristics, such as hump (Associação Brasileira de Angus, 2013).

In the Natural Nellore Program, animals must have 75% Nellore blood and display prominent traits such as dewlap and hump. They should be primarily fed on forage with or without supplementation, and during finishing, they may receive total or partial diets in troughs (ABCN, 2020).

The JBS Beacon system considers sex, maturity, weight, and fat finishing defined as the degree of subcutaneous fat cover on the carcass using a 1-to-5 scale. Carcasses are classified based on the number of permanent teeth and the amount of fat, categorized as absent, sparse, average, uniform, or excessive. The system uses red, yellow, and green colors to indicate whether the carcass meets "undesirable," "tolerable," or "desirable" standards (Friboi, 2021; JBS, 2022).

The Hilton Quota, also known as the Hilton Beef Quota or High Quality Beef Quota, is a tariff-rate quota that allows certain countries, such as Brazil, to export a specified amount of high-quality beef to the European Union at reduced or zero import tariffs from accredited establishments on the Traces list, which refers to a system used by the European Union to manage and control the import, export, and intra-EU trade of animals, food, feed, and plants with regard to traceability, ensuring food safety, animal health, and compliance with EU regulations (European Commission, 2025). Carcasses must have SISBOV traceability - the official system of Brazil for the individual identification of cattle and buffaloes which allows the traceability of animals from birth to slaughter (MAPA, 2018) - be pasture-raised, be identified until weaning, have low to medium fat finishing, and weigh a minimum of 16 and 13 arrobas for males and females, respectively.

It is evident that carcass grade systems value characteristics related to both the animals and the production system. The degree of finish, a key factor in carcass classification, is significantly influenced by the production system used during the breeding, rearing, and finishing phases. Additionally, breed plays a fundamental role (Silva et al., 2015). Vargas and Silveira (2020) explored strategies to meet the desired standards for carcass bonuses and enhance the economic feasibility and sustainability of production systems. For example, crossbreeding Zebu with Aberdeen-Angus may produce precocious offspring that reach the slaughter point earlier, regardless of the finishing system, pasture, or feedlot. These animals may achieve the desired weight and finishing by 24 months (Silva et al., 2018).

Currently, there are no consolidated national data on the percentage of cattle slaughtered in Brazil that receive carcass quality-based bonuses. However, regional information indicates that this practice is expanding. In 2023, the *Precoce MS* Program, an initiative of the state government of Mato Grosso do Sul, reported that 40.4% of the cattle slaughtered in the state were classified as “early-maturing steers”, meeting criteria related to age, weight, and carcass finish. Of these, approximately 79% received financial bonuses, amounting to around BRL 117 million in incentives (SEMADESC, 2024).

In this sense, it is necessary to evaluate the influences of the production system characteristics, as well as the correct choice of management adopted according to the racial, sexual and age characteristics of the herd, on the possible grade classifications received by the carcasses in the slaughterhouses. This study aims to investigate whether the beef cattle production system adds greater value to the commercialization of beef carcasses and to identify which characteristics of the system are most influential, using mixed factor analysis on data from a commercial property.

2. Material and methods

2.1. Data collection

This study utilized a database of 3,612 commercially slaughtered cattle from a property in Nova Andradina, Mato Grosso do Sul, Brazil (−22.165064, −53.573592), in 2019. The database included both qualitative and quantitative variables.

2.2. Qualitative and quantitative variables

Qualitative explanatory variables included breed and crossbreeds (Nellore, Aberdeen-Angus half-bloods [Nellore × Aberdeen-Angus], and Three-quarters [Aberdeen-Angus × Nellore]), sex (male [M] and female [F]), type of finishing (pasture or feedlot), and slaughterhouse (two commercial facilities identified as slauJ and slauM). For fat finishing (ffin) and dentition (dent), also considered qualitative explanatory variables, individual scores were recorded for each animal based on information from the slaughterhouses, which included analysis of dental chronology and the degree of finish of the carcass. For fat finishing carcasses were classified as: 1 – absent: total absence of fat in the carcass; muscle contours are sharply defined due to the absence of external fat deposition. 2 – scarce: 1 to 3 mm of fat distributed throughout the carcass; major muscle groups are still visible, though their outlines are less pronounced due to minimal fat deposition. 3 – medium: 3 to 6 mm of fat distributed throughout the carcass; outlines of major muscle groups are not evident due to the thicker fat deposition. 4 – uniform: 6 to 10 mm of fat evenly distributed throughout the carcass; outlines of major muscle groups are not evident due to the thicker fat deposition. 5 – excessive: more than 10 mm of fat distributed throughout the carcass; outlines of major muscle groups are not evident due to the thicker fat deposition.

Dental chronology may be described as the presence of permanent incisor teeth: up to 18 months - zero teeth or baby teeth (0d); around 18 to 24 months - two permanent teeth (2d); after 24 months – four permanent teeth (4d); after 30 to 36 months - six permanent teeth (6d) and after four years: eight permanent teeth or a full mouth (8d).

Quantitative variables comprised live weight (kg), measured at the farm (farm_weight), and hot carcass weight (HCW) recorded at slaughter. Carcass weight was converted into arrobas - a unit of measurement where 1 arroba = 15 kg of carcass weight. Carcass yield was then calculated as the ratio between the hot carcass weight and the live weight recorded at the farm (yield).

The “value” variable represents the amount paid per arroba, as determined by the slaughterhouse at the time of purchase, based on national and international quotations (e.g., Esalq, B3, Chicago Stock Exchange). This base value is expressed in Brazilian Reais per arroba (BRL/@). The additional bonuses obtained through carcass grades are added to this base value to calculate the “paid value,” which represents the total amount paid per carcass, considering all applicable bonuses, and is also presented in BRL/arroba.

2.3. Payment schemes

The study considered payment according to carcass grade protocols in Mato Grosso do Sul, including the Precocious prize, Angus certification, the JBS Beacon (beacon), and the Natural Nellore Program (nel_natural). The classification criteria for these protocols include precocity, fat finishing, breed, sex, and slaughterhouse. It is important to note that a single carcass may qualify for multiple carcass grade protocols, resulting in multiple increases in the amount paid. For instance, an Aberdeen-Angus half-blood animal meeting the minimum requirements for Angus certification could also qualify for the precocious prize if it meets the relevant criteria (Table 1).

Table 1 - Minimum requirements adopted for carcass classification in each carcass classification protocols used by the selected slaughterhouses

Carcass grade	Characteristics
JBS Beacon	Dentition (0d, 2d and 4d), fat finishing (2 scarce, 3 medium and 4 uniform), sex (M/F), weight (>12@ for females and >14@ for males)
Precocious prize	Dentition (0d, 2d and 4d), fat finishing (2 scarce, 3 medium and 4 uniform), sex (M/F), weight (>12@ for females and >14@ for males)
Natural Nellore program	Dentition (0d, 2d and 4d), fat finishing (2 scarce, 3 medium and 4 uniform), sex (M/F), weight (>12@ for females and >14@ for males) and Nellore breed
Angus certification	Dentition (0d, 2d and 4d), fat finishing (2 scarce, 3 medium and 4 uniform), sex (M/F), weight (>12@ for females and >14@ for males) and minimum 50% Angus breed

2.4. Statistical analysis

Data consistency was verified to ensure the reliability of the analysis. Observations identified as statistical outliers—defined as values falling more than three standard deviations above or below the mean—were considered atypical and excluded from the dataset. These extreme values were deemed unrepresentative of standard slaughter practices or of the general characteristics of the animals, and their removal aimed to improve the overall quality and accuracy of the results.

Descriptive statistics were generated from the database, showing means, minimum and maximum values, standard deviations, and the number of observations for the selected variables: live weight on the farm (farm_weight, kg), hot carcass weight (HCW, kg), yield (yield, %), arroba (@, kg), trace (BRL/@), Hilton (BRL/@), beacon (BRL/@), nel_natural (BRL/@), angus (BRL/@), precocious_prize (BRL/@), and value (BRL/@). All values are presented without distinguishing between qualitative characteristics such as sex, breed, and type of finishing (Table 2).

Table 2 - Summary of descriptive statistics (mean, minimum, maximum, and standard deviation) of the variables analyzed to evaluate the influence of beef cattle production characteristics on carcass traits

Variable[1]	Min	Max	Average	Standard deviation	Selected no.
Farm weight (kg)	330	830	542.24	± 0.11	3.374
HCW (kg)	146.60	464.40	293.99	± 0.14	3.374
Yield (%)	37	67	54	± 0.05	3.374
Arroba (@)	9.77	30.96	19.60	± 0.14	3.374
Trace (BRL/@)	0	2	1.79	± 0.34	3.374 / 348
Hilton (BRL/@)	0	2	0.83	± 1.19	3.374 / 1.977
Beacon (BRL/@)	0	5	1.25	± 0.85	3.374 / 1.347
Nel_natural (BRL/@)	0	0.50	0.19	± 1.28	3.374 / 2.096
Angus (BRL/@)	0	14.49	0.19	± 7.32	3.374 /3.295
Precocious prize (BRL/@)	0	6.98	3.91	± 0.54	3.374 / 661
Value (BRL/@)	131	176	149.70	± 0.08	3.374
Paid_value (BRL/@)	131	189.48	157.87	± 0.09	3.374

Farm weight - animal weight on the farm; HCW - hot carcass weight; yield - carcass yield per animal; arroba - 15 kg of meat in dead weight; trace - traceability carcass bonus; Hilton - traceability carcass bonus; beacon - JBS quality beacon; nel_natural - ABCA bonus; Angus - ABCA bonus; precocious prize - precocious program bonus; value - amount paid for kilograms of meat in dead weight (15 kg or 1 arroba); paid_value - amount with added bonuses received.

A Factor Analysis of Mixed Data (FAMD) was conducted after data cleaning and descriptive analysis. FAMD is a variation of Principal Component Analysis (PCA) designed to handle both qualitative and quantitative data types. FAMD was performed to explore associations among both qualitative and quantitative variables within the dataset. This method allows the simultaneous analysis of mixed data types by integrating Principal Component Analysis (PCA) for continuous variables and Multiple Correspondence Analysis (MCA) for categorical variables. Unlike traditional correlation-based approaches, FAMD treats each variable according to its nature, enabling a balanced contribution to the factorial dimensions. The analysis was conducted using the FactoMineR package in R, and the resulting dimensions were interpreted based on the contribution of each variable to the total variance. The adequacy of the data for FAMD was assessed using the Kaiser-Meyer-Olkin (KMO) measure, with a value above 0.60 indicating suitability for analysis (Eyduran et al., 2010). Eigenvalues were also used as criteria for extracting the main factors to explore the sources of variance in the data, and only those greater than 1 were considered (Kuppusamy and Giridhar, 2006; Zarei and Bilondi, 2013).

All analyses were performed using RStudio software (version 2024.12). The following packages were utilized: pastecs (Grosjean and Ibanez, 2018) for descriptive statistics; ggplot2 and factorextra (Wickham, 2016; Kassambara and Mundt, 2020) for graphical representation; and FactoMineR (Lê et al., 2008) for implementing FAMD and constructing alternative graphics.

The correlation matrix for the variables analyzed was based on type of finishing, breed, sex, and slaughterhouse, generating correlation coefficients as the primary data needed to produce principal components. According to Everitt et al. (2001), PCA is a method for transforming a set of correlated variables (x1, x2, ... xp) into a set of uncorrelated variables (y1, y2, ... yp), which capture decreasing proportions of the total variance in the original variables. The principal components are defined as:

$$y1 = a11x1 + a12x2 + ... + a1pxp$$

$$y2 = a21x1 + a22x2 + ... + a2pxp$$

$$yp = ap1x1 + ap2x2 + ... + a2pxp$$

These principal components reduce the variance in the original variables, with the goal of maximizing orthogonal rotation for clearer interpretation of the extracted components (Everitt et al., 2001).

The new variables, or principal components, explain the variability in the data related to sex, breed, dentition, type of finishing, and slaughterhouse, as well as other quantitative variables such as bonus type, fat finishing, yield, weights, value, and the amount paid for each individual.

The results were presented using correlation circles and individual graphics, with 107 individuals analyzed across the first and second dimensions. These 107 individuals represent the synthetic individuals (clusters) formed by the combination of quantitative factors with similar profiles, as obtained through the Factorial Analysis for Mixed Data (FAMD).

3. Results

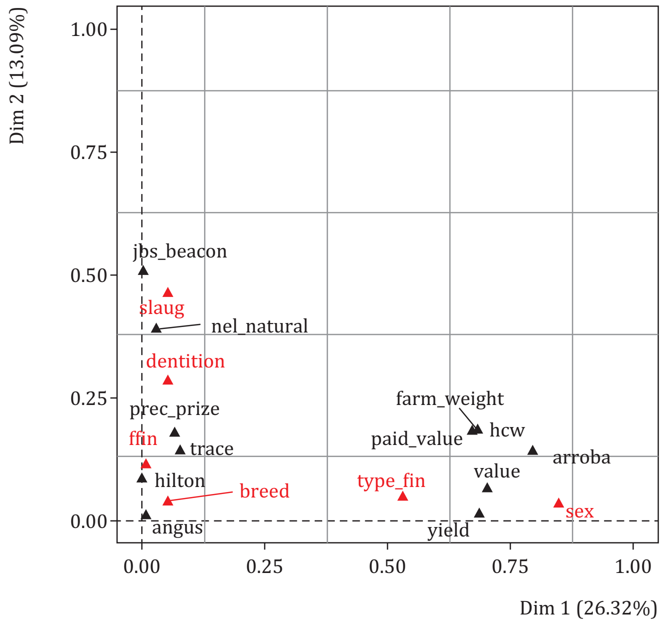
Principal Component Analysis (PCA) was conducted, and eigenvalues were used as criteria for extracting the main factors to explore the sources of variance in the data, with only those greater than 1 being considered (Kuppusamy and Giridhar, 2006; Zarei and Bilondi, 2013). The analysis revealed that eigenvalues greater than 1 explained 76.98% of the total variance, indicating an appropriate application of the analysis to the dataset (Table 3).

Table 3 - Explained and cumulative variance of the principal components across the analyzed dimensions (Dim), evaluating the influence of beef cattle production characteristics on carcass traits

Dimension	Eigen value	Explained variance (%)	Cumulative variance (%)
Dim1	6.05	26.32	26.32
Dim2	3.01	13.09	39.41
Dim3	2.31	10.04	49.46
Dim4	1.65	7.15	56.61
Dim5	1.27	5.52	62.13
Dim6	1.24	5.39	67.52
Dim7	1.13	4.93	72.44
Dim8	1.04	4.53	76.98

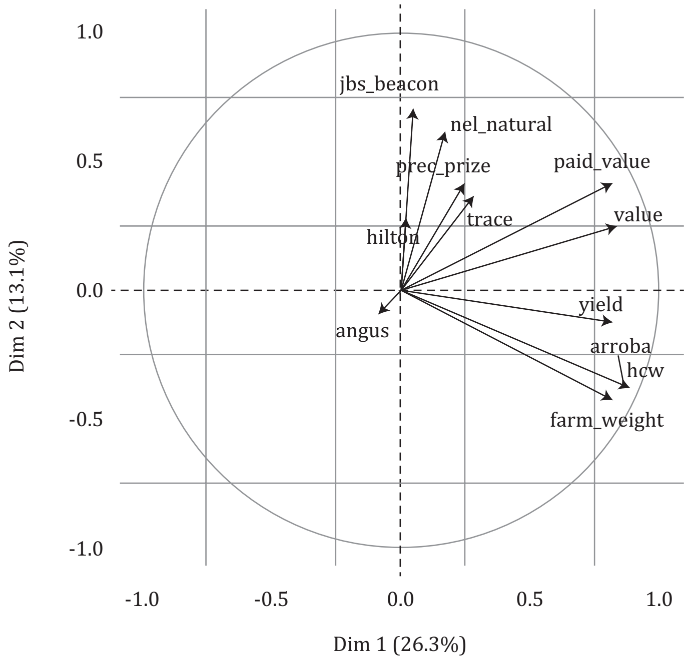
The variables related to Dimension 1 include type of finishing (type_fin), farm weight (farm_weight), value, paid_value, yield, arroba, HCW, and sex. In Dimension 2, the variables with significant relationships include beacon, slaughterhouse (slaug), nel_natural, dentition, fat finishing (ffin), precocious_prize, breed, and angus (Figure 1).

The correlation circle of quantitative variables shows the positive relationships between variables, visualized by the proximity of the arrows, while negative relationships are positioned on opposite sides of the figure. The distance between the variable's point and the arrow's origin measures the variable's quality in the factor map (Figure 2).



jbs_beacon - JBS quality beacon; slaug - meatpacking industry; nel_natural - Natural Nellore Program; dentition - dental chronology of the animal at slaughter; ffin - fat finishing; prec_prize - precocious program bonus; breed - animal breed; angus - ABCA bonus; type fin - type of cattle finishing; paid_value - amount paid for 15 kg of meat (one arroba); farm_weight - animal weight on the farm; hcw - hot carcass weight; value - the amount paid for an arroba; arroba - 15 kg of meat in dead weight after slaughter; yield - carcass yield; sex - male or female.
Red font presents qualitative explanatory variables; black font presents quantitative variables.

Figure 1 - Geometric distribution of variables in the first two dimensions, with positively related variables grouped together and negatively related variables positioned in opposite directions.



jbs_beacon - JBS quality beacon bonus; nel_natural - Natural Nellore Program; prec_prize - precocious program bonus; angus - ABCA bonus; paid_value - the amount paid after slaughter for one arroba; value - amount negotiated for one arroba; yield - carcass yield; hcw - hot carcass weight; arroba - 15 kg of hot carcass meat after slaughter; farm_weight - the weight of the animal on the farm.

Figure 2 - Circle of explanation for quantitative variables, showing positive and negative groupings according to the direction of the arrows.

The contributions of the analyzed variables to the first five dimensions of the Factor Analysis of Mixed Data (FAMD) revealed distinct patterns of influence (Table 4). In Dimension 1, the variables most strongly associated with data variability were related to weight and yield characteristics, with sex (13.99%), arroba (13.08%), hot carcass weight (hcw) (13.08%), value (11.60%), yield (11.35%), farm weight (11.28%), paid value (11.11%) and type of finishing (type_fin) (8.77%) showing the highest contributions. Dimension 2 was primarily characterized by slaughterhouse and carcass grade systems, notably jbs_beacon (16.85%), slaughterhouse (slaug) (15.32%) and Nelore Natural (nel_natural) (12.90%). In Dimension 3, variables associated with product quality and carcass grade systems, including precocious prize (prec_prize) (24.36%), dentition (23.03%), and Hilton quota classification (hilton) (13.60%) were the most influential. Dimension 4 was mainly explained by fat finishing (ffin) (37.20%) and angus breed prize (angus) (17.39%), indicating the relevance of breed its specific finishing characteristics. Finally, Dimension 5 was most influenced by breed (29.44%), trace (28.92) and again dentition (10.67%), reinforcing the role of genetic background and animal age in carcass characterization. These findings indicate that different sets of variables contribute to distinct dimensions of variability in the dataset, underscoring the multifactorial nature of carcass traits in beef cattle production.

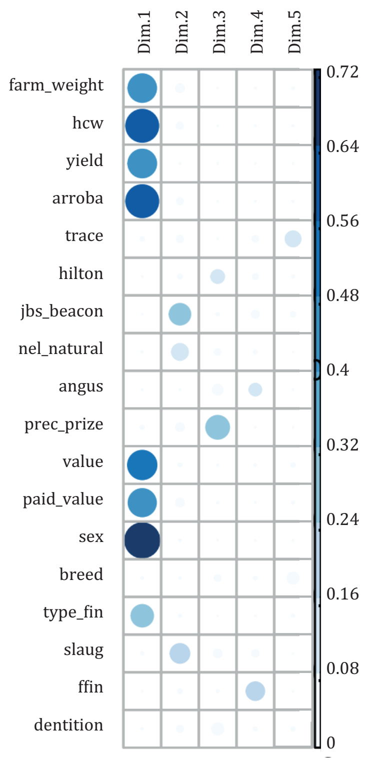
The association between each variable and its respective dimension is identified at the intersection of rows and columns in Figure 3. The larger and darker the circumference, the stronger the association with the dimension. Therefore, the variables most associated with Dimension 1 included HCW, sex, and arroba, while those most associated with Dimension 2 included slaughterhouse and beacon. Meanwhile, Dimension 3 included precocious_prize and dentition.

After identifying the distribution of individuals across the dimensions, the qualitative variables were expressed in the first two dimensions and differentiated by color. The closer a variable is to red, the greater its influence on the dimension (Figure 4). Figures 5–8 must be interpreted with reference to Figure 4, as it provides the graphical scale and color gradient that indicate the contribution of each variable to the dimensions.

Table 4 - Contribution of each variable to the first five principal component dimensions in the analysis evaluating the influence of beef cattle production characteristics on carcass traits

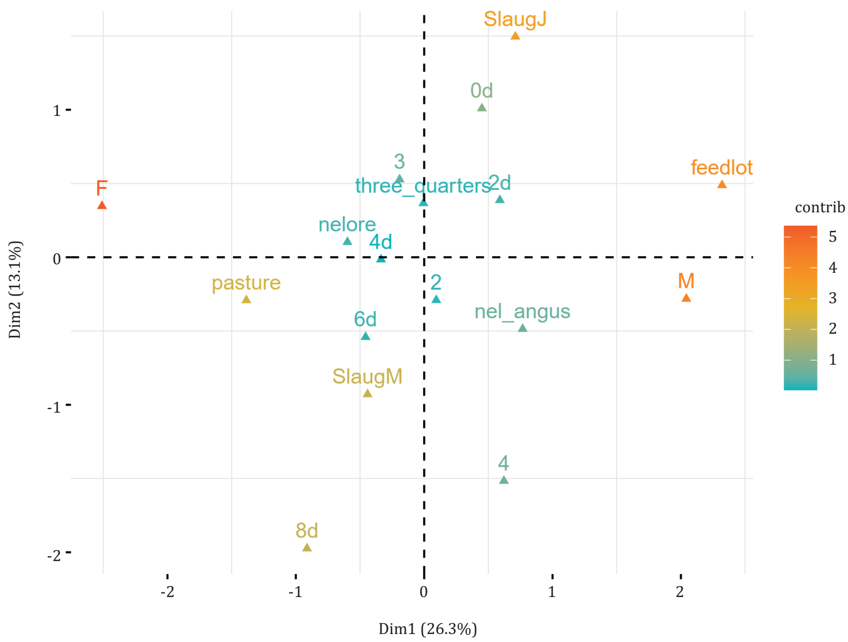
Variable	Contribution to dimentions				
	Dim1	Dim2	Dim3	Dim4	Dim5
Farm_weight	11.28	6.10	0.24	1.15	2.29
HCW	13.08	4.67	0.13	0.68	1.44
Yield	11.35	0.44	0.01	0.02	0.01
Arroba	13.08	4.67	0.13	0.68	1.44
Jbs_beacon	0.03	16.85	2.21	9.77	7.58
Nel_natural	0.46	12.90	5.49	3.39	0.26
Trace	1.30	4.68	0.31	7.61	28.92
Hilton	0.01	2.83	13.60	7.02	3.14
Angus	0.13	0.30	9.97	17.39	0.70
Prec_prize	1.09	5.98	24.36	0.68	0.27
Value	11.60	2.13	1.04	1.69	5.91
Paid_value	11.11	6.03	0.90	0.03	2.81
Sex	13.99	1.08	0.12	0.44	0.86
Breed	0.88	1.29	8.09	5.05	29.44
Type_fin	8.77	1.57	0.07	0.07	3.64
Slaug	0.86	15.32	7.87	0.01	0.14
Ffin	0.14	3.76	2.42	37.20	0.48
Dentition	0.83	9.41	23.03	7.13	10.67

Farm_weight - animal weight on the farm; HCW - hot carcass weight; yield - carcass yield per animal; arroba - 15 kg of meat in dead weight; trace - traceability carcass bonus; Hilton - traceability carcass bonus; jbs_beacon - JBS quality beacon; nel_natural - ABCZ bonus; Angus - ABCA bonus; prec_prize - precocious program bonus; value - amount paid for kilograms of meat in dead weight (15 kg or 1 arroba); paid_value - amount with added bonuses received; Type_fin - finishing system type; Slaug - two commercial facilities identified as slauJ and slauM; dentition - dental chronology.



farm_weight - animal weight on the farm; hcw - hot carcass weight; yield - carcass yield per animal; arroba - 15 kg of meat in dead weight; jbs_beacon - JBS quality beacon; nel_natural - ABCA bonus; angus - ABCA bonus; prec_prize - precocious program bonus; value - the amount paid for an arroba; sex - male or female; breed - animal breed; type_fin - type of finishing; slaug - slaughterhouse; ffin - finishing; dentition - number of teeth.

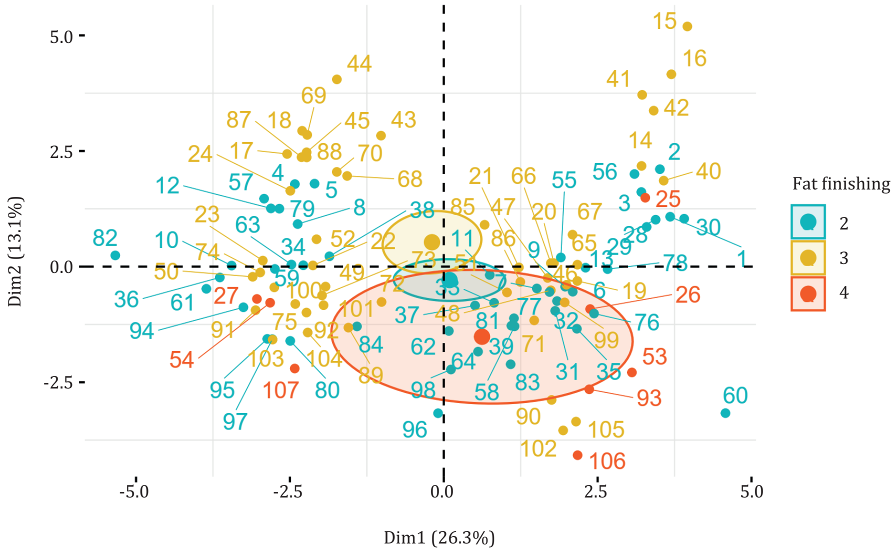
Figure 3 - Association map depicting the relationship between variables and dimensions, indicating the quality of representation of the variables within each dimension.



SlaugJ - slaughterhouse J.; SlaugM - slaughterhouse M.; nelore - Nellore breed.; nel_angus - F1 ½ Nellore ½ Aberdeen-Angus; three-quarters - ¾ Aberdeen-Angus × Nellore crossbreed; M - male; F - female; 2, 3, 4 - fat finishing; 0d, 2d, 4d, 6d, 8d - dentition.

Figure 4 - Qualitative characteristics and their contributions, represented by color intensity, showing the influence on the first two dimensions.

Regarding carcass finishing, the grouping of finishing 4 formed the largest red ellipse, which was associated with the Angus breed. Meanwhile, finishing 3 was closer to the ¾ individuals, and finishing 2 was closer to the Nellore animals (Figures 5 and 6).



Fat finishing - degree of finishing score levels.

Figure 5 - Factor map of individuals grouped by degree of carcass finish, represented by ellipses in the first two dimensions.

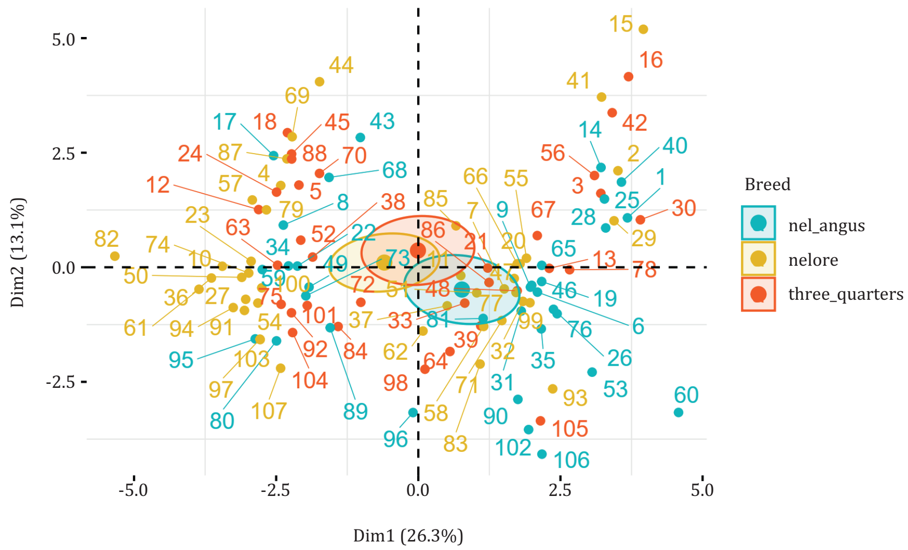


Figure 6 - Factor map of individuals grouped by breed, represented by ellipses in the first two dimensions.

Regarding the sex and finishing of the animals slaughtered in this study, carcasses were separated into distinct groups (Figures 7 and 8), in which the finishing type groups coincided with the sex distribution groups.

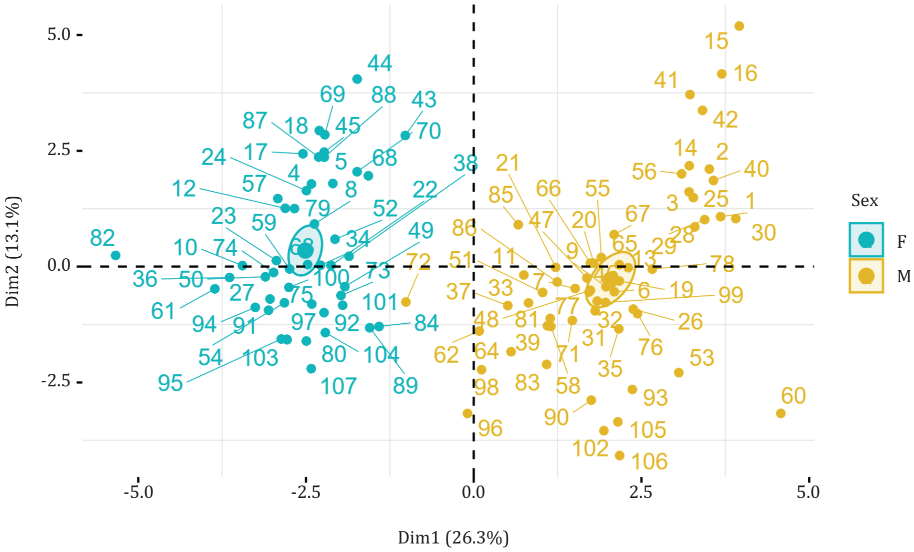


Figure 7 - Factor map of individuals grouped by sex, represented by ellipses in the first two dimensions.

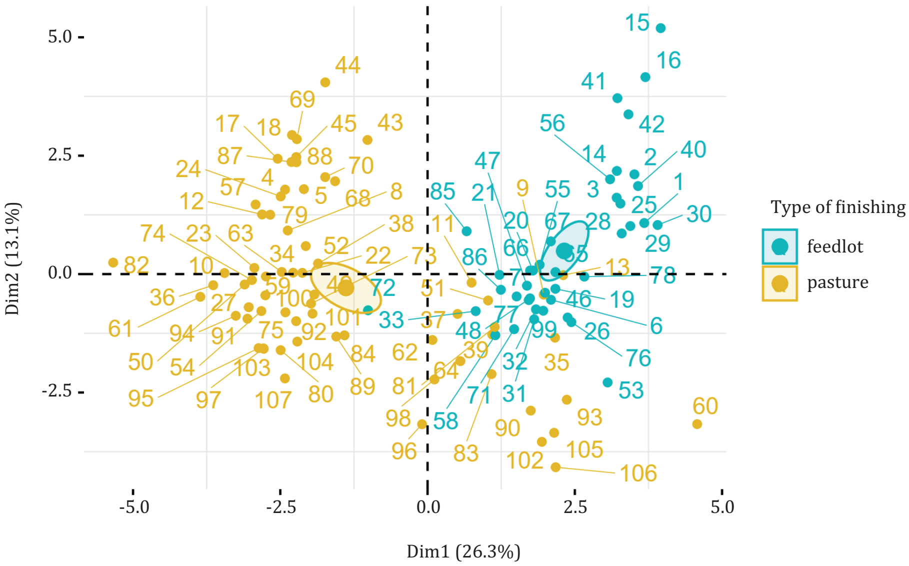


Figure 8 - Factor map of individuals grouped by type of finishing, represented by ellipses in the first two dimensions.

4. Discussion

The calculated eigenvalues represent the variances associated with the principal components. They measure the magnitude of the variability captured by each principal component, representing the contribution of each dimension to explaining the total variance of the results obtained (Kuppusamy and Giridhar, 2006; Zarei and Bilondi, 2013; German et al., 2013).

The variables grouped in the first dimension (Figure 1) indicate that, among the qualitative variables, sex, followed by type of finishing, exerts the greatest influence on factors associated with higher added value in the commercialization of arrobas, particularly those linked to increased carcass weight. Meanwhile, in the second dimension, the slaughterhouse is grouped with the beacon and nel_natural carcass grade protocols, which are positioned opposite the weight variable, suggesting that precocious-grade animals may be classified with a lower commercialization weight.

The variables with the strongest relationships to the dimensions hold the greatest importance in the principal component. In other words, the higher the percentage of contribution, the greater its influence on the formation of a dimension, that is, the greater the influence of that variable in explaining the variability in the dataset. In Dimension 1, arroba, hot carcass weight, and sex are the variables that best explain the variation in the data, while in Dimension 2, jbs_beacon, nel_natural, and slaughterhouse are the most explanatory.

The beacon variable is grouped with the nel_natural and precocious_prize variables, as they share similar evaluation standards for classification in the carcass grade protocols. Desirable characteristics for these protocols include sex, maturity, weight, and fat finishing (Friboi, 2021).

The analysis also reveals a spread in the grouping of individuals with higher weights, particularly older animals such as cows and bulls, which do not fit into most carcass grade protocols. This influences quality standards and fat finishing (Figure 2). Furthermore, older animals affect the production of arrobas and HCW, explaining their grouping. Animals with different slaughter weights may also have inconsistent carcass standards, suggesting that herd uniformity may help identify more productive animals, providing better-quality and standardized cuts (Vieira et al., 2019).

Moreover, the beacon, nel_natural, and precocious_prize variables are relatively closer to paid_value, indicating that younger animals ensure a higher return upon commercialization, as the animal's age is a criterion evaluated in all of these carcass grade protocols.

On the other hand, the arroba and farm_weight variables are positioned far from paid_value, beacon, nel_natural, and precocious_prize, suggesting that excessively heavy animals—likely older—are not associated with premium payments and may present lower carcass yields. This may be due to age-related physiological changes such as increased organ mass, fat deposition, and bone weight, which reduce the dressing percentage. While Valadares Filho et al. (2023) indicate that heavier animals can have improved yield due to lower gastrointestinal tract proportion, this relationship may not be linear or universal, particularly in older or over-finished animals. Our findings align with the observations of Vaz et al. (2002), who noted that although cows had higher live weights than steers, they exhibited lower carcass yields due to differences in body composition and internal organ size.

Quality programs implemented by the beef industry aim to improve coordination and standardization across the production chain. These programs typically classify animals based on carcass traits such as age and subcutaneous fat thickness, contributing to greater uniformity and predictability in supply (Caleman and Zylbersztajn, 2009). However, these parameters provide a limited assessment of overall meat quality, as sensory attributes such as tenderness, juiciness, and flavor are more directly influenced by factors including intramuscular fat (marbling), breed, slaughter practices, and the anatomical location of the cut (Hocquette et al., 2007).

The qualitative variables that most significantly explain the variability of the data and contribute to the first dimension included sex (male) and feedlot finishing, followed by 0d and 2d dentition.

In contrast, the variables with the greatest contribution to the second dimension included fat classification 3, sex (female), followed by Nellore breed animals, three-quarters, and 4d dentition.

The sexes are positioned in opposite dimensions, as are the slaughterhouses to which the animals were sent for slaughter. This reflects the farm's management strategy, with males being slaughtered at slaugJ and females at slaugM. This approach is aimed at optimizing carcass grade protocols and, consequently, maximizing remuneration for the producer.

Based on the distribution of individuals in the first and second dimensions (Figure 4), groupings of individuals represented by ellipses (Figures 5 to 8) were formed according to the qualitative variables and analyzed alongside the circle of quantitative variable explanations.

The degree of growth, tissue development, and fat deposition in animals varies according to breed. Nardon et al. (2013) pointed out that fat deposition in tissues follows a chronological order. Latimori et al. (2008) stated that the Aberdeen-Angus breed is classified as precocious in terms of growth and fat deposition. The production of F1 Aberdeen-Angus × Nellore crossbred calves aims to enhance hybrid vigor. Vieira et al. (2019), when evaluating the body biometrics and physical composition of the carcass of Nellore and half-blood Aberdeen-Angus steers, observed lower croup height in crossbred animals compared with the Nellore breed, which is negatively correlated with physiological maturity. At the same chronological age, animals with greater frame size (e.g., taller rumps) are less physiologically mature and thus exhibit lower fat deposition. These findings align with Dolezal et al. (1993), who indicated that both chronological age and frame size are important factors in determining fat finishing. Therefore, while Nellore cattle may have greater structural size at the same age, they tend to be less mature physiologically, leading to delayed fat deposition compared with more precocious British breeds such as Aberdeen-Angus.

When comparing the ellipses with the circle of quantitative variable explanations, it is evident that carcasses from male animals have greater valuation, primarily due to the higher yield of meat cuts in males compared to females. Additionally, udders and muscle:bone ratio are important distinguishing features between male and female carcass yields (Field, 1971).

Furthermore, when comparing the ellipses formed by sex with those formed by the degree of finish (Figures 7 and 5), there is a higher concentration of males in degree of finish 4, reflecting the finishing methods adopted for each sex on the property, where male animals are finished in feedlots and females are finished on pasture.

The production of animals on pasture results in meat with less fat, while more intensive systems using feedlots can produce cuts with more fat, mainly due to diets with higher concentrations of protein and energy (Garcia et al., 2008), which also explains the proximity of finishing 4 to males in the graphs.

The management practices adopted by the farm to finish different categories in different systems align with the productive efficiency of the animals. The finishing of older animals is predominantly conducted on pasture since these categories, such as cull cows and bulls, are not highly valued. They contribute with greater weight in arrobas, ensuring a better cost-benefit ratio in pasture finishing, which is the most economical method. Moreover, these categories require high dry matter consumption when finished in feedlots, increasing their production costs.

Young animals are more efficient in food utilization in both pasture and feedlot systems, as they consume feed according to their maintenance and production requirements, ensuring faster weight gain due to efficient feed conversion. Santos et al. (2017), when evaluating the weight gain of steers, bulls, and cull cows in feedlots, observed better feed conversion for young animals compared to older ones. There was an improvement in biological efficiency for converting dry matter into tissue in young animals, making them 24.6% more productive than older categories, and resulting in lower nutrition costs.

When comparing Figures 5, 6, 7, and 8 regarding carcass finishing, breed, type of finishing, and sex, there is a higher concentration of females in carcass classifications 2 and 3 for the Nellore and three-quarter breeds finished on pasture. In contrast, there is a slight dispersion for finishing classification 4 regarding breed, with Angus males finished in feedlots predominating.

The positive association between carcass finishing and the Angus breed may be explained by the fact that Angus and crossbred animals tend to reach slaughter readiness and carcass finishing standards earlier than Nellore cattle. This is largely due to their greater physiological precocity and superior capacity for fat deposition, which enable them to achieve adequate fat cover at younger ages and lighter weights. These characteristics allow Angus-type animals to be finished over a shorter period, particularly under high-energy feeding systems, compared to the typically later-maturing Nellore breed (Euclides Filho et al., 2001). It is important to note that this relationship reflects practical commercial conditions, in which Angus cattle are predominantly grain-finished and Nellore or Nellore-cross animals are more often grass-finished. As such, the observed differences represent the combined effect of both breed and production system, and not the genetic component in isolation.

Regarding carcass grading, the analysis showed that male Angus or three-quarter Angus individuals finished in feedlots achieved higher carcass yields, produced more arrobas, and received higher paid values, either from each possible carcass grade or from the estimated total value, paid based on the sum of the bonuses.

According to Vieira et al. (2019), the growth rate of an animal, which varies according to breed and production system, is the most critical factor within the production system, as it underpins the efficient production of quality meat. By identifying the characteristics of the animals, such as breed and finishing modality, it is possible to provide optimal conditions and environments for appropriate body growth, maximizing their genetic potential from birth to the finishing period. Therefore, there is considerable interest in finishing F1 crossbred males in feedlots, mainly due to their greater genetic potential for weight gain. Although these animals tend to achieve higher final weights, their feed intake is also greater, which may result in similar or only slightly improved biological feed efficiency. In terms of carcass characteristics, F1 males often show superior fat deposition and greater uniformity within the herd. However, their carcass yield is generally lower than that of purebred Nellore cattle. Still, when compared to females in feedlot conditions, F1 males may perform better, as observed by Miguel et al. (2014), where males achieved a carcass yield of 55.93% compared to 54.59% for females.

The higher carcass yield in male cattle results from greater muscle tissue production, while females have lower yields due to the removal of non-carcass components, such as the reproductive system (Vaz et al., 2002). As a result, finishing females on pasture is a production strategy aimed at reducing costs, given that they are generally less profitable.

The beef production chain seeks efficiency, with practices that enhance reproductive and growth efficiencies leading to better use of productive and feed resources. Moreover, profitability in the system requires improvements that meet the demands of the target market, utilizing appropriate animals and management practices to produce higher-value and premium-quality beef (Greenwood, 2021). However, in Brazil, the heterogeneity in production systems and cattle management and commercialization practices (Carvalho and Zen, 2017) creates disparities in beef production and its outcomes.

The organization of finishing activities and the choice of slaughterhouse are determining factors in obtaining higher carcass grades, and consequently, higher total value. The mixed factor analysis model used was effective in describing the farm's production system, decision-making regarding finishing methods, and the choice of slaughterhouse, considering the potential for carcass grades based on the characteristics of the animals and the herd. The farm's approach of sending animals to feedlots, despite the higher costs, results in higher returns and carcass grades. Conversely, less efficient animals finished in less intensive systems, such as semi-feedlots, achieve adequate but less costly finishing.

5. Conclusions

The primary productive characteristics that influenced carcass remuneration were weight, sex, and type of finishing. These characteristics are intrinsically linked to the production system employed by the property where the animals were finished. Through mixed factor analysis, we identified that the production and finishing management adopted by the farm was strategically structured, with males directed to feedlot finishing and females to pasture finishing. This approach optimizes the productive potential of each category and maximizes carcass grade eligibility, thereby enhancing the added value in carcass commercialization.

Data availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: Burbarelli, M. F. C. and Caldara, F. R. **Data curation:** Oliveira, L. F. and Silveira, E. S. **Formal analysis:** Burbarelli, M. F. C. and Seno, L. O. **Funding acquisition:** Caldara, F. R. **Investigation:** Oliveira, L. F.; Almeida, A. A. and Silveira, E. S. **Methodology:** Seno, L. O. and Almeida, A. A. **Project administration:** Garcia, R. G. **Resources:** Garcia, R. G. and Komiyama, C. M. **Software:** Seno, L. O. and Silveira, E. S. **Supervision:** Garcia, R. G.; Burbarelli, M. F. C. and Seno, L. O. **Validation:** Komiyama, C. M. and Caldara, F. R. **Visualization:** Komiyama, C. M. **Writing – original draft:** Oliveira, L. F. **Writing – review & editing:** Burbarelli, M. F. C. and Almeida, A. A.

Conflict of interest

The authors declare no conflict of interest.

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References

Amaral, T. A.; Gomes, R. C. and Rosa, G. J. M. 2021. Produção de novilho precoce no estado de Mato Grosso do Sul. Comunicado Técnico, 162. Embrapa. Available at: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/229678/1/COT-162-Final-em-alta1.pdf>. Accessed on: Feb. 24, 2023.

ABCN - Associação Brasileira dos Criadores de Nelore. 2020. Projeto da Associação dos Criadores de Nelore do Brasil pode melhorar remuneração dos pecuaristas. Available at: <http://www.nelore.org.br/Noticia/VerNoticia/1920>. Accessed on: Feb. 24, 2023.

Associação Brasileira de Angus. 2013. Manual do criador de Angus. Available at: <https://angus.org.br/wp-content/uploads/2018/04/Manual-do-Criador_WEB.pdf>. Accessed on: Feb. 24, 2023.

Caleman, S. M. Q. and Zylbersztajn, D. 2009. Contracts and incentives in quality beef chain: analyzing organizational failures. Revista de Economia e Administração 8:296-311.

Carvalho, T. B. and Zen, S. 2017. A cadeia de Pecuária de Corte no Brasil: evolução e tendências. Revista iPecege 3:85-99. https://doi.org/10.22167/r.ipecege.2017.1.85

Costa, E. C. D.; Restle, J.; Vaz, F. N.; Alves Filho, D. C.; Bernardes, R. A. L. C. and Kuss, F. 2002. Características da carcaça de novilhos Red Angus superprecoces abatidos com diferentes pesos. Revista Brasileira de Zootecnia 31:119-128. https://doi.org/10.1590/S1516-35982002000100014

Dolezal, H. G.; Tatum, J. D. and Williams, F. L. 1993. Effects of feeder cattle frame size, muscle thickness, and age class on days fed, weight, and carcass composition. Journal of Animal Science 71:2975-2985. https://doi.org/10.2527/1993.71112975x

Euclides Filho, K.; Euclides, V. P. B.; Figueiredo, G. R. and Barbosa, R. A. 2001. Eficiência bionutricional de animais Nelore e seus mestiços com Simental e Aberdeen Angus, em duas dietas. Revista Brasileira de Zootecnia 30:77-82. https://doi.org/10.1590/S1516-35982001000100013

European Commission. 2025. Non-EU countries: Authorised establishments for imports of animal products. Available at: <https://food.ec.europa.eu/food-safety/biological-safety/food-hygiene/non-eu-countries-authorised-establishments_en>. Accessed on: June 2, 2025.

Everitt, B. S.; Landau, S. and Leese, M. 2001. Cluster analysis. 4th ed. Arnold Publisher, London.

Eyduran, E.; Topal, M. and Sonmez, A. Y. 2010. Use of factor scores in multiple regression analysis for estimation of body weight by several body measurements in brown trouts (*Salmo trutta fario*). International Journal of Agriculture e Biology 12:611-615.

Field, R. A. 1971. Effect of castration on meat quality and quantity. Journal of Animal Science 32:849-858. https://doi.org/10.2527/jas1971.325849x

Flores, B. S. C.; Souza, C. V.; Limoni, B. H. S.; Gomes, M. N. B.; Duarte, M. T.; Leite, B. F. C. and Silva, L. A. R. 2018. Carne premium: Um novo agente de modificações na pecuária de corte brasileira. In: Anais da XI Mostra Científica FAMEZ. UFMS, Campo Grande.

Friboi. 2021. Farol da qualidade. Available at: <https://www.friboi.com.br/pecuarista/comercializacao?id=1>. Accessed on: Feb. 28, 2023.

Garcia, P. T.; Pensel, N. A.; Sancho, A. M.; Latimori, N. J.; Kloster, A. M.; Amigone, M. A. and Casal, J. J. 2008. Beef lipids in relation to animal breed and nutrition in Argentina. Meat Science 79:500-508. https://doi.org/10.1016/j.meatsci.2007.10.019

German, D. M.; Adams, B. and Hassan, A. E. 2013. The evolution of the R software ecosystem p.243-252. In: 2013 17th European Conference on Software Maintenance and Reengineering, Genova, Italy.

Gomes, C. E. S.; Gomes, M. N. B.; Pereira, M. W. F.; Surita, L. M. A. and Silva, L. G. P. 2019. Programas de bonificação de carcaça no estado de Mato Grosso do Sul. p.1-6. In: XII Mostra Científica FAMEZ & I Mostra Regional de Ciências Agrárias, Campo Grande.

Greenwood, P. L. 2021. An overview of beef production from pasture and feedlot globally, as demand for beef and the need for sustainable practices increase. Animal 15:100295. https://doi.org/10.1016/j.animal.2021.100295

Grosjean, P. and Ibanez, F. 2018. Pastecs: Package for Analysis of Space-Time Ecological Series_. R package version 1.3.21.

Hocquette, J. F.; Lehnert, S.; Barendse, W.; Cassar-Malek, I. and Picard, B. 2007. Recent advances in cattle functional genomics and their application to beef quality. Animal 1:159-173. https://doi.org/10.1017/S1751731107658042

JBS. 2022. Classificação de carcaças bovinas pelo acabamento. Available at: <https://beefpoint.com.br/wp-content/uploads/2014/09/Livro-classificacao-carca%C3%A7a-JBS-vf.pdf>. Accessed on: July 12, 2024.

Kassambara, A. and Mundt, F. 2020. factoextra: Extract and Visualize the Results of Multivariate Data Analyses_. R package version 1.0.7.

Kuppusamy, M. R. and Giridhar, V. V. 2006. Factor analysis of water quality characteristics including trace metal speciation in the coastal environmental system of Chennai Ennore. Environment International 32:174-179. https://doi.org/10.1016/j.envint.2005.08.008

Latimori, N. J.; Kloster, A. M.; García, F. J.; Carduza, G.; Grigioni, A. and Pensel, N. A. 2008. Diet and genotype effects on the quality index of beed produced in the Argentine Pampeana region. Meat Science 79:463-469. https://doi.org/10.1016/j.meatsci.2007.10.008

Lê, S.; Josse, J. and Husson, F. 2008. FactoMineR: An R Package for Multivariate Analysis. Journal of Statistical Software 25:1-18. https://doi.org/10.18637/jss.v025.i01

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. 2018. Instrução Normativa MAPA nº 51, de 1º de outubro de 2018. Available at: <https://www.gov.br/agricultura/pt-br/assuntos/sanidade-animal-e-vegetal/saude-animal/transito-animal/cgtqa-legis/in-mapa-no-51-1-10-2018.pdf>. Accessed on: May 3, 2023.

Miguel, G. Z.; Faria, M. H.; Roça, R. O.; Santos, C. T.; Suman, S. P.; Faitarone, A. B. G.; Delbem, N. L. C.; Girao, L. V. C.; Homem, J. M.; Barbosa, E. K.; Su, L. S.; Resende, F. D.; Siqueira, G. R.; Moreira, A. D. and Savian, T. V. 2014. Inmunocastration improves carcass traits and beef color attributes in Nellore and Nellore × Aberdeen Angus crossbred animals finished in feedlot. Meat Science 96:884-891. https://doi.org/10.1016/j.meatsci.2013.08.030

Nardon, R. F.; Sampaio, A. A. M.; Razook, A. G.; Tedeschi, L. O.; Boin, C.; Figueiredo, L. A.; Lima, M. L. E. and Castro Júnior, F. G. 2013. Efeitos da raça e seleção para peso pós-desmama no desempenho de bovinos em confinamento. Boletim de Indústria Animal 58:9-19.

Peel, D. S.; Anderson, D.; Anderson, J.; Bastian, C.; Brown, S.; Koontz, S. R. and Maples, J. 2024. Fed cattle price discovery: Issues and considerations. OSU Extension, Oklahoma.

Santos, P. B.; Santana Junior, H. A.; Araújo, M. J.; Oliveira, A. P.; Freitas, T. B. and Viana, P. T. 2017. Production and economic viability of feedlot beef cattle categories. Acta Scientiarum. Animal Sciences 39:195-199. https://doi.org/10.4025/actascianimsci.v39i2.33452

SEMADESC - Secretaria de Estado de Meio Ambiente, Desenvolvimento, Ciência, Tecnologia e Inovação. 2024. Precoce MS avança na pecuária com abate de 1,3 milhão de cabeças e remunera em quase R$ 117 milhões os produtores. Governo do Estado de Mato Grosso do Sul, Campo Grande. Available at: <https://www.semadesc.ms.gov.br/precoce-ms-avanca-na-pecuaria-com-abate-de-13-milhao-de-cabecas-e-remunera-em-quase-r-117-milhoes-os-produtores/>. Accessed on: May 28, 2025.

Silva, A. M.; Araújo, T. L. A. C.; Favero, R.; Pereira, E. S.; Nogueira, E.; Feijó, G. L. D.; Oliveira, L. O. F. and Gomes, R. C. 2018. Efeito do mérito genético para acabamento de carcaças sobre características de carcaça de novilhos precoces cruzados terminados a pasto. In: Anais da 55ª Reunião Anual da Sociedade Brasileira de Zootecnia; 28º Congresso Brasileiro de Zootecnia. SBZ, ABZ, Goiânia.

Silva, R. M.; Restle, J.; Missio, R. L.; Bilego, U. O.; Pacheco, P. S.; Rezende, P. L. P.; Fernandes, J. J. R.; Silva, A. H. G. and Pádua, J. T. 2015. Característica de carcaça e carne de novilhos de diferentes predominâncias genéticas alimentados com dietas contendo níveis de substituição do grão do milho pelo grão de milheto. Semina: Ciências Agrárias 36:943-960. https://doi.org/10.5433/1679-0359.2015v36n2p943

Valadares Filho, S. C.; Rotta, P. P.; Paulino, P. V. R. F.; Detmann, E. and Valadares, R. F. D. 2023. BR-CORTE 2023: Tabelas brasileiras de exigências nutricionais para bovinos de corte. 4.ed. Universidade Federal de Viçosa, Viçosa, MG.

Vargas, L. P. and Silveira, V. C. P. 2020. Serviços ecossistêmicos na produção animal: Uma análise da percepção dos pecuaristas de Alegrete (RS). Revista em Agronegócio e Meio Ambiente 13:235-258.

Vaz, F. N.; Restle, J.; Brodani, I. L.; Costa, E. C.; Vaz, R. Z.; Roso, C. and Carrilho, C. O. 2002. Suplementação energética sobre a qualidade da carcaça e da carne de vacas de descarte idades, terminadas em pastagens cultivadas de estação fria sob pastejo horário. Revista Brasileira de Zootecnia 31:173-182. https://doi.org/10.1590/S1516-35982002000100020

Viegas, I.; Santos, J. M. L. and Fontes, M. A. 2015. Percepção dos consumidores relativamente à carne de bovino: Cenários de escolha a partir de grupos de discussão. Revista de Economia e Sociologia Rural 53:S049-S062. https://doi.org/10.1590/1234-56781806-94790053s01004

Vieira, D. G.; Fernandes, H. J.; Neves, A. P.; Araújo, T. L. A. C.; Ferreira, J. R. and Gomes, R. C. 2019. Composição física da carcaça e biometria corporal de novilhos precoces de diferentes grupos genéticos raciais e méritos genéticos para acabamento. In: 29º Congresso Brasileiro de Zootecnia. ABZ, Uberlândia.

Wickham, H. 2016. ggplot2: Elegant graphics for data analysis. Springer-Verlag New York.

Zarei, H. and Bilondi, M. P. 2013. Factor analysis of chemical composition in the Karoon River basin, southwest of Iran. Applied Water Science 3:753-761. https://doi.org/10.1007/s13201-013-0123-0