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Research Article

Estimates of phenotypic interrelationships for beef cattle destined for slaughter

Estimativas de inter-relações fenotípicas para bovinos de corte destinados ao abate

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ABSTRACT

This work aimed to carry out a mapping of a meat production system in southern Brazil, seeking to investigate the estimates of phenotypic interrelationships through the measurement of variables: body condition score (BCS), final weight (FW), rump fat thickness (RFT), hot carcass weight (HCW), finishing and yield of cattle destined for slaughter. Totaling 200 Angus animals, 14±2 months old, healthy steers, evaluated at the time they were loaded into the slaughterhouse. The finishing degree of the animals presented a coefficient of variation of 21.87 and for RFT of 18.53. The determinant variables for the finishing degree were the BCS, the yield and the weight, where animals with the highest finishing degree had BCS greater than 4, weight greater than 497 kg, and yield greater than 57%. The final weight of the animals still on the farm proved to be an important variable for predicting results such as finishing degree, yield and hot carcass weight. Evidences that the variables of income, weight and body condition score are decisive for obtaining desirable rump fat thickness, as well as the finishing degree.

KEYWORDS: Carcass. Rump fat thickness. Animal production. Weight. Zootechnical parameters.

RESUMO

Este trabalho teve como objetivo realizar um mapeamento de um sistema de produção de carne no Sul do Brasil, buscando investigar as estimativas de inter-relações fenotípicas por meio da mensuração das variáveis: escore de condição corporal (BCS), peso final (FW), espessura de gordura da picanha (RFT), peso de carcaça quente (HCW), acabamento e rendimento de bovinos destinados ao abate. Os resultados foram coletados de 200 animais Angus, 14±2 meses de idade, novilhos hígidos, avaliados no momento do embarque no frigorífico. O grau de acabamento dos animais apresentou coeficiente de variação de 21,87 e para RFT de 18,53. As variáveis determinantes para o grau de acabamento foram o BCS, o rendimento e o peso, onde os animais com maior grau de acabamento apresentaram BCS superior a 4, peso superior a 497 kg e rendimento superior a 57%. O peso final dos animais ainda na fazenda mostrou-se uma variável importante na predição de resultados como grau de acabamento, rendimento e peso de carcaça quente. Evidenciam-se que as variáveis rendimento, peso e escore de condição corporal são decisivas para a obtenção da espessura desejável de gordura da picanha, bem como o grau de acabamento.

PALAVRAS-CHAVE: Carcaça. Espessura de gordura da picanha. Produção animal. Peso. Parâmetros zootécnicos.

INTRODUCTION

Brazilian livestock has expanded production by 122%, with a reduction in pasture area to 13.6% (ABIEC 2021), which demonstrates the efficiency in productivity

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by technologies and selection of quality animals in the last three decades. Although these productive results are largely related to the selection of animals by weight (JÚNIOR et al. 2004), it is important to consider that there is a diversity of variables that will impact the quality of the final product.

In 1964, Lush (LUSH 1964) was already discussing the adoption of strategies for implementing selection methods through scores and field data, in order to meet the market demand for valorization and obtain indirect responses to selection for productivity. Advances in methods for estimating associations and correlations of morphological traits with growth, final weight and carcass quality contribute to the knowledge and selection of superior animals and favorable traits through desirable visual and biotic evaluation (FARIA et al. 2007).

The measurement of variables such as body condition score (BCS), live weight, finishing precocity, rump fat thickness (RFT) and finishing degree are relevant, accessible and economically viable information for the selection of animals that produce more meat or carcass in less time. Farms that have a herd with standardized animals, well-structured forage, sanitary and reproductive planning and aim to produce quality meat, should routinely use the measurement and evaluation of zootechnical markers that will reflect on the slaughterhouse and economic results of the system (VAZ et al. 2021).

Therefore, this work aimed to carry out a mapping of a meat production system in southern Brazil, seeking to investigate the estimates of phenotypic interrelationships through the measurement of variables: body condition score, final weight, rump fat thickness, hot carcass weight, finishing and yield of cattle destined for slaughter.

MATERIALS AND METHODS

All procedures involving animals had the approval of Animal Experimentation Ethics Committee in the project registered under number 23110.013239/2021-31.

A total of 200 Angus animals, 14±2 months old, healthy steers, from Granja 4 Irmãos, located in the city of Rio Grande – RS (32º 15’48” S, 52º 34’ 18” W) were evaluated. The animals were kept in a single lot, during three months, in cultivated pasture and with energy supplementation once a day. For the experimental design of this work and carrying out the collections, the animals sent for slaughter, randomly, according to the management and selection of the farm, they had monitoring and collecting weekly, totaling 13 lots, with 10 to 15 animals in each lot.

On the day of shipment to the slaughterhouse, each animal had its weight individually collected, using a digital scale, when each ox entered the containment trunk. Following the evaluation of the rump fat thickness (RFT) of the animals, ultrasound was performed with a Mindray DP-10 VET ultrasound device, with a linear probe, and a frequency of 3.5 MhZ, from the insertion of the probe into the intersection of the *Gluteus medius* and *Biceps femoris* muscles, located between the ilium and ischium (YOKOO et al. 2011). When viewing the ideal image, the equipment screen was paused and saved, with the identification of the animal in the batch, for later evaluation. Subsequently, through the saved images and use of the resources of the device itself, measurements from two points to obtain the RFT of each animal.

Upon departure of the animals, the variable body condition score was determined, conducted according to the method proposed by LOWMAN et al. (1976), in which the animal with BCS 1 considered severely thin, and the animal with BCS 5, classified as obese. At the end of the evaluations and collections described above, the animals were loaded in a cattle truck to the slaughterhouse.

The animals arrived at the refrigerator around two and a half hours after loading, and were restricted from solid diet for 24 hours. Prior to slaughter, the animals were observed in the corrals and to the bath and stunned.

After the inspection, before carcass division, the fat coverage/finishing degree evaluation took place by a trained team member, using the Brazilian System of Evaluation and Typing of Bovine Carcasses (MAPA 2020) to evaluate the finish. Observing the distribution of fat in five specific regions in the carcass: height of the sixth rib, over the *Longissimus dorsi* muscle in its dorsal part; at the level of the ninth rib, over the *Longissimus dorsi* muscle in its ventral part; at the level of the 12th rib, over the caudal dorsal serratus muscle; in the lumbar region and in the thigh. The finishing degree used is classified into 5 scores, where: 1 is absent (no fat coating on the carcass); 2 scanty (covered by a layer of 1 to 3 mm thick of fat); 3 median (topside covered by a layer of 3 to 6 mm of subcutaneous fat); 4 uniform (covered by a layer of 6 to 10 mm thick of subcutaneous fat) and 5 excessive (lumbar region, rump and lateral face of the thigh evenly covered by a layer greater than 10 mm thick of subcutaneous fat).

At the end of the slaughter line, the carcasses were weighed to measure the hot carcass weight (HCW), and kept for 24 hours in a cold chamber at 0 to 4ºC for later weighing and obtaining the cold carcass weight and packing slip, obtaining the value of Hot Carcass Weight Adjustment. Yield, expressed as a percentage, calculated from the equation: Yield (%) = HCW/Final Weight*100.

The data obtained were submitted to the assumptions of normality and homogeneity of residual variances and, then, to descriptive analyses. With the need to understand the linear relationships between the measured variables, there was a performance of a linear correlation analysis with a significance of 5% by the t test. Performance of a regression tree, using machine learning to verify the determinant variables for the desired characteristics and Biplot principal components analysis. Analysis took place using the software R (R CORE TEAM 2025).

RESULTS AND DISCUSSION

Table 1 presents the descriptive analysis of the data obtained in order to evaluate especially the amplitude of the variables and the coefficient of variation. Since the work consists of a survey of results to identify where the biggest challenges and indicators to improve are to seek in the future to standardize the animals and the result in the final product. The finishing of the animals presented a CV of 21.87 and for RFT of 18.53.

Table 1. Dispersion and position measurements through descriptive analysis of the data collected.

Variable	CV[1]	Max.[2]	Mean	Median	Min.[3]	SD[4]	SE[5]	IC[6]
HCWA [a]	7.784	319.98	266.70	266.78	224.18	20.76	2.3659	4.71
BCS[b]	11.4303	5	4.33	4,5	3.5	0.495	0.0407	0.08
Finishing	21.8799	4	3.05	3	2	0.669	0.0928	0.1863
Hot carcass weight	7.7139	328	275.1675	274.8	232.2	21.2261	2.4189	4.8177
Final weight	6.5648	548	468.4286	465.5	358	30.7516	2.3725	4.684
Yield	6.5899	74.463	56.4006	56.2484	46.4927	3.7167	0.4236	0.8436
RFT[c]	18.5341	4.3	3.1443	3.18	2.13	0.5828	0.0673	0.1341

Abbreviations on the line: [1]Coefficient of Variation; [2]Maximum; [3]Minimum; [4]Standard Deviation; [5]Standard Error; [6]Interval Coefficient. Abbreviations in column: [a]Hot Carcass Weight Adjust; [b]Body Condition Score; [c]Rump Fat Thickness.

Most of the variables evaluated show that a significant part of the sample is close to the mean, with an acceptable coefficient of variation because they are animals, where although they are part of the same production system, there is individual variation, with competing measures that can not be eliminated.

It is important to highlight the high variability for the main characteristics evaluated so far in this work, in terms of meat quality: finishing degree and rump fat thickness. The finishing degree and the RFT of the animals showed a high coefficient of variation, which demonstrates that there is a clear need to carry out work on the farm to improve the finishing degree of the animals and the thickness of subcutaneous fat. Finishing and fat thickness are extremely important to protect the carcass from the rapid and intense drop in temperature in the cold room.

Animals with low fat deposition will show hardening of the meat and may lose tenderness by up to 5 times, in addition to the browning caused by the burning caused by the cold, which compromises the presentation of the product in the package (ROSA et al. 2013). In recent years, there has been an important evolution in the slaughter age of young animals (baby tooth and two teeth), which demonstrates the advance in the use of technologies that accelerate and intensify the production process (FERNANDES et al. 2020). On the farm where this work was carried out, the production of precocious animals is a reality and is already the result of years of genetic and nutritional improvement for this to occur, which reflected in the low variability between the average weight of the lots.

The final weight of the animals (Figure 1A) showed that there was little variability between the average weight of the lots, with some dispersion of animals especially in lot 4 and lot 8, with animals weighing between 540 and 424 kg, and 487 and 358 kg, respectively.

However, within the same batch there was weight variation between animals, which is not interesting for any of the links involved in the production system. For the farm, thinking from the point of view that in the same batch of animals, there are animals that were selected and could have stayed longer within the production system, or there is a non-uniformity in the pattern of animals in terms of food conversion capacity. If the animals come from the same genetic pattern, the same nutrition, the

same age, they had phenotypic and genotypic conditions to express similar productive traits. The relevance of seeking standardized batches, both in yield and in weight of production animals, is given in indicators of interest to the farm and the industry, as they express the value of the final product and operating costs, since carcasses with light weights and heavier ones require the same labor and processing time (COSTA et al. 2002).

In the animals of this work, as the lots selection in the field, through the visualization of the conformation and BCS of the animals, observe that there is not a great variation of body condition within each lot (Figure 1B). There was the exception of lot 12 that presented the highest coefficient of variation (13.907), with animals with BCS 3.5 and animals with BCS 5.

The assessment of the body condition score is a subjective method of metabolizable energy reserves in adipose tissue, based on the evaluation of the animal's external appearance, which reflects on body fat reserves (SCHRODER & STAUFENBIEL 2006), which does not exempt the carrying out of other assessments. Thus, driven by quality requirements and market expectations, the use of ultrasound to assess croup fat thickness has been a tool that helps more accurately in the selection of standardized animals. As observed in other results, the animals showed a great variation within the same batch (Figure 1C), with emphasis on batch 7, with CV of 24.54. Result found that when evaluating the animals individually within the lot, animals with RFT of 14.2 and 5.6 mm.

To verify the association of the BCS and RFT variables, there was a performance of a linear regression to understand the general trend, which showed a linear and positive association, as the animals BCS increased, there was also an increase in the RFT (Figure 2). DOMECQ et al. (1995) validated the evaluation of BCS with ultrasound measurements of subcutaneous fat finding coefficients of determination of the models ranging from 0.36 and 0.65, stating that the BCS score can be related to the thickness of fat. YADAV et al. (2018), when verifying the association of RFT and BCS in buffaloes, found a positive (r=0.604) and significant correlation, as well as SCHRODER & STAUFENBIEL (2006) in cattle, which proved that 1 mm of RFT corresponds to 5 kg of total body fat.

Consistently producing superior quality meat products is a daily challenge for the industry, partly due to the complexity of the biochemistry involved in post-mortem processes but also due to the finishing degree and weight that these animals arrive from the farm to slaughter (EGOLF et al. 2021). The HCW is directly associated with the commercial value of the animal, since payments to livestock farmers are largely determined based on this parameter (GORDO et al. 2018).

Observe regarding the HCW and Final Weight of the evaluated animals, a linear and positive association, with an increase in HCW according to the increase in final weight. The equation presented in Figure 3 allows an estimate of the hot carcass weight to be performed, based on the final live weight of the animals, still on the farm. Therefore, as you increase 0.38 x kilograms, there will be an increase in hot carcass weight, where Y is equal to HCW.

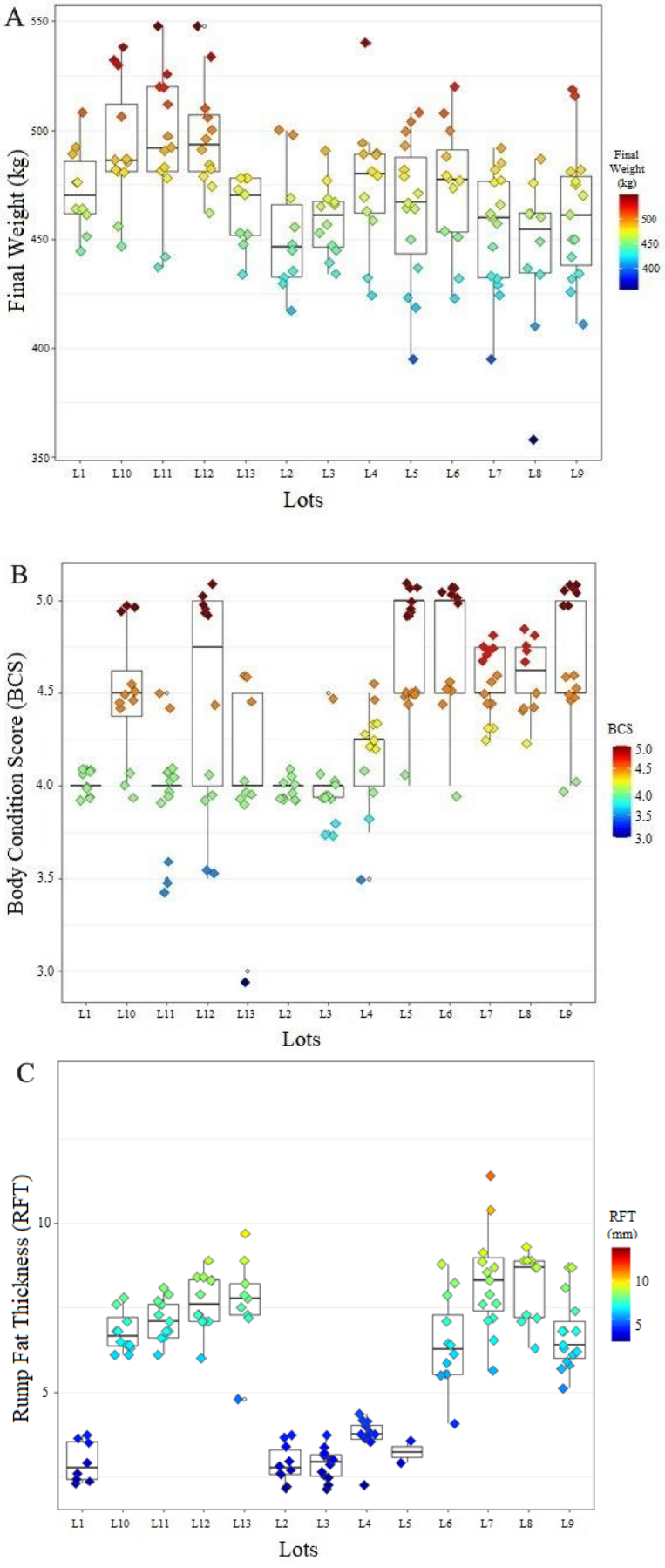


Figure 1. Box plot with stratified ranking by lots of the final weight of steers sent for slaughter (A), ranking of body condition score (BCS) of steers sent to slaughter (B), lots of rump fat thickness (RFT) of steers sent for slaughter (C).

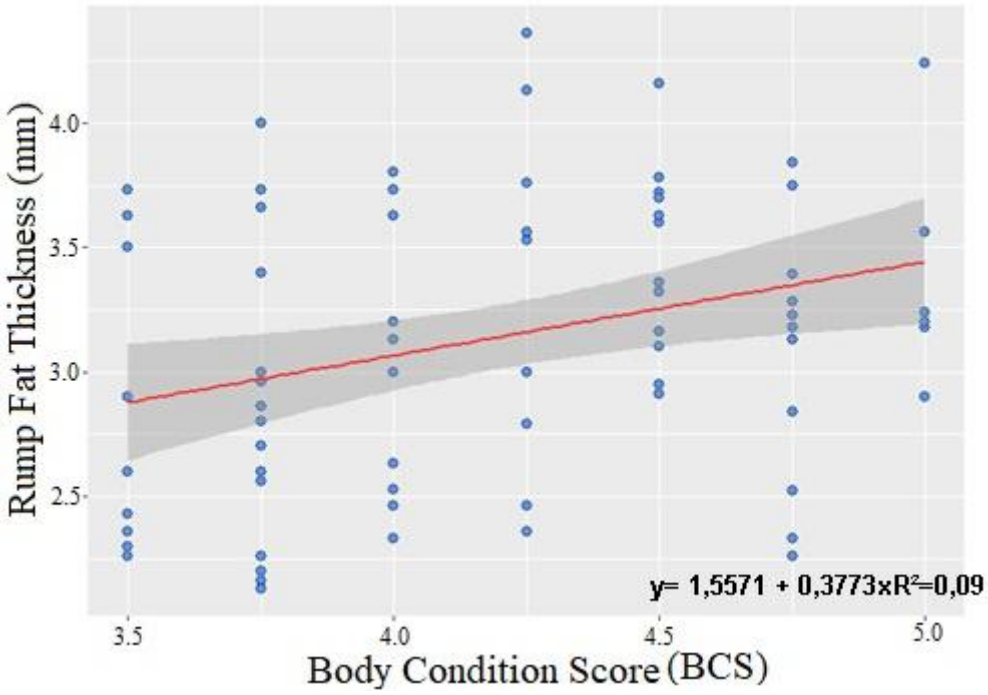


Figure 2. Linear regression with significance by t test at 5% probability of rump fat thickness (RFT) and body condition score (BCS) of steers sent to slaughter.

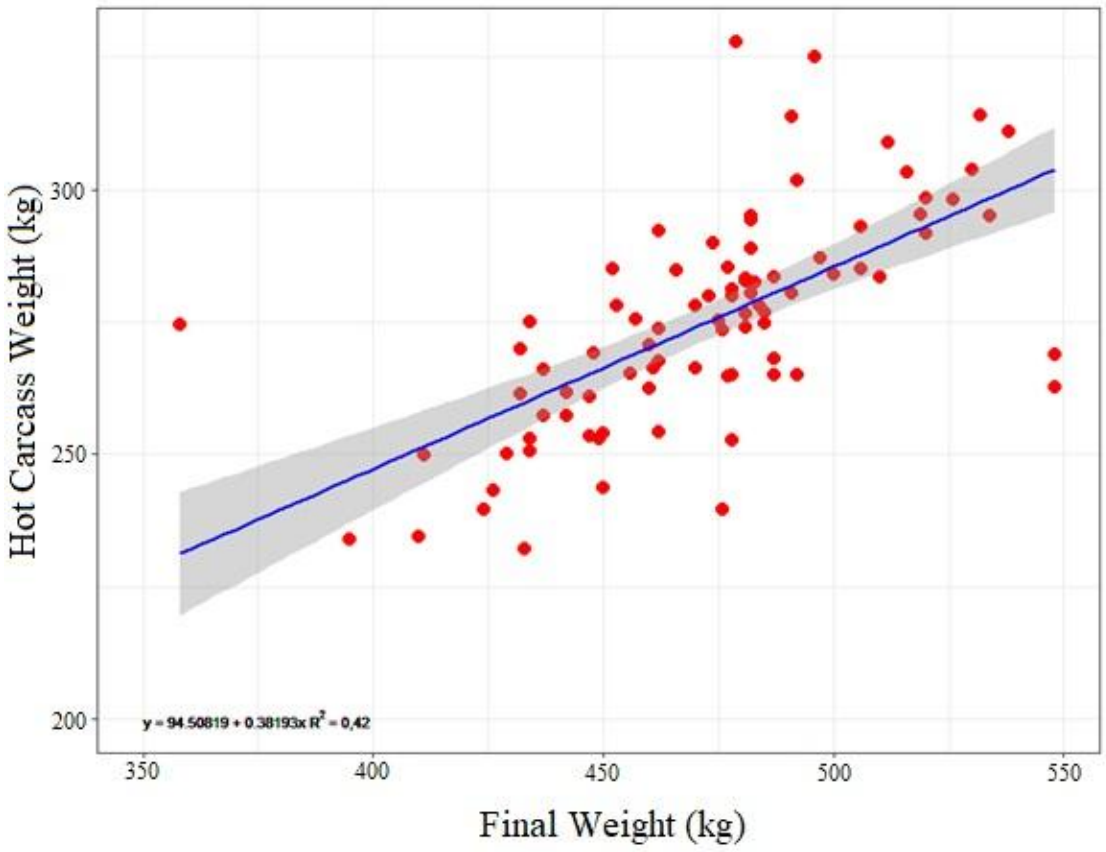


Figure 3. Linear regression with significance by t test at 5% probability of hot carcass weight (HCW) and final weight of steers sent to slaughter.

Figure 4 shows Pearson's correlation analysis for 6 variables: final weight, body condition score (BCS), hot carcass weight (HCW), hot carcass weight adjustment (HCWA), yield, rump fat and (RFT) revealing 15 associations, where 9 were significant.

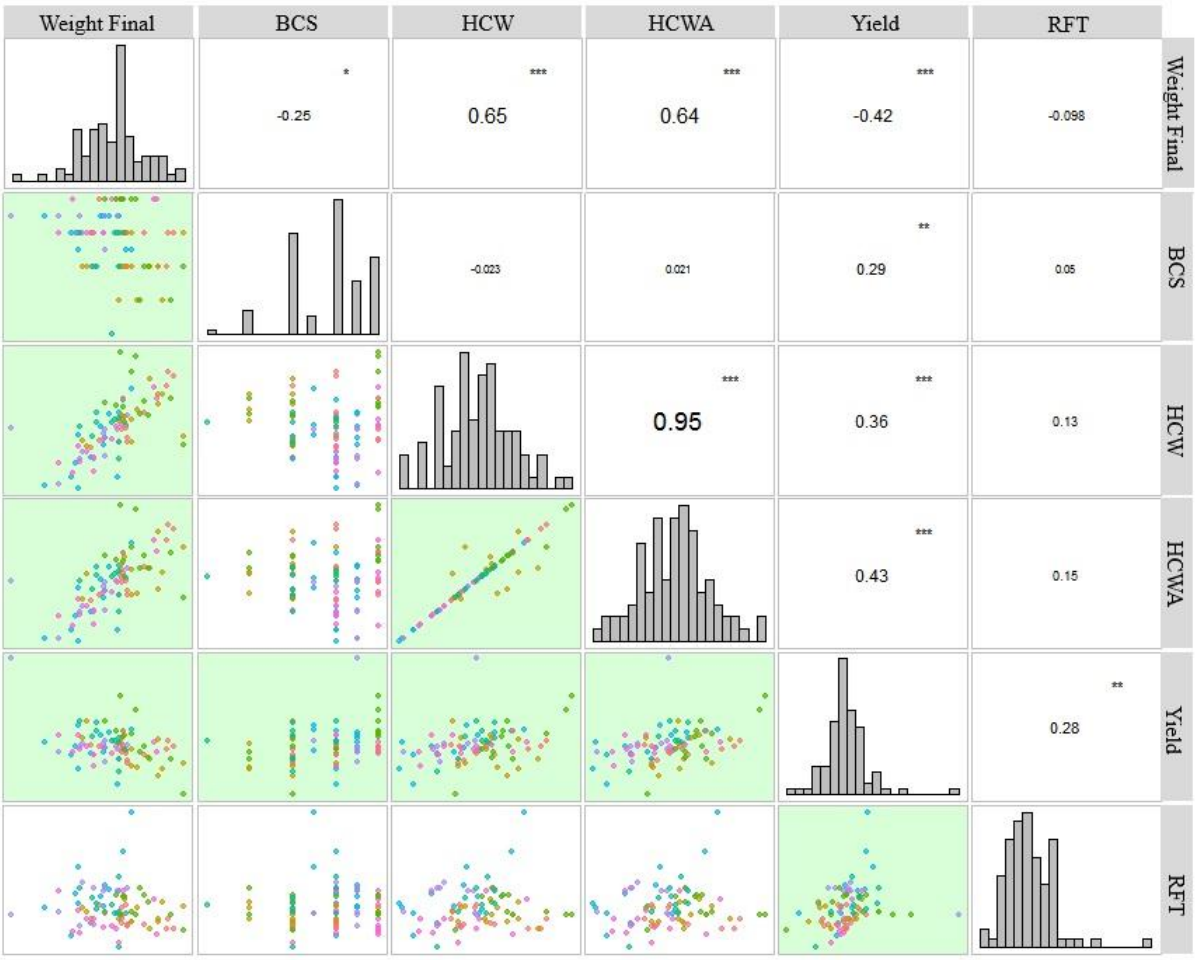


Figure 4. Pearson's linear correlation coefficients (n=100) with significance at 5% probability by the t test for 6 zootechnical characters of steers sent to slaughter.

Detailing each of the significant associations, in the analysis of final live weight, positive correlation coefficients were observed for HCW (r=0.65) and HCWA (r=0.64), and negative for BCS (r= -0 .25) and yield (r= -0.42). In the BCS analysis, a slight but significant correlation was found for yield (r=0.29), and hot carcass weight a strong correlation for HCWA (r=0.95) and yield (r=0.36).

The decision tree (Figure 5) took place with the objective of investigating which were the main results that are decisive to define the finishing degree within the evaluated production system. According to the results obtained, the finishing degree was based on the response of 3 major variables: body condition score (BCS), weight (Final Weight) and carcass yield (RCA). The BCS was considered the basis for defining the finishing degree, with two segments, animals with BCS less than 4.3 (yes) and animals with BCS greater than 4.3 (no).

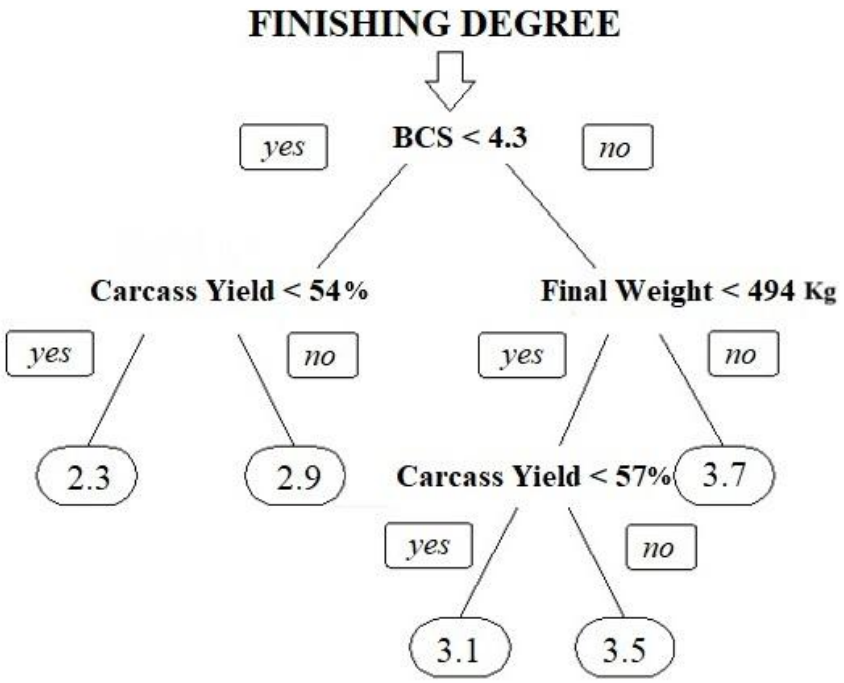


Figure 5. Regression tree obtained by machine learning, to determine the finishing degree of the evaluated steers. Significance based on the x^2 test.

Animals with a finishing score of 2.3 had BCS < 4.3 and carcass yield (RCA) lower than 54%. On the other hand, animals with BCS < 4.3 but carcass yield greater than 54% tend to have a finishing degree of 2.9.

When we worked with animals that presented BCS greater than 4.3, the highest degrees of finishing were found, varying according to carcass weight (HCW). Steers with higher BCS and weighing more than 494 kg tend to have a finishing degree of around 3.7. On the other hand, animals weighing less than 494 kg and a carcass yield of less than 57% presented an average finishing degree of 3.1, and animals with higher carcass yield, a finishing degree of 3.5.

It is important to remember that the finishing degree is a whole number, on a scale from 1 to 5, however, as the data were analyzed from the average of the results of the evaluated animals, the numbers are presented fragmented (2.3; 2 .9; 3.1; 3.5; 3.7). Thus, it is demonstrated that higher degrees of finishing were characterized by steers with a body condition score greater than 4.3 and weight greater than 494 kg.

Animal nutrition during finishing rearing has a significant effect on carcass yield in cattle. Strategies such as concentrated supplementation in this phase, in grazing animals, favors obtaining heavier animals in the finishing phase (REZENDE et al. 2009). On the farm, the animal nutrition is based on oat and ryegrass pasture, sorghum silage supplementation and corn feed, rice bran, soybean hulls and soybean meal. RESTLE et al. in 1999 he already stated that there are two important points when looking for the production of precocious steers: the slaughter weight and the finishing degree of the carcass. These factors are associated with the success of the final product, when it comes to meat quality.

In figure 6, in order to verify the determinant variables to obtain a good RFT, the results were based on the response of 4 major variables: carcass yield, body condition

score (BCS), hot carcass weight (HCW) and final weight. Animals with better RFT results, according to this analysis, consequently, have a yield greater than 56%, and BCS around 4.6, reaching RFT of 7.9 and 8.8 mm.

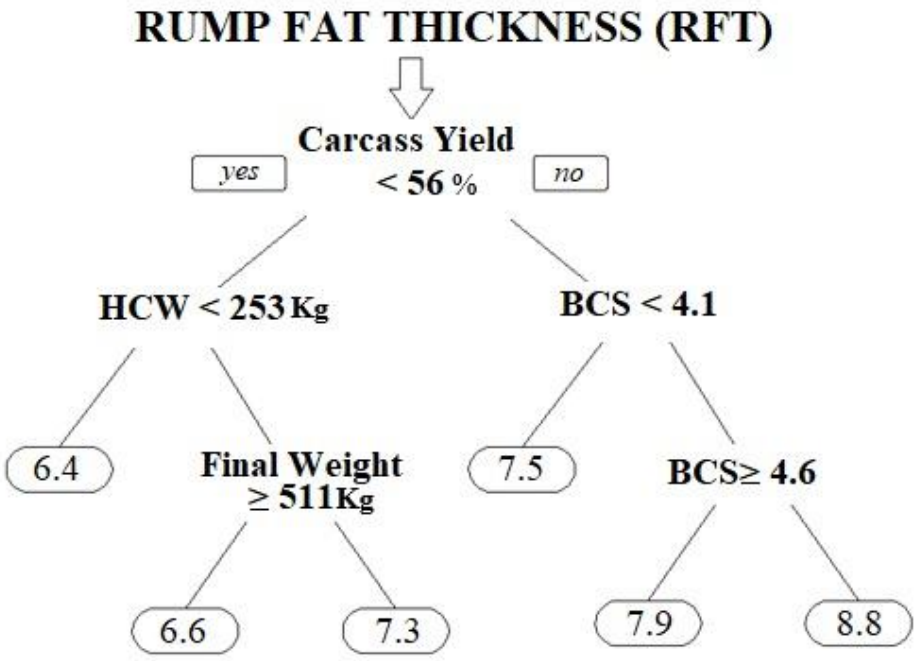


Figure 6. Regression tree obtained by machine learning to determine the rump fat thickness (RFT) of the evaluated steers. Significance based on the x^2 test.

In these results presented, ways of selecting animals in the field to obtain products of superior quality are elucidated, even before the animal arrives at the slaughterhouse. And even more innovatively, but not as applicable in everyday life, PORTO NETO et al. (2012), present variations in the XKR4 gene, with a significant association for RFT and composition of subcutaneous fat, which allows to explain and encourage population genetic selection for traits of interest.

In the analysis of the main components (Figure 7), the animals were grouped in batches according to weight, with steers weighing more than 490 kg in group 1 and animals weighing less than 450 kg in group 7. It is noted that the animals in group 3, weighing around 470 kg, have an affinity to potentiate the increase in final live weight, HCW and consequently HCWA. In group 5, grouping those steers weighing around 450 kg, there was a potential to increase BCS and RFT.

The evaluations of morphological and quantitative variables provide complementary information that is useful to determine and predict trends and promote the selection of expected results over the period (FARIA et al. 2007). Numerous updates have already been implemented using new biotechnologies, however, there is still ample room to progress using better tools and data that already exist within the production systems but which most of the time are unexplored.

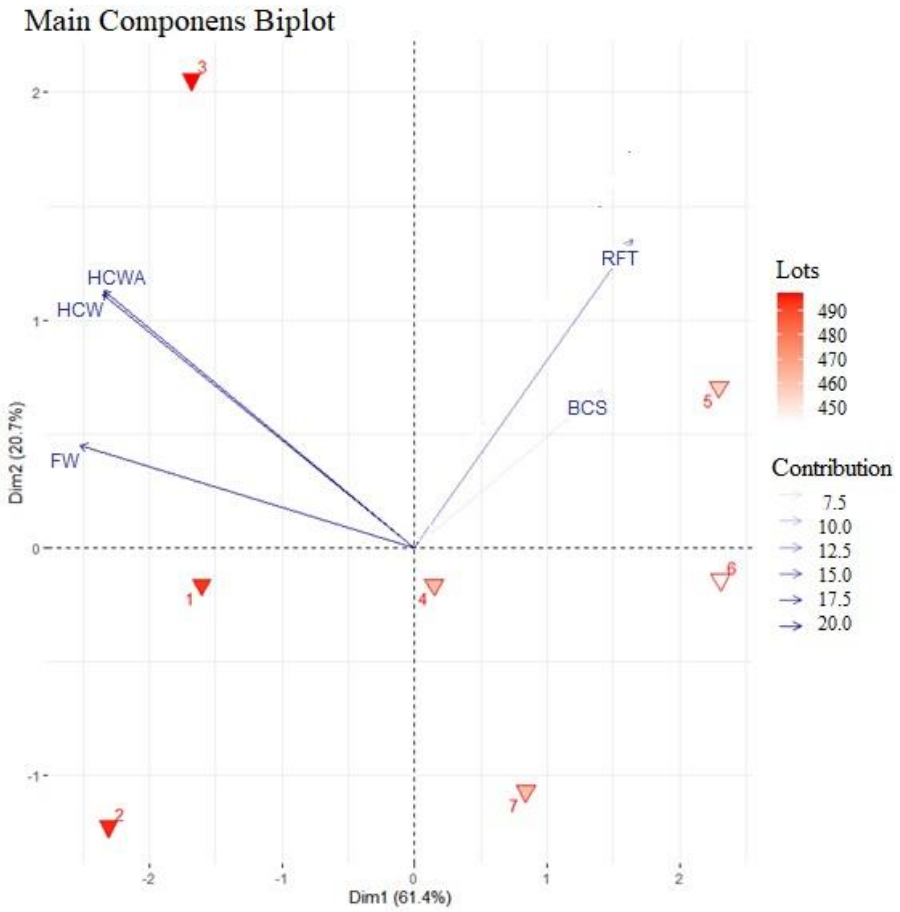


Figure 7. Main components Biplot with multiple representation of batches categorized from 1 to 7 according to weight and determining variables related to the due effects (HCWA, HCW, WF, RFT and BCS).

Animal weight data, BCS, RFT are information that can easily be measured within the routine of the farms, and the analysis of these phenotypic interrelationships with variables of interest for the production of the final product with superior quality (finishing degree, marbling, yield) allow the producer to verify results that need to be improved within the system and also to carry out programming in relation to market offers and planning of the production system.

CONCLUSION

The final weight of the animals still on the farm proves to be an important variable for predicting results such as finishing degree, yield and hot carcass weight.

The variables weight and body condition score are decisive for obtaining desirable rump fat thickness, as well as the finishing degree.

The results found in this work made it possible to carry out a mapping of the production system, relating the zootechnical data and carcass characteristics, revealing those that can be improved and demonstrating field variables that have an important relationship with carcass results.

NOTES

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Gabriela Bueno Luz, and Edgard Malaguez; investigation, Gabriela Bueno Luz; resources and data curation, Gabriela Bueno Luz, Ivan Ricardo Carvalho and Leonardo Pradebon; writing-original draft preparation, Gabriela Bueno Luz and Leonardo Pradebon; writing-review and editing, Gabriela Bueno Luz; visualization, supervision, project administration, Marcio Nunes Corrêa and Cassio Cassal Brauner. All authors have read and agreed to the published version of the manuscript.

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INSTITUTIONAL REVIEW BOARD STATEMENT

All procedures involving animals had the approval of Animal Experimentation Ethics Committee in the project registered under number 23110.013239/2021-31.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available under request.

ACKNOWLEDGEMENTS

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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