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Meta-analysis on beef cattle carcass chilling loss

Abstract – The objective of this work was to evaluate, through meta-analysis, the factors that influence the weight loss of beef cattle carcass during chilling. Scientific articles were searched on Scielo and Google Scholar platforms, following the PICO tool, which refers to population, intervention, comparison, and outcome, using the terms beef cattle, carcasses, sex of the animal, and the chilling loss, respectively. The following filters for the articles were used: peer view, English or Portuguese, and dated from 1990 onwards. The total of 154 articles were found on Scielo and 136 on Google Scholar. The database comprised 47 selected articles based on title, abstract criteria, and a final selection regarding data presentation. The Iterated Principal Factor method was used with the Varimax rotation method. The path diagram was used to show the factored model results. The variance of chilling breakage was ranked using a statistical software. The breakdown of bovine carcasses on chilling ranges from 0.47% to 4.93%, with an average of 2.24%. Better conformations and greater fat thickness determine lower carcass chilling losses. Higher body weights at slaughter and hot and cold carcasses provide smaller breaks in the carcass chilling whereas moisture loss depends on the animal size. Meta-analytical methods allow evaluating a larger number of samples, which indicate better values for variations, such as the influence of the animal size.

Index terms: carcass yield, conformation, marbling, slaughter weight, subcutaneous fat.

Metanálise sobre perdas por resfriamento de carcaças de bovinos de corte

Resumo – O objetivo deste trabalho foi avaliar, por meio de metanálise, os fatores que influenciam na perda de peso da carcaça de bovinos de corte durante o resfriamento. Foram realizadas buscas de artigos científicos nas plataformas Scielo e Google Scholar, por meio da ferramenta PICO, que se refere a população, intervenção, comparação e resultado, usando os termos bovinos de corte, carcaças, sexo do animal e quebra ao resfriamento, respectivamente. Foram utilizados os seguintes filtros para os artigos: peer view, em inglês ou português e datados a partir de 1990. O total de 154 artigos foram encontrados na Scielo e 136 no Google Scholar. O banco de dados foi composto por 47 artigos selecionados com base nos critérios de título, resumo e uma seleção final relacionada à apresentação dos dados. O método de Fator Principal Iterado foi usado com o método de rotação Varimax. O diagrama de caminho foi usado para mostrar os resultados do modelo fatorado. A variância da quebra ao resfriamento foi ranqueada a partir de software estatístico. A quebra ao resfriamento das carcaças bovinas varia de 0,47% a 4,93%, com a média de 2,24%. Melhores conformações e maior espessura de gordura determinam menores perdas de resfriamento. Maiores pesos corporais no abate e nas carcaças quentes e frias proporcionam intervalos menores no resfriamento da carcaça, enquanto que a perda de umidade depende do tamanho do animal. Os métodos metanalíticos permitem avaliar um maior

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número de amostras, o qual indica melhores valores dessas variações, como a influência do tamanho do animal.

Termos de indexação: rendimento de carcaça, conformação, marmoreio, peso de abate, gordura subcutânea.

Introduction

The efficiency in beef production is not limited to the handling of animals: it includes transport, pre-slaughter, and carcass cooling (Vaz et al., 2023), which must be improved to avoid losses and guarantee quality, healthiness, and safety for consumers.

During its chilling process, the carcass dehydrates and loses weight, which is known as chilling loss, resulting in lower yields for the refrigeration industry (Pflanzer et al., 2019). Until 2022, in the Southern region of Brazil, slaughterhouses and cattle breeders estimated cold carcass weight by the hot carcass weight minus 2% (Nunes et al., 2024). This deal was used to avoid waiting 24 hours for the carcass cooling process to pay the livestock farmer, which generated, for years, dissatisfaction among the beef cattle system class and a discussion of the real loss of post-slaughter chilling (Pascoal et al., 2011).

Studies have shown that the carcass chilling loss is influenced by carcass conformation (Barbut, 2014), pre-slaughter nutritional level of animals (Honig et al., 2020), genetic group of animals and/or individual variation within genetic groups (Silva et al., 2015), slaughter weights (Moomak & Tuntivisoottikul, 2020), gender (Pascoal et al., 2011), and cattle age (Gomes, 2021), all correlating the results with the fat coverage of the carcasses (Boito et al., 2018). However, the analysis of the factors and their variability for greater or lesser weight loss of carcasses during chilling process is not simple, since it requires more advanced statistical resources considering and grouping several factors at the same time (Baldassini et al., 2017).

To elucidate the factors that determine the carcass chilling loss, a meta-analytic study, using several experiments with different variants, was carried out, quantifying the most relevant ones, correlating them, and establishing elements to be considered by producers and industries to minimize the losses (Baldassini et al., 2017; Santos Torres et al., 2023). Meta-analysis provides an innovative approach, since its use can encompass several studies evaluating the same factors to work with the average of the results

obtained under different conditions. Meta-analysis is widely used in animal science to provide insights in the search for studies, allowing the compilation and use of experimental data and ensuring more reliable results (Almeida & Goulart, 2017).

The objective of this work was to evaluate, through meta-analysis, the factors that influence the weight loss of beef cattle carcass during chilling.

Materials and Methods

During June and July 2021, the selection and assessment of the eligibility of articles for a database on Scielo (2021) and Google Scholar (2021) platforms were carried out. The criteria for choosing the articles was conducted following PICO tool, which refers to population, intervention, comparison, and outcome (McGowan et al., 2016), in which the factors corresponded to cattle, beef cattle, or bovine; carcass, carcasses, carcass trait, or meat quality; sex of the animal, steers, heifer, cows, or bulls; and carcass chilling break, breaking chilling, chilling loss, cooling loss, or carcass chilling, respectively. In total, 154 articles were found on Scielo and 136 on Google Scholar, which were tabulated in electronic spreadsheets to be evaluated in the screening process, according to the following information: author, periodical, year, title, meets the selection criteria, and reason the article does not meet the selection criteria.

Eligibility criteria of the articles were previously defined by title, abstract, and full text. The title had to present specific characteristics of bovine carcasses; the abstract, carcass quality data and both hot and cold carcass weight data. In the final selection phase, the inclusion criteria were as follows: carcass chilling break, presentation of original data, articles published in journals, articles published after 1990, and articles in English and Portuguese. At the end of all steps, 47 articles were selected (Table 1).

After preliminary data analysis, based on graphical analysis to obtain general averages, was carried out, correlation hypotheses were formulated to define the statistical models (Backhaus et al., 2021). Afterwards, exploratory factor analysis was applied to verify the latent and underlying variables observed in the data set, and the Iterated Principal Factor method (Backhaus et al., 2021) was applied to decompose the factor correlation matrix. To compose the latent variables,

Table 1. Overview of studies included in the meta-analysis on beef cattle carcass chilling loss.

Author	Breed	Objective of the study
Alencar et al. (2016)	Dutch x Zebu	Evaluate the effect of diets based on millet and inclusion of BMB on the carcass and meat characteristics of dairy steers finished in feedlot.
Arboitte et al. (2012)	Aberdeen Angus	Evaluate the carcass of super-young steers of small and medium biotypes, finished in feedlot and slaughtered with similar thickness of subcutaneous fat.
Augusto et al. (2019)	Angus x Nelore	Evaluate the performance in feedlot and the carcass and meat characteristics of F1 Angus-Nelore steers and heifers with a high degree of finishing.
Brondani et al. (2006)	Charolais	Evaluate the effects of corn silage or whole sugar cane on the carcass characteristics of steers.
Brondani et al. (2004)	Aberdeen Angus; Hereford	Evaluate the quantitative characteristics of the carcass of non-castrated male cattle, finished in feedlot and slaughtered at 13–14 months of age.
Comparin et al. (2013)	Brangus	Verify the use of nutritional additives (protected fat, calcareous seaweed meal, organic Se, vitamins E and D) on the performance, carcass, and meat characteristics of heifers supplemented on pasture.
Donicht et al. (2011)	Charolais x Nelore	Compare the effect of different sources of fat in the diet of feedlot steers on carcass and meat characteristics.
Feijó et al. (2001)	Angus x Nelore	Evaluate the yield and carcass quality of animals in different supplementation alternatives during rearing and finishing.
Ferreira et al. (2006)	Charolais; Charolais x Nelore	Study the carcasses of young non-castrated cattle from different genetic groups originating from the alternating rotational mating system between Charolais and Nelore breeds finished in feedlot.
Freitas et al. (2008)	Nelore	Evaluate the characteristics and primary cuts of carcasses, body measurements, and indirect measures of performance of secondary cuts of non-castrated or castrated animals at 13 and 18 months of age, feedlot-finished in feedlot at 22 months.
Ítavo et al. (2008)	Canchim x Nelore	Compare the productive performance, carcass characteristics, and economic viability of the system of raising castrated and non-castrated steers on <i>Brachiaria decumbens</i> pastures.
Kuss et al. (2009)	Purunã x Canchim	Evaluate the quantitative characteristics of the carcass of non-castrated and castrated steers from the young and super-young categories finished in feedlot.
Kuss et al. (2009)	Charolais x Nelore	Evaluate the carcass of culled cows finished in feedlot, submitted to diets with and without monensin sodium.
Kuss et al. (2005)	Charolais x Nelore	Evaluate carcasses of crossbred culled cows finished in feedlot and slaughtered at different weights.
Leão et al. (2013)	Not specified dairy breeds	Evaluate the carcass and meat characteristics of dairy culled cows and castrated steers in feedlot-system receiving crude glycerin levels.
Miotto et al. (2012)	Brown Swiss x Nelore	Evaluate the replacement of corn with babassu mesocarp meal in feedlot-diets on the carcass and qualitative characteristics of beef.
Maciel et al. (2016)	Dutch x Zebu	Evaluate diets containing levels of crude glycerin for crossbred steers finished in feedlot.
Mendes et al. (2012)	Dutch x Zebu	Evaluate the replacement of sorghum silage with marandu grass silage based on the characteristics of the heifer carcass.
Menezes et al. (2014)	Devon	Evaluate energy levels supplementation in tropical pasture on the carcass and meat characteristics of super-young steers.
Menezes et al. (2010)	Devon	Evaluate the carcass and meat characteristics of super-young steers finished in feedlot, on winter and summer grass.
Menezes et al. (2009)	Charolais x Nelore	Evaluate supplementation with corn silage and ground sorghum grain on the performance, carcass, and meat characteristics of culled cows of different ages under restricted grazing on <i>Avena strigosa</i> and <i>Lolium multiflorum</i> pasture.
Menezes et al. (2005)	Charolais; Nelore	Evaluate the level of concentrate in the diet of steers finished in feedlot.
Menezes et al. (2005)	Charolais; Nelore	Evaluate the quantitative and qualitative characteristics and proportion of carcass commercial cuts and the heterosis of the second, third, and fourth generation steers from the alternating Charolais x Nelore crossing breeds, finished in feedlot-system.
Metz et al. (2009)	Charolais x Nelore	Evaluate the carcass characteristics and meat quality of steers feedlot-finished with two initial weights.
Missio et al. (2013)	Purunã	Evaluate the carcass characteristics of culled cows slaughtered at different weights.
Missio et al. (2010)	Charolais x Nelore	Compare concentrate increasing levels in the diet on bull carcass and meat characteristics of 14–16 month slaughtered.
Pacheco et al. (2013)	Charolais	Compare the carcass and empty body of steers, heifers, and culled cows slaughtered with similar finishing system.
Pacheco et al. (2005)	Charolais x Nelore	Evaluate the quantitative characteristics of the carcass of young or super-young steers of genetic groups 5/8 Charolais 3/8 Nelore and 5/8 Nelore 3/8 Charolais.

Continuation...

Table 1. Continuation.

Author	Breed	Objective of the study
Pacheco et al. (2013)	Charolais x Nelore	Evaluate the carcass of super-precocious, non-castrated, and castrated cattle, in different genetic groups, finished in feedlot.
Pascoal et al. (2011)	Braford	Evaluate the total and individual meat yields of boned cuts, edible scrap, discarded flap, and bones from carcasses of castrated steers slaughtered at 22 months of age after finishing in feedlot.
Perobelli et al. (2005)	Charolais; Nelore	Compare carcass characteristics of Charolais and Nelore culled cows.
Restle et al. (2000)	Charolais x Nelore	Study the effect of alternating Charolais x Nelore crossing, in the first and second generations of crossing, and the different levels of heterozygosity on the carcass characteristics of non-castrated and castrated beef cattle finished at two years of age.
Restle et al. (1999)	Charolais x Nelore	Compare the carcass characteristics of Charolais x Nelore cross steers, weaned at 90 or 210 days.
Restle et al. (1999)	Braford	Study the carcass characteristics of steers weaned early or not, finished in confinement for slaughter at 14 months.
Restle & Vaz (1997)	Hereford	Compare the carcass characteristics of intact and castrated animals 14 months slaughtered and estimate the percentage of commercial cuts.
Restle et al. (1997)	Charolais	Compare the effect of different slaughter weights on the carcass characteristics of steers finished in feedlots.
Rezende et al. (2020)	Nelore	Evaluate the production and carcass performance and meat characteristics of cattle finished in feedlot.
Rezende et al. (2019)	Nelore	Examine the carcass characteristics of culled heifers slaughtered at different weights.
Rezende et al. (2012)	Gir x Dutch	Evaluate the effects of different nutritional strategies in rearing and finishing on carcass and meat characteristics of 24 crossbred Holstein predominance cattle, slaughtered at 15 months of age with 395 kg of live weight.
Santos et al. (2008)	Charolais x Nelore	Evaluate the effect of reducing the slaughter age from 22 to 13 months on the quantitative characteristics of the carcass of steers finished in feedlot, slaughtered with similar carcass weight and subcutaneous fat thickness.
Silva et al. (2008)	Nelore	Evaluate weight gain and carcass characteristics of castrated and non-castrated cattle finished in confinement.
Vaz et al. (2014)	Gir x Dutch	Analyze the effects of different castration methods of dairy crossbred males on carcass and meat characteristics, compared to non-castrated animals.
Vaz et al. (2013)	Nelore	Evaluate economically slaughter and estimation of carcass characteristics of young, non-castrated Nelore males, slaughtered at different weights, comparing them with animals with more advanced maturity.
Vaz et al. (2010)	Braford	Study the carcass and meat characteristics of castrated steers and super-young heifers.
Vaz & Restle (2005)	Hereford	Evaluate the use of corn and sugar cane silage in the feedlot finishing of early breed steers, on the quantitative and qualitative characteristics of the carcass and meat.
Vaz et al. (2002)	Hereford; Jersey; Nelore	Evaluate the qualitative characteristics of the carcass and meat of steers finished in feedlot and slaughtered at 14 months, from two types of crosses, and compare them to origin pure Hereford.
Vaz et al. (2011)	Braford	Compare the characteristics of carcasses of steers subjected to early weaning or not, with rearing and finishing on cultivated pastures and aged between 14 and 16 months.

the communality and load of each one were estimated. Eigenvalues were retained using the Kaiser method (eigenvalues >1) and rotation by Varimax (Backhaus et al., 2021). The reliability of the factorial model was determined using Cronbach's alpha coefficient and the factored model was represented in a path diagram. The exploratory analysis was carried out using the Factor procedure (SAS Institute Inc., 2018).

The rank procedure (SAS Institute Inc., 2018) of fat thickness (2 df) and slaughter weight (2 df) variables was conducted for analysis of variance. To separate the effects of the variables studied on categories, fat thickness and slaughter weight variables were divided

into three classes: low, medium, and high, to verify their effect on chilling breakdown. The categories were created from the means and standard deviations of the means reported in the studies composing the database.

A completely randomized design was adopted, under the methodology of mixed models, with the incorporation of fixed and random effects into the model (SAS Institute Inc., 2018), and the article was inserted as a random effect. The adjustment with the addition of random effects and the choice of the mathematical model was carried out using the corrected Akaike information criterion (AICc) and a mixed procedure (SAS Institute Inc., 2018). Fat

thickness and slaughter weight were considered fixed effects and articles, random effects, which were both tested. The inclusion or exclusion of other random effects from the model was based on the best fit, according to the mentioned criteria. SAS OnDemand was used for statistical analysis.

Results and Discussion

The minimum and maximum values of the characteristics showed variations in the 47 articles analyzed (Table 2). The present meta-analysis found weight loss in carcasses during chilling from 0.47% to 4.93%, which was higher than the 2.0% usually discounted by the industry in negotiations between producers and slaughterhouses to estimate cold carcass weight (Vaz et al., 2021). Therefore, by 2022, the industry in the state of Rio Grande do Sul had a loss, as it paid more than the quantity available to be processed. This variation may be explained by the differences in size and characteristics of the cold rooms, as well as the cold chain quality of the slaughterhouses (Missio et al., 2013).

The relationship between the animals' slaughter weight and hot and cold carcass weights (Figure 1) is high and positive, in agreement with the literature, which means that the heavier the animal, the greater the hot and cold carcass weights are (Monteiro et al., 2022), because greater deposition of muscle and fat increases carcass weight in relation to slaughter weight. In different studies, it was observed a break in chilling, which may be associated with fluctuations in the cold chamber, such as temperature, wind speed, number of carcasses, and time of animal slaughter, in

addition to animal individual variation and finishing systems (Barbut, 2014).

Breakage due to cooling had an inverse relationship with conformation, in which the greatest breakages occurred in carcasses with the worst conformation. Body and carcass weights correlate with the percentage of fat that is separable from the carcasses, since, within a given category, the heaviest animals are those that had a longer finishing period or with a higher level of net energy gain, resulting in an accumulation of body fat (Blanco et al., 2020). Furthermore, as the animals get mature, the weight increases, modifying their gain composition (Schumacher et al., 2022). During growth, most animals' body gain is muscle tissue, whereas in the final stages, the weight gain is most composed of fat (Honig et al., 2020).

The carcass chilling did not contribute to the formation of the second factor, unlike marbling, which demonstrated a high relationship with subcutaneous fat, contributing to the formation of the first factor (Figure 2). Boito et al. (2018) stated that adequate subcutaneous fat thickness reduces weight losses during carcass chilling, showing a negative correlation between these variables (Arboitte et al., 2004), because the fat forms a protective layer against the cold, preventing carcass dehydration (Missio et al., 2013). The correlation between subcutaneous and marbling fats is explained by the priority of their deposition, with marbling fat not being a priority in the animals' body reserves. Fat deposition on the carcass initiates with intermuscular fat, then subcutaneous fat, and, finally, intramuscular fat (Schumacher et al., 2022).

In a meta-analysis study, Pacheco et al. (2023) found that the increase in the thickness of

Table 2. Descriptive analyzes of the variables studied in the systematic review and meta-analysis on beef cattle carcass chilling loss.

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Chilling loss	121	2.24	0.7717	0.469	4.93
Subcutaneous fat thickness	145	4.45	2.3780	0.880	17.70
Conformation ⁽¹⁾	125	10.86	6.6420	7.750	83.00
Slaughter weight	145	427.63	55.6990	310.300	580.86
Hot carcass weight	135	230.17	31.2660	168.600	340.09
Cold carcass weight	131	222.20	27.5580	167.800	311.07
Marbling score ⁽²⁾	65	6.10	2.5020	1.770	13.70

⁽¹⁾Scale from 1 to 18 points: 1 to 3, inferior; 4 to 6, bad; 7 to 9, average; 10 to 12, good; 13 to 15, very good; and 16 to 18, superior. ⁽²⁾Scale from 1 to 18 points: 1 to 3, traces; 4 to 6, light; 7 to 9, small; 10 to 12, medium; 13 to 15, moderate; and 16 to 18, abundant.

subcutaneous fat of the carcass is not responsible for the greater deposition of marbling fat, which is determined by slaughter weight, although there is a positive correlation between both, with subcutaneous fat exceeding 6 mm. For the adequate deposition of marbling fat, adipogenesis during the individual's pregnancy is essential (Du et al., 2010). The 230 kg of carcass in the present meta-analysis did not match high levels of marbling. Data from studies in the United States, Australia, and Japan showed no increase in marbling up to 200 kg of carcass, increasing from 200 to 450 kg, with the maximum being 500 kg of carcass (Pethick et al., 2004).

The fat thickness and slaughter weight variables divided into three classes were on average 5.27 cm and 429.11 kg, respectively (Table 3). It was verified that losses during the chilling of carcasses were

not influenced by increases in slaughter weight or subcutaneous fat thickness (Table 4). The literature is consistent in stating that adequate subcutaneous fat thicknesses minimize weight losses during carcass chilling (Pacheco et al., 2023), consequently, lower chilling losses occur because fat forms a protective layer against the cold, preventing dehydration of the carcasses, in which higher degrees of finishing have a negative correlation with lower chilling losses (Pacheco et al., 2023). In the present meta-analysis, there is no difference between subcutaneous fat coverage and carcass weight during chilling, probably due to the small average variation of the low, medium, and high classes (Table 3). Furthermore, the heavier the animal is in finishing, regardless of sex, results in an increase in the carcass weight: for each increase in the degree of finishing of the females, the carcass

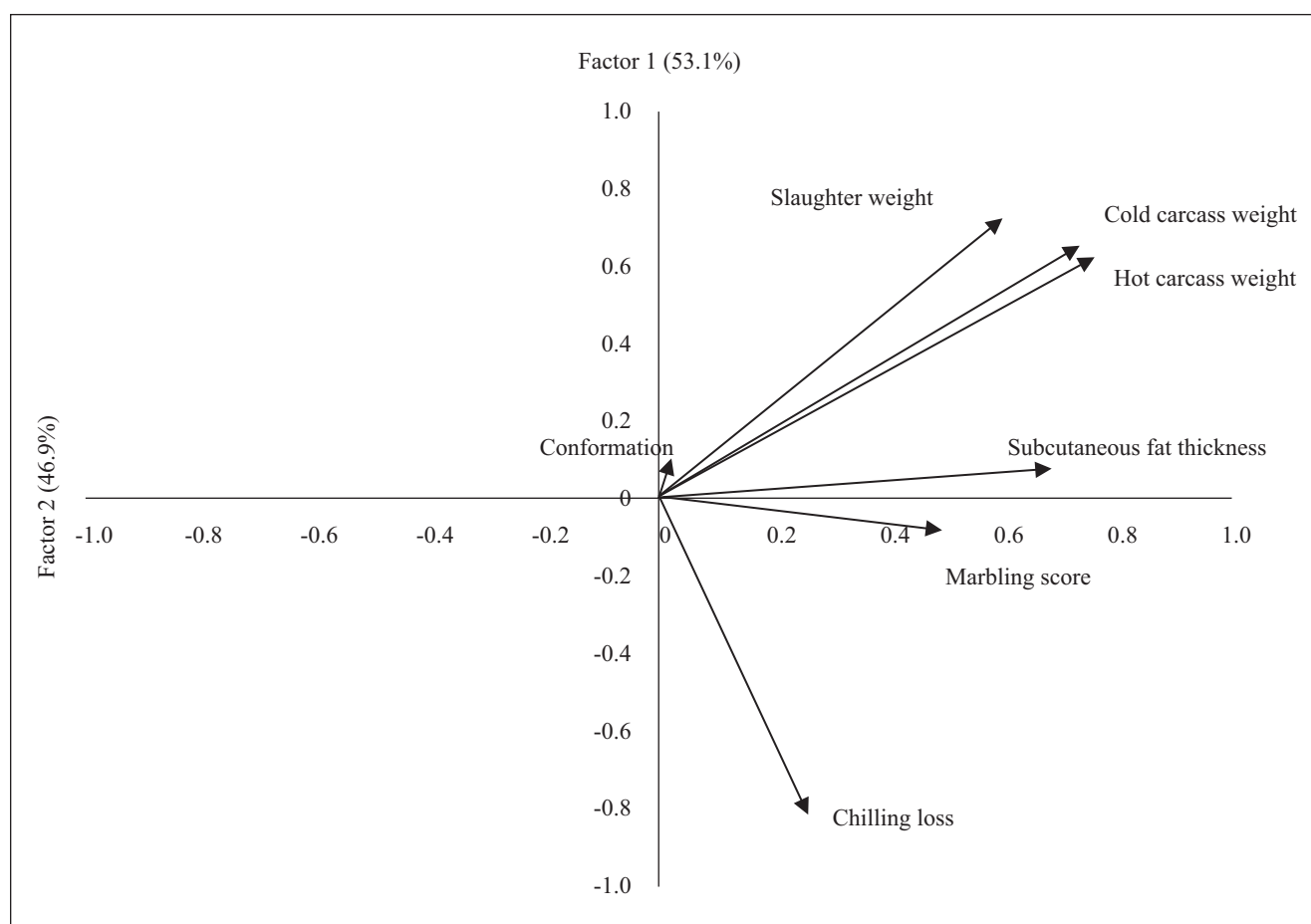


Figure 1. Principal component analysis based on the variance-covariance matrix of the dimension scores on beef cattle carcass chilling loss.

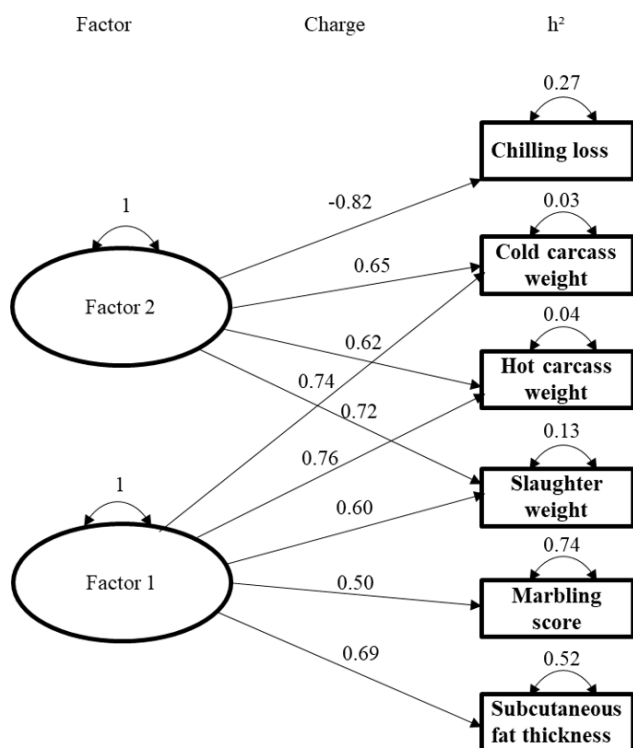


Figure 2. Path diagram, factor loading and commonality in physical factors. Commonality quality factors (h^2) after Varimax rotation.

weight increases by 20.3 kg, while in males it is 11.2 kg (Vaz et al., 2021).

Conformation and weight of animals showed an inverse relation with the reduction in carcass chilling, which may be associated with the deposition of tissues in the carcass, providing greater size and convexity of the muscles. Greater muscle expression in different areas of the carcass provides greater muscle thickness, causing dehydration during chilling of the internal tissues of the carcass. Higher chilling loss in less muscular and thicker carcasses during chilling is partly because in cold chambers temperature and wind speed are constant. Kuss et al. (2005) found a decrease in chilling breakage with increased slaughter weight due to greater conformation and cushion thickness. The carcass conformation can also be improved by the degree of fattening, as intermuscular fat can act by pressing the tissues, providing greater muscle volume (Missio et al., 2013), which demonstrates the positive association between subcutaneous fat thickness, slaughter and carcass weights with improved carcass conformation.

Santos Torres et al. (2023) highlighted that studies involving meta-analytic methods provide more

Table 3. Descriptive analyzes of the variables fat thickness and body weight of cattle classified into three classes according to the categories studied.

Characteristic	Rank ⁽¹⁾	Mean	SD ⁽²⁾	SEM	Maximum	Minimum	N
Subcutaneous fat thickness							
Cows	Low	2.72	1.279	0.522	4.00	1.11	6
	Medium	4.95	0.519	0.196	5.84	4.40	7
	High	10.73	4.714	1.782	17.70	5.86	7
Heifers	Low	4.16	0.508	0.293	4.59	3.60	3
	Medium	5.15	0.301	0.151	5.58	4.88	4
	High	7.74	3.550	1.775	13.05	5.76	4
Males	Low	2.50	0.697	0.113	3.50	0.88	38
	Medium	3.89	0.279	0.045	4.40	3.52	38
	High	5.57	1.346	0.218	12.09	4.46	38
Weight							
Cows	Low	446.920	26.988	11.018	476.00	401.00	6
	Medium	493.370	11.872	4.487	508.10	480.11	7
	High	548.080	21.615	8.170	580.86	522.00	7
Heifers	Low	329.320	23.480	13.559	355.57	310.30	3
	Medium	367.470	3.701	18.506	372.07	363.25	4
	High	416.030	48.952	24.476	482.09	374.71	4
Males	Low	369.934	21.951	3.561	398.00	324.80	38
	Medium	419.280	11.115	1.803	436.86	400.00	38
	High	471.620	27.510	4.463	578.40	437.00	38

⁽¹⁾ Rank classes for subcutaneous fat thickness and body weight of cattle, which was carried out using the rank procedure (SAS Institute Inc., 2018). ⁽²⁾SD, standard deviation; SEM, standard error of the mean; N, number of observations.

Table 4. Means and standard deviations for chilling breakdown of beef carcasses as a function of fat thickness and body weight of different animal categories.

Category	Classe ⁽¹⁾			p-value
	Low	Medium	High	
Subcutaneous fat thickness ranking				
Cow	2.21 + 0.426	2.49 + 0.394	2.50 + 0.602	0.8697
Heifer	1.92 + 0.564	2.03 + 0.564	1.78 + 0.488	0.9410
Male	2.31 + 0.149	2.24 + 0.146	2.13 + 0.149	0.4632
Slaughter weight				
Cow	2.19 + 0.419	2.38 + 0.388	2.81 + 0.592	0.7029
Heifer	2.29 + 1.043	2.22 + 0.536	1.24 + 0.536	0.3274
Male	2.29 + 1.044	2.24 + 0.147	2.15 + 0.163	0.7228

⁽¹⁾Ranking was carried out, using the rank procedure (SAS Institute Inc., 2018) of the variable fat thickness and slaughter weight.

accurate results due to the high number of repetitions and samples. Several studies on beef carcass quality have been carried out with different focuses, in different countries and in large research centers; however, none of them has addressed the losses and the main causes related specifically to chilling losses failure or through meta-analysis technique. The use of meta-analytical methods with the aim of compiling data from different studies and evaluating their results was an approach that allows evaluating a larger number of samples and more reliable values, indicating averages and causes related to chilling loss, as well as better values of this variation, such as the influence of the animal size.

Conclusions

1. The breakdown of bovine carcasses on chilling ranges from 0.47% to 4.93%, with an average of 2.24%.
2. Better conformations and greater fat thickness determine lower carcass chilling losses.
3. Higher body weights at slaughter and hot and cold carcasses provide smaller breaks in the carcass chilling, whereas moisture loss depends on animal size.
4. Meta-analytical methods allow evaluating a larger number of samples, which indicate better values for variations, such as the influence of the animal size.

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References

- ALENCAR, W.M.; RESTLE, J.; MISSIO, R.L.; NEIVA, J.N.M.; MIOTTO, F.R.C.; SANTANA, A.E.M.; AUGUSTO, W.F.; FREITAS, I.B.; ELEJALDE, D.A.G. Carcass and meat characteristics from dairy-origin steers fed with diets based on ground pearl millet grain, containing inclusion levels of babassu mesocarp meal. **Semina: Ciências Agrárias**, v.37, p.449-460, 2016. DOI: <https://doi.org/10.5433/1679-0359.2016v37n1p449>.
- ALMEIDA, C.P.B. de; GOULART, B.N.G. de. How to avoid bias in systematic reviews of observational studies. **Revista CEFAC**, v.19, p.551-555, 2017. DOI: <https://doi.org/10.1590/1982-021620171941117>.
- ARBOITTE, M.Z.; BRONDANI, I.L.; RESTLE, J.; FREITAS, L. da S.; PEREIRA, L.B.; CARDOSO, G. dos S. Carcass characteristics of small and medium-frame Aberdeen Angus young steers. **Acta Scientiarum. Animal Sciences**, v.34, p.49-56, 2012. DOI: <https://doi.org/10.4025/actascianimsci.v34i1.12463>.
- ARBOITTE, M.Z.; RESTLE, J.; ALVES FILHO, D.C.; PASCOAL, L.L.; PACHECO, P.S.; SOCCAL, D.C. Características da carcaça de novilhos 5/8 Nelore - 3/8 Charolês abatidos em diferentes estádios de desenvolvimento. **Revista Brasileira de Zootecnia**, v.33, p.969-977, 2004. DOI: <http://doi.org/10.1590/S1516-35982004000400017>.
- AUGUSTO, W.F.; BILEGO, U.O.; MISSIO, R.L.; GUIMARÃES, T.P.; MIOTTO, F.R.C.; REZENDE, P.L.P.; NEIVA, J.N.M.; RESTLE, J. Animal performance, carcass traits and meat quality of F1 Angus-Nellore steers and heifers slaughtered in feedlot with a similar carcass finishing. **Semina: Ciências Agrárias**, v.40, p.1681-1694, 2019. DOI: <https://doi.org/10.5433/1679-0359.2019v40n4p1681>.
- BACKHAUS, K.; ERICHSON, B.; GENSLER, S.; WEIBER, R.; WEIBER, T. Factor analysis. In: BACKHAUS, K.; ERICHSON, B.; GENSLER, S.; WEIBER, R.; WEIBER, T. **Multivariate analysis: an application-oriented introduction**. Wiesbaden: Springer Gabler, 2021. p.381-450. DOI: https://doi.org/10.1007/978-3-658-32589-3_7.
- BALDASSINI, W.A.; CHARDULO, L.A.L.; SILVA, J.A.V.; MALHEIROS, J.M.; DIAS, V.A.D.; ESPIGOLAN, R.; BALDI, F.S.; ALBUQUERQUE, L.G.; FERNANDES, T.T.; PADILHA, P.M. Meat quality traits of Nellore bulls according to different degrees of backfat thickness: a multivariate approach. **Animal Production Science**, v.57, p.363-370, 2017. DOI: <https://doi.org/10.1071/AN15120>.
- BARBUT, S. Review: automation and meat quality-global challenges. **Meat Science**, v.96, p.335-345, 2014. DOI: <https://doi.org/10.1016/j.meatsci.2013.07.002>.
- BLANCO, M.; RIPOLL, G.; DELAVALD, C.; CASASÚS, I. Performance, carcass and meat quality of young bulls, steers and heifers slaughtered at a common body weight. **Livestock**

- Science, v.240, art.104156, 2020. DOI: <https://doi.org/10.1016/j.livsci.2020.104156>.
- BOITO, B.; KUSS, F.; MENEZES, L.F.G. de; LIBINSKI, E.; PARIS, M. de; CULLMANN, J.R. Influence of subcutaneous fat thickness on the carcass characteristics and meat quality of beef cattle. *Ciência Rural*, v.48, e20170333, 2018. DOI: <https://doi.org/10.1590/0103-8478cr20170333>.
- BRONDANI, I.L.; RESTLE, J.; ARBOITTE, M.Z.; MENEZES, L.F.G.; ALVES FILHO, D.C.; AMARAL, G.A. do; PAZDIORA, R.D. Efeito de dietas que contêm cana-de-açúcar ou silagem de milho sobre as características das carcaças de novilhos confinados. *Ciência Rural*, v.36, p.197-202, 2006. DOI: <https://doi.org/10.1590/S0103-84782006.0000100030>.
- BRONDANI, I.L.; SAMPAIO, A.A.M.; RESTLE, J.; BERNARDES, R.A.L.C.; PACHECO, P.S.; FREITAS, A.K. de; KUSS, F.; PEIXOTO, L.A. de O. Aspectos quantitativos de carcaças de bovinos de diferentes raças, alimentados com diferentes níveis de energia. *Revista Brasileira de Zootecnia*, v.33, p.978-988, 2004. DOI: <https://doi.org/10.1590/S1516-35982004000400018>.
- COMPARIN, M.A.S.; MORAIS, M. da G.; ALVES, F.V.; COUTINHO, M.A. da S.; FERNANDES, H.J.; FEIJÓ, G.L.D.; OLIVEIRA, L.O.F. de; COELHO, R.G. Desempenho, características qualitativas da carcaça e da carne de novilhas Brangus suplementadas em pastagem recebendo diferentes aditivos nutricionais. *Revista Brasileira de Saúde e Produção Animal*, v.14, p.574-586, 2013. DOI: <https://doi.org/10.1590/S1519-99402013000300015>.
- DONICHT, P.A.M.M.; RESTLE, J.; FREITAS, L. da S.; CALLEGARO, A.M.; WEISE, M.S.; BRONDANI, I.L. Fat sources in diets for feedlot-finished steers - carcass and meat characteristics. *Ciência Animal Brasileira*, v.12, p.487-496, 2011. DOI: <https://doi.org/10.5216/cab.v12i3.14008>.
- DU, M.; TONG, J.; ZHAO, J.; UNDERWOOD, K.R.; ZHU, M.; FORD, S.P.; NATHANIELSZ, P.W. Fetal programming of skeletal muscle development in ruminant animals. *Journal Animal Science*, v.88, p.E51-E60, 2010. Suppl. DOI: <https://doi.org/10.2527/jas.2009-2311>.
- FEIJÓ, G.L.D.; EUCLIDES FILHO, K.; EUCLIDES, V.P.B.; FIGUEIREDO, G.R. Avaliação das carcaças de novilhos F1 Angus-Nelore em pastagens de *Brachiaria decumbens* submetidos a diferentes regimes alimentares. *Revista Brasileira de Zootecnia*, v.30, p.1015-1020, 2001. Supl.1. DOI: <https://doi.org/10.1590/S1516-35982001000400015>.
- FERREIRA, J.J.; BRONDANI, I.L.; LEITE, D.T.; RESTLE, J.; ALVES FILHO, D.C.; MISSIO, R.L.; HECK, I.; SEGABINAZZI, L.R. Características da carcaça de tourinhos Charolês e mestiços Charolês x Nelore terminados em confinamento. *Ciência Rural*, v.36, p.191-196, 2006. DOI: <https://doi.org/10.1590/S0103-84782006000100029>.
- FREITAS, A.K. de; RESTLE, J.; PACHECO, P.S.; PADUA, J.T.; LAGE, M.E.; MIYAGI, E.S.; SILVA, G.F.R. da. Características de carcaças de bovinos Nelore inteiros vs castrados em duas idades, terminados em confinamento. *Revista Brasileira de Zootecnia*, v.37, p.1055-1062, 2008. DOI: <https://doi.org/10.1590/S1516-35982008000600016>.
- GOMES, M. de N.B. (Org.). **Manual de avaliação de carcaças bovinas**. Campo Grande: Ed. da UFMS, 2021. 60p.
- GOOGLE SCHOLAR. 2021. Available at: <<https://scholar.google.com/>>. Accessed on: May 18 2025.
- HONIG, A.C.; INHUBER, V.; SPIEKERS, H.; WINDISCH, W.; GÖTZ, K.-U.; ETTLE, T. Influence of dietary energy concentration and body weight at slaughter on carcass tissue composition and beef cuts of modern type Fleckvieh (*German Simmental*) bulls. *Meat Science*, v.169, art.108209, 2020. DOI: <http://doi.org/10.1016/j.meatsci.2020.108209>.
- ÍTAVO, L.C.V.; DIAS, A.M.; ÍTAVO, C.C.B.F.; EUCLIDES FILHO, K.; MORAIS, M.G.; SILVA, F.F.; GOMES, R.C.; SILVA, J.P.B. Desempenho produtivo, características de carcaça e avaliação econômica de bovinos cruzados, castrados e não-castrados, terminados em pastagens de *Brachiaria decumbens*. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, v.60, p.1157-1165, 2008. DOI: <https://doi.org/10.1590/S0102-09352008000500018>.
- KUSS, F.; LÓPEZ, J.; BARCELLOS, J.O.J.; RESTLE, J.; MOLETTA, J.L.; PEROTTO, D. Características da carcaça de novilhos não-castrados ou castrados terminados em confinamento e abatidos aos 16 ou 26 meses de idade. *Revista Brasileira de Zootecnia*, v.38, p.515-522, 2009. DOI: <https://doi.org/10.1590/S1516-3598200900030017>.
- KUSS, F.; RESTLE, J.; BRONDANI, I.L.; PASCOAL, L.L.; MENEZES, L.F.G. de; PAZDIORA, R.D.; FREITAS, L. da S. Características da carcaça de vacas de descarte de diferentes grupos genéticos terminadas em confinamento com distintos pesos. *Revista Brasileira de Zootecnia*, v.34, p.915-925, 2005. DOI: <http://doi.org/10.1590/S1516-35982005000300025>.
- LEÃO, J.P.; NEIVA, J.N.M.; RESTLE, J.; MÍSSIO, R.M.; PAULINO, P.V.R.; MIOTTO, F.R.C.; SANTANA, A.E.M.; SOUSA, L.F.; ALEXANDRINO, E. Carcass and meat characteristics of different cattle categories fed diets containing crude glycerin. *Semina: Ciências Agrárias*, v.34, p.431-444, 2013. DOI: <https://doi.org/10.5433/1679-0359.2013v34n1p431>.
- MACIEL, R.P.; NEIVA, J.N.M.; RESTLE, J.; MIOTTO, F.R.C.; SOUSA, L.F.; CUNHA, O.F.R.; MORON, S.E.; PARENTE, R.R.P. Performance and carcass characteristics of dairy steers fed diets containing crude glycerin. *Revista Brasileira de Zootecnia*, v.45, p.677-685, 2016. DOI: <https://doi.org/10.1590/s1806-92902016001100006>.
- MCGOWAN, J.; SAMPSON, M.; SALZWEDEL, D.M.; COGO, E.; FOERSTER, V.; LAFEBVRE, C. PRESS Peer Review of Electronic Search Strategies: 2015 guideline statement. *Journal of Clinical Epidemiology*, v.75, p.40-46, 2016. DOI: <https://doi.org/10.1016/j.jclinepi.2016.01.021>.
- MENDES, G.A.; ROCHA JÚNIOR, V.R.; RUAS, J.R.M.; SILVA, F.V. e; CALDEIRA, L.A.; PEREIRA, M.E.G.; SOARES, F.D. dos S.; PIRES, D.A. de A. Características de carcaça e qualidade da carne de novilhas alimentadas com silagem de capimmarandu. *Pesquisa Agropecuária Brasileira*, v.47, p.1774-1781, 2012. DOI: <https://doi.org/10.1590/S0100-204X2012001200014>.

- MENEZES, L.F.G.; SEGABINAZZI, L.R.; BRONDANI, I.L.; RESTLE, J.; ARBOITTE, M.Z.; KUSS, F.; PACHECO, P.S.; ROSA, J.R.P. Silagem de milho e grão de sorgo como suplementos para vacas de descarte terminadas em pastagem cultivada de estação fria. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.61, p.182-189, 2009. DOI: <https://doi.org/10.1590/S0102-09352009000100026>.
- MENEZES, L.F.G. de; RESTLE, J.; BRONDANI, I.L.; ALVES FILHO, D.C.; KUSS, F.; SILVEIRA, M.F. da; AMARAL, G.A. do. Características da carcaça de novilhos de gerações avançadas do cruzamento alternado entre as raças Charolês e Nelore, terminados em confinamento. **Revista Brasileira de Zootecnia**, v.34, p.934-945, 2005. DOI: <https://doi.org/10.1590/S1516-35982005000300027>.
- MENEZES, L.F.G. de; RESTLE, J.; BRONDANI, I.L.; SILVEIRA, M.F. da; FREITAS, L. da S.; PIZZUTI, L.A.D. Características da carcaça e da carne de novilhos superjovens da raça Devon terminados em diferentes sistemas de alimentação. **Revista Brasileira de Zootecnia**, v.39, p.667-676, 2010. DOI: <https://doi.org/10.1590/S1516-35982010000300028>.
- MENEZES, L.F.G. de; SEGABINAZZI, L.R.; FREITAS, L. da S.; RESTLE, J.; BRONDANI, I.L.; CALLEGARO, A.M.; JONER, G.; ALVES FILHO, D.C. Aspectos qualitativos da carcaça e carne de novilhos superjovens da raça Devon, terminados em pastagem tropical, recebendo diferentes níveis de concentrado. **Semina: Ciências Agrárias**, v.35, p.1557-1568, 2014. DOI: <https://doi.org/10.5433/1679-0359.2014v35n3p1557>.
- METZ, P.A.M.; MENEZES, L.F.G. de; ARBOITTE, M.Z.; BRONDANI, I.L.; RESTLE, J.; CALLEGARO, A.M. Influência do peso ao início da terminação sobre as características de carcaça e da carne de novilhos mestiços Nelore × Charolês. **Revista Brasileira de Zootecnia**, v.38, p.346-353, 2009. DOI: <https://doi.org/10.1590/S1516-35982009000200018>.
- MIOTTO, F.R.C.; RESTLE, J.; NEIVA, J.N.M.; RESENDE, P.L. de P.; LAGE, M.E.; PRADO, C.S.; PADUA, J.T.; ARAÚJO, V.L. de. Farelo de mesocarpio de babaçu (*Orbygnia* sp.) na terminação de bovinos: composição física da carcaça e qualidade da carne. **Ciência Rural**, v.42, p.1271-1277, 2012. DOI: <https://doi.org/10.1590/S0103-84782012005000041>.
- MISSIO, R.L.; BRONDANI, I.L.; ALVES FILHO, D.C.; RESTLE, J.; ARBOITTE, M.Z.; SEGABINAZZI, L.R. Características da carcaça e da carne de tourinhos terminados em confinamento, recebendo diferentes níveis de concentrado na dieta. **Revista Brasileira de Zootecnia**, v.39, p.1610-1617, 2010. DOI: <https://doi.org/10.1590/S1516-35982010000700030>.
- MISSIO, R.L.; RESTLE, J.; MOLETTA, J.L.; KUSS, F.; NEIVA, J.N.M.; MOURA, I.C.F. Características da carcaça de vacas de descarte abatidas com diferentes pesos. **Revista Ciência Agronômica**, v.44, p.644-651, 2013. DOI: <https://doi.org/10.1590/S1806-66902013000300029>.
- MONTEIRO, P.A.M.; MACIEL, I.C.F.; ALVARENGA, R.C.; OLIVEIRA, A.L.; BARBOSA, F.A.; GUIMARÃES, S.T.; SOUZA, F.A.; LANNA, D.P.D.; RODRIGUES, B.M.; LOPES L.S. Carcass traits, fatty acid profile of beef, and beef quality of Nelore and Angus x Nelore crossbred young bulls finished in a feedlot. **Livestock Science**, v.256, art.104829, 2022. DOI: <https://doi.org/10.1016/j.livsci.2022.104829>.
- MOOMAK, P.; TUNTIVISOOTTIKUL, K. Effect of sex, age and final live mass on carcass traits of fattening dairy cattle. **International Journal of Agricultural Technology**, v.16, p.87-96, 2020.
- NUNES, C.L. de C.; PFLANZER, S.B.; REZENDE-DE-SOUZA, J.H.; CHIZZOTTI, M.L. Beef production and carcass evaluation in Brazil. **Animal Frontiers**, v.14, p.15-20, 2024. DOI: <https://doi.org/10.1093/af/vfad074>.
- PACHECO, P.S.; RESTLE, J.; MISSIO, R.L.; MENEZES, L.F.G.; ROSA, J.R.P.; KUSS, F.; ALVES FILHO, D.C.; NEIVA, J.N.M.; DONICHT, P.A.M.M. Características da carcaça e do corpo vazio de bovinos Charolês de diferentes categorias abatidos com similar grau de acabamento. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.65, p.281-288, 2013. DOI: <https://doi.org/10.1590/S0102-09352013000100040>.
- PACHECO, P.S.; SILVA, J.H.S. da; RESTLE, J.; ARBOITTE, M.Z.; BRONDANI, I.L.; ALVES FILHO, D.C.; FREITAS, A.K. de. Características quantitativas da carcaça de novilhos jovens e superjovens de diferentes grupos genéticos. **Revista Brasileira de Zootecnia**, v.34, p.1666-1677, 2005. DOI: <https://doi.org/10.1590/S1516-35982005000500029>.
- PACHECO, R.F.; MACHADO, D.S.; RESTLE, J.; SARTORI, D.B.S.; COSTA, P.T.; VAZ, R.Z. Meta-analysis of meat quality of cattle slaughtered with different subcutaneous fat thicknesses. **Pesquisa Agropecuária Brasileira**, v.58, e03110, 2023. DOI: <http://doi.org/10.1590/S1678-3921.pab2023.v58.03110>.
- PASCOAL, L.L.; VAZ, F.N.; VAZ, R.Z.; RESTLE, J.; PACHECO, P.S.; SANTOS, J.P.A. DOS. Relações comerciais entre produtor, indústria e varejo e as implicações na diferenciação e precificação de carne e produtos bovinos não-carcaça. **Revista Brasileira de Zootecnia**, v.40, p.82-92, 2011. Suppl.
- PEROBELLI, Z.V.; RESTLE, J.; MÜLLER, L. Estudo das carcaças de vacas de descarte das raças charolês e nelore. **Pesquisa Agropecuária Brasileira**, v.30, p.409-412, 1995.
- PETHICK, D.W.; HARPER, G.S.; ODDY, V.H. Growth, development and nutritional manipulation of marbling in cattle: a review. **Australian Journal of Experimental Agriculture**, v.44, p.705-715, 2004. DOI: <https://doi.org/10.1071/EA02165>.
- PFLANZER, S.B.; GOMES, C.L.; FELÍCIO, P.E. de. Delayed carcass chilling improves tenderness of the beef gluteus medius muscle. **Pesquisa Agropecuária Brasileira**, v.54, e00099, 2019. DOI: <https://doi.org/10.1590/S1678-3921.pab2019.v54.00099>.
- RESTLE, J.; KEPLIN, L.A.S.; VAZ, F.N.; Características quantitativas da carcaça de novilhos Charolês, abatidos com diferentes pesos. **Pesquisa Agropecuária Brasileira**, v.32, p.851-856, 1997.
- RESTLE, J.; VAZ, F.N. Aspectos quantitativos da carcaça de machos hereford, inteiros e castrados, abatidos aos quatorze meses. **Pesquisa Agropecuária Brasileira**, v.32, p.1091-1095, 1997.
- RESTLE, J.; VAZ, F.N.; BRONDANI, I.L.; GONÇALVES, J.M.; ANDREATTA, E. Estudo da carcaça de machos

- Braford desmamados aos 72 ou 210 dias, abatidos aos catorze meses. **Pesquisa Agropecuária Brasileira**, v.34, p.2137-2144, 1999. DOI: <https://doi.org/10.1590/S0100-204X1999001100021>.
- RESTLE, J.; VAZ, F.N.; FEIJÓ, G.L.D.; BRONDANI, I.L.; ALVES FILHO, D.C.; BERNARDES, R.A.C.; FATURI, C.; PACHECO, P.S. Características de carcaça de bovinos de corte inteiros ou castrados de diferentes composições raciais Charolês x Nelore. **Revista Brasileira de Zootecnia**, v.29, p.1371-1379, 2000. DOI: <https://doi.org/10.1590/S1516-35982000000500015>.
- REZENDE, P.L. de P.; RESTLE, J.; FERNANDES, J.J. de R.; FREITAS NETO, M.D. de; PRADO, C.S.; PEREIRA, M.R.L. Carcass and meat characteristics of crossbred steers submitted to different nutritional strategies at growing and finishing phases. **Ciência Rural**, v.42, p.875-881, 2012. DOI: <https://doi.org/10.1590/S0103-84782012000500019>.
- REZENDE, P.L. de P.; RESTLE, J.; FERNANDES, J.J. de R.; MISSIO, R.L.; BILEGO, U.O.; GUIMARÃES, T.P. Levels of substitution of corn by soybean hulls in high-concentrate diets for finishing beef heifers. **Semina: Ciências Agrárias**, v.41, p.2245-2258, 2020. Supl.1. DOI: <https://doi.org/10.5433/1679-0359.2020v41n5Supl1p2245>.
- REZENDE, P.L.P.; RESTLE, J.; BILEGO, U.O.; FERNANDES, J.J.R.; MISSIO, R.L.; GUIMARÃES, T.P. Carcass characteristics of feedlot-finished Nelore heifers slaughtered at different weights. **Acta Scientiarum. Animal Sciences**, v.41, e44826, 2019. DOI: <https://doi.org/10.4025/actascianims.v41i1.44826>.
- SANTOS TORRES, R. de N.; COELHO, L. de M.; GHEDINI, C.P.; MACHADO NETO, O.R.; CHARDULO, L.A.L.; TORRECILHAS, J.A.; VALENÇA, R. de L.; BALDASSINI, W.A.; ALMEIDA, M.T.C. Potential of nutritional strategies to reduce enteric methane emission in feedlot sheep: a meta-analysis and multivariate analysis. **Small Ruminant Research**, v.220, art.106919, 2023. DOI: <http://doi.org/10.1016/j.smallrumres.2023.106919>.
- SANTOS, A.P. dos; BRONDANI, I.L.; RESTLE, J.; MENEZES, L.F.G. de; OLIVEIRA, L. de; SILVEIRA, S.R.L. da. Características quantitativas da carcaça de novilhos jovens e superjovens com peso de abate similares. **Ciência Animal Brasileira**, v.9, p.300-308, 2008. DOI: <https://doi.org/10.5216/cab.v9i2.1191>.
- SAS INSTITUTE INC. **SAS/STAT 15.1 user's guide**: high-performance procedures. Cary, 2018.
- SCHUMACHER, M.; DELCURTO-WYFFELS, H.; THOMSON, J.; BOLES, J. Fat deposition and fat effects on meat quality - a review. **Animals**, v.12, art.1550, 2022. DOI: <https://doi.org/10.3390/ani12121550>.
- SCIELO. **Scientific Electronic Library Online**. 2021. Available at: <<https://scielo.org/>>. Accessed on: May 18 2025.
- SILVA, F.V. e; ROCHA JÚNIOR, V.R.; BARROS, R.C. de; PIRES, D.A. de A.; MENEZES, G.C. de C.; CALDEIRA, L.A. Ganho de peso e características de carcaça de bovinos Nelore castrados ou não-castrados terminados em confinamento. **Revista Brasileira de Zootecnia**, v.37, p.2199-2205, 2008. DOI: <https://doi.org/10.1590/S1516-35982008001200018>.
- SILVA, R.M. da; RESTLE, J.; MISSIO, R.L.; BILEGO, U.O.; PACHECO, P.S.; REZENDE, P.L. de P.; FERNANDES, J.J. de R.; SILVA, A.H.G. da; PÁDUA, J.T. Características de carcaça e carne de novilhos de diferentes predominâncias genéticas alimentados com dietas contendo níveis de substituição do grão de milho pelo grão de milheto. **Semina: Ciências Agrárias**, v.36, p.943-960, 2015. DOI: <https://doi.org/10.5433/1679-0359.2015v36n2p943>.
- VAZ, F.N.; MAYSONNAVE, G.S.; PASCOAL, L.L.; VAZ, R.Z.; SEVERO, M.M.; FABRÍCIO, E. de A. Analysis of added value in bovines sold for the angus meat program in the south of Brazil. **Brazilian Animal Science**, v.22, e57079, 2021. DOI: <https://doi.org/10.5216/1809-6891v22e-57079>.
- VAZ, F.N.; RESTLE, J. Características de carcaça e da carne de novilhos Hereford terminados em confinamento com diferentes fontes de volumoso. **Revista Brasileira de Zootecnia**, v.34, p.230-238, 2005. DOI: <https://doi.org/10.1590/S1516-35982005000100027>.
- VAZ, F.N.; RESTLE, J.; ARBOITE, M.Z.; PASCOAL, L.L.; ALVES FILHO, D.C.; PACHECO, R.F. Características de carcaça e da carne de novilhos e novilhas superjovens, terminados com suplementação em pastagem cultivada. **Ciência Animal Brasileira**, v.11, p.42-52, 2010. DOI: <https://doi.org/10.5216/cab.v11i1.5131>.
- VAZ, F.N.; RESTLE, J.; PACHECO, P.S.; FREITAS, A.K. de; PEIXOTO, L.A. de O.; CARRILHO, C. de O. Características de carcaça e da carne de novilhos superprecoces de três grupos genéticos, gerados por fêmeas de dois anos. **Revista Brasileira de Zootecnia**, v.31, p.1973-1982, 2002. DOI: <https://doi.org/10.1590/S1516-35982002000800013>.
- VAZ, F.N.; RESTLE, J.; PÁDUA, J.T.; FONSECA, C.A.; PACHECO, P.S. Características de carcaça e receita industrial com cortes primários da carcaça de machos Nelore abatidos com diferentes pesos. **Ciência Animal Brasileira**, v.14, p.199-207, 2013. DOI: <https://doi.org/10.5216/cab.v14i2.121123>.
- VAZ, F.N.; RESTLE, J.; PÁDUA, J.T.; MORALES, D.C.S.P.; PACHECO, P.S.; MAYSONNAVE, G.S. Características de carcaça e da carne de bovinos mestiços não-castrados ou submetidos a diferentes métodos de castração. **Ciência Animal Brasileira**, v.15, p.428-436, 2014. DOI: <https://doi.org/10.590/1089-6891v15i426218>.
- VAZ, R.Z.; LOBATO, J.F.P.; VAZ, F.N.; RESTLE, J.; PASCOAL, L.L. Características da carcaça de novilhos desmamados aos 91 ou 160 dias terminados em pastagem e abatidos aos dezesseis meses com diferentes pesos. **Ciência Animal Brasileira**, v.12, p.90-100, 2011. DOI: <https://doi.org/10.5216/cab.v12i1.10642>.
- VAZ, R.Z.; SILVA, H.R.; GHEDINI, C.P.; LUCAS, J.D.; DUTRA, M.M.M.; VAZ, F.N.; REIS, N.P.; RESTLE, J. Effects of animal type, handling, and transportation conditions on beef cattle temperament pre-slaughter. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.75, p.735-743, 2023. DOI: <https://doi.org/10.1590/1678-4162-12904>.