BIA
BOLETIM DE INDÚSTRIA ANIMAL

RUMINANT PRODUCTION

META-ANALYSIS OF CARCASS AND MEAT CHARACTERISTICS OF YOUNG OR SUPER YOUNG STEERS AND OF DIFFERENT SEXUAL CONDITIONS FINISHED IN CONFINEMENT

Sabrina Amalia Jappe,
Instituto Federal Farroupilha (IFFAR), Frederico Westphalen, RS, Brazil,
https://orcid.org/0000-0002-1568-1748
Email correspondente:
sabrina.2018005682@aluno.iffar.edu.br

Rudinei Klahn Muniz Júnior,
Instituto Federal Farroupilha (IFFAR), Frederico Westphalen, RS, Brazil,
https://orcid.org/0000-0003-4655-6074

Jullia Sehorek Teixeira,
Instituto Federal Farroupilha (IFFAR), Frederico Westphalen, RS, Brazil,
https://orcid.org/0000-0003-4897-7120

Rangel Fernandes Pacheco,
Instituto Federal Farroupilha (IFFAR), Frederico Westphalen, RS, Brazil,
https://orcid.org/0000-0002-4444-870X

Received: 08/06/2022
Approved: 13/12/2023

Abstract

The objective was to evaluate the carcass and meat characteristics of feedlot steers based on sexual condition and age at the beginning of the finishing phase, through a systematic review and meta-analysis. The selection of articles was carried out by two reviewers, who selected articles from the Google Scholar and Scielo platforms. The criteria for choosing articles followed the PICO tool. After searching for articles, they were subjected to analysis under the methodological conditions of the research. After this phase, 61 research articles carried out in Brazil remained, from which information was extracted from the material, methods and results. The data were compared according to the age of the steers: young (between 20 and 26 months of age) and super young (between 10 and 16 months of age); and depending on sexual condition: castrated or not castrated. Young steers have higher slaughter weights and higher hot and cold carcass weights. Meat from super young steers presented a higher score for tenderness when evaluated by the panel of evaluators. Uncastrated steers had higher slaughter weight, hot and cold carcass weight and rib eye area, while castrated steers demonstrated greater thickness of subcutaneous fat in the carcass and meat with higher marbling score. Slaughtering super young and castrated steers improves the quality aspects of the carcass and meat, however it reduces the amount of meat.

Keywords age, hot carcass, non-castrated, PICO tool, tenderness.

META-ANÁLISE DAS CARACTERÍSTICAS DA CARCAÇA E CARNE DE NOVILHOS JOVENS OU SUPER JOVENS E DE DIFERENTES CONDIÇÕES SEXUAIS TERMINADOS EM CONFINAMENTO

Resumo

Objetivou-se avaliar as características de carcaça e da carne de novilhos confinados em virtude da condição sexual e da idade ao início da fase de terminação, por meio de revisão sistemática e meta-análise. A seleção dos artigos foi realizada por dois revisores, que selecionaram artigos das plataformas Google Acadêmicos e Scielo. O critério de escolha dos artigos seguiu a ferramenta PICO. Após a busca dos artigos, eles foram submetidos a análises nas condições metodológicas das pesquisas. Após essa fase, restaram 61 artigos de pesquisas desenvolvidas no Brasil, as quais foram extraídas informações do material e métodos e resultados. Os dados foram comparados em função da idade dos novilhos: jovem (entre 20 a 26 meses de idade) e super jovem (entre 10 a 16 meses de idade); e em função da condição sexual: castrado ou não castrado. Novilhos jovens apresentam maior peso no abate, maior peso de carcaça quente e fria. A carne de novilhos super jovens apresentou maior pontuação para maciez quando avaliada pelo painel de avaliadores. Novilhos não castrados apresentaram maior peso de abate, peso de carcaça quente e fria e área de olho de lombo, enquanto que novilhos castrados demonstraram maior espessura de gordura subcutânea na carcaça e carne com maior nota de marmoreio. Abater novilhos com idade super jovem e castrados melhora os aspectos qualitativos da carcaça e da carne, no entanto reduz a quantidade de carne.

Palavras-chave carcaça quente, ferramenta PICO, idade, maciez, não-castrado.

INTRODUCTION

Brazil is an important player in the production and export of beef worldwide. It is estimated that in 2022, the country will remain the main exporter of beef, as a result of the resumption of exports to China (USDA, 2022). However, the production costs of feed in confinement still represent barriers to further intensification, putting pressure on these systems to seek greater biological efficiency for animals and greater added value to carcasses and meat.

An alternative widely used in countries where the use of exogenous anabolic hormones is prohibited is the finishing of uncastrated steers. Since the effect of testosterone promotes greater protein anabolism and consequently a positive body nitrogen balance (Moletta *et al*., 2014), improving feed efficiency (Silva *et al*., 2019) and generating heavier carcasses (Moreira *et al* ., 2018). However, when animals are from breeds with a lower capacity for fat deposition, such as those of zebu origin (Jacinto-Valderrama *et al*., 2019) or when compared to castrated animals (Blanco *et al*., 2020), there may be impairment carcass and meat quality. Carcasses of uncastrated steers tend to have less subcutaneous fat deposition (Jacinto-Valderrama *et al*., 2019), less marbling fat (Moran *et al*., 2017) and darker colored meat (Miguel *et al*., 2014) .

Reducing the slaughter age of steers is a strategy that allows improving the qualitative characteristics of the carcass (Blanco *et al*., 2020), reducing greenhouse gas (GHG) emissions and pollutants from finishing systems (McAuliffe *et al* . , 2018) and improve the sensory characteristics of meat from uncastrated animals (Silva *et al*., 2017). Although qualitative gains are observed in the system, with the reduction in the slaughter age of steers, other characteristics can be negatively affected, such as slaughter weight, hot carcass weight and carcass yield (Silva *et al*., 2017; Silva *et al*., 2019).

There is a reasonable volume of research carried out in Brazil that evaluated the effects of the sexual condition of steers during the finishing phase and the age of slaughter, on the performance and characteristics of the carcass and meat. Much of the research presents conflicting results, due to high variability in production factors, experimental bias or low analytical power. In these cases, one can evaluate them through a meta-analysis using rigorous statistical procedures, with greater analytical

power, to analyze a combined data set obtained from several research studies (Zwetsloot *et al*., 2017; Pacheco *et al* . , 2021). The use of meta-analytic procedures based on systematic review and meta-analysis to study the impact of technologies and characteristics of production systems on aspects related to performance, carcass and meat of beef cattle has been reported in the literature (Lean *et al* ., 2014; Pacheco *et al*. 2015; Machado *et al*. 2018).

Thus, the objective was to evaluate the carcass and meat characteristics of confined steers due to sexual condition and age at the beginning of the finishing phase, through a systematic review and meta-analysis.

MATERIAL AND METHODS

Between June and December 2019, two independent reviewers selected articles related to the carcass and meat of steers finished in confinement through an electronic search in the Scielo and Google Scholar databases. The criteria for choosing the question used in the search for articles was broken down following the PICO tool (Young, 2002), which represents an acronym for Patient, Intervention, Comparison and *"Outcomes"* (outcome). On the Google Scholars electronic platform, criteria were established to search for pages in Portuguese, without year restrictions. On the Scielo electronic platform there were no language or year restrictions. Table 1 presents the four components of the PICO strategy and the construction of the keywords used in this research.

Table 1 Description of the PICO strategy and elaboration of keywords

Acronym	Definition	Search protocol	Search strategy
P	Patient or problem	Beef cattle	Beef cattle
I	Intervention	Different sexual conditions and different categories	Steers OR cattle OR steers young
W	Control or comparison	That they were finished in confinement	Confined steers OR finished in confinement
O	Outcome (*"Outcomes"*)	Quantitative and qualitative characteristics of the carcass and meat	Carcass weight OR carcass yield OR tenderness of the meat OR muscle yield

At the end of the search process, 380 articles were found, 193 obtained from the Google Scholars platform and 187 obtained from the Scielo platform. In the next step, the titles of the articles were read and duplicate articles were eliminated, each article had its summary copied to Google Forms electronic forms for blind evaluation.

10 electronic forms were created and saved in a virtual Google Drive folder. In the evaluation stage, 10 evaluators were chosen and instructed to access the Google Drive electronic address that contained the 10 electronic forms, one specific for each reviewer according to the order in which the electronic address was accessed. Each abstract appeared in 2 different forms and the evaluators had to classify the articles between "suitable" and "not suitable" to enter the database. "Suitable" articles would have to: (1) come from primary research (fieldwork); (2) have addressed the carcass and meat characteristics of confined steers; (3) should have been developed in Brazil. If one of the aforementioned criteria was not met, the abstract would be classified as "not suitable" and the article would not enter the database.

After this screening, 61 articles remained that were evaluated in full to build the database. The database was created in an Excel spreadsheet, in which each article treatment was considered a sampling unit (one line) in the database. For each sampling unit, information on the material and methods and results and discussion of the respective treatment were collected. To create the database related to meat characteristics, the selected articles should follow the methodology described by Metz *et al*. (2009).

Table 2 Degree of heterogeneity of variables depending on age and sexual condition of confined steers

	Articles	Average	Standard deviation	Minimum	Maximum
Termination period, days	45	117.2	31.4	35	194
Initial body weight, kg	51	308.1	68.9	163.3	519.0
Slaughter body weight, kg	49	450.8	51.7	325.6	570.0
Hot carcass, kg	36	250.9	28.8	171.8	322.3
Hot carcass yield, %	34	57.9	2.2	48.9	59.3
Rib eye area, cm²	34	66.7	7.5	46.7	83.6
Subcutaneous fat thickness, mm	53	4.6	1.7	0.62	9.58
Muscle, %	32	63.2	3.5	53.0	71.6
Bone, %	32	15.8	1.6	13.4	20.0
Fat, %	32	21.3	3.4	13.2	28.3
Marbling, dots	38	5.47	1.9	1.60	10.35
Texture, dots	36	4.01	0.7	2.90	7.48
Coloring, dots	33	3.88	0.6	2.67	5.00
Juiciness, points	28	6.16	0.7	4.07	7.50
Softness, spots	28	6.57	0.8	4.50	8.25
Shear force, kgf/cm²	44	4.97	1.8	1.92	10.02

The data was grouped according to the age of the steers at the beginning of the finishing phase, with those between 11 and 16 months of age classified as super young and steers between 20 and 26 months of age as young. They were also identified based on their sexual condition, being classified as castrated and non-castrated. Table 2 shows the number of articles used for each variable generated, the means, standard deviation, minimum and maximum values of the studied characteristics of the articles developed in Brazil and which evaluated the characteristics of the carcass and meat of confined steers.

Statistical analysis was performed using the general linear model (GLM) procedure of SAS 9.2. The consistency of results between experiments was quantified using the Chi -square test (Q) heterogeneity measures and I2 statistic (Higgins *et al*., 2003), which quantifies the impact of heterogeneity in the meta-analysis, with an independent criterion the number of studies and the metric effect of each treatment. Although the Q test is useful in identifying heterogeneity, the I2 measure was used to measure heterogeneity (Lean *et al*., 2009). The I2 statistic is given by:

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

Where: Q is the heterogeneity statistic $\chi 2$ and k is the number of trials. The I2 statistic describes the percentage of variation between studies due to heterogeneity. Negative values of I2 are equal to zero; consequently, I2 is between 0 and 100% (Lean *et al*., 2009). Heterogeneity may be unimportant in the range of 0–40%, moderate in the range of 30–60%, substantial in the range of 50–90%, and considerable in the range of 75–100% (Higgins *et al*., 2003). To identify articles that caused greater heteroscedasticity in the data, the r- student statistic was used as a criterion for excluding articles that had an excess of observations with values above 2 and below -2.

The data were tested for normality using the Kolmogorov-Smirnov test and for homogeneity of variances using the Levene's and Brow-Forsythe tests. Subsequently, the data were subjected to analysis of variance using the F test. The variables finishing period, slaughter body weight, cold carcass weight, muscle weight, bone weight, texture, shear force, color, did not meet the assumptions of normality and homogeneity of residues and were subjected to the Kruskal -Wallis Test.

The mathematical model used for the variance analysis is described below:

$$Y_{ijkl} = \mu + Art_i + GG_j + Sex_k + Category_l + eijkl$$

Considering : Yijk , the dependent variables; μ, the average of all observations; Art_i, effect of the article; GG_j, effect of genetic group; Sex_k, effect of sexual condition; $Category_l$, category effect; and $_{ijkl}$, random error associated with each observation, NID (0, σ2).

RESULTS

When comparing performance and quantitative carcass characteristics of feedlot steers depending on age at finishing (Table 3), the finishing period for super young steers was longer than for young steers (139.7 kg *vs* 103.9 kg). The initial body weight (273.6 kg *vs* 345.1 kg) and slaughter body weight (427.5 kg *vs* 469.3 kg) were lower in the super young compared to the young. The difference in body weight extended to the weight of hot carcass (231.9 kg *vs* 266.1 kg) and cold carcass (222.9 kg *vs* 251.5 kg), which were also lower for the super young compared to young. Carcass yields, both hot and cold, were similar between slaughter ages (P=0.8467 and P=0.0838; respectively).

Table 3 Performance and quantitative carcass characteristics of feedlot steers as a function of age at finishing

Variable	Category		*P value*
	Super young	Young	
Termination period, days*	139.7 ± 5.00	103.9 ± 3.93	<0.0001
Initial body weight, kg	273.6 ± 9.11	345.1 ± 8.4	<0.0001
Slaughter body weight, kg*	427.5 ± 7.00	469.3 ± 6.11	<0.0001
Hot carcass weight, kg	231.9 ± 3.91	266.1 ± 3.74	<0.0001
Cold carcass weight, kg*	222.9 ± 4.07	251.5 ± 3.48	<0.0001
Hot carcass yield, %	54.5 ± 0.43	54.4 ± 0.44	0.8467
Cold carcass yield, %	53.0 ± 0.74	54.4 ± 0.51	0.0838

* Rated by Kruskal -Wallis test

When comparing the performance of the steers and the quantitative characteristics of the carcass, depending on sexual condition (Table 4), the finishing period was similar (P=0.2072), as was the initial body weight (P=0.2959) . However, body weight at slaughter was higher for non-castrated steers compared to castrated steers (468.2 kg *vs* 428.6 kg). Difference that extends in favor of the non-castrated for

the weight of hot carcass (262.2 kg *vs* 235.8 kg) and cold carcass (246.4 kg *vs* 228.1 kg). Hot carcass yield was not altered by sexual condition (P=0.3022). While the cold carcass yield was higher for non-castrated steers (54.7%) compared to castrated ones (52.8%).

Table 4 Performance and quantitative characteristics of the carcass of confined steers as a function of sexual condition

Variable	Sexual condition		*P value*
	Castrated	Not castrated	
Termination period, days*	117.9 ± 4.39	125.7 ± 4.73	0.2072
Initial body weight, kg	303.4 ± 8.57	315.3 ± 9.15	0.2959
Slaughter body weight, kg*	428.6 ± 6.17	468.2 ± 7.22	<0.0001
Hot carcass weight, kg	235.8 ± 3.83	262.2 ± 3.97	<0.0001
Cold carcass weight, kg*	228.1 ± 3.38	246.4 ± 4.45	0.0021
Hot carcass yield, %	54.1 ± 0.44	54.7 ± 0.46	0.3022
Cold carcass yield, %	52.8 ± 0.61	54.7 ± 0.71	0.0418

* Rated by Kruskal -Wallis test

In the evaluation of the qualitative characteristics and physical composition of the carcass of confined steers depending on the age of the steers (Table 5), the rib eye area (P=0.2995); the thickness of subcutaneous fat (P=0.1952) and the percentage of muscle (P=0.2727), bone (P=0.9501) and fat (P=0.6649) in the carcass were similar among steers super young and young.

Table 5 Qualitative characteristics and physical composition of the carcass of feedlot steers as a function of age at finishing

Variable	Category		*P value*
	Super young	Young	
Rib eye area, cm²	67.2 ± 1.44	68.8 ± 1.09	0.2995
Subcutaneous fat thickness, mm	4.44 ± 0.29	3.99 ± 0.25	0.1952
Muscle, %*	63.53 ± 0.71	65.19 ± 0.90	0.2727
Bone, %*	15.86 ± 0.32	15.88 ± 0.34	0.9501
Fat, %	19.58 ± 0.87	19.97 ± 0.94	0.6649

* Rated by Kruskal -Wallis test

For the qualitative characteristics and physical composition of the carcass according to sexual condition (Table 6), non-castrated cattle demonstrated a greater rib eye area (70.8 cm² *vs* 65.17 cm²), while castrated cattle showed a greater thickness of subcutaneous fat (4.59 mm *vs* 3.84 mm). The percentage of muscle (P=0.3894), bone (P=0.5384) and fat (P=0.2730) were similar between castrated and non-castrated steers.

When evaluating meat quality according to age (Table 7), only tenderness was

Table 6 Qualitative characteristics and physical composition of the carcass of confined steers depending on sexual condition

Variable	Sexual condition		
	Castrated	Not castrated	*P value*
Rib eye area, cm²	65.17 ± 1.09	70.8 ± 1.49	0.0008
Subcutaneous fat thickness, mm	4.59 ± 0.25	3.84 ± 0.31	0.0412
Muscle, %*	64.26 ± 0.79	65.33 ± 1.07	0.3894
Bone, %*	15.77 ± 0.28	15.98 ± 0.38	0.5384
Fat, %	20.29 ± 0.77	19.25 ± 1.04	0.2730

* Rated by Kruskal -Wallis test

affected by treatments. Super young steers have meat with a higher tenderness score, compared to meat from young steers (6.91 points *vs* 6.18 points). Marbling (P=0.1405), texture (P=0.5420), color (P=0.3968), juiciness (P=0.5382) and shear strength (P=0.3844) were similar between the super young and young categories.

Table 7 Meat quality of feedlot steers depending on age at finishing

Variable	Category		
	Super young	Young	*P value*
Marbling, dots	4.58 ± 0.34	3.89 ± 0.39	0.1405
Texture, dots*	4.43 ± 0.13	4.43 ± 0.13	0.5420
Coloring, dots*	3.76 ± 0.15	3.90 ± 0.12	0.3968
Juiciness, points	6.17 ± 0.17	6.01 ± 0.20	0.5382
Softness, spots	6.91 ± 0.21	6.18 ± 0.26	0.0064
Shear force, kgf/cm²*	4.24 ± 0.30	4.58 ± 0.27	0.3844

* Rated by Kruskal -Wallis test

When the evaluation of meat quality was based on sexual condition (Table 8), castrated steers demonstrated meat with more marbling (5.15 *vs* 3.33 points). The other characteristics associated with meat, such as texture (P=0.7761), color (P=0.0672), juiciness (P=0.2476), tenderness (P=0.5139) and strength shear stress (P=0.0805) were similar between castrated and non-castrated steers.

Table 8 Meat quality of confined steers according to sexual condition

Variable	Sexual condition		*P value*
	Castrated	Not castrated	
Marbling, dots	5.15 ± 0.29	3.33 ± 0.43	0.0001
Texture, dots*	4.51 ± 0.11	4.46 ± 0.14	0.7761
Coloring, dots*	3.98 ± 0.10	3.67 ± 0.16	0.0672
Juiciness, points	6.24 ± 0.15	5.94 ± 0.23	0.2476
Softness, spots	6.46 ± 0.18	6.64 ± 0.29	0.5139
Shear force, kgf/cm²*	4.77 ± 0.24	4.05 ± 0.34	0.0805

* Rated by Kruskal -Wallis test

DISCUSSION

Reducing the slaughter age of steers is a widely used strategy to increase the productivity of livestock systems (Soares, 2004; Rubiano *et al*., 2009), as well as maintaining non-castrated steers to take advantage of the biological efficiency of the category (Moletta *et al*., 2014) . However, as observed in this meta-analysis, reducing the slaughter age of steers results in longer confinement time, lower body weight and carcass weight (hot and cold) when compared to young steers. The difference in confinement time between ages can be explained by the low performance of the steers in rearing, causing these animals to arrive at the confinement with low weight at a very young age. Associated with this, there are requirements from Brazilian slaughterhouses for a carcass weighing at least 13 arrobas(@) and a minimum subcutaneous fat thickness of 3 mm, to qualify for carcass bonus programs, which increases the challenge of the category.

The similarity between body weight at the beginning of confinement between castrated and non-castrated steers can be explained by the experimental design of Brazilian research that seeks to equalize the weight of steers at the beginning of the confinement phase. When body weight is evaluated at the time of slaughter, superiority is observed for non-castrated steers, demonstrating the greater efficiency of weight gain in this category. The greater biological efficiency of non-castrated animals and the consequence of greater body weight at slaughter, greater carcass weight and greater rib eye area is due to the action of androgenic hormones, mainly testosterone, which is a factor that promotes changes in growth. animal (Moletta *et al*., 2014) and carcass characteristics (Silva *et al*., 2019).

The proximity of the subcutaneous fat thickness values of super young steers in relation to young ones is due to finishing protocols that seek to meet the minimum requirements of slaughterhouses for this variable (3 mm), as discussed previously. For it to be attended to in super young animals, a longer period of confinement was necessary. In the comparison depending on sexual condition, castration promoted greater fat deposition. This was expected and reflects a barrier to finishing systems that aim to slaughter uncastrated steers. Because the fat covering the carcasses is a determining factor for the protection and quality of the meat, which requires a minimum degree to guarantee a correct transformation of the muscle into meat during the maturation process (Baldassini *et al*., 2016) . The degree of finishing of the

carcasses, in addition to being affected by sexual condition (Venkata Reddy *et al*., 2015) and the age of the animal (Bures & Barton, 2012), it is also affected by breed (He *et al*., 2020), period and finishing weight (Asimwe *et al*., 2015), dietary energy level (Nassu *et al*., 2017) and fetal programming (Mohrhauser *et al*., 2015). Although the thickness of subcutaneous fat in uncastrated steers was lower than that of castrated ones, it met the minimum requirement of 3 mm.

Reducing the age at finishing promoted an improvement in meat tenderness, due to the fact that finishing super young animals in confinement requires high energy density diets, impacting the quality of the meat due to rapid muscle growth that promotes the formation of collagen with greater solubility. (Menezes *et al*., 2015) improving the tenderness of the meat. In the comparison between castrated and non-castrated, there was no difference in the tenderness of the meat. In the study by Kuss *et al.* (2010), the authors found that the meat of young non-castrated animals was less soft, palatable and juicy compared to the meat of young castrated animals. However, when the authors compared meat from super young steers, the values of tenderness, palatability and juiciness were similar between castrated and non-castrated animals, demonstrating that by reducing the slaughter age, meat from non-castrated animals can demonstrate significant improvements. in quality, which is similar to meat from castrated super young bulls.

The greater degree of marbling in the meat of castrated steers is associated with greater deposition of subcutaneous fat. Marbling fat is recognized as being a genetic factor (Philippe *et al*., 2020) and dependent on the energy level of the diet and the degree of carcass finishing. Another determining factor for marbling in beef is the nutritional level during the individual's pregnancy, as adipogenesis occurs in the middle third of pregnancy , responsible for the manifestation of marbling fat in beef (Júnior *et al*., 2015).

CONCLUSION

Slaughtering super young steers should be viewed sparingly. The improvement in the tenderness of meat in this category must be accompanied by compensation to producers due to losses in production, such as longer confinement time.

Finishing uncastrated steers promotes greater biological efficiency of the

system and greater meat production. However, the losses caused by less fat deposition, seen in the thickness of subcutaneous fat and marbling, could compromise markets that pay for the quality aspect.

REFERENCES

ASIMWE, L.; KIMAMBO, A.E.; LASWAI, G.H.; MTENGA, L.A.; WEISBJERG, M.R.; MADSEN, J. Effect of days in feedlot on growth performance, carcass and meat quality attributes of Tanzania shorthorn zebu steers. **Tropical animal health and production**, v.47, n.5, p.867-876, 2015. https://doi.org/10.1007/s11250-015-0801-z

BALDASSINI, W.A.; CHARDULO, L.A.L.; SILVA, J.A.V.; MALHEIROS, J.M.; DAYS, V.A.D.; ESPIGOLAN, R.; PADILHA, P.M. Meat quality traits of Nellore bulls according to different degrees of backfat thickness: a multivariate approach. **Animal Production Science**, v.57, n.2, p.363-370, 2016. https://doi.org/10.1071/AN15120

BLANCO, M.; RIPOLL, G.; DELAVAUD, C.; CASASÚS, L. Performance, carcass and meat quality of young bulls, steers and heifers slaughtered at a common body weight. **Livestock Science**, v.240, 2020. https://doi.org/10.1016/j.livsci.2020.104156

BUREŠ, D.; BARTOŇ, L. Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages. **Czech Journal of Animal Science**, v.57, p.34-43, 2012. https://doi.org/10.17221/5482-CJAS

HE, M.L.; STANFORD, K.; DUGAN, M.E.; MARQUESS, L.; MCALLISTER, T.A. Association of leptin genotype with growth performance, adipocyte cellularity, meat quality, and fatty acid profile in beef steers fed flaxseed or high-oleate sunflower seed diets with or without triticale dried distiller's grains. **Journal of animal science**, v.98, 2020. https://doi.org/10.1093/jas/skaa104

HIGGINS, J.P.T.; THOMPSON, S.G.; DEEKS, J.J.; ALTMAN, D.G. Measuring inconsistency in meta-analyses. **TheBMJ,** v.327, p.557-560, 2003. https://doi.org/10.1136/bmj.327.7414.557

JACINTO-VALDERRAMA, R.A.; SAMPAIO, G.S.L.; LIMA, M.L.P.; CYRILLO, J.N.S.; PFLANZER, S.B. Immunocastration on performance and meat quality of Bos indicus (Nellore) cattle under different nutritional systems. **Scientia Agricola**, v.78, n.2, 2021. https://doi.org/10.1590/1678-992x-2019-0136

JÚNIOR, M. F. D.; ZERVOUDAKIS, L. K. H.; ZERVOUDAKIS, J. T.; TSUNEDA, P. P.; SILVA, J. A.; SILVA, R. P.; ALMEIDA, R. D. Supplementation of grazing bovine females: nutritional and reproductive aspects. **Veterinary Medicine and Animal Science**, PUBVET, v.9, n.7, p. 321-336, 2015. https://doi.org/10.22256/pubvet.v9n7.321-336

KUSS, I.; LÓPEZ, J.; RESTLE, J.; BARCELLOS, J.O.J.; MOLETTA, J.L.; MILK, M.C.P. Meat quality from steers finished in confinement and slaughtered at 16 or 26 months of age. **Brazilian Journal of Animal Science**, Viçosa, v.39, n.4, p.924-931, 2010. https://doi.org/10.1590/S1516-35982010000400029

LEAN, I.; RABIEE, A.; DUFFIELD, T.; DOHOO, I. Invited review: Use of meta-

analysis in animal health and reproduction: Methods and applications. **Journal of Dairy Science,** v.92, p.3545-3565, 2009. https://doi.org/10.3168/jds.2009-2140

LEAN, I.J.; THOMPSON, J.M.; DUNSHEA, F.R. A meta-analysis of zilpaterol and ractopamine effects on feedlot performance, carcass traits and shear strength of meat in cattle. **Plos One 9**, 2014. https://doi.org/10.1371/journal.pone.0115904

MACHADO, D.S.; JONER, G.; PEREIRA, L.B.; P¨OTTER, L.; BRONDANI, I.L.; ALVES FILHO, D.C. Meta-analysis of the immunocastration technique (anti-GnRH) for male bovines in the finishing phase. Pesquisa Agropecuária Brasileira. v. 53, p.961-969, 2018. https://doi.org/10.1590/s0100-204x2018000800011

McAULIFFE, G.A.; TAKAHASHI, T.; ORR, R.J.; HARRIS, P.; LEE, M.R.F. Distributions of emissions intensity for individual beef cattle reared on pasture-based production systems. **Journal of Cleaner Production**, v. 171, p. 1672-1680, 2018. https://doi.org/10.1016/j.jclepro.2017.10.113

MENEZES, B.B.; BENAGLIA, B.B.; LIMA, F.C.S. **Relationship between body composition and age of cattle and sheep** . FAMEZ - UFMS, [sl], 2015.

METZ, P.A.M.; MENEZES, L.F.G.; ARBOITTE, M.Z.; BRONDANI, I.L.; RESTLE, J.; CALLEGARO, A.M. Influence of weight at the beginning of finishing on carcass and meat characteristics of Nellore × Charolais crossbred steers. **Revista Brasileira de Zootecnia**, v.38, n.2, p.346-353, 2009. https://doi.org/10.1590/S1516-35982009000200018

MIGUEL, G.Z.; FARIA, M.H.; TOUCH T.H.E.; SANTOS, C.T.; SUMAN, S.P.; FAITARONE, A.B.G.; DELBEM, N.L.C.; GIRAO, L.V.C.; MAN, J.M.; BARBOSA, E.K.; SU, L.S.; RESENDE, F.D.; SIQUEIRA, G.R.; MOREIRA, A.D.; SAVIAN, T.V. Immunocastration improves carcass traits and beef color attributes in Nellore and Nellore×Aberdeen Angus crossbred animals finished in feedlot. **Meat Science**, v.96, p.884-891, 2014. https://doi.org/10.1016/j.meatsci.2013.08.030

MOHRHAUSER, D.A.; TAYLOR, A.R.; UNDERWOOD, K.R.; PRITCHARD, R.H.; WERTZ-LUTZ, A.E.; BLAIR, A.D. The influence of maternal energy status during midgestation on beef offspring carcass characteristics and meat quality. **Journal of animal science**, v.93, p.786-793, 2015. https://doi.org/10.2527/jas.2014-8567

MOLETTA, J.L.; MEADOW, I.N.; FUGITA, C.A.; EIRAS, C.E.; CARVALHO, C.B.; PEROTTO, D. Carcass and meat characteristics of non-castrated or castrated cattle finished in confinement and fed with three levels of concentrate. **Semina: Ciências Agrárias**, v.35, p.1035-1050, 2014. https://doi.org/10.5433/1679-0359.2014v35n2p1035

MOLETTA, J.L.; TORRECILHAS, J.A.; ORNAGHI, M.G.; PASSETTI, R.A.C.; EIRAS, C.E.; PRADO, I.N.D. Feedlot performance of bulls and steers fed at three levels of concentrate in the diets. **Minutes Scientiarum**, v.36, p.323-328, 2014. https://doi.org/10.4025/actascianimsci.v36i3.23736

MORAN, L.; O'SULLIVAN, M.G.; KERRY, J.P.; PICARD, B.; MCGEE, M.; O'RIORDAN, E.G.; MOLONEY, A.P. Effect of a grazing period prior to finishing on a high concentrate diet on meat quality from bulls and steers. **Meat Science**, v.125. p. 76-83, 2017. https://doi.org/10.1016/j.meatsci.2016.11.021

MOREIRA, A.D.; SIQUEIRA, G.R.; LAGE, J.F.; BENATTI, J.M.B.; MORETTI, M.H.; MIGUEL, G.Z.; OLIVEIRA, I.M.; RESENDE, F.D. Castration methods in crossbred cattle raised on tropical pasture. **Animal Production Science**, v.58, p. 1307, 2018. https://doi.org/10.1071/AN16580

NASSU, R.T.; TULLIO, R.R.; BERNDT, A.; FRANCISCO, V.C.; DIESEL, T.A.; ALENCAR, M.M. Effect of the genetic group, production system and sex on the meat quality and sensory traits of beef from crossbred animals. **Tropical animal health and production**, v.49, p.1289-1294, 2017. https://doi.org/10.1007/s11250-017-1327-3

PACHECO, R.F.; MAYER, A.R.; VAZ, M.A.B.; PETTER, L.; CATTELAM, J.; CALLEGARO, A.M.; PIZZUTI, L.A.; BRONDANI, I.L.; ALVES FILHO, D.C.; PACHECO, P.S. Qualitative characteristics of meat from cull cows of different genotypes and age class slaughter under different finishing systems: a meta-analytic approach. **Annals of the Brazilian Academy of Sciences**, Rio de Janeiro, v. 87, n. 2, p. 1083-1093, 2015. https://doi.org/10.1590/0001-3765201520140353

PACHECO, R.F.; MACHADO, D.S.; VIANA, A.F.P.; TEIXEIRA, J.S.; MILANI, D. Comparison of the effects of slow-release urea vs conventional urea supplementation on some finishing cattle parameters: A meta-analysis. **Livestock Science**, v. 250, p. 104549, 2021. https://doi.org/10.1016/j.livsci.2021.104549

PHILIPPE, M.G.; CLEMENTINO, F.M.M.; GADOTTI, G.A.; PUEL, A.C.; MARTINS, C.E.N.; MOREIRA, F.; PERIPOLLI, V. Carcass and meat characteristics of certified beef cattle. **Brazilian Journal of Development**, v.6, p.52942-52951, 2020. https://doi.org/10.34117/bjdv6n7-805

SILVA, L.H.P.; ASSIS, D.E.F.; ESTRADA, M.M.; ASSIS, G.J.F.; ZAMUDIO, G.D.R.; CARNEIRO, G.B.; VALADARES FILHO, S.C.; PAULINO, M.F.; CHIZZOTTI, M.L. Carcass and meat quality traits of Nellore young bulls and steers throughout fattening. **Livestock Science**, v.229, p.28-36, 2019. https://doi.org/10.1016/j.livsci.2019.09.012

SILVA, L.H.P.; PAULINO, P.V.R.; ASSIS, G.J.F.; ASSIS, D.E.F.; ROAD, M.M.; SILVA, M.C.; SILVA, J.C.; MARTINS, T.S.; VALADARES FILHO, S.C.; PAULINO, M.F.; CHIZZOTTI, M.L. Effect of post-weaning growth rate on carcass traits and meat quality of Nellore cattle. **Meat Science**, v.123, p. 192-197, 2017. https://doi.org/10.1016/j.meatsci.2016.10.005

USDA - United States Department of Agriculture. **Foreign Agricultural Service**. January, n.12, 2022.

VENKATA REDDY, B.; SIVAKUMAR, AS; JEONG, DW; WOO, YB; PARK, S.J.; LEE, SY; HWANG, I. Meat quality characteristics of heifer meat compared to steer, bull and cow in feeding various environments. **Animal Science Journal**, v. 86, p.1-16, 2015. https://doi.org/10.1111/asj.12266

YOUNG S. Evidence-based management: a literature review. **Journal o Nursing Management**, v.10, p.145-51, 2002. https://doi.org/10.1046/j.1365-2834.2002.00309.x

ZWETSLOOT, P.P.; VAN DER NAALD, M.; SENA, E.S.; HOWELLS, D.W.;

INTHOUT, J.; GROOT, J.A.H.; CHAMULEAU, S.A.J.; MACLEOD, M.R.; WEVER, K.E. Standardized mean differences cause funnel plot distortion in publication bias assessments. **eLife,** v.6, 2017. https://doi.org/10.7554/eLife.24260