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Probability of beef tenderness in confined cows - a meta-analytic approach

Probabilidade de maciez na carne de vacas confinadas - abordagem meta-analítica

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Abstract

This study aimed to assess the probability of meat tenderness in confined cows. For this purpose, CAPES and SciELO platforms were searched for papers under this subject published in Brazil between 2000 and 2015. A total of 43 articles were found, of which eleven were used. Those selected approached the finishing of confined cows and specified animal genetic group, breed, and age at experiment start. Moreover, all these studies evaluated sensory and organoleptic characteristics of meat, following the same method. Each variable was analyzed by logistic regression, using the LOGISTIC procedure of SAS. The factors were evaluated by odds ratio (OR), in which changes in the probability of meat tenderness were estimated by means of an add-on function in regression variable units. Animal age at the beginning of termination, percentages of zebuine blood and heterozygosity, and marbling score are factors that affect ($p < 0.30$) the chance of beef tenderness. The probabilities of obtaining a tender meat increase when age at termination beginning and zebuine genotype participation are reduced, as well as when heterozygosity (via crosses) and meat marbling score increases.
Key words: Heterozygosity. Logistic regression. Meta-analysis. Odds ratio. Panel of evaluators.

Resumo

Objetivou-se avaliar a probabilidade de maciez da carne de vacas confinadas. Para isso foram avaliados todos os artigos publicados no Brasil entre os anos de 2000 a 2015 com acesso via plataforma CAPES e SciELO. Ao total foram localizados 43 artigos dos quais foram utilizados onze, que envolveram a terminação de vacas em confinamento; além de informar o grupo genético e raça dos animais, a idade das vacas ao início do período experimental e que tivessem estudado características sensoriais e organolépticas da carne seguindo a mesma metodologia. Para análise de cada variável foi utilizada a regressão logística, por meio do procedimento LOGISTIC, disponível no SAS. Os parâmetros foram

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avaliados pela estatística de razão de chances (*odds ratio*), em que a mudança nas chances de maciez foi estimada a partir da função de acréscimos nas unidades das variáveis regressoras. A idade em que as vacas iniciam a terminação, assim como o percentual de sangue zebuíno e heterozigose juntamente com o marmoreio são fatores que afetam ($p < 0,30$) a chance de maciez da carne das vacas. Reduzir a idade ao início da terminação e a participação de zebuíno no genótipo das vacas, aliado a aumento na heterozigose por meio de cruzamentos e incremento no marmoreio da carne, aumenta a probabilidade de vacas de descarte demonstrarem carne macia.
Palavras-chave: Heterozigose. Metanálise. Painel de avaliadores. Razão de chance. Regressão logística.

Introduction

Production system characteristics and carcass or meat traits are generally used to set prices for beef purchases. In a large number of studies focused on animal science, quantifying these measurable factors is restricted to correlating variables individually, without considering their interactions.

Meta-analytic procedures using multivariate statistics can help to better understand how production system features and carcass and meat quality influence beef tenderness. In addition, the decision-making about the use of technologies in the production phase, still at the farm level, can be aided for a sample increase and identification of the effects and potential trends undetectable in experiments.

Among the generalized linear models, logistics regression has been used in several areas of knowledge. This is because, from a mathematical point of view, it is easy to use and presents a rich and direct interpretation of results, besides allowing the evaluation of coefficients by means of odds ratio testing (HOSMER et al., 2013). In addition to these procedures, the proportion of each factor effect on beef tenderness is relevant to determine its importance on this characteristic, which is of the greatest interest to consumers.

By adapting these procedures, a powerful tool is created for predictions about meat tenderness. Given this, the present study aimed to evaluate the probability of beef tenderness in cows at culling and estimate the proportion of the effect of independent variables on this trait, using a compilation of articles published in Brazil between the years of 2000 to 2015 that evaluated the quality of beef meat.

Material and Methods

We retrieved papers that dealt with studies carried out in Brazil regarding carcass and discard meat evaluations. Only studies published between 2000 and 2015 in the SciELO and Capes research platforms were assessed. These papers were accessed online, using a combination of the following keywords: carcass, meat, female bovines, heifers, and cows. A total of 43 articles were found.

To be incorporated into database, the papers had to meet the following terms: (1) animals had to be finished in feedlot, (2) provide information on animal genetic group and breed, (3) inform animal age at termination start, and (4) have a meat tenderness evaluation made by panel of evaluators, following the method for sensory and organoleptic traits described by Metz et al. (2009).

Each treatment in the papers was considered as a database unit, from which some information was drawn. From Material and Methods section, we extracted data on termination period and roughage: concentrate ratio. From Results and Discussion sections, we gathered information on carcass traits such as average subcutaneous fat thickness and slaughter weight, and on meat treats such as coloration, marbling level, texture, juiciness, and palatability. Genetic effects were estimated by calculating individual heterozygosity and prevalence of zebu genotypes. Table 1 lists the papers that composed the database of this study.

As observed in Table 1, eleven articles met the requirements for composing the database. In all studies, carcasses were split in half after cooling. On the right cold half carcass, a cut was made between the 12th and 13th ribs, so that *Longissimus dorsi* muscle was exposed for subjective scoring for color (1 = dark red and 5 = lively red), texture (1 = very coarse and 5 = very fine), and marbling level (1 to 3 = traces, 4 to 6 = light, 7 to 9 = little, 10 to 12 = average, 13 to 15 = moderate; 16 to 18 = abundant). Samples of *Longissimus dorsi* muscle were packed in plastic film and wrapped with brown paper, identified, and frozen for later organoleptic analyses. Also, 2.5-cm thick stakes were extracted and cooked until internal temperature reached 70° C. Then, a panel of tasters made subjective analyses regarding tenderness (1 = very hard and 9 = extremely tender), palatability (1 = no taste and 9 = extremely tasty), and juiciness (1 = no juiciness and 9 = extremely juicy) by chewing (Panel).

Table 1. Papers selected to compose the database with respective information on the tested effect, number of treatments, and number of evaluated animals

Paper	Tested effect	Nº treat.	n
Cattelam et al. (2009)[1]; Ferreira et al. (2009)[1]	Genetic group	2	12
Kuss et al. (2005a,b)[1]	Genetic group	4	24
Marques et al. (2006)	Anestrous	3	19
Moura et al. (2013)	Concentrate Level	2	20
Restle et al. (2001)	Genetic group	2	25
Restle et al. (2002a,b)[1]	Genetic group	4	45
Restle et al. (2003)	Genetic group	3	25
Vaz et al. (2002)	Animal category	1	12
Total	-	21	182

[1] Complementary study.

For the purpose of analysis, meat was considered tender if the values were above 6 points, and tough if they were below that.

The data underwent a logistic regression testing by the LOGISTIC procedure of SAS. The regression variables tested were: paper effect, animal age, subcutaneous fat thickness, genetic group, percentage of zebu breed in genotypes, individual heterozygosity, percentage of roughage in diet, finishing period, as well as meat marbling, coloration, texture, juiciness, and palatability.

Several multiple regression models with linear and quadratic effects were tested using a stepwise procedure at 0.25 level to enter and 0.30 to remain in the model, respectively (HOSMER et al., 2013). The best fit model was chosen by the Hosmer and Lemeshow test for fit quality.

After fitting the model (βi›s parameter estimation), the quality of the fit model and the individual significance of the set of parameters of the model were tested using a likelihood ratio test at 5% significance.

The best calculated multiple regression model for the probability of the ith cow presenting tender meat and being considered for data analysis is described by:

$$\ln\left(\frac{p_{ijklmno}}{1-p_{ijklmno}}\right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2j} + \beta_3 x_{3k} + \beta_4 x_{4l} + \beta_5 x_{5m} + \beta_6 x_{6n} + \varepsilon_{ijklmno}$$

Wherein: *pijklmn* is the probability of obtaining tenderness, X_{1i} is the effect of the article, X_{2j} is the animal age at the beginning of termination, X_{3k} is the zebu breed percentage in the genotype, X_{4l} is the heterozygosity, X_{5m} is the marbling score, X_{6n} is the termination period, β (0, 1, 2, 3, 5, and 6) are the regression coefficients of the regression variables *Xh*, and εijklmn is the random error associated with each observation.

An inconsistency test (I^2) was used to quantify the degree of heteroscedasticity in the data, which defines the variability percentage in effect estimates that is due to heterogeneity rather than to chance (SOUZA; RIBEIRO, 2009). The effect of each regression variable of the Logistic Regression model was measured by the coefficient of partial and total determination (R^2) obtained by the stepwise statistic. These coefficients were interpreted using the odds ratio (OR), which was estimated by the equation: OR = exp (bk). This is the ratio between two potential results, i.e., the probability of success (πj) and failure (1 - πj) in obtaining tender meat. These ORs were based on the average denominator of the data set for each model. The regression variable change units were: 10 months for cow age, 10% for zebuine breed percentage, 10% for heterozygous percentage, and 1 point for marbling score.

Results

Besides each article effect, the variables that composed the logistic regression model for beef tenderness were animal age, zebu breed percentage in genotype, individual heterozygosity, termination period, and meat marbling score (Table 2). These six factors could explain 65% of the variance in meat tenderness (Table 3). Given the subjective nature of this trait, our result is relevant considering the range of surveyed studies and number of variables considered (15 years of publications).

The study effect, or isolated article effect, was significant at 9% on the variation of this qualitative characteristic, which is of greatest interest to consumers. The inconsistency index (I^2), which evaluated the degree of heteroscedasticity on beef tenderness, showed no substantial heteroskedasticity among studies (46.8 %).

The average age of cows was 70.8 months, i.e., around six years. The standard deviation and the maximum and minimum values demonstrate the wide range of this variable in the studied articles. The result of partial R^2 showed that animal age had an effect of 17.9% on this characteristic of the meat.

Table 2. Characteristics of the data used to develop the logistic regression model for the probability of beef tenderness.

Factor	N	Average	Standard-deviation	Minimum	Maximum
Tenderness by panel scores	21	6.0	0.7	4.1	7.3
Age, in months	21	70.8	30.9	18	102
Proportion of zebuine breed, in %	21	36.1	28.4	0	100
Heterozygosity, in %	21	64.7	39.1	0	100
Termination period, in days	21	89.5	15.4	63	112
Marbling score, in points	21	6.1	0.5	4.7	6.9

Zebu breeds represented only 36.1% of the cow genotypes. This result shows that most of the studies carried out in Brazil do not use genotypes that reflect the reality of production in the country. In this study, the trait zebuine breed percentage explained 12.7% of the variation in beef tenderness. About 80% of the herd in Brazil is composed by Zebu breeds, among which 90% is Nellore, given the greater adaptability of these breeds to the prevailing tropical climate in the country (SANTANA Jr. et al., 2016).

Table 3. Total and partial coefficients of determination (R^2) for regression variables composing the logistic model for meat tenderness in slaughter beef cows.

Factor	R^2 - Partial	R^2 - Total accumulated
Animal age	0.1790	0.1790
Zebu breed proportion	0.1275	0.3065
Heterozygosity	0.1204	0.4269
Article	0.0903	0.5172
Marbling	0.0887	0.6059
Termination period	0.0439	0.6498

In the present study, heterozygosity had a value close to that of F5-generation genotypes from crosses between two different breeds (69%). The effect of this characteristic on meat tenderness was of the order of 12%. This factor is calculated and expressed in percentage, and it estimates the probability of alleles of a given locus coming from different breeds, thus assuming values ranging from 0 to 100% (PACHECO, 2016).

Termination period and marbling score were also significant for the logistic regression model. The effect of these factors on meat tenderness was 4.4 and 8.9%, respectively. Based on the Hosmer and Lemeshow test, there is no evidence that the regression model was not well fit for the chance of beef tenderness (p = 0.9002) (Table 4).

Table 4. Regression equation and probability estimate for the regression variables in evaluating meat tenderness of confined cows.

Tenderness	Parameter	Standard error	*Odds ratio*	HLT
Intercept	-1.6519	4.6382		0.9002
Product	-0.8945	0.5619		
Cow age	-0.1655	0.1361	0.191	
Percentage of Zebu	-0.1425	0.0595	0.240	
Heterozygosity	0.0809	2.5706	2.245	
Marbling	3.0477	1.6247	21.066	

HLT= Hosmer and Lemeshow test.

As for the odds ratio, a 10-month increase was estimated for cow age at termination start in relation to the mean age (70.8 months). Thus, the chance of obtaining tender meat is expected to reduce in 80.9%. A negative relationship was also observed for the percentage of Zebu breed in genotype, wherein for each 10% increase in this proportion, there was an estimated 76% reduction in the chance of meat tenderness.

Whereas 10% increase in heterozygous compared to 64.7% calculates an increase of 2.24 times the chance of obtaining tenderness meat. Also, a positive relationship with the marbling, wherein for each first point above 6.1 points is expected a 21-fold increase in the chance of meat tenderness.

Although the termination period was significant (p <0.3) to compose the logistic regression model,

it did not enter the equation that explains the chance of meat tenderness, showing an average of 90 days, with a minimum of 63 and a maximum of 112 days.

Discussion

Our main objective was to identify factors affecting beef tenderness of culling cows, using measurable and/or observable variables in the production systems, and by carcass and meat characteristics. This proposal was based on the marketing importance of beef tenderness, since there are several factors related to its variation (GARMYN; MILLER, 2014).

Evaluating meat tenderness changes by quantifying other variables, or even defragmenting its influencing effects, is a procedure of analysis well known and employed in science. This approach comes from Newtonian and Cartesian mechanics and guides the basis of natural sciences. It seeks to understand the complexity of an event by breaking it down into factors, which can be further decomposed into new other factors until the minimum level, in order to understand how they act and their relationships.

Variables for a given model are selected by algorithm-based statistical procedures, which evaluates the importance of each variable to the model, being aligned to a decision rule that includes or excludes it from the model (AGRESTI, 2007). Conversely, a stepwise method, in linear models, uses F-test to select the variables for the model, using logistic regression; this is because the errors have a binomial distribution, thus significance is ensured by a likelihood ratio test. From a mathematical point of view, the more a variable generates a change in a likelihood logarithm, the greater its importance for the model (HOSMER et al., 2013).

The logistic regression showed that carcass traits were minor parameters for estimating the chance of obtaining tender meat if compared to genetic traits, animal age, and marbling scores. We chose the model for discussion based on the Hosmer and Lemeshow test. This test relates the data to its estimated probabilities, from the lowest to the highest ones, followed by a chi-square test to determine whether the estimated frequencies are close to those observed. So, the closer to 1, the better the fit of the model to the data (HOSMER et al., 2013).

The effect of the article on tenderness results was significant, as observed in the ratio of effect and logistic regression, but without substantial heteroscedasticity. Thus, we did not have to adjust or remove any of the studies. Rotta et al. (2012) suggested that the inconsistency index is an important way of quantifying the heteroskedasticity of meta-analysis so that values above 0.50 can be considered high heteroskedasticity and require interventions.

As expected, cow age at termination beginning had a negative influence on the chances of obtaining meat tenderness and was the variable with the highest proportion of effect. This result can be related to the properties of muscle fibers (LEPETIT, 2008; PATTEN et al., 2008). With advancing age, these fibers can be modulated from FOG fibers (fast twitch fibers, oxidative-glycolytic metabolism, and intermediate color) and FG (fast twitch fibers, glycolytic metabolism, and white color) to SO fibers (slow twitch fibers, oxidative metabolism and red color), setting fewer tenderness features to the cow meat. Another significant point is the solubilization of collagen, which also decreases with advancing age, making the meat tougher (JURIE et al., 2006; GALLI et al., 2008; WEBER et al., 2013).

In general, cow meat has less acceptance at a retail level, what consequently impacts the other segments of the bovine production chain. This trend is mainly associated with the lower tenderness of this meat, which in turn, is jeopardized by age effect, as seen in our study. Livestock management practices, such as confinement, and meat maturation procedures are strategies aimed at minimizing this age effect (ROSE et al., 2010).

The percentage of Zebu 'blood' showed a negative effect on the chance of met tenderness. Numerous studies have widely documented and supported this effect (CROUSE et al., 1989; LAGE et al., 2012; PACHECO et al., 2015). The main explanation for this is the action of enzymes linked to myofibrillar proteolysis during *rigor mortis*, called calpamine and calpastatin, since the relationship between them, in zebuine animals, decreases meat tenderness (CASAS et al., 2006; DUARTE et al., 2013; TIZIOTO et al., 2014). This effect is related to the frequency of certain genes responsible for meat tenderness depreciation and to a strong additive genetic effect in zebuine breeds for this feature (CASAS et al., 2006; SILVA et al., 2016).

By contrast, heterozygosity showed a positive effect on meat tenderness probability, with the same proportion as that of zebuine breed on the response variable. This result demonstrates that including animals of taurine origin in crosses of Brazilian herds may be an alternative to increase the qualitative variable of beef. It has also been recommended in Asian countries with low commercial competitiveness in the beef chain and herds with high participation of zebu 'blood'. In recent years, these issues have been discussed in order to improve the local bovine chain, through the exploration of heterosis from crosses (CHAIWANG et al., 2014). A model proposed by Koger et al. (1975) have shown linearity between heterozygosis and heterosis, such phenomenon has been widely identified, explored, and documented in various production systems. For the characteristic tenderness, Menezes et al. (2005) reported heterosis values of 11.63 and 10.80 in F2 and F3 generation steers from the crossing between Charolais and Nellore breeds, respectively.

An increasing beef marbling promotes a significant increase in the probability of obtaining tender meat. Although this variable contributed only 8% to explain the tenderness results by the effect probability analysis, it demonstrated a relevant role in the analysis of odds ratio. There is controversy as to the participation of marbling in beef tenderness, most of the studies have demonstrated the lack of influence on meat tenderness when measured by shear force. However, when measured by a panel of evaluators, this effect may be more representative, in view of the alteration of other organoleptic characteristics such as palatability and juiciness, contributing to a greater perception of meat tenderness when chewing, due to the stimulating effect of fat on salivation (OURY et al., 2009).

Conclusions

Reductions in animal age at slaughter and zebuine breed participation in genotypes, associated with increased heterozygosis values and meat marbling scores enhance the likelihood of obtaining meat tenderness.

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