Factors underlying tenderness of beef from Nellore cattle classified by dental maturity

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Abstract— **The objective of this study was to identify factors underlying beef tenderness. Measurements of carcass weight (CW), ultimate pH (pHu), myofibrillar fragmentation index (MFI), Warner-Bratzler shear force (WBSF), steak liquid loss (SLL) and collagen solubility (CS) were taken from *Longissimus dorsi* samples of 63 Nellore bulls classified by dental maturity (2, 4, 6 or 8 permanent incisors). Data was analyzed trough principal components (PC) analysis and logistic regression (LR). For the LR analysis, samples were classified in two groups according to WBSF values. Samples with values over 4.5 kg were classified as "tough" and those with less than 4.5 kg were classified as "tender". The LR was performed fitting dental classification and MFI in a model to predict these two groups. Three PCs were retained in the analysis accounting for 70% of the variability, where PC1 was related to WBSF, SLL and MFI, PC2 with MFI, CW and CS, and PC3 related pHu and MFI. There was significant effect of dental maturity for scores from PC1 and PC2 (P>0.05). The probability of the LR was modeled for the "tender" group and presented a correct classification rate of 76.2%. There was a significant effect of MFI (P<0.1; odds ratio = 1.046) and dental maturity (P<0.1), where animals with 2 and 4 permanent incisors presented higher odds ratios to classify samples as "tender" than those with 6 and 8 permanent incisors (P<0.1). Dental maturity has effect on MFI, WBSF, CW, SLL and CS, and moderate potential to classify beef cuts according to tenderness.**

Keywords— **Beef, Nellore, Tenderness**

I.INTRODUCTION

Improving beef quality, uniformity and consistency have been identified as one of the major challenges for the Brazilian beef industry. In Brazil, the main problems faced by the beef supply chain are the undesirable levels of fatness and tenderness.

It seems to be a result of the production system of grazing cattle in Brazil, which has a low adoption of production technologies. Consequently, animal growth is slowed, especially due to the distribution and seasonal variation, in quantity and quality, of forage, so animals are commonly harvested older than 42 months of age.

Several studies have evaluated the relationship between meat tenderness and the age of animals at slaughter [1]; [2]. Most of these studies have suggested that the solubility and amount of collagen are the main reasons for the decrease in beef tenderness as the animals get older. However, a more comprehensive study is needed to simultaneously compare many factors that would account for variability in beef tenderness of cattle classified by dental maturity.

Therefore, the objective of this study was to identify factors underlying tenderness of beef from Nellore cattle classified by dental maturity.

II.MATERIAL AND METHODS

A. Carcass selection

Sixty-three beef carcasses from Nellore bulls raised in pasture and from the same ranch were selected at a commercial beef plant. Pre-harvest handling was in accordance with good animal welfare practices, and slaughtering procedures followed the Sanitary and Industrial Inspection Regulation for Animal Origin Products (Brasil, 1997). Immediately post-harvest and following head inspection, the number of permanent incisors was recorded for each bull. A pair of teeth was considered to be present when either tooth of a pair had penetrated the gum. The carcasses were assigned to a completely randomized design and

grouped in four categories according to dental maturity (two, four, six or eight permanent incisors).

B. Carcass data and Longissimus samples collection

After 24 h postmortem chill (4ºC), ultimate carcass pH (pHu) and cold carcass weight (CW), were recorded. L*ongissimus dorsi* samples were collected from the posterior end of the wholesale rib, individually vacuum packaged and frozen at -20ºC. Each frozen sample was standardized into one 2.54 cm thick samples for Warner-Bratzler shear force measurement (WBSF), and two 1 cm thick samples for determination of collagen solubility (CS) and myofibrillar fragmentation index (MFI). Steak liquid loss (SLL) was evaluated on steaks also used for WBSF measurement.

C. Statistical Analyses

Data of CW, pHu, MFI, WBSF, SLL, and CS were analysed trough principal component (PC) analysis, logistic regression (LR) and discriminant analysis. Prior to the analyses, the multinormality of the residuals and homogeneity of variance were assessed by fitting dental maturity in the model. All analyses were carried out using SAS 9.2 (Statistical Analysis System Institute, Inc., Cary, NC, USA).

The PC analysis was performed using the factor procedure (method=prin) on the correlation matrix. The varimax rotation of the PCs was used to simplify interpretation of the PC loadings. Principal components with eigenvalues (λ) greater than 0.9 were extract from the analysis, and only loadings greater than 0.4 were discussed. In addition, PC scores were generated for each extracted PC and univariate models fitting dental maturity were investigated. In case of significant effect ($P<0.05$), least square means (LS Means) of dental maturity were compared using Tukey-Kramer's multiple comparison adjustment.

For the logistic regression (LR), steak samples were classified in two groups, "tender" or "tough", according to their WBSF values, where samples with values greater than 4.5 kg were classified as "tough". The probability of the LR was modelled for the "tender" group, including the effects of MFI (continuous variable) and dental maturity (categorical variable).

III.RESULTS

Three PCs were extracted from the analysis, accounting for 70% of the total variability (Table 1).

Table 1. Principal Components (PC), Eigenvalues (λ), Proportion (p) and Cumulative Proportion (Cp) of the Principal Component Analysis

PC	λ	p	Cp
PC1	2.055	0.3426	0.3426
PC2	1.201	0.2002	0.5428
PC3	0.9434	0.1572	0.7000
PC4	0.7206	0.1201	0.8201
PC5	0.5858	0.0976	0.9178
PC6	0.4934	0.0822	1.0000

The PC loadings in Table 2 indicate that, for PC1, substantial increased values of WBSF and SLL are associated with decreased MFI. For PC2, animals with higher CW may show slightly decrease in MFI, but substantial reduction in CS. Variation due to pHu was only observed in PC3, where high values of this variable are associated with a low increase on MFI.

Table 2. Loadings of the extracted rotate PCs

Variable[1]	Loadings*		
	PC1	PC2	PC3
WBSF	0.75537	-0.22537	-0.01863
pHu	0.08383	-0.12061	0.92589
SLL	0.83688	0.02347	0.04156
MFI	-0.42462	0.43752	0.45441
CW	0.33595	-0.68573	-0.13175
CS	0.07732	0.8715	-0.2299

[1] WBSF = warner-bratzler shear force; pHu = ultimate pH; SLL = steak liquid loss; MFI = myofibrillar fragmentation index; CW = carcass weight; CS = collagen solubility

*Only loadings > 0.4 were considered

There was a significant effect of dental maturity (P<0.05) on PC scores of PC1 and PC2 (Table 3). Figure 1 depicts the distribution of dentition classes by the carcass and meat quality traits on PC1 and PC2.

Table 3. Least square means (LS Means) of the PC scores from PC1 and PC2 among dental maturity groups (2, 4, 6, and 8 permanent incisors)

Dental Maturity	LS Means (S.E.)		
	PC1	PC2	PC3
2 p.i.	-0.299^{ab} (0.25)	0.842^{a} (0.20)	0.400 (0.26)
4 p.i.	-0.381^{a} (0.21)	0.241^{ab} (0.17)	-0.195 (0.22)
6 p.i.	0.257^{ab} (0.24)	0.014^{b} (0.19)	-0.396 (0.25)
8 p.i.	0.505^{b} (0.24)	-1.105^{c} (0.19)	0.270 (0.25)

Within each PC, least square means without a common superscript letter are statistically different (P<0.05).

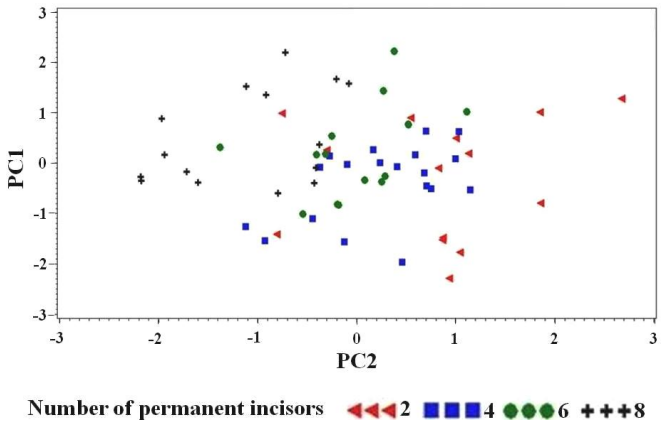

Figure 1. Dental maturity groups plotted by carcass and meat quality traits for PC1 and PC2

Classification of the samples based on the threshold WBSF value of 4.5 kg allocated 43 samples in the "tough" group and 20 in the "tender" group. The averages (±standard error) were, in kg, 7.242 (±0.274) and 3.143 (±0.157) for the "tough" and "tender" groups respectively. There was significant effect (P<0.1) of MFI and dental maturity in predicting the group, "tough" or "tender", in which samples came from. Samples had increased probability in being classified as "tender" as MFI values increased (odds ratio=1.05). In addition, a leave-one-out-crossvalidation using discriminant analysis resulted in an overall correct classification of 74.6% of the samples. Thirty-seven samples were classified as "tough", whereas only 5 (13.5%) were misclassified (true "tender" samples). In contrast, of the 26 samples classified as "tender", eleven where actually from the "tough" group (42.3%).

IV.DISCUSSION

Several enzyme systems in skeletal muscle have been implicated in the postmortem proteolytic degradation of myofibrillar proteins, which consequently affects meat tenderness. Therefore, various techniques have been studied intensively in order to measure the degree of myofibril fragmentation, including MFI. Values of MFI are inversely related to WBSF, and can also be used to predict meat tenderness. Thus, values of WBSF increases with the decrease of MFI, since reduced proteolysis activity during postmortem period implies in a reduction in tenderness, which explains the relationship between these variables in PC1 (Table 2).

Another factor that affects meat tenderness is water hold capacity of muscle tissue. The ability of meat to retain water during application of external forces such as cutting and heating is highly variable. Some loss of moisture occurs even during the mildest application of these treatments because a portion of the water present is in free form. A great loss of meat liquids is likely to occur during cooking through evaporation and drip, leading to dryness and toughness of meat, which may explain the association of increased values of SLL and WBSF observed in PC1 (Table 2).

For PC2, animals with greater values of CW presented slightly decrease in MFI (Table 2). This can be explained by the fact that the heaviest carcasses observed in this study were from animals with 8 permanent incisors. According to [3] there is a reduction of the specific activity of the calpain enzyme as the animal ages. Therefore, since calpain is the main enzyme responsible for myofibrillar

degradation, a decrease on MFI is also observed as the animal ages, explaining the association between those factors observed on PC2 (Table 2). These differences are well visualized in Figure 1, where most of animals with 2 permanent incisors (red rectangles) were plotted at the right-hand side (positive values) whereas those with 8 permanent incisors (black crosses) had negative values for PC2, indicating that MFI, CW and CS have potential to discriminate animals from these two dental classifications.

With regard to PC3, according to [4], during the postmortem period, the process of meat tenderization is directly influenced by muscle pH, when high pH values are related to decreased proteolytic activity with consequent lower levels of protein degradation, which may explain the relationship of the slightly increase in MFI with high values of pHu observed in PC3 (Table 2).

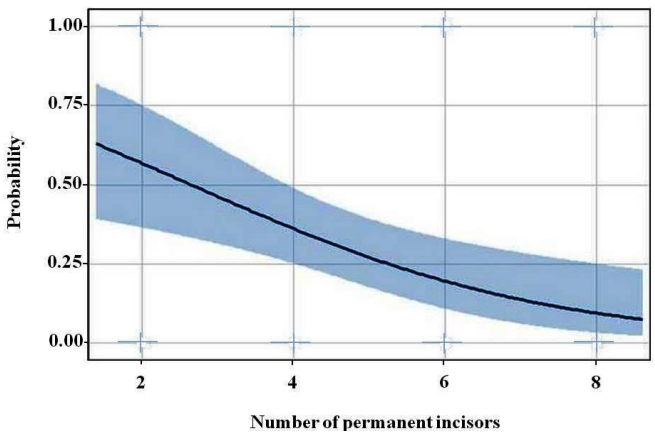

Figure 2. Predicted probability (with 90% confident limits) of classifying samples as "tender" across number of permanent incisors at average level of MFI = 53.8%.

As shown by Figure 2, the probability of beef being classified as "tender" decreased ($P<0.1$) as the number of permanent incisors increased for a fixed MFI value. This can be explained by the collagen solubility, which has been reported as a factor determining meat tenderness. Intermolecular cross-links present in collagen found in muscle of young animals are unstable to heat, however these links are converted into complex structures as the animal ages, becoming thermostable. These changes are associated with substantial increases in stiffness and insolubility of collagen and, consequently, a reduction in meat tenderness from older animals.

The discriminant analysis, using dental classification and MFI, showed overall good results. The correct classification of 74.6% of the samples is considerably high when we take into consideration the fact that these animals came from low input production system. Although most of samples classified as "tough" were true "tough" samples, those classified as "tender" had a high number of false "tender" samples. In this manner, it seems that there is a slightly bias in misclassifying "tough" samples as "tender", and thus, this may reduce the use of these traits to classify meat samples for tenderness.

V.CONCLUSION

The data suggests that carcass dental maturity has effect on MFI, WBSF, CW, SLL and CS, and moderate potential to classify beef of Nellore cattle according to tenderness.

VI.REFERENCES

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