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Ciências Agrárias

Comparison of meat quality traits of steers raised in semi-intensive and extensive beef production systems in Manacapuru, Amazonas, Brazil

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Abstract

The purpose of this study was to compare the improvement in tenderness during aging of meat from steers raised in extensive (n=4) and semi-intensive (n=4) beef cattle production systems in Manacapuru, Amazonas, Brazil. Samples of the *Longissimus dorsi* muscle (rib eye) of Nelore steers were collected at 1 day p.m., subdivided, vacuum packed and kept refrigerated until analysis. Samples were assessed for shear force, cooking loss, myofibrillar fragmentation index (MFI), sensory analysis and microbial growth at 1, 2, 5, 8, 12 and 15 days p.m. The results of the shear force and MFI measurements indicated that the muscles from the steers raised in the extensive production system showed a greater aging response resulting in significantly higher MFI values and a difference in shear force of about 1 kg at 12 and 15 days p.m. It remains to be determined whether this effect was due to differences in the production systems or differences in the processing conditions on the day of slaughter. Microbiological counts did not deviate from the sanitary hygienic standards set by Brazilian legislation.

Keywords: meat tenderness, beef cattle, meat technology, *Bos indicus,* Amazonas.

Comparação das características de qualidade da carne de novilhos criados em sistemas de produção de carne semi-intensiva e extensiva de Manacapuru, Amazonas, Brasil. O processo de maturação de cortes cárneos é uma abordagem tecnológica que visa aumentar a maciez da carne. O objetivo desse trabalho foi comparar o processo de maturação da carne de animais criados em sistema de produção extensivo e semi-intensivo no município de Manacapuru, Amazonas, Brasil. Amostras do músculo *Longissimus dorsi* (contrafilé) de oito animais machos, mestiços anelorados, castrados, rastreados, sendo quatro produzidos em sistema extensivo e quatro em sistema semi-intensivo, foram coletadas, embaladas a vácuo e mantidas sob refrigeração durante todo o período de análise. A cada três dias foram coletadas amostras até o décimo quarto dia de maturação. Foram quantificados: índice de

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fragmentação miofibrilar (IFM); perda de água por cocção (PPC); força de cisalhamento (FC), análise do crescimento microbiológico, determinação do pH e análise sensorial. Os resultados indicaram, ao longo do processo de maturação, aumento significativo da fragmentação das miofibrilas e diminuição significativa da textura da carne nos dois sistemas de produção comparados. As contagens microbiológicas não diferiram dos padrões higiênico-sanitários estabelecidos pela legislação brasileira. De acordo com as análises realizadas foi possível observar que não houve diferença significativa entre os sistemas avaliados quanto ao processo de maturação, sugerindo que no décimo primeiro dia de maturação foi o período ideal de maturação nas condições avaliadas para ambos.

Palavras-chave: maturação, gado de corte, tecnologia da carne, *Bos indicus,* Amazonas.

1. Introduction.

Amazonas is a state in northwestern Brazil, and it is a gigantic territory that is almost entirely covered by tropical jungle. It is the largest in territorial area, with 1,570,745.680 km^2, equivalent to that of four countries: France, Spain, Sweden, and Greece (SAMPAIO et al., 2015). This area consists of low altitude topography and an equatorial climate that has high temperatures and high rainfall, with variations in weather patterns due to the climate phenomena known as El Niño and La Niña (LANGERWISCH et al., 2013) and to large scale deforestation, due to pasture or soybean cropland expansion, based on a low technology approach, potentially causing the destruction of natural ecosystems and unsustainable development (SAMPAIO et al., 2007; FEARNSIDE, 2018).

To prevent these risks from becoming reality, the current deforested areas need to be used for profitable and environmentally sustainable agricultural activities (HOMMA et al., 2012). The consumption of beef has been gaining importance in the diet of Amazonians and improving meat processing technology is an opportunity to reduce the economic losses in beef cattle production (CARRERO et al., 2015). Beef aging is an effective technological process of meat tenderization that has been known since the turn of the last century (KOOHMARAIE, 1994). In practice, this entails refrigerated storage of vacuum-packed beef for about two weeks. The improvement in tenderness is due to the degradation of the muscle structure by endogenous proteolytic enzymes (OLIVEIRA, 2000; ZEOLA et al., 2007; CARVALHO et al., 2014; KAHRAMAN & GURBUZ, 2018). The quality of Brazilian beef is quite variable due to the high *Bos indicus* content of the cattle and to inadequate finishing systems. The interaction of these variables can result in tough meat (ANDRADE et al., 2010; CABRAL NETO et al., 2011; MALHEIROS et al., 2018; ZAMORANO et al., 2019).

The purpose of this work was to compare meat quality traits of aged *Longissimus dorsi* (rib eye) samples from Nellore steers reared in extensive and semi-intensive beef cattle production systems in Manacapuru, Amazonas, Brazil.

2. Material and methods.

2.1. Animals

Eight Nellore steers were purchased from the VDA group farm (3°09'04.1"S, 60°20'41.9"W), Manacapuru, Amazonas, Brazil. The municipality has a humid tropical climate, with average minimum and maximum temperatures of 22 and

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35°C, respectively and an average annual precipitation of 2012 mm.

The steers were divided into two groups (n=4/group). The first group was raised in an extensive pasture (*Brachiaria brizanta*) system, supplemented with mineralized salt, and had an average live weight and hot carcass weight of 528,5 and 282,2 kg, respectively, at about 36 months old. The second group was raised in a semi-intensive system, which included 90 days of finishing on a grain supplement and *Pennisetum purpureum* diet containing 12% crude protein. The average live weight and hot carcass weight of these steers were 547,5 and 297,1 kg, respectively, at about 40 months old.

2.2. Sampling.

Approximately 2.5 kg of *Longissimus dorsi* muscle (rib eye) from each carcass side of the steers were collected at 1 day postmortem (p.m.), packed on ice and transported to the Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Amazonas, Brazil. Each piece of rib eye was divided into 12 sub-samples of 150 grams. The samples were vacuum packed and kept under refrigeration (0.5°C) for 0, 1, 4, 7, 11 or 14 days. After the different storage periods, samples were analyzed for physicochemical traits (myofibrillar fragmentation index, cooking loss, shear force) sensory analysis and microbiological growth. These analyses were performed on the samples frozen after the different storage periods. Most of the analyses were performed in triplicate.

2.3. Determination of the myofibrillar fragmentation index (MFI).

Myofibrillar fragmentation index (MFI) was determined according to GEESINK *et al*. (2000). Briefly, this method consists of homogenizing the muscle in buffer, the removal of soluble proteins by repeated centrifugation, resuspension of the myofibrillar proteins in MFI buffer, and measurement of the absorbance of a myofibrillar suspension (0.5 mg protein/mL) using a spectrophotometer.

2.4. Analysis of cooking loss (CL).

Cooking loss was determined according to Muller (1987). Briefly, samples were cut in cubes of 2x2x2 cm, weighed and roasted in a preheated grill to 170°C until they reached an internal temperature of 71°C at the geometric center of the sample, followed by chilling at room temperature. Weight loss during cooking was expressed as a percentage of the weight before and after cooking.

2.5. Determination of shear force.

The tenderness of samples was measured instrumentally by determining the shear force using a Texturometer TAXT2 equipped with a Warner Bratzler meat cell. Samples of about 10 g were cooked, using a grill, until the internal temperature reached 71°C, chilled at 4°C for 24 h. Two cylindrical subsamples with a 1.27 cm diameter were cut in the direction of the muscle fiber. Shear force, perpendicular to the fiber direction was determined with a shear speed of 20 cm/min. The results were expressed as maximum shear force in kilograms force (DUCKETT et al., 1998).

2.6. Analysis of microbiological growth.

Quantitative analyses of yeasts and molds, total heterotrophic bacteria, total coliforms at 35°C and 45°C, fecal coliforms, psychrophilic bacteria at 20°C and 7°C, were performed according to APHA (1992).

2.7. Sensory analysis.

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A group of 14 panelists evaluated the tenderness using a preference test with multiple comparisons per person. Samples were thawed to 4°C, cut into cubes of 2x2x2 cm and grilled at 170°C until they reached a 70°C internal temperature and allocated to the panelists according to IFT-SED (1981). Briefly, each person was presented with six samples (aged 0 to 14 days) from one production system and asked to identify the most tender sample. Thereafter, a similar evaluation was conducted for samples from the other system. Finally, panelists were asked to judge which of the most tender samples from each evaluation was the most tender.

2.8. Statistical analysis.

The significance (P<0.05) of differences was determined using analysis of variance (ANOVA), *a priori,* and the Tukey test, *a posteriori* using SYSTAT 7.0 statistical software. Correlation analysis was conducted using STATISTIC 5.0 statistical software, according to ZAR (2009).

3. Results and Discussion.

Aging resulted in a significant decrease in shear force (P<0.001), but production system did not have a significant effect on the overall shear force (P>0.05), or the shear force at any time postmortem (Table 1).

Table 1. The effect on myofibrillar fragmentation index (MFI), cooking loss (CL) and shear force (SF) of the *Longissimus dorsi* muscle of steers raised in extensive and semi-intensive production systems, according to aging period.

		Days postmortem					
System	Trait	1	2	5	8	12	15
Extensive	MFI[1]	15.7^{a}	18.6^{a}	30.9^{b}	36.8^{b}	39.0^{bc,x}	50.8^{bc,x}
	CL[2]	31.7^{ab}	31.6^{ab}	30.0^{a}	38.0^{c}	36.4^{bc}	34.4^{abc}
	SF[3]	8.4^{a}	8.2^{a}	6.0^{ab}	6.2^{ab}	5.1^{b}	4.0^{b}
Semi-intensive	MFI[1]	21.5^{ab}	23.1^{a}	25.5^{ab}	28.7^{ab}	30.9^{ab,y}	34.1^{b,y}
	CL[2]	32.1	35.2	29.6	30.0	33.8	35.6
	SF[3]	6.9^{ab}	8.0^{a}	6.73^{ab}	6.4^{ab}	6.7^{ab}	5.0^{b}

[1-] Dimensionless values; [2-] percentage values; [3-] values expressed as kilograms force.
^{abc} Means, within rows, not containing a common letter in the superscript differ significantly (P<0.05). ^{xy} Means, within columns and traits, not containing a common letter in the superscript differ significantly (P<0.05).

Although the numerical differences in shear force at 12 and 15 days p.m. are relatively large, the number of steers used in this study is probably too low to detect significant differences resulting from the effect of the production system. However, the rate of improvement in tenderness during aging appears to be lower in the muscles from steers in the semi-intensive group than in the extensive group (Figure 1).

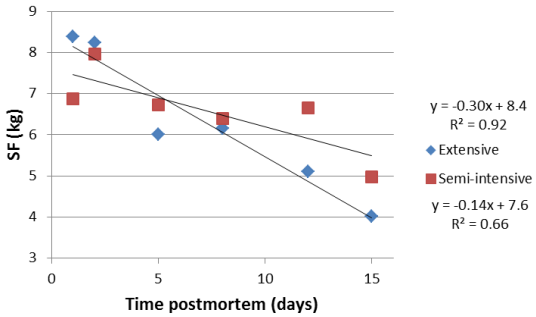

Figure 1. Shear force (SF) of bovine *M. longissimus* samples on different days postmortem from steers raised in extensive or semi-intensive production systems (n=4/ system)

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This impression is supported by the results of the MFI measurements. The MFI can be considered as a selective assessment of the fragility of the myofibrillar structure, and thus more sensitive to the effects of aging than shear force, which is also affected by contraction status (sarcomere length) and the contribution of connective tissue (HOPKINS et al., 2000). Overall, the mean MFI values correlated strongly with the mean shear force values for the different combinations of production system/aging period (Figure 2).

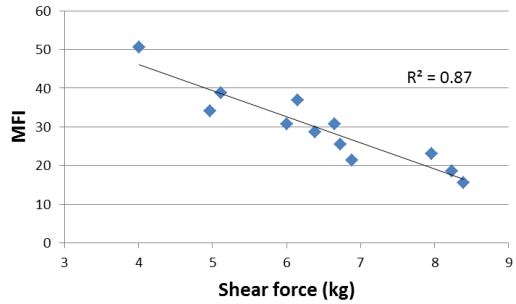

Figure 2. The relation between the myofibrillar fragmentation index (MFI) and shear force of bovine *M. longissimus* samples (n=4/system/day postmortem).

The rate of increase in MFI during aging was greater in muscles from the extensive system than the semi-intensive system (Figure 3).

This resulted in significantly higher MFI values in the extensive group at 12 and 15 days postmortem (Table 1).

The shear force and MFI results strongly suggest that the ageing response differed between the groups. However, it is unclear whether this was due to an effect of the production system, or possible differences in the processing (abattoir) conditions at the time of slaughter of the different groups. Given that postmortem proteolysis is mostly due to the action of μ-calpain, as modulated by its endogenous inhibitor calpastatin (KOOHMARAIE & GEESINK, 2006), the possibility that the production system affected the ageing response can be addressed by measurement of at-death μ-calpain and calpastatin activities. If differing processing conditions are responsible for the differences observed in aging response, a relatively high muscle temperature at the onset of *rigor mortis* (heat toughening conditions) would explain the limited aging response (GEESINK et al., 2000; BATH et al., 2018). Unfortunately, we did not address this possibility by monitoring the rate of pH and temperature decline in the muscles.

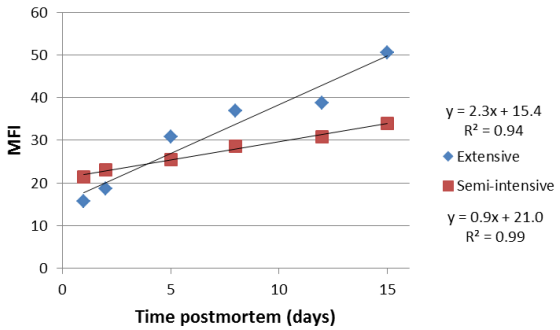

Figure 3. Myofibrillar fragmentation index (MFI) of bovine *M. longissimus* samples at different times postmortem from animals raised in extensive or semi-intensive production systems (n=4/system)

The taste panel results confirm the shear force results in the sense that tenderness increased with aging (Figure 4).

Although the number of observations is too small to perform a reliable chi-square test, the results suggest a decrease in tenderness between 12 and 15 days postmortem. This observation does not contradict

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the objective measurement of tenderness (shear force), but it is probably explained by a decrease in other quality traits like flavor, affecting the judgement of untrained (consumer) panels (WATSON et al., 2008). When asked to judge which series of evaluations (extensive vs semi-intensive) contained the most tender sample, 9 of the 14 panelists chose samples from the extensive system. Again, the number of observations is too low for a proper statistical analysis, but the trend observed supports the trend observed in the shear force results.

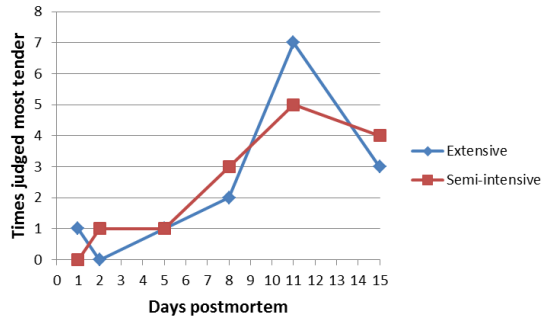

Figure 4. Frequency of samples judged to be most tender by a 14-member taste panel, according to aging period within each production system.

Cooking loss was not significantly affected by production system (P>0.05). Although the aging period had a significant effect on cooking loss (P<0.05), this did not appear to be directly related to aging period (Table 1). The cooking loss values reported here are somewhat higher than those generally reported in other studies. However, this is most likely due to differences in the preparation method, where the high surface to volume ratio of our samples led to relatively high cooking losses.

The yeast and mold counts reached maximum values of 1.80 x 10^2 and 2.20 X 10^2 CFU per gram of muscle at 15 days postmortem in samples from the extensive and semi-intensive systems, respectively. The fecal coliforms (45°C) or psychrophilic (7°) counts were detected throughout the storage period and the total counts for heterotrophic bacteria, total coliforms at 35°C, psychrophilic counts at 20°C were well below the maximum levels permitted under current Brazilian legislation (BRASIL, 2017).

To our knowledge, this is the first piece of research on meat technology in the state of Amazonas. In addition, these data are very important in the context of deforestation control in the Brazilian Amazon. The improvement of meat tenderness is one alternative to aggregate economic value to the final product, stimulating the costumers to pay higher prices (GRIFFITH & THOMPSON, 2012). In practical terms, this can preserve the tropical forests of the Amazon region, because cattle producers do not need to clear new areas to gain higher profits from this economic activity, which reduces clearing, that is, deforestation and the removal of other types of native vegetation (CARVALHO et al., 2019).

4. Conclusions

The results from this limited study indicate that the improvement in tenderness during aging differed between steers raised in extensive and semi-intensive production systems. The myofibrillar fragmentation index (MFI) results suggest that this was due to differences in the rate and extent of postmortem proteolysis of myofibrillar proteins. Whether this was due to an effect of the production system *per se* and/or differences during processing remains to be determined.

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Disclosure

This article is unpublished and is not being considered for publication anywhere else. The authors and reviewers did not report any conflict of interest during their evaluation. Therefore, the journal Scientia Amazonia owns the copyrights and has the approval and the permission of the authors for disclosure of this article by electronic means.

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