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FOOD TECHNOLOGY

Influence of muscle source on proximate composition, texture profile and protein oxidation of beef from grain-finished *Bos indicus* cattle

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ABSTRACT: *The aim of this research was to investigate the influence of muscle type on protein oxidation, texture profile (hardness, springiness, cohesiveness and chewiness) and proximate composition of beef from grain-finished Bos indicus (Nellore) cattle in Brazil. The muscles longissimus lumborum (LL) and psoas major (PM) were collected 24 h post mortem from eight (n=8) Nellore bull carcasses, fabricated into five steaks (1.5-cm) and displayed under aerobic conditions for nine days at 4 °C. Proximate composition and texture profile were analyzed on day 0, whereas protein oxidation was analyzed during 9 days of storage. LL exhibited greater (P<0.05) protein concentration than PM steaks, whereas PM demonstrated greater (P<0.05) lipid and ash content than their correlative LL. In addition, LL steaks exhibited greater (P<0.05) hardness, springiness, cohesiveness and chewiness than PM steaks. In contrast, protein oxidation was greater (P<0.05) in PM than in LL steaks throughout the storage. The results suggest that the differences of muscle metabolism and composition contributed to the variation on biochemical attributes and texture profile of LL and PM steaks. Muscle-specific strategies are indicated to improve the color stability of PM steaks from grain-finished Bos indicus cattle.*
Key words: *beef texture, muscle type, Nellore, oxidation stability.*

Influência do tipo muscular na oxidação proteica, perfil de textura e composição centesimal da carne de bovinos *Bos indicus* terminados em grãos

RESUMO: *O objetivo desse estudo foi investigar a influência do tipo muscular na oxidação proteica, perfil de textura (dureza, elasticidade, coesividade e mastigabilidade) e composição centesimal da carne de bovinos Bos indicus (Nelore) terminados com grãos no Brasil. Os músculos longissimus lumborum (LL) e psoas major (PM) foram obtidos 24 horas post mortem de oito (n=8) carcaças de touros Nelore, cortados em cinco bifes (1,5 cm), e dispostos em condições aeróbicas por nove dias a 4 °C. Composição centesimal e perfil de textura foram analisados no dia 0, enquanto que a oxidação proteica foi analisada durante 9 dias de estocagem. Os bifes LL demonstraram maior (P<0.05) concentração de proteína em relação aos bifes PM, enquanto que PM apresentou maior (P<0.05) conteúdo de lipídeos e cinzas que LL. Além disso, os bifes LL exibiram maior (P<0,05) dureza, elasticidade, coesividade e mastigabilidade em relação aos bifes PM. Em contraste, a oxidação proteica foi maior (P<0,05) nos bifes PM do que nos bifes LL em todos os dias de estocagem. Os resultados sugerem que as diferenças no metabolismo e na composição muscular contribuíram para a variação nos atributos bioquímicos e perfil de textura entre os bifes LL e PM. Estratégias músculo-específicas são indicadas a fim de promover a estabilidade de cor nos bifes PM oriundos de bovinos Bos indicus terminados com grãos.*
Palavras-chave: *textura da carne bovina, tipo muscular, Nelore, estabilidade de oxidação.*

INTRODUCTION

Brazil occupies the top position of beef production and exportation in the world. The Brazilian beef herd is composed mainly of *Bos indicus* cattle, represented by Nellore breed (FERRAZ & FELÍCIO, 2010). Nellore cattle are well-adapted to Brazilian climatic conditions and production systems, which is pasture-based with implementation of finishing diets (FERRAZ & FELÍCIO, 2010; FREITAS et al., 2013). During the finishing period, the cattle are raised in feedlots for 3–4 months and fed with grain-based (corn) or forage-based (grass silage and sugar cane) diet, in order to improve carcass fat deposition and weight gain (FREITAS et al., 2013).

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Muscles in a beef carcass demonstrate differences in biochemistry and composition (HWANG et al., 2010), and muscle source is a major intrinsic factor influencing texture (LORENZO et al., 2013; LANG et al., 2016) and oxidative stability of beef (CANTO et al., 2016).

Beef *longissimus lumborum* (LL) is composed of glycolytic fibers, whereas *psoas major* (PM) is composed mainly of oxidative fibers (HWANG et al., 2010); both demonstrate differences in chemical composition, affecting texture parameters (STOLOWSKI et al., 2006) and influencing the susceptibility of meat to oxidative deterioration (CANTO et al., 2016).

Among intrinsic factors, breed plays an important role in texture parameters (STOLOWSKI et al., 2006; NIAN et al., 2017). Meat from *Bos indicus* cattle contains higher calpastatin levels than the meat from *Bos taurus* cattle, which in turn negatively affects beef texture (HIGHFILL et al., 2012). In addition, breed also influences the oxidative stability of fresh beef (CANTO et al., 2016). Nellore (*Bos indicus*) cattle are characterized by their excitable temperament, which influences ante mortem handling practices, favoring the process of meat oxidation during the post mortem period.

Diet also influences on texture and oxidative capacity of meat (NIAN et al., 2017). Compared to pasture-fed, meat from grain-fed cattle contains high intramuscular fat content and marbling, which is associated to the increase of juiciness and texture-related scores (NIAN et al., 2017; HWANG et al., 2017). Nevertheless, fresh meat from pasture-fed cattle contains high content of natural antioxidants (TANSAWAT et al., 2013), which in turn, exerts a protective effect against oxidation.

Nonetheless, the present study aimed to investigate the protein oxidation, texture profile and proximate composition of muscles *longissimus lumborum* and *psoas major*, obtained from *Bos indicus* (Nellore) cattle finished in grain, during nine days of storage (4 °C).

MATERIALS AND METHODS

Experimental design

Eight (n=8) carcasses from Nellore (*Bos indicus*) bulls were used in this experiment. The bulls were pasture-fed until 15-21 months of age and subsequently allocated in feedlots, in which were fed with grain-based (corn) diet. The animals were harvested at 18-24 months age in an abattoir with federal inspection service (Espirito Santo, Brazil). After 24 h post mortem the carcasses exhibited an average cold weight of 285.0 kg, and average of muscle pH of 5.55 in LL and 5.67 in PM. After the pH measurement, the LL and PM muscles were excised from the right sides of the carcasses vacuum packed and shipped under refrigeration (4 °C) to the Universidade Federal Fluminense (Niteroi, Rio de Janeiro, Brazil). Five steaks (1.5-cm thick) were cut from each LL and PM muscle and placed individually onto polystyrene trays with absorbent pads, over-wrapped with oxygen-permeable polyvinyl chloride (PVC film;15,500 – 16,275 $cm^3/m^2/24$ h oxygen transmission rate at 23 °C), and assigned for 0, 5 and 9 days of refrigerated (4 °C) storage in darkness. Analyzes of proximate composition and texture profile were performed on day 0, whereas the evaluation of protein oxidation was performed at three different time-points (days 0, 5 and 9). The analyses were performed in duplicate.

Proximate composition

The content of moisture, protein, and ash were determined according to the methodology described by AOAC (2012).The content of total lipid was determined according to BLIGH &DYER(1959).

Texture profile analysis

The texture profile analysis (TPA) was performed using a texture analyzer (TA.XT Plus; Stable Micro System, United Kingdom) equipped with a cylindrical metal probe (72 mm diameter) according to HUIDOBRO et al. (2005). Cubes of 1.0 cm×1.0 cm×1.0 cm were obtained from LL and PM muscles at 10 °C, and subjected to compression of 75% of their height in two cycles: pre-test (3 mm/s), test (1 mm/s), and post-test (3 mm/s), with interval between compressions of 2 s. Each sample was tested four times, and the average of readings were considered before statistical analyses. Texture Exponent Software (Stable Micro System, United Kingdom) was utilized to process the data obtained, expressed as hardness, springiness, cohesiveness and chewiness.

Protein oxidation

Protein oxidation was determined according to OLIVER et al. (1987) with modifications proposed by ARMENTEROS et al. (2009) and MERCIER et al. (1998). LL and PM samples (3 g) were homogenized with 30 mL of KCl (0.15 M; pH 7.4) using a Turrax (T18 basic; IKA, Wilmington, USA) for 90 seconds. The homogenates (0.1 mL) were separated into two parts and added of 1 mL of TCA (10%) and centrifuged (5,000×g/ 5 min) at 4 °C. After discarding the supernatants, the pellets were homogenized with 1 mL of HCl (2 N) or 1 mL of 1 mL of DNPH (10 mM) in HCl (2 N) aiming to obtain the content of protein and carbonyl, respectively. Both homogenates were incubated at 25 °C for 1 h, and periodic vortex was performed every 15 min. Subsequently, 1 mL of TCA (10%) was added to the homogenates, followed by a centrifugation (11,000 × g /10 min) at 4 °C. The pellets were washed three times with 1 mL of ethanol/ethyl acetate (1:1; v/v) and centrifuged (15,000 × g /10 min) at 4 °C. Then, the proteins were dissolved in 1.5 mL of sodium phosphate (20 mM; pH 6.5) and guanidine hydrochloride (6 M) and centrifuged (11,000×g/10 min). The absorbance at 280 nm was utilized to estimate the protein content of the sample, whereas the absorbance at 370 nm and the absorptivity coefficient for the protein hydrazones of 21.0 mM^{-1} cm^{-1} were utilized to determine the carbonyls content. The data obtained was expressed as nmol of carbonyl per mg of protein.

Statistical analysis

The experimental design was completely randomized design with eight (n=8) replications (beef carcasses). One-way ANOVA (XLSTAT software; Version 2014.5.03, Addinsoft, Inc., Brooklyn, USA) was utilized for analyses of texture profile and proximate composition. A two-way ANOVA (XLSTAT software; Version 2014.5.03, Add in soft, Inc., Brooklyn, USA) was utilized for analysis of protein oxidation to assess the effect of muscle (LL and PM) and days of storage (0, 5, and 9). In addition, treatment means were compared using Tukey test at 5% significance level.

RESULTS AND DISCUSSION

Proximate composition

Proximate composition was influenced (P<0.05) by muscle source (Table 1). A greater (P<0.05) protein and lower (P<0.05) ash and lipid contents were observed in LL than in PM steaks. The intramuscular fat content varies with differences in the muscle fiber characteristics (LORENZO et al., 2013). Glycolytic muscles, composed mainly of type IIA and IIB fibers, contain lower lipid contents than the oxidative muscles comprising primarily of type I fibers (HWANG et al., 2010). HWANG et al. (2010) reported correlations between lipid content and fiber area in the muscles (longissimus, psoas major, and semimembranosus) of Hanwoo (*Bos taurus* x *Bos indicus*) cattle; while lipid content was negatively correlated to fiber area of type IIA and IIB, it was positively correlated to the area of type I fibers. In agreement, PATTEN et al. (2008) reported a greater protein and lower fat and ash contents in muscle longissimus than in PM from *Bos taurus* cattle. In addition, BRACKEBUSCH et al. (1991) reported a greater protein and lower fat content in longissimus muscle than in PM from *Bos taurus* carcasses (steers and heifers) with different marbling scores. On contrary, CANTO et al. (2016) did not find differences in the protein and ash content between the LL and PM muscles from grass-fed *Bos indicus* (Nellore) cattle.

Moisture content was not affected (P>0.05) by muscle source. In agreement, previous studies did not observe differences in moisture content of beef longissimus and PM (PATTEN et al., 2008; BRACKEBUSCH et al., 1991). In contrast, CANTO et al. (2016) reported greater moisture in LL steaks than in their PM counterparts from grass-fed *Bos indicus* cattle. Moreover, HWANG et al. (2010) also documented greater moisture in *psoas major* than in longissimus muscle from Hanwoo cattle.

Texture profile analysis

LL exhibited greater (P<0.05) hardness than PM steaks (Table 1). Hardness is related to cross-section area and thickness of muscle fiber (LACHOWICZ et al., 2004). According to CHOI & KIM (2009), muscles with smaller-sized fibers (type IIB fibers) such as LL (HWANG et al., 2010) exhibit greater toughness than muscles of smaller fiber (type I fibers) size such as PM (HWANG et al., 2010). LANG

Table 1 - Proximate composition, and texture profile parameters (hardness, springiness, cohesiveness and chewiness) of LL and PM steaks (n=8) from grain-finished Nellore (*Bos indicus*) cattle.

Parameter	----------------------Muscle---------------------	
	LL	PM
Moisture (%)	74.28±0.69[a]	74.35±1.78[a]
Protein (%)	17.62±0.27[a]	16.93±0.50[b]
Ash (%)	1.19±0.05[b]	1.27±0.09[a]
Lipid (%)	1.18±0.14[b]	2.72±0.31[a]
Hardness (kg)	19.24±2.85[a]	10.53±1.38[b]
Springiness	0.78±0.03[a]	0.71±0.03[b]
Cohesiveness	0.38±0.04[a]	0.32±0.04[b]
Chewiness (kg)	6.09±1.28[a]	2.17±0.44[b]

Results are expressed as mean ± standard error.
[a–b]Means with different superscripts in a row were significantly different (P<0.05).

et al. (2016) and ZOCHOWSKA et al. (2005) reported a correlation of hardness with muscle fiber area and percentage of type IIB fibers. In support, LANG et al. (2016) documented greater hardness in *longissimus thoracis* than in their PM counterparts, from Chinese Simmental cattle. In partial agreement, KOLCZAK et al. (2005) documented lower hardness in PM than in semitendinosus muscle from *Bos taurus* cattle.

LL exhibited greater (*P*<0.05) springiness than PM steaks (Table 1). According to ZOCHOWSKA et al. (2005) springiness is correlated with muscle fiber size. Muscles composed of small fibers (type I) such as PM (HWANG et al., 2010) exhibit lower springiness than muscles composed of large fibers (type IIB) such as LL (HWANG et al., 2010). In partial agreement, KOLCZAK et al. (2005) documented lower springiness in PM than in semitendinosus muscle from *Bos taurus* cattle. On contrary, LANG et al. (2016) reported greater springiness in PM than in longissimus muscle from Chinese Simmental cattle.

LL exhibited greater (*P*<0.05) cohesiveness than PM steaks (Table 1). LANG et al. (2016) reported that muscle composed by type IIB fibers, such as LL (HWANG et al., 2010) exhibited greater cohesiveness than the muscles composed of type I fibers, such as PM (HWANG et al., 2010). In agreement, LANG et al. (2016) documented greater cohesiveness in muscle longissimus than in PM from Chinese Simmental cattle. In partial agreement, KOLCZAK et al. (2005) documented lower cohesiveness in PM than in semitendinosus muscle from *Bos taurus* cattle.

LL exhibited greater (*P*<0.05) chewiness than PM steaks (Table 1). KOLCZAK et al. (2005) reported a correlation between chewiness and the content of muscle fiber type IIB. In support, greater chewiness in longissimus thoracis muscle than in PM counterparts was documented in Chinese Simmental cattle (LANG et al., 2016). In partial agreement, KOLCZAK et al. (2005) documented lower chewiness in PM than in semitendinosus muscle from *Bos taurus* animals.

Protein oxidation

Protein oxidation (carbonyl content) was greater (*P*<0.05) in PM steaks than in their LL counterparts throughout the storage (Figure 1). Muscles composed by muscle fiber type I such as PM (HWANG et al., 2010) exhibited greater myoglobin (CHOI & KIM, 2009), iron (CHIKUNI et al., 2010; UTRERA et al., 2014) and lipid contents than the muscles composed of fiber type IIB such as LL (HWANG et al., 2010). This in turn, leads to the generation of primary and secondary

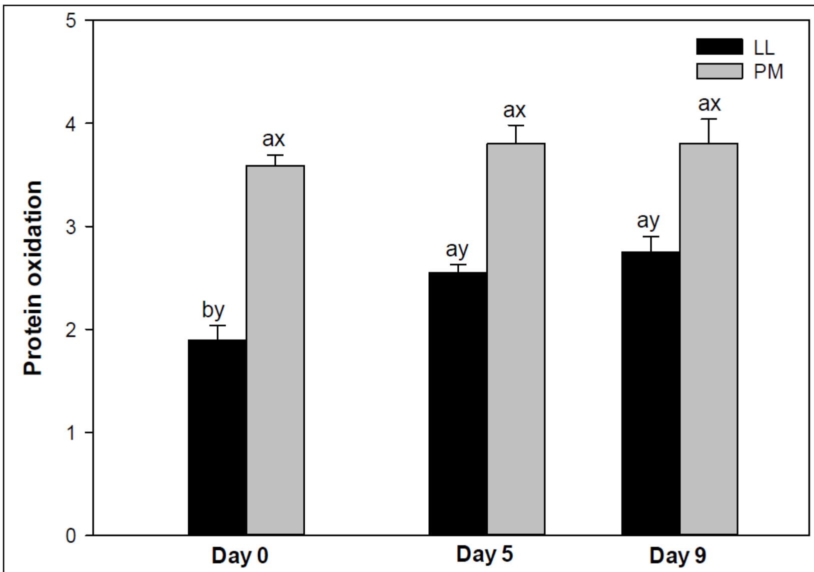

Figure 1 - Protein oxidation of *longissimus lumborum* (LL) and *psoas major* (PM) steaks from grain-finished Nellore (*Bos indicus*) cattle during aerobic storage at 4 ºC for 9 days.

Standard error bars are indicated.
[a–c]Means with different superscripts within a muscle were significantly different (*P*<0.05).
[x–y]Means with different superscripts within a day of storage were significantly different (*P*<0.05).

products, favoring lipid oxidation (FAUSTMAN et al., 2010); and consequently, enhance protein oxidation (FAUSTMAN et al., 2010; ESTEVEZ, 2011). In agreement, UTRERA et al. (2014) reported greater protein oxidation in beef patties prepared from PM than in their counterparts from longissimus during 12 weeks of frozen storage. In partial agreement, CANTO et al. (2016) documented greater protein oxidation in PM than in LL counterparts from grass-fed *Bos indicus* cattle on days 0 and 9 of storage. In contrast, CHIKUNI et al. (2010) documented no differences in the carbonyls content between muscle longissimus and PM from Japanese and Holstein cattle.

The carbonyl content was not affected ($P>0.05$) by storage in PM steaks, whereas LL steaks exhibited an increase in protein oxidation ($P<0.05$) from day 5 of storage (Figure 1). Muscles composed by muscle fiber type I such as PM (HWANG et al., 2010) exhibited greater content of iron (CHIKUNI et al., 2010) than the muscles composed of fiber type IIB such as LL (HWANG et al., 2010). The greater concentrations of iron favor the generation of free radicals, leading to the increase of protein oxidation (ESTEVEZ, 2011) in PM than in LL steaks.

In partial agreement, CANTO et al. (2016) reported an increase of carbonyl content in LL and PM steaks from grass-fed *Bos indicus* cattle. In addition, UTRERA et al. (2014) reported an increase of protein oxidation in beef patties prepared from PM and longissimus muscles during 12 weeks of frozen storage.

CONCLUSION

Muscle source influenced the proximate composition, as well as texture profile and protein oxidation of beef from grain-finished *Bos indicus* animals. A greater oxidative stability and texture-scores were observed in LL than in PM steaks. Muscle-specific strategies are indicated during meat processing in order to improve oxidative stability and texture attributes of beef from grain-finished *Bos indicus* cattle.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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REFERENCES

AOAC, Association of Official Analytical Chemists. **Official methods of analysis**. Washington: AOAC International, 2012. 19th ed.

ARMENTEROS, M. et al. Analysis of protein carbonyls in meat products by using the DNPH-method, fluorescence spectroscopy and liquid chromatography–electrospray ionisation–mass spectrometry (LC–ESI–MS). **Meat Science**, v.83, n.1, p.104-112, Sep. 2009. Available from: <https://doi.org/10.1016/j.meatsci.2009.04.007>. Accessed: Mar. 20, 2018. doi: 10.1016/j.meatsci.2009.04.007.

BLIGH, E. G.; DYER, W. J. A rapid method of total lipid extraction and purification. **Canadian Journal of Biochemistry and Physiology**, v.37, n.8, p.911-917, Aug. 1959. Available from: <http://www.nrcresearchpress.com/doi/pdf/10.1139/o59-099>. Accessed: Mar. 20, 2018. doi: 10.1139/o59-099.

BRACKEBUSCH, S. A. et al. Relationship between longissimus composition and the composition of other major muscles of the beef carcass. **Journal of Animal Science**, v.69, n.2, p.631-640, Feb. 1991. Available from: <https://academic.oup.com/jas/article-abstract/69/2/631/4705555>. Accessed: Apr. 03, 2018. doi: 10.2527/1991.692631x.

CANTO, A. C. V. C. S. et al. Color attributes and oxidative stability of *longissimus lumborum* and *psoas major* muscles from Nellore bulls. **Meat Science**, v.121, p.19-26, Nov. 2016. Available from:<https://doi.org/10.1016/j.meatsci.2016.05.015>. Accessed: Apr. 03, 2018. doi: 10.1016/j.meatsci.2016.05.015.

CHIKUNI, K. et al. Effects of muscle type on beef taste-traits assessed by an electric sensing system. **Animal Science Journal**, v.81, n.5, p.600-605, Oct. 2010. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1740-0929.2010.00773.x>. Accessed: Apr. 05, 2018. doi: 10.1111/j.1740-0929.2010.00773.x.

CHOI, Y. M.; KIM, B. C. Muscle fiber characteristics, myofibrillar protein isoforms, and meat quality. **Livestock Science**, v.122, p.105-118, Jun. 2009. Available from: <https://doi.org/10.1016/j.livsci.2008.08.015>. Accessed: Apr. 03, 2018. doi: 0.1016/j.livsci.2008.08.015.

ESTEVEZ, M. Protein carbonyls in meat systems: A review. **Meat Science**, v.89, n.3, p.259-279, May 2011. Available from: <https://doi.org/10.1016/j.meatsci.2011.04.025>. Accessed: Apr. 10, 2018. doi: 10.1016/j.meatsci.2011.04.025.

FAUSTMAN, C. et al. Myoglobin and lipid oxidation interactions: Mechanistic bases and control. **Meat Science**, v.86, n.1, p.86-94, Sep. 2010. Available from: <https://doi.org/10.1016/j.meatsci.2010.04.025>. Accessed: Apr. 10, 2018. doi: 10.1016/j.meatsci.2010.04.025.

FERRAZ, J. B. S.; FELÍCIO, P. E. Production systems—An example from Brazil. **Meat Science**, v.84, n.2, p.238-243, Feb. 2010. Available from: <https://doi.org/10.1016/j.meatsci.2009.06.006>. Accessed: Mar. 30, 2018. doi: 10.1016/j.meatsci.2009.06.006.

FREITAS, A. K. et al. Nutritional composition of the meat of Hereford and Braford steers finished on pastures or in a feedlot in southern Brazil. **Meat Science**, v.96, n.1, p.353-360, Jul. 2013. Available from: <https://doi.org/10.1016/j.meatsci.2013.07.021>. Accessed: Mar. 28, 2018. doi: 10.1016/j.meatsci.2013.07.021.

HIGHFILL, C. M. et al. Tenderness profiles of then muscles from F1 *Bosindicus* x *Bos taurus* and *Bos taurus* cattle cooked as steaks and roasts. **Meat Science**, v.90, n.4, p.881–886, Nov. 2012. Available from: <https://doi.org/10.1016/j.meatsci.2011.11.022>. Accessed: May, 15, 2018. doi: 10.1016/j.meatsci.2011.11.022.

HUIDOBRO, F. R. et al. A comparison between two methods (warner–bratzler and texture profile analysis) for testing either raw meat or cooked meat. **Meat Science**, v.69, n.3, p.527-536, Mar. 2005. Available from: <https://doi.org/10.1016/j.meatsci.2004.09.008>. Accessed: Apr. 22, 2018. doi: 10.1016/j.meatsci.2004.09.008.

HWANG, Y. H. et al. The relationship between muscle fiber characteristics and meat quality traits of highly marbled ***Hanwoo*** (Korean native cattle) steers. **Meat Science**, v.86, n.2, p.456-461, Oct. 2010. Available from: <https://doi.org/10.1016/j.meatsci.2010.05.034>. Accessed: May, 05, 2018. doi: 10.1016/j.meatsci.2010.05.034.

HWANG, Y. H.; JOO, S.T. Fatty acid profiles, meat quality, and sensory palatability of grain-fed and grass-fed beef from Hanwoo, American, and Australian crossbred cattle. **Korean Journal for Food Science of Animal Resources**, v.37, n.2, p.153-161, Mar. 2017. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5434201/>. Accessed: Aug. 13, 2018. doi: 10.5851/kosfa.2017.37.2.153.

KOLCZAK, T. et al. Water retention, shear force and texture parameters of cattle psoas and semitendinosus muscles unfrozen and frozen during post-mortem ageing. **Polish Journal of Food and Nutrition Sciences**, v.55, n.1, p.17-26, 2005. Available from: <http://journal.pan.olsztyn.pl/WATER-RETENTION-SHEAR-FORCE-AND-TEXTURE-PARAMETERS-OF-CATTLE-PSOAS-AND-SEMITENDINOSUS,97844,0,2.html>. Accessed: May, 15, 2018.

LACHOWICZ, K. et al. Comparison of the texture and structure of selected muscles of piglets and wild boar juveniles. **Polish Journal of Food and Nutrition Sciences**, v.54, n.1, p.75-79, 2004. Available from: <http://agris.fao.org/agris-search/search.do?recordID=PL2004000789>. Accessed: May, 15, 2018.

LANG, Y. et al. Myofiber characteristics and eating quality of three major muscles from Chinese Simmental cattle. **Canadian Journal of Animal Science**, v.97, p.101-108, Jul. 2016. Available from: <http://www.nrcresearchpress.com/doi/pdf/10.1139/cjas-2015-0182>. Accessed: May, 15, 2018. doi: 10.1139/cjas-2015-0182.

LORENZO, J. M. et al. Influence of muscle type on physicochemical and sensory properties of foal meat. **Meat Science**, v.94, n.1, p.77–83, May 2013. Available from: <https://doi.org/10.1016/j.meatsci.2013.01>. Accessed: Aug. 07, 2018. doi: 10.1016/j.meatsci.2013.01.001.

MERCIER, Y. et al. Effect of dietary fat and vitamin E on colour stability and on lipid and protein oxidation in turkey meat during storage. **Meat Science**, v.48, n.3-4, p.301-318, Mar. 1998. Available from: <https://doi.org/10.1016/S0309-1740(97)00113-7>. Accessed: Apr. 22, 2018. doi: 10.1016/S0309-1740(97)00113-7.

NIAN, Y. et al. Physico-chemical and sensory characteristics of young dairy bull beef derived from two breed types across five production systems employing two first season feeding regimes. **Journal of the Science of Food and Agriculture**, v.98, n.5, p.1-13, Sep. 2017. Available from: <https://onlinelibrary.wiley.com/doi/full/10.1002/jsfa.8674>. Accessed: Aug. 01, 2018. doi: 10.1002/jsfa.8674.

OLIVER, C. N. et al. Age-related changes in oxidized proteins. **Journal of Biological Chemistry**, v.262, n.12, p.5488-5491, Abr. 1987. Available from: <https://pdfs.semanticscholar.org/dbc3/f4448f15abf6eca29c618fc55b239525c3a7.pdf>. Accessed: Apr. 22, 2018.

PATTEN, L. E. et al. Chemical properties of cow and beef muscles: Benchmarking the differences and similarities. **Journal of Animal Science**, v.86, n.8, p.1904-1916, Aug. 2008. Available from: <https://doi.org/10.2527/jas.2007-0478>. Accessed: Apr. 22, 2018. Accessed: May, 15, 2018.

STOLOWSKI, G. D. et al. Factors influencing the variation in tenderness of seven major beef muscles from three Angus and Brahman breed crosses. **Meat Science**, v.73, p.475-483, Jul. 2006. Available from: <https://doi.org/10.1016/j.meatsci.2006.01.006>. Accessed: Aug. 01, 2018. doi: 10.1016/j.meatsci.2006.01.006.

TANSAWAT, R. et al. Chemical characterisation of pasture- and grain-fed beef related to meat quality and flavour attributes. **International Journal of Food Science and Technology**, v.48, n.3, p.484-495, Mar, 2013. Available from: <https://doi.org/10.1111/j.1365-2621.2012.03209.x>. Accessed: Apr. 22, 2018. doi: 10.1111/j.1365-2621.2012.03209.x.

UTRERA, M. et al. Protein oxidation during frozen storage and subsequent processing of different beef muscles. **Meat Science**, v.96, n.2, p.812-820, Feb. 2014. Available from: <https://doi.org/10.1016/j.meatsci.2013.09.006>. Accessed: May, 15, 2018. doi: 10.1016/j.meatsci.2013.09.006.

ZOCHOWSKA, K. et al. Effects of carcass weight and muscle on texture, structure and myofibre characteristics of wild boar meat. **Meat Science**, v.71, n.2, p.244-248, Mar. 2005. Available from: <https://doi.org/10.1016/j.meatsci.2005.03.019>. Accessed: May, 15, 2018. doi: 10.1016/j.meatsci.2005.03.019.