Short Communication: Influence of some meat quality parameters on beef tenderness

Rymer R. Tullio[1,2], Manuel Juárez[1], Ivy L. Larsen[2], John A. Basarab[3], and Jennifer L. Aalhus[1,4]

[1]Agriculture and Agri-Food Canada, Lacombe Research Centre, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1; [2]Embrapa Southeast Livestock, Rodovia Washington Luis km 234, São Carlos, SP, Brazil 13560-970; and [3]Alberta Agriculture and Rural Development, Lacombe Research Centre, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1. Received 7 October 2013, accepted 25 April 2014. Published on the web 5 May 2014.

Tullio, R. R., Juárez, M., Larsen, I. L., Basarab, J. A. and Aalhus, J. L. 2014. **Short Communication: Influence of some meat quality parameters on beef tenderness**. Can. J. Anim. Sci. **94**: 455–458. Steaks from longissimus lumborum and semimembranosus muscles, aged 2 or 27 d, were obtained from a population of steers ($n = 112$) managed to produce a range in tenderness (shear force range from 2.57 to 17.2 kg). All available carcass (live weight, hot commercial weight, pH, temperature, marbling, rib-eye area) and meat (objective colour, cook loss, cook time, Warner–Bratzler shear force, myoglobin content, proximate composition and collagen content) quality data were used for the analyses. Multivariate analyses determined which factors influenced tenderness between and within muscles, both before or after ageing. In unaged muscles, soluble collagen explained differences in tenderness among muscles, while factors related to the myofibrillar component explained differences within a muscle. In contrast, in aged muscles, total collagen content was related to tenderness among muscles and the percent soluble collagen content was related to tenderness differences within a muscle.

Key words: Ageing, regression analyses, shear force, texture

Tullio, R. R., Juárez, M., Larsen, I. L., Basarab, J. A. et Aalhus, J. L. 2014. **Communication Brève: Influence de certains paramètres de qualité de viande sur la tendreté du bœuf**. Can. J. Anim. Sci. **94**: 455–458. Des steaks des muscles longissimus lumborum et semimembranosus, maturés 2 ou 27 jours, ont été obtenus d'une population de bovins ($n = 112$) gérés pour la production d'une gamme de tendreté (force de découpe de 2,57 à 17,2 kg). Toutes les données de qualité de carcasse (poids vif, poids commercial à chaud, pH, température, persillage, surface du faux-filet) et de viande (couleur objective, perte d'eau à la cuisson, temps de cuisson, force de découpe Warner Bratzler, teneur en myoglobine, composition en micronutriments et teneur en collagène) ont été utilisées pour les analyses. Les analyses multivariées ont déterminé quels facteurs influençaient la tendreté entre et dans les muscles, soit avant ou après la maturation de la viande. Dans les muscles sans maturation, le collagène soluble expliquait les différences de tendreté entre les muscles, tandis que les facteurs reliés aux composantes myofibrillaires expliquaient les différences dans un même muscle. Au contraire, dans les muscles ayant subi la maturation, la teneur totale en collagène était reliée à la tendreté entre les muscles et le pourcentage de collagène soluble était relié aux différences de tendreté dans un même muscle.

Mots clés: Maturation de la viande, analyses de régression, force de découpe, texture

Tenderness is one of the most important meat quality attributes affecting consumer satisfaction and positive perception of beef (Jayasooriya et al. 2007). The mechanism of tenderization is complex and affected by a number of variables, including animal age and gender, rate of glycolysis, amount and solubility of collagen, sarcomere length, ionic strength, and degradation of myofibrillar proteins (Koohmaraie 1994). Due to complex relationship between carcass and meat palatability traits, multivariate analysis represents an alternative to obtain reliable predictors for beef tenderness and palatability (Jerez-Timaure et al. 2013). The aim of this study was to evaluate the multivariate relationship between beef carcass and meat quality parameters and shear force.

All dietary treatments and experimental procedures were approved by the Lacombe Research Centre Animal Care Committee and the animals were cared for in accordance with guidelines established by the Canadian Council on Animal Care in Science (Canadian Council on Animal Care 2009). One hundred and twelve steers (Continental × British breed-cross) from the Agriculture and Agri-Food Canada Lacombe Research Centre were arranged in two production systems (calf-fed vs. yearling-fed) described in detail by Basarab et al. (2007) and Basarab et al. (2011) to create a wide range in tenderness (from 2.57 to 17.2 kg).

Steers were targeted for slaughter at a constant backfat end point of 8 to 9 mm as determined by ultrasound measurements (using an Aloka 500W diagnostic real time

[4]Corresponding author (e-mail: jennifer.aalhus@agr.gc.ca).

ultrasound machine with a 172 mm 3.5 Mhz linear array transducer; Overseas Monitor Corporation Ltd., Richmond, BC). Steers were stunned, exsanguinated and dressed at the federally inspected research abattoir of the Lacombe Research Centre, where procedures are in accordance with current commercial practices. Carcasses were then weighed and chilled overnight at 2°C. At the time of slaughter, final live and hot carcass weights were obtained from all steers. At 24 h after slaughter, carcasses were knife-ribbed at the grade site between the 12th and 13th ribs, and assessed for longissimus thoracis area (−9) and marbling (USDA 1989) by two certified graders. Temperature and pH were measured at 45 min and 24 h after slaughter (Hanna HI9025C pH meter, Hannah Instruments, Mississauga, ON). The longissimus lumborum and semimembranosus muscles were removed and trimmed of subcutaneous fat and overlying muscles prior to meat quality analyses. Controlling by location within steak, both muscles were cut into steaks (2.54 cm thickness). The steaks were aged for 2 or 27 d post mortem, in order to analyse the texture, and to determine proximate composition. Samples were labelled, individually vacuum packaged (Ultravac Model UV2100; Koch Instruments, Kansas City, MO) and aged in a cooler at 2°C.

After 2 or 27 d of ageing, steaks were removed from vacuum packaging and objective colour measurements, proximate analyses, shear force determinations, myoglobin components and soluble and insoluble collagen content were measured on both muscles. Objective colour measurements were recorded three times per steak for lightness (L^*), red-green spectral (a^*) and yellow-blue spectral (b^*) using a Minolta CR300 with Spectra QC-300 Software (Minolta Canada Inc., Mississauga, ON). Chroma and hue were determined as chroma ($\text{Cab} = \sqrt{a^{*2} + b^{*2}}$) and hue ($h_{ab} = \arctan\ b^*/a^* \times 57.296$). Metmyoglobin, myoglobin and oxymyoglobin contents were determined based on reflex attenuance of incident light by interpolation of the isobestic points at 473, 525, 572, and 730 nm (Krzywicki 1979). For shear force determination (Juárez et al. 2012b), steaks were grilled (Garland Grill ED30B, Condon Barr Food Equipment Ltd., Edmonton, AB) preheated to approximately 210°C, to an internal temperature of 35°C, turned and cooked to a final internal temperature of 71°C, cooled overnight in a 1°C cold room to determine cook losses. Six cores, 1.9 cm in diameter, were removed parallel to the fiber grain and peak shear force was determined on each core perpendicular to the fibre grain using a TA-XT Plus Texture Analyzer equipped with a Warner–Bratzler shear head at a crosshead speed of 20 cm min^{-1} using a 30-kg load cell and Texture Exponent 32 Software (Texture Technologies Corp., Hamilton, MA). Peak shear force was expressed as the average of results from the six cores. For proximate analysis, the steaks were trimmed of all subcutaneous fat and finely comminuted (Robot Coupe Blixir BX3; Robot Coupe USA INC., Ridgeland, MS). Moisture content was determined as the weight lost during heating 100 g of ground tissue at 102°C for 24 h until constant weight was reached (VWR Scientific Model 1370M; Mississauga, ON). After that, samples were analyzed for crude protein [Association of Official Analytical Chemists (AOAC), 1995; Official Method 981.10] and crude intramuscular fat extracted with petroleum ether (AOAC 1995; Official Method 991.36). Soluble and insoluble collagen contents were quantified by determination of the hydroxyproline content with a modified version of Bergman and Loxley (1963) and Hill (1966). The factor 7.52 was used to convert the hydroxyproline content to the soluble collagen content (Cross et al. 1973) and the factor 7.25 was used to convert to insoluble collagen content (Goll et al. 1963).

Data were analyzed using MIXED model Covtest procedure of SAS software (PROC MIXED) and stepwise regression techniques (PROC REG) procedures of SAS software. Tests for colinearity were performed, and related variables were entered as a group. The independent variable entered into the model when significant at $P < 0.15$.

The mean, minimum, and maximum values for live weight of the animals were 651, 493 and 849 kg, respectively. The average hot carcass weight was 386 kg (minimum 295 kg and maximum 510 kg), with a hot carcass dressing value of 59.29%. The mean, minimum, and maximum values for rib-eye area and marbling were 89.0, 65.0, 120.0 cm^2, and 484, 380, 680, respectively. The minimum and maximum values for hot carcass weight were similar to those reported by McGilchrist et al. (2012), although rib-eye area was higher in the present study. The Continental × British cross-breeding and the production systems led to this great variation in live weight and, consequently, in hot carcass weight, rib-eye area and marbling. Values for pH ranged between 5.53 and 6.11, with an average of 5.70 (only three were above 5.9). Since the post-slaughter handling was similar for all carcasses, this variation is due to variations in genotype and production system as well as inherent individual responses to pre-slaughter management.

Shear force decreased with ageing ($P < 0.05$) in both muscles (Table 1). However, while in the longissimus muscle shear force decreased by 49%, in the semimembranosus muscle the decrease was only 27%. Previous studies (Juárez et al. 2010) have shown a range in response to ageing among different muscles. During ageing, enzymatic and osmotic processes affect myofibrillar breakdown. Following rigor shortening, which occurs in the longissimus muscle in a hanging carcass, denaturation and proteolytic degradation of the myofibrillar proteins result in a continuous improvement in tenderness over time. In the semimembranosus muscle, limited improvement to tenderness occurs, despite similar environmental conditions for denaturation and proteolysis. This may in part be due to an initial limited rigor contraction, which occurs due to the slower rate of

Table 1. Interactive effect of muscle × ageing time for muscle quality parameters in the longissimus lumborum and semimembranosus of beef aged for 2 or 27 d

	Muscle				
	Longissimus		Semimembranosus		
	Days of ageing		Days of ageing		
Quality parameters	2	27	2	27	SEM
Shear force (kg)	9.15*a*	4.65*d*	7.89*b*	5.76*c*	0.25
Collagen (mg g^{-1})					
Insoluble	2.15*b*	2.15*b*	2.74*a*	2.69*a*	0.10
Soluble	0.26*b*	0.31*a*	0.19*c*	0.17*c*	0.01
Total	2.40*b*	2.45*b*	2.93*a*	2.86*a*	0.10
Cook loss (mg g^{-1})	202*b*	208*b*	265*a*	263*a*	6.31
Cook time (s g^{-1})	4.20*a*	4.09*ab*	3.76*bc*	3.65*c*	0.18
Moisture (%)	72.5*a*	71.4*c*	72.7*a*	72.3*b*	0.25
Fat (%)	3.76*a*	4.14*a*	2.31*b*	2.70*b*	0.26
Protein (%)	22.8*b*	23.4*a*	23.8*a*	23.8*a*	0.17
Metmyoglobin	0.13*d*	0.23*b*	0.19*c*	0.31*a*	0.01
Myoglobin	0.23*a*	0.19*b*	0.09*c*	0.07*c*	0.01
Oxymyoglobin	0.63*b*	0.58*c*	0.72*a*	0.62*b*	0.01
L^*	38.6*a*	39.2*a*	36.7*b*	38.7*a*	0.37
Chroma (%)	22.2*b*	19.7*d*	25.4*a*	21.5*c*	0.29
Hue (°)	34.7*c*	38.9*b*	35.7*c*	42.6*a*	0.48
pH	5.67	5.67	5.64	5.65	0.02

a–d Means in the same line with different letters are significantly different ($P < 0.05$).

temperature decline in the deep muscle of the hip (Aalhus et al. 2004). Total and insoluble collagen contents and cook loss were higher in semimembranosus muscle, but no ageing effect was observed for these traits ($P < 0.05$). Soluble collagen was higher in longissimus and it increased at 27 d of ageing for this muscle only ($P < 0.05$). Fat content was higher ($P < 0.05$) in longissimus, compared to semimembranosus.

As expected, the relative proportion of metmyoglobin significantly increased ($P < 0.05$) during ageing to a similar extent in both muscles. On the other hand, ageing decreased the relative proportion of oxymyoglobin in both muscles ($P < 0.05$). The content for both traits was always higher in semimembranosus. The results for metmyoglobin were similar to those found by Lindahl (2011). However, this author did not report differences in oxymyoglobin in muscles aged for 5 or 25 d. Higher L^* values were obtained after 14 and 28 d of ageing compared with the non-aged samples (Polak et al. 2009). However, this was only observed in the semimembranosus muscle in the present study ($P < 0.05$).

The summary of regression analyses for predicting overall shear for both muscles is presented in Table 2. After 2 d of ageing, the percentage of soluble collagen and proximate composition (moisture, fat and protein content) accounted for most of the explainable variation observed in shear force values (42%) for the combined data from longissimus and semimembranosus muscles. While proteolysis is the major determinant of longissimus tenderness, connective tissue content is a major contributor to tenderness of semimembranosus muscle (Koohmaraie et al. 2002).

However, when the individual muscles were evaluated, colour traits (L^* and chroma), cook loss, and live and hot carcass weights had the largest influence on shear force values for both longissimus and semimembranosus muscles. The variability in collagen solubility within each muscle after 2 d of ageing is much lower than among muscles and its influence on shear force values is minimal compared to other meat quality traits.

After 27 d of ageing, when data from both muscles were included in the analysis, the most influential traits were again related to collagen (total collagen) and proximate composition (moisture fat and protein). This time, when quality traits from individual muscles were used to predict shear force values, for both longissimus and semimembranosus muscles, the percentage of soluble collagen became the most important variable in the regression analysis, followed again by proximate composition. This seems to indicate that while soon after slaughter the influence of collagen solubility on shear force is only responsible for differences among muscles, the ageing process within each individual muscle leads to a stronger impact of collagen solubility on the final tenderness of beef. At the same time, total collagen content has greater impact on tenderness between muscles after ageing.

Table 2. Summary of regression analyses for predicting overall shear when muscles [longissimus lumborum (LL) and semimembranosus (SM)], aged for 2 or 27 d, are combined and when analysed separately

Muscle	R^2	Factors included
		Shear force – 2 d
LL and SM	0.416	% soluble collagen, moisture, fat, protein, metmyoglobin, myoglobin, L^*, chroma, cook loss, live weight, hot commercial weight and initial temperature
LL	0.531	Chroma, cook loss, live weight, hot commercial weight, marbling, initial ph and temperature
SM	0.349	L^*, cook loss, live weight and hot commercial weight
		Shear force – 27 d
LL and SM	0.440	Total collagen, moisture, fat, protein, chroma, cook loss, rib eye area and marbling
LL	0.449	% soluble collagen, moisture, fat, protein, metmyoglobin, myoglobin, cook time, live weight, hot commercial weight, rib eye area and marbling
SM	0.479	% soluble collagen, moisture, fat, protein, chroma, cook loss and rib eye area

Any variable within the model is statistically significant ($P < 0.05$).

The pattern of tenderization for individual muscles can be quite variable over extended ageing times (Juárez et al. 2010). While inter-muscular variations in texture are usually explained by their different fat and moisture content, shape, sarcomere length, fibre type and connective tissue, the evolution of different texture parameters during ageing are more related to the extent of post-mortem rigor shortening (Olsson et al. 1994), myofibrillar proteolysis, moisture loss and collagen breakdown content (Juárez et al. 2012a). Numerous studies report that breakdown of actomyosin bonds occurs through enzymatic proteolysis by the calpains or cathepsins (Koohmaraie 1994; Koohmaraie et al. 2002) leading to an increase in beef tenderness. This is not as important in muscles with high collagen content (Juárez et al. 2010). However, the model did not explain the totality of variation in beef shear force. Some of the potential factors that could contribute to this variation are related to fibre type, sarcomere length and metabolic enzyme activity.

Results from the present study confirm that, while collagen solubility is related to tenderness differences among muscles, other factors related to the myofibrillar component are more important to tenderness within a muscle prior to ageing. However, following an extended post-mortem ageing the total content of collagen was most significantly related to tenderness among muscles, while the percent soluble collagen content was most significantly related to tenderness within a muscle. Further research should evaluate the interactions among these and other quality factors and their influence on final beef tenderness.

Financial support was received from the Alberta Livestock and Meat Agency Ltd., Alberta Agriculture and Rural Development (ARD), Agriculture and Agri-Food Canada (AAFC) Matching Initiatives Program, Alberta Environment and Elanco Animal Health. The authors gratefully acknowledge the in-kind contribution in animals, facilities and manpower received from AAFC–Lacombe. Rymer Ramiz Tullio is grateful to the Brazilian Agricultural Research Corporation, Brazil, for financial assistance during post-doctoral fellowship.

Aalhus, J. L., Dugan, M. E. R., Robertson, W. M., Best, D. R. and Larsen, I. L. 2004. A within-animal examination of postmortem ageing for up to 21 d on tenderness in the bovine longissimus thoracis and semimembranosus muscles. Can. J. Anim. Sci. **84**: 301–304.

Association of Official Analytical Chemists. 1995. Official methods of AOAC International, 16th ed. AOAC, Washington, DC.

Basarab, J. A., Colazo, M. G., Ambrose, D. J., Novak, S., McCartney, D. and Baron, V. S. 2011. Residual feed intake adjusted for backfat thickness and feeding frequency is independent of fertility in beef heifers. Can. J. Anim. Sci. **91**: 573–584.

Basarab, J. A., McCartney, D., Okine, E. K. and Baron, V. S. 2007. Relationships between progeny residual feed intake and dam productivity traits. Can. J. Anim. Sci. **87**: 489–502.

Bergman, I. and Loxley, R. 1963. Two improved and simplified methods for the spectrophotometric determination of hydroxyproline. Anal. Chem. **35**: 1961–1965.

Canadian Council on Animal Care in Science. 2009. CCAC guidelines on: the care and use of farm animals in research, teaching and testing. CCAC, Ottawa, ON.

Cross, H. R., Carpenter, Z. L. and Smith, G. C. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. **38**: 998–1003.

Goll, D. E., Bray, R. W. and Hoekstra, W. G. 1963. Age-associated changes in muscle composition. The isolation and properties of a collagenous residue from bovine muscle. J. Food Sci. **28**: 503–509.

Hill, F. 1966. The solubility of intramuscular collagen in meat animals of various ages. J. Food Sci. **31**: 161–166.

Jayasooriya, S. D., Torley, P. J., D'Arcy, B. R. and Bhandari, B. R. 2007. Effect of high power ultrasound and ageing on the physical properties of bovine Semitendinosus and Longissimus muscles. Meat Sci. **75**: 628–639.

Jerez-Timaure, N., Huerta-Leidenz, N., Ortega, J. and Rodas-Gonzalez, A. 2013. Prediction equations for Warner-Bratzler shear force using principal component regression analysis in Brahman-influenced Venezuelan cattle. Meat Sci. **93**: 771–775.

Juárez, M., Aldai, N., López-Campos, Ó., Dugan, M. E. R., Uttaro, B. and Aalhus, J. L. 2012a. Beef texture and juiciness. Pages 177–206 *in* Y. H. Hui, ed. Handbook of meat and meat processing. CRC Press, Boca Raton, FL.

Juárez, M., Dugan, M. E. R., Aldai, N., Basarab, J. A., Baron, V. S., McAllister, T. A. and Aalhus, J. L. 2012b. Beef quality attributes as affected by increasing the intramuscular levels of vitamin E and omega-3 fatty acids. Meat Sci. **90**: 764–769.

Juárez, M., Larsen, I. L., Gibson, L. L., Robertson, W. M., Dugan, M. E. R., Aldai, N. and Aalhus, J. L. 2010. Extended ageing time and temperature effects on quality of sub-primal cuts of boxed beef. Can. J. Anim. Sci. **90**: 361–370.

Koohmaraie, M. 1994. Muscle proteinases and meat aging. Meat Sci. **36**: 93–104.

Koohmaraie, M., Kent, M. P., Shackelford, S. D., Veiseth, E. and Wheeler, T. L. 2002. Meat tenderness and muscle growth: is there any relationship? Meat Sci. **62**: 345–352.

Krzywicki, K. 1979. Assessment of relative content of myoglobin, oxymyoglobin and metmyoglobin at the surface of beef. Meat Sci **3**: 1–10.

Lindahl, G. 2011. Colour stability of steaks from large beef cuts aged under vacuum or high oxygen modified atmosphere. Meat Sci. **87**: 428–435.

McGilchrist, P., Alston, C. L., Gardner, G. E., Thomson, K. L. and Pethick, D. W. 2012. Beef carcasses with larger eye muscle areas, lower ossification scores and improved nutrition have a lower incidence of dark cutting. Meat Sci. **92**: 474–480.

Olsson, U., Hertzman, C. and Tornberg, E. 1994. The influence of low temperature, type of muscle and electrical stimulation on the course of rigor mortis, ageing and tenderness of beef muscles. Meat Sci. **37**: 115–131.

Polak, T., Andrenšek, S., Žlender, B. and Gašperlin, L. 2009. Effects of ageing and low internal temperature of grilling on the formation of heterocyclic amines in beef Longissimus dorsi muscle. LWT Food Sci. Technol. **42**: 256–264.

USDA. 1989. Official U.S. standards for grades of carcass beef. USDA, Washington, DC.