EFFECT OF QUALITY PARAMETERS ON BEEF MEAT TENDERNESS

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Abstract – Multivariate analysis represents an alternative to obtain reliable predictors for beef tenderness and palatability. Steaks from one-hundred and twelve steers were vacuum-packed and aged for 2 and 27 days. Objective colour, Warner Bratzler shear forces, pH, cook loss, cook time, myoglobin forms, proximate analysis, collagen content and marbling were determined. Differences (*P*<0.05) were found in soluble collagen, shear force, moisture, protein, myoglobin components, and colour parameters for the *longissimus* muscle and shear force, myofibrillar, moisture, myoglobin components, and colour parameters for *semimembranosus* muscle. For collagen content, only soluble collagen in the *longissimus* was affected by ageing (*P*<0.05). Shear force decreased in both muscles (*P*<0.05). After 2 days of ageing, soluble collagen and proximate composition accounted for most of the explainable variation observed in shear force values from both muscles when the data were combined, but this was not observed using data from the individual muscles. After 27 days of ageing, total collagen and proximate composition explained most of the variability for shear force between (total collagen) and within (% soluble collagen) muscles. Thus, total collagen content is related to tenderness differences among muscles and soluble collagen content is related to tenderness changes associated with ageing.

Key Words – Ageing, Regression analyses, Shear force, Texture.

- INTRODUCTION

The term quality includes many factors. Colour and texture are among the main ones, with texture being identified as the most important for consumers [1]. In fact, tenderness is one of the most important quality attributes affecting consumer satisfaction and positive perception of beef [2]. The mechanism of tenderization is complex and affected by a number of variables. Over the years, the following variables have been proposed to influence meat tenderness: animal age and gender, rate of glycolysis, amount and solubility of collagen, sarcomere length, ionic strength, and degradation of myofibrillar proteins [3]. Due to complex relationship between carcass and meat palatability traits, multivariate analysis represents an alternative to obtain reliable predictors for beef tenderness and palatability [4]. The aim of this study was to evaluate the multivariate relationship between quality parameters and shear force of beef meat.

- MATERIALS AND METHODS

One hundred and twelve steers (Continental × British breed-cross) from the Agriculture and Agri-Food Canada Lacombe Research Centre were arranged in production systems described in detail by Basarab *et al.* [5] to create a wide range in tenderness. Steers were slaughtered at a constant backfat end point of 8 to 9 mm as determined by ultrasound measurements. Carcasses were then weighed and chilled at 2°C overnight for 24 h. Temperature and pH were measured at 45 min and 24 h after slaughter (Hanna HI9025C pH metre, Hannah Instruments, Mississauga, ON, Canada). Marbling [6] and *longissimus thoracis* area (REA) were assessed between the 12th and 13th ribs. At 24 h after slaughter, the *longissimus* and *semimembranosus* muscles were removed and trimmed of subcutaneous fat and overlying muscles for subsequent analyses. Two steaks (2.54 cm thickness) of the *longissimus* and *semimembranosus* muscles were aged for 2 or 27 days. Samples were individually labeled, vacuum packaged (Ultravac Model UV2100; Koch Instruments, Kansas City, MO, USA) and placed in a cooler at 2°C. After 2 or 27 days of ageing steaks were removed from vacuum packaging. 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, Canada). Chroma and hue were determined as chroma (C_{ab}=) and hue (h_{ab}=arctan × 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 [7]. For shear force determination, steaks were grilled (Garland Grill ED30B; Condon Barr Food Equipment Ltd., Edmonton, AB, Canada) to a final temperature of 71°C. Steaks were placed into polyethylene bags, sealed and immediately immersed in ice-water to prevent further cooking. The next day, steak weights were recorded for determination of cook loss and six cores, 1.9 cm in diameter, were removed parallel to the fiber grain and peak shear force determined on each core perpendicular to the fiber grain using a TA-XT Plus Texture Analyzer equipped with a Warner-Bratzler shear head (Texture Technologies Corp., Hamilton, MA, USA). Peak shear force was expressed as the average of the six cores. For proximate analysis, the steaks were finely comminuted (Robot Coupe Blixir BX3; Robot Coupe USA INC., Ridgeland, MS USA). Moisture content was determined as the weight lost during heating 100 g of ground tissue at 102°C for 24 h until constant weight (VWR Scientific Model 1370M; Mississauga, ON, Canada). After that, samples were analyzed for crude protein and crude intramuscular fat extracted with petroleum ether [8]. Soluble and insoluble collagen contents were quantified by determination of the hydroxyproline content with a modified version of Bergman & Loxley [9] and Hill [10].

Data were analyzed using mixed model (PROC MIXED) and stepwise regression techniques (PROC REG) procedures of SAS. Tests for colinearity were performed, and related variables were entered as a group. The independent variable entered into the model when its value was <0.15.

- RESULTS AND DISCUSSION

The results of basic carcass traits are shown in Table 1.

Table 1 Descriptive statistics for basic carcass traits

Carcass trait	Average	Min	Max	sem
Live Weight, kg	651	493	849	6.12
Hot carcass weight, kg	386	295	511	3.76
Rib eye area, cm^2	89.0	65.0	120.0	0.70
Marbling	484	380	680	4.36
pH 45 min	6.82	6.37	7.14	0.01
Temperature 45 min, °C	38.4	35.6	40.6	0.07
pH 24 h	5.70	5.53	6.11	0.01

The mean, minimum, and maximum values for live weight of the animals were 651, 493 kg, and 849 kg, respectively. The hot carcass weight was 386 kg, with a hot carcass dressing value of 59.29%.

The mean, minimum, and maximum values for REA 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.* [11]. These authors presented lower values for REA than the values presented in this present study. The descriptive parameters of muscle *longissimus* and *semimembranosus* aged for 2 or 27 days are present in Table 2. Differences were observed (P<0.05) in soluble collagen, shear force, moisture, protein, myoglobin components, and colour parameters for the *longissimus* muscle, and shear force, moisture, myoglobin components, and colour parameters for *semimembranosus* muscle. Ageing had no effect (P>0.05) on insoluble and total collagen, cook loss, cook time, fat, and pH for both muscles. While ageing had no effect (P>0.05) for soluble collagen, protein and myoglobin for *semimembranosus* muscle, for *longissimus* muscle, ageing had no effect (P>0.05) on L^*. For collagen content, only soluble collagen was affected by ageing (P<0.05), increasing from 0.26 to 0.31 mg/g for the *longissimus* muscle aged 2 or 27 days, respectively. Shear force decreased (P<0.05) in both muscles. However, while in *longissimus* muscle shear force decreased 49%, in the *semimembranosus* muscle the decrease was only 27%.

Table 2 Descriptive statistics for muscle quality parameters in the *longissimus* and *semimembranosus* of beef aged for 2 or 27 days

Quality parameters	Muscle				
	longissimus		*semimembranosus*		sem
	Days of ageing		Days of ageing		
	2	27	2	27	
Collagen, mg/g					
Insoluble	2.15	2.15	2.74	2.69	0.10
Soluble	0.26^b	0.31^a	0.19	0.17	0.01
Total	2.40	2.45	2.93	2.86	0.10
Shear Force, kg	9.15^a	4.65^b	7.89^a	5.76^b	0.25
Cook loss, mg/g	201.8	207.6	265.0	262.8	6.31
Cook time, sec/g	4.20	4.09	3.76	3.65	0.18
Moisture, %	72.50^a	71.40^b	72.71^a	72.27^b	0.25
Fat, %	3.76	4.14	2.31	2.70	0.26
Protein, %	22.78^b	23.36^a	23.80	23.83	0.17
Metmyoglobin	0.13^b	0.23^a	0.19^b	0.31^a	0.01
Myoglobin	0.23^a	0.19^b	0.09	0.07	0.01
Oxymyoglobin	0.63^a	0.58^b	0.72^a	0.62^b	0.01
L^*	38.64	39.17	36.73^b	38.68^a	0.37
Chroma, %	22.20^a	19.66^b	25.36^a	21.50^b	0.29
Hue, °	34.69^b	38.88^a	35.68^b	42.57^a	0.48
pH	5.67	5.67	5.64	5.65	0.02

^{a,b}Means in the same line with different superscripts, inside each muscle, are significantly different (P<*0.05*).

The content of metmyoglobin significantly increased (P<0.05) during ageing to a similar extent in both the *longissimus* and *semimembranosus*. On the other hand, ageing decreased the oxymyoglobin content in both muscles (P<0.05). The results for metmyoglobin were similar to those found by Lindahl [12]. However, this author did not report differences in oxymyoglobin for the muscles aged for 5 or 25 days.

The summary of regression analyses for predicting overall shear for both muscles is presented in Table 3.

After two days 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. Widely reported differences in collagen content between these muscles explain these results. While proteolysis is the major determinant of *longissimus* tenderness, connective tissue content is a major contributor to tenderness of *semimembranosus* muscle [13].

Table 3 Summary of regression analyses for predicting overall shear when muscles (*longissimus* – LL and *semimembranosus* – SM), aged for 2 or 27 days, are combined and when analysed separately

Muscle	R^2	Factors included
		Shear force - 2 Day
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 Day
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

However, when the individual muscles were evaluated, colour traits (*L** and chroma), cook loss and live and carcass weights had the largest influence on shear force values for both *longissimus* and *semimembranosus* muscles. The variability in collagen within each muscle after two days 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 days 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 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.

The pattern of tenderization for individual muscles can be quite variable over extended ageing times [14]. 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 , myofibrillar proteolysis, moisture loss and collagen breakdown [15]. Numerous studies report that breakdown of actomyosin bonds occur through enzymatic proteolysis by the calpains or cathepsins [3,13], leading to an increase in beef tenderness. However, this is not as important in muscles with high collagen content [14].

- CONCLUSION

Results from the present study appear to confirm that while collagen content is related to tenderness differences among muscles, other factors related to the myofibrillar component are more important to tenderness prior to ageing. However, following an extended *post-mortem* ageing the percent soluble collagen content was most significantly related to tenderness.

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