THE INTERRELATIONSHIP BETWEEN SENSORY TENDERNESS AND WARNER BRATZLER SHEAR FORCE OF THREE MUSCLES AS INFLUENCED BY VARIOUS PRODUCTION AND POST-HARVEST CONDITIONS

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Abstract – This paper describes the linear relationship between sensory tenderness and Warner Bratzler shear force (WBSF) for the longissimus (LL), biceps femoris (BF) and semitendinosus (ST muscles of beef cattle of various ages finished on grass- and grain-feeding systems. Grain-fed cattle were supplemented with a beta agonist or no beta agonist. All muscles were aged for either 3 or 21 days. LL and ST were prepared according to a dry-heat cooking method and ST according to a moist-heat cooking method. Linear regression components for the three muscles were different suggesting that a single WBSF value cannot be used unilaterally for all muscles as threshold value for sensory tenderness. Slope and intercept differences among the regression equations suggest that pre-slaughter, slaughter and post-slaughter conditions will influence myofibrillar and connective tissue properties of different muscles probably creating unique predictions equations for different conditions and/or muscles.

Key Words – beef, modeling, animal age, beta agonist.

I. INTRODUCTION

Many studies have been conducted in Australia, USA and other countries to relate objective measurements of tenderness to sensory assessments by trained or consumer panels [1, 2, 3, 4]. Statistical models resulting from these studies are used to predict sensory tenderness without the need of expensive sensory tests. In addition, the models are used to determine threshold values for benchmarking meat tenderness at consumer level and to segregate cuts or carcasses into categories of tenderness acceptability [5, 6, 7]. Most of the studies under discussion used the longissimus muscle (LL) as reference and some assumed that a the same model or WBSF value could be used to benchmark sensory tenderness of different muscles in the carcass [7]. In contrast Shackelford et al. [8] reported different models for different muscles. Furthermore, the relationship between WBSF and sensory tenderness ranged from very weak for the gluteus medius (r^2 = 0.00) to strong for the LL (r^2 = 0.73)[8]. One reason for this result could be that young grain-fed cattle were used in their study so that the range across WBSF values for the LL was much broader than those for biceps femoris (BF) and semitendinosus (ST) of due to extensive ageing, while for high connective tissue cuts like the ST and BF range was narrow. Shorthouse and Harris [1] reported larger increases in WBSF for high connective tissue cuts compared to low connective tissue cuts over a range of age categories of slaughter animals. It is therefore possible that in a dataset where age through connective tissue properties and post mortem ageing through myofibrillar properties may have different effects on the relationships of WBSF and sensory tenderness for different muscles [9].

We investigated the relationship between WBSF and tenderness as recorded by trained sensory panel of three different muscles from cattle of different age groups and different feeding regimes. In addition, within the grain-fed group we created variation by means of a beta agonist (BA). Linear equations for three different muscles were obtained.

II. MATERIALS AND METHODS

Bonsmara steers of different age (based on permanent incisors, p.i.)[10] and feeding regimes were used. Twenty each of AB– (1-2 p.i.) and B–age (4-6 p.i.) steers purchased as slaughter animals from a commercial farmer represented two grass-fed groups. Thirty weaner steers representing the A–age group (0 p.i.) were grain-fed under commercial feedlot conditions for approximately 110 days. Fifteen steers were supplemented with a BA (zilpaterol) (AZ) for the final 30 days followed by 2 days withdrawal. The remaining fifteen received no zilpaterol, and were used as the control group (AC). Animals were slaughtered and carcasses electrically stimulated. LL, BF and ST muscles were sampled, vacuum-packaged and aged for 3 and 21 days at 1-2°C, and stored frozen at -20°C.

For WBSF and sensory analyses, LL (from first three lumbar vertebrae) and ST (from the mid-section) steaks were oven broiled (dry heat cooking method) [11], while BF muscle was prepared according to a moist heat cooking method to an internal temperature of 70°C. Six cylindrical samples (12.5 mm core diameter) of each steak used for WBSF were cored parallel to the grain of the meat, and sheared perpendicular to the fibre direction using a Warner Bratzler shear device mounted on an Universal Instron apparatus (cross head speed = 200 mm/minute, one shear in the centre of each core). The reported value in kg represented the average of the peak force measurements of each sample. For sensory analysis, cubes of approximately one square cm were cut from the centre of each steak (avoiding the dryer sides), wrapped in coded aluminium foil and presented to 10 trained panelists to evaluate the overall tenderness, i.e. the impression of tenderness while chewing with a light chewing action. Panelists were trained to score an 8 for extremely tender and a score of 1 for extremely tough samples. The results of the 10 panelists for each muscle sample were averaged for a final overall tenderness score.

Data were explored using the Modelling data function of XLSTAT 2015 for summary statistics and preliminary exploration of linear regressions with log WBSF as dependent variable and sensory tenderness score as independent variable. Log transformation was done to improve variance homogeneity.

III. RESULTS AND DISCUSSION

The dataset consisted of 140 observations for each muscle. The difference between the highest and lowest WBSF values ranged between 5 (BF and ST) and 8 kg (LL), while that of sensory scores ranged between 4 (ST and LL) and 5 (BF)(Table 1). Shackelford et al. [8] and Rhee et al. [12] that used the same protocols as our study recorded much smaller ranges in WBSF and sensory tenderness for all three muscles.

Table 1 Summary statistics for three muscles

Muscle/attribute	Min.	Max.	Mean	s.d.
LL: WBSF	2.6	10.6	4.6	1.26
LL: Tenderness	2.3	6.5	4.6	0.93
BF: WBSF	3.2	8.3	5.0	1.18
BF: Tenderness	1.8	6.0	3.7	0.98
ST: WBSF	3.1	8.4	5.1	0.97
ST: Tenderness	2.2	6.0	4.1	0.94

LL - *m. longissimus lumborum;* BF - *m. biceps femoris*; ST - *m. semitendinosus*; WBSF – Warner Bratzler shear force; Min. - minimum value; Max. – maximum value; s.d. – standard deviation.

ST showed the best linear relationship between sensory tenderness and WBSF (r^2=0.644), followed by BF (r^2=0.547) and LL (r^2=0.537). Similar predictability scores were recorded for LL by other studies [3, 8, 12] but Hopkins et al. [4] recorded much lower (11% - 17%) predictability scores between WBSF and consumer panel scores which they accounted to a narrow range across their sensory scores. For the same reason Shackelford et al. [8] recorded poor relationships between WBSF and sensory scores for BF and ST muscles since data of only young grain-fed animals were used and meat was aged for 14 days.

Shackelford et al. [2] reported a threshold value for WBSF of 4.6 kg for LL to be rated “slightly tender” (sensory score of 5) by at least 50% trained panelists. Various other researchers used this value for benchmarking of tenderness for LL and other muscles [5, 6, 7]. According to our models 4.6 kg WBSF predicts an average sensory score of 4.5 that lies between "slightly tough" and "slightly tender" for LL. Should the 4.6 kg value unilaterally be used for the other two muscles, then predicted tenderness scores of 3.9 (4 = "slightly tough") and 5.1 (5 = "slightly tender") were calculated for BF and ST, respectively. By substituting a sensory score of 5 (slightly tender) in the models and converting the logWBSF to WBSF, values of 3.9, 3.2, and 4.0 kg were calculated for LL, BF and ST. Therefore, our dataset demonstrates that LL will be judged by the taste panel as slightly tough at lower WBSF values, compared to the panel in the study of Shackelford et al. [2]. Furthermore, for a tenderness score of 5 ("acceptably tender"), our data also show that the ST muscle should record almost the same WBSF as the LL while that of the BF will be slightly lower. However, due to the differences in slope, the LL, BF and ST will record WBSF 8.1, 6.1 and 6.6 kg, respectively when the taste panel score the samples as "moderately tough" (score 3) and 1.9, 1.7 and 2.4 kg when the taste panel give a score of 7 ("very tender").

Table 2 Linear regression models for three muscles with WBSF as dependent variable and sensory tenderness as independent variable

	Min.	r^2	MSE.
LL	y = -2.722x + 8.691	0.537	0.413
BF	y = -3.133x + 8.668	0.547	0.437
ST	y = -3.913x + 10.404	0.644	0.318

LL - *m. longissimus lumborum;* BF - *m. biceps femoris*; ST - *m. semitendinosus*
y = predicted sensory tenderness; x = natural log (log_e) of Warner Bratzler shear force; r^2 = square of the correlation coefficient; MSE – mean square error

Various factors may have contributed to different outcomes of our dataset compared to other studies [2, 3] and others as well as different threshold values for the three muscles. While shear force techniques can be standardized to have higher repeatability among institutions [13], sensory panels are human instruments and it can probably not be expected that scores across institutions can exactly be duplicated. It is, however, worth mentioning that various studies [2, 3, 14] found that WBSF values less 4.3 kg to less than 4.6 kg will be regarded as acceptably tender. Apart from the lack of reproducibility between different panels other factors unique to our dataset could also have contributed to the lower WBSF required for an acceptable tenderness score of 5 in our study. Our study used animals with a broader range of age categories than in other studies [2, 3] while the samples of Shackelford et al. [2] also contained higher marbling in general (mean muscle fat = 5%;) than our samples [15]. The higher fat and lower effect of connective tissue could have contributed to a more "positive" scoring of taste panels in the other studies for the same WBSF values due to improved mouth feel. Perry et al. [9] emphasized that there is no objective laboratory test that accurately mimic the actions of biting and chewing and the contribution that fat and moisture have on the final perception of tenderness by the taste panelist. Furthermore, the relative contribution of myofibrillar and connective tissue components of meat to toughness may vary depending on factors such as post mortem aging and electrical stimulation. Such factors may impact on the value of objective measures of the myofibrillar and connective tissue components as indicators of sensory tenderness [9]. In our study, additional factors, namely age, the use of a beta agonist and cooking method combined with the inherent properties of the different muscles most likely contributed to the relationship between WBSF and sensory tenderness. Rhee et al. [12] found similar levels of collagen for ST and BF muscles, that were both higher than that of the LL, but lower ageing ability (% desmin degraded) for ST compared to the BF and LL. LL was more tender according to a taste panel than ST and ST more tender than BF, while no differences were found in WBSF between LL and BF (BF numerically lower), ST was tougher (higher WBSF) than BF and LL. All cuts were prepared according to a dry cooking method over a short time. In our study, the higher value for b (slope) in the ST equation compared to BF means that the change in sensory score over the same range in WBSF will be higher for ST than BF. The moist heat cooking would have diminished the effect of connective tissue in the BF muscle, reducing its effect on peak force (WBSF). In addition the myofibrillar contribution to tenderness would also have benefitted the BF muscle [12]. Although the difference in WBSF between LL and ST at tenderness score 5 was unexpectedly small considering the fact that the same cooking method was used, much larger differences were found when tougher meat was scored by the panel. Bouton et al. [16] reported that peak force (WBSF) was much more influenced by factors like age, connective tissue properties and muscle type than by factors influencing myofibrillar properties. It therefore make sense that the slope of both ST and BF models tended to be steeper than that of LL, meaning that changes in WBSF for ST and BF muscles were noted by panelists much quicker than for LL.

IV. CONCLUSION

WBSF threshold values for the LL, BF and ST muscles were different indicating that muscle conditions contributing to differences in connective tissue and myofibrillar properties of muscles, such as age, post-mortem ageing, muscle type and beta agonists will affect the way that changes in WBSF are responded to by trained sensory panels.

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