PREDICTING AND SEGREGATING BEEF TENDERNESS AMONG URUGUAYAN STEER CARCASSES UNDER COMMERCIAL CONDITIONS USING *POSMORTEM* CARCASS TRAITS, PH, TEMPERATURE AND COLORIMETER READINGS

Gustavo Brito[1], Dean Pringle[2], Roberto San Julián[3], and Fabio Montossi[3]

[1] National Institute of Agricultural Research, Beef Cattle Program, INIA Tacuarembó, Uruguay.
[2] The University of Georgia, Animal Science Department, Athens, Georgia, USA.
3 National Institute of Agricultural Research, Sheep and Goat Program, INIA Tacuarembó, Uruguay.

Background

In the food industry consumer-oriented quality approaches are more and more used if we consider the large development of marketing. The perception of the quality could be defined prior to purchase (beliefs and attitudes), at the point of purchase (intrinsic and extrinsic cues) and upon consumption (sensory attributes). The National Beef Tenderness Survey conducted in US (1990), documented a relative high incidence of toughness problems among different beef cuts for sale and identified the need to improve retail beef tenderness (George *et al*., 1999). The US beef industry has made it a priority to address the inconsistency in beef tenderness and has been developed strategies to ensure that all beef has acceptably tender. The development of tenderness based classification systems makes possible to identify carcasses with superior tenderness and add value to these carcasses that are undervalued in current systems. Studies have demonstrated that consumers recognized consistently differences in tenderness and they are willing to pay for this attribute (Boleman *et al*., 1997). Most of these systems evaluated by research are based on the relationship between muscle pH (Purchas, 1990; Wulf and Page, 2000), color (Wulf *et al*., 1997; Vote *et al*., 2003) and temperature (Jones and Tatum, 1994) with meat tenderness. This strategy to improve consistency of meat palatability –tenderness as main factor- is also followed by principal meat export countries, such as Australia (Guarantee tenderness) and New Zealand (NZ Beef and Lamb Quality Mark). Uruguay, as a meat export country in South America ought to follow this approach making a diagnostic of the variation of this attribute and according to the information gathered identifying the critical control points along the meat chain to ensure the consistency on it.

Objectives

This study was conducted to determine whether carcass traits and objective measures of muscle color, pH and temperature are useful to predict tenderness on selected beef steer carcasses of unknown origin, and to determine whether the application of USDA quality grading standards to Uruguayan beef carcasses could improve their segregation by tenderness.

Materials and Methods

One hundred seventy four beef steer carcasses of unknown origin were selected at one packing plant in Uruguay. Carcasses were selected at the time of grading by the Uruguayan official system without electric stimulation. Hot carcass weight (HCW) and fatness are associated with the age, for this reason it was decided to study whether within age could exist differences in quality traits, considering two HCWs and two backfat thickness (0-2 teeth carcasses: HCW < and ≥ 225 kg and Fat < and ≥ 5 mm; 4 teeth carcasses, HCW < and ≥ 240 kg and Fat < and ≥ 5mm; and 6-8 teeth carcasses, HCW < and ≥ 265 kg and Fat < and ≥ 7 mm). Carcasses were segregated into appropriate fat thickness categories based on actual carcass backfat measured at the 11th rib surface. Two official classification systems were applied, the American (USDA, 1997) and the Uruguayan (INAC, 1997) at different moments. The pH and temperature of the *longissimus lumborum* (LL) was determined at three different times: 1, 3 and 18-24 (ultimate) hs postmortem. The pH and temperature at 1 and 3 hs *postmortem* were measured between the 10 and 11th rib on the left side of the carcasses, at a depth of 2 cm. The measurement of ultimate pH was realized at the 11th rib cut surface in the pistol cut. The muscle pH was measured using a hand-held pH meter (Orion A 230) with a probe type electrode (BC 200, Hanna Instruments), standardized against two pH buffers (4 and 7). The probe was cleaned with alcohol and rinsed with water between uses. The temperature was determined by a thermometer (Barnant 115) with stainless steel thermocouple (type E). Muscle color measurements followed the CIE color convention (CIE, 1986).

Color measurements were made using a Minolta Colorimeter (model C-10). They were recorded in triplicate from the exposed LL muscle between the 10-11th rib immediately following ribbing (left side). A 8-cm portion of the LL was removed from the left side of carcasses, labeled, vacuum-packaged and transported to the Meat Science Laboratory at INIA Tacuarembó for shear force analysis considering 7 and 14 days of aging at 2 - 4 ^{o}C. The steaks were cooked by immersion within a plastic bag in a water bath at an internal temperature of 70^{o}C for 75 min. The internal temperature was monitored using type E thermocouples placed in the approximate geometric center of the steak. Six cores (1.27 cm diameter) parallel to the muscle fiber orientation were removed from each steak. A single peak WBSF measurement was obtained for each core using a WBSF machine (G-R Electric Manufacturing Co, Manhattan, KS). Individual-core peak shear force values were averaged to assign a mean peak WBSF value to each steak. *Statistical analysis* Descriptive statistics were computed in this experiment for selected carcass traits, pH, temperature, colorimeter readings and WBSF values. The model used in this experiment was $Y_{ijkl} = \mu + A_i + B_j + C_k + ABC_{ijk} + E_{ijkl}$ being Y_{ijkl} = ijklth Warner-Bratzler shear force at 7 and 14 days of aging, μ = overall mean, A_i = effect of the ith dentition, B_j = effect of the jth hot carcass weight, C_k= effect of the kth fat thickness, ABC_{ijk}= interaction effect of ijkth dentition * hot carcass weight*fat thickness, and E_{ijkl} = residual error. Least squares means were calculated using PDIFF procedure. To better understand the relationship between the independent and dependent (WBSF values) variables the information was analyzed by correlation and regression procedures (stepwise procedures, SAS, 1990).

Results and Discussion

In this study, it was not detected significant differences (P>0.05) in WBSF 7 and WBSF 14 explained by dentition, HCW and Fat. The WBSF mean obtained for 7 and 14 days of aging were 4.06 kg (CV: 35.3%) and 3.42 kg (CV: 30.7%). These results agree with Lawrence *et al* (2001) who did not find significant differences in WBSF and sensory panel tenderness among five dental classes. These authors supported the concept that carcass classification based on dentition should not be used in place of USDA carcass maturity to segregate carcasses for *longissimus* steak tenderness. The carcasses were majority classified as Traces (35.1%) and Slight (55.2%) according to USDA marbling score and as A (76.4%) to USDA overall maturity category. QG scores varied from Utility to Choice, where 88.5% of the carcasses were classified as Standard (44.3%) and Select (44.3%). As it was expected, the pH values (pH_1, pH_3 and pH_u) were lower (P<0.05) and the T records were higher (T_1, P<0.01, and T_3, P<0.05) for the fattest group in each age group. The positive relationship between muscle temperature and subcutaneous fat thickness resulted from the insulation effect of fat. Correlation Analyses. YG was the main variable negatively correlated (P<0.01) with both WBSF 7 and WBSF 14 (Table 1). This could be explained by subcutaneous fat thickness, where higher levels of this variable would be associated to lower WBSF values. All correlation coefficients between muscle color and WBSF were negative. These findings have also been reported by Wulf *et al*. (1997), Wulf and Page (2000) and Vote *et al*. (2003), showing that dark color muscles could be associated to tough steaks. Lean maturity presented a low correlation with WBSF 7 and WBSF 14 (r=0.17 and 0.19, respectively). Studying the relationship between color parameters with some of the measured variables, lean L*, a* and b* were moderately and highly correlated (P<0.01) with pH_u, presenting a* the highest correlation (r=-0.81). This suggests the importance of lean a* as indicator of meat quality and especially of tenderness in the present study. Ledward *et al*. (1992) reported that the negative correlations between colorimeter readings and pH_u could be explained by the oxygenation of the myoglobin and the reflectance of the light. Lean L* was most closely related with lean maturity (r=-0.61, P<0.01). This result is concordant with the information reported by Vote *et al*. (2003) who found correlation values (P<0.05) between both characteristics in the range of -0.52 and -0.69 in different experiments using the CVS BeefCam color output. *Regression analyses* The application of the USDA quality grade factors to Uruguayan steers (Table 2) explained in most of the cases 4 to 6 % of the WBSF 7 and WBSF 14 variation, with the exception of WBSF 14 in 6-8 teeth carcass group where lean maturity explained 21% of its variation. Vote *et al*. (2003) reported a partial R^2 for lean maturity of 6 and 8% in the WBSF 14 variation for 2 different experiments. Marbling showed low correlation (P>0.05) to WBSF 7 (r=-0.13) and WBSF 14 (r=-0.14). Wulf *et al*. (1996) in a research containing mostly carcasses classified as USDA Select reported no correlation between variables (P>0.05) and Vote *et al*. (2003) considered that marbling score did not explain WBSF variation in Select carcasses. When it was ran multiple linear regression procedures using all the measurements to predict WBSF values, the main single variable in predicting tenderness for all evaluated carcasses was lean a* (Table 3). This colorimeter reading explained by itself 16 and 24% of the WBSF 14 and WBSF 7 variation, respectively. Vote *et al*. (2003)

considering Choice and Select carcasses found that lean a* from the CVS BeefCam explained 16% of the WBSF 14 variation. The lean a* parameter was followed by pH_u and T (T_1 or T_3) in entering into the model for all steer carcasses. This tendency was also observed in 0-2 and 4 teeth carcasses. However, for the 6-8 teeth carcass group, variables associated to yield as REA (r=-0.37, P<0.01), YG and HCW contributed to explain the tenderness variation. REA singularly account for 30% of the WBSF 14 variation. The REA has been related to carcass yield, however Wyle *et al*. (2003) and Vote *et al*. (2003) had observed a limited relationship between this variable and palatability and the possibility to identify tough steaks using REA from CVS BeefCam adjusted by carcass weight. In this age category (6-8 teeth) QG explained an additional 24% of the WBSF 14 variation.

Conclusions

The population of cattle utilized in this study was representative of slaughtered steers in Uruguay according to age. For these animals, objective measures of muscle color, specifically lean a*, was the most effective in predicting WBSF, which explained 24 and 16% of WBSF 7 and WBSF 14 variation. However, analyzing the information by age category, the prediction of WBSF in 6-8 teeth carcasses was better accounted for other variables like pH_3 or REA (for WBSF 7 and WBSF 14, respectively). The addition of the USDA QG standards to the Uruguayan steer carcasses grading would seem do not contribute to improve the effectiveness to sort carcasses into tenderness group, with the exception of WBSF 14 prediction in 6-8 teeth carcass group. For this population, ultimate pH and lean a* measured at ribbing might be useful in sorting beef carcasses likely to yield tough or tender steaks depending on the defined WBSF critical point. Further research should be conducted to better understanding the relationship between pH/color and tenderness and how to improve it for Uruguayan conditions.

References

Boleman, S.J., S.L. Boleman, R.K. Miller, J.F. Taylor, H.R. Cross, T.L. Wheeler, M. Koohmaraie, S.D. Shackelford, M.F. Miller, R.L. West, and J.W. Savell. 1997. Consumer Evaluation of beef of known categories of tenderness. J. Anim. Sci. 75:1521-1524.

George, M.H., J.D. Tatum, K.E. Belk, and G.C. Smith. 1999. An audit of retail beef loin steak tenderness conducted in eight U.S. cities. J. Anim. Sci. 77: 1735-1741.

Jones, B.K. and J.D. Tatum. 1994. Predictors of beef tenderness among carcasses produced under commercial conditions. J. Anim. Sci. 72:1492-1501.

Lawrence, T.E., J.D. Whatley, T.H. Montgomery, L.J. Perino, and M.E. Dikeman. 2001. Influence of dental carcass maturity classification on carcass traits and tenderness of *longissimus* steaks from commercially fed cattle. J. Anim. Sci. 79:2092-2096.

Ledward, D.A. 1992. Color of the raw and cooked meat. In D.E. Johnston, M. Knight, and D.A. Ledward. *The chemistry of muscle based foods*. Cambridge, UK:Royal Society of Chemistry .pp:128-144.

Purchas, R.W. 1990. An assessment of the role of pH differences in determining the relative tenderness of meat from bulls and steers. Meat Sci. 27:129-140.

Vote, D.J., K.E. Belk, J.D. Tatum, J.A. Scanga, and G.C. Smith. 2003. Online prediction of beef tenderness using a computer vision system equipped with a BeefCam module. J. Anim. Sci. 81:457-465.

Wulf, D.M., J.B. Morgan, J.D. Tatum, and G.C. Smith. 1996. Effects of animal age, marbling score, calpastatin activity, subprimal cut, calcium injection, and degree of doneness on the palatability of steaks from Limousin steers. J. Anim. Sci. 74: 569-576.

Wulf, D.M., S.F. O'Connor, J. D. Tatum, and G. C. Smith. 1997. Using objective measures of muscle color to predict beef *longissimus* tenderness. J. Anim. Sci. 75:684-692.

Wulf, D.M. and J.K. Page. 2000. Using measurements of muscle color, pH, and electrical impedance to augment the current USDA beef quality grading standards and improve the accuracy and precision of sorting carcasses into palatability groups. J. Anim. Sci. 78:2595-2607.

Wyle, A.M., D.J. Vote, D.L. Roeber, R.C. Cannell, K.E. Belk, J.A. Scanga, M. Goldberg, J.D. Tatum, and G.C. Smith. 2003. Effectiveness of the SmartMV prototype BeefCam system to sort beef carcasses into expected palatability groups. J.Anim.Sci. 81:441-448.

Table 1 Main simple correlations between carcass variables and tenderness and color for all steer carcasses

Variables	WBSF7	WBSF14	Variables	L*	a*	b*
YG	- 0.20**	- 0.22**	Dentition	- 0.27**	0.14	0.04
Lean mat.	0.17	0.19*	Lean mat.	- 0.61**	- 0.43**	- 0.32**
MARB	- 0.13	- 0.14	QG	0.26**	0.35**	0.26**
QG	- 0.11	- 0.14	pH_1	- 0.52**	- 0.53**	- 0.44**
a*	- 0.19*	- 0.16*	pH_3	- 0.62**	- 0.63**	- 0.52**
b*	- 0.17*	- 0.13	pH_u	-0.67**	- 0.81**	- 0.66**

Note: ** Significative at 1% . * Significative at 5%.

Table 2. Multiple regression equations to predict WBSF 7 and WBSF 14 using USDA quality variables for all, 0-2, 4 and 6-8 teeth steer carcass group

WBSF 7			**WBSF14**		
Independent variables	R^2	**RMSE**	**Independent variables**	R^2	**RMSE**
All carcasses					
Lean maturity	0.03	1.33	Lean maturity	0.04	0.97
Lean maturity, Skeletal maturity	0.06	1.32	Lean maturity, Marbling	0.06	0.96
0-2 teeth carcasses					
No variables met 0.2 significance level for entry into the model for both dependent variables (WBSF7 and WBSF14)					
4 teeth carcasses					
Lean maturity	0.04	1.57	Skeletal maturity	0.04	1.08
6-8 teeth carcasses					
Lean maturity	0.04	0.85	Lean maturity	0.21	0.57

Note: Models were developed using stepwise procedure. R^2= coefficient of determination. RMSE=root mean square error

Table 3. Multiple regression equations to predict WBSF 7 and WBSF 14 using YG, QG, pH, temperature and color for all, 0-2, 4 and 6-8 teeth steer carcass group

WBSF 7			**WBSF14**		
Independent variables	R^2	**RMSE**	**Independent variables**	R^2	**RMSE**
All carcasses					
a*	0.24	1.60	a*	0.16	0.94
a*, pH_u	0.29	1.50	a*, T_1	0.20	0.90
a*, pH_u, T_3	0.32	1.45	a*, T_1, pH_u	0.24	0.87
0-2 teeth carcasses					
pH_u	0.11	1.32	a*	0.18	1.63
pH_u, T_3	0.27	1.14	a*, T_3	0.26	1.54
4 teeth carcasses					
a*	0.31	1.88	a*	0.23	1.00
a*, T_3	0.42	1.60	a*, T_1	0.38	0.82
a*, T_3, skeletal mat	0.50	1.43	a*, T_1, skeletal mat	0.43	0.77
a*, T_3, skeletal mat, pH_u	0.53	1.36			
6-8 teeth carcasses					
pH_3	0.17	0.63	REA	0.30	0.29
pH_3, YG	0.28	0.56	REA, QG	0.54	0.20
pH_3, YG, REA	0.34	0.54	REA, QG, HCW	0.58	0.19

Note: Models were developed using stepwise procedure. R^2= coeff. of determination. RMSE=root mean square error