Meat quality

Subgroup 1

The management of meat tenderness

PREDICTING LAMB TENDERNESS AMONG CARCASSES PRODUCED UNDER COMMERCIAL CONDITIONS IN URUGUAY

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Background

Consumers judge the quality of meat at the point of sale on color, visible fat content and odour. However, for palatability, tenderness, juiciness and flavor are the most important. Supermarket surveys of consumer preferences indicated that tenderness is now the primary concern to the meat industry as it changes from a production-led to a consumer-driven industry. This meat quality attribute is the most desired by consumers and it will encourage them to be repeated buyers. The ability of consumers to segregate meat into varying tenderness levels is essential for establishing the value of meat tenderness. The lamb industry must identify precise methods of distinguishing the palatable lamb from the unpalatable one. Previous research (Jeremiah et al.; 1991, Shackelford et al., 1994; Wulf et al., 1997) has shown relationships between muscle pH, color and temperature during rigor mortis with meat tenderness. For this reason, it is imperative that the lamb industry in Uruguay knows its level of tenderness and eliminates the opportunity for their shortfalls at the foodservice and retail level as well as at the export market. Some of these markets require tenderness values below 5 kg to be retained. The New Zealand meat industry recognized these requirements and implemented Quality Mark standards for meat tenderness improving the consistency of the product.

Objectives

The present study was conducted to determine the level of lamb meat tenderness in Uruguay and to provide information about the potential for use of muscle pH, temperature and color as criteria to predict and sort lamb carcasses for tenderness.

Methods

In this research data were collected on 400 lamb carcasses composed by 20% females (F) and 80% castrated males (M). The animals were predominantly Corriedale (other minor breeds were also analyzed), with 12 months of age, live weights between 34 and 50 kg and body condition score (Russell et al., 1969) between 3 to 4.5. The lambs were slaughtered in two packing plants (PP). Hot and cold carcass weights and GR at the 12th rib were recorded. Personnel of INAC, according to Uruguayan lamb grading system, graded the carcasses at 24 hours *post mortem*. The left side of the carcasses was chosen for collecting data and ribbed (8 rib cut, between the 5th and 13th ribs) for further analysis. **Temperature (T) and pH determinations**: They were determined at 1 h (pH_1, T_1), 3 h (pH_3, T_3) and 24 h (pH_{24}, T_{24}) *post mortem* in the center of the *longissimus dorsi* (LD) muscle at the 12-13th rib space. The pH and T were recorded using an Orion 210 A pH meter and a Barnnant thermometer with a stainless steel E thermocouple, respectively. **Muscle color evaluations**: The color of LD cut at 12-13th rib was measured in the L* a* b* space using a Minolta C-10 colorimeter at 24 h *post mortem*. Special care was taken to avoid scanning intramuscular fat. **Shear force values**: Two steaks (2.54 cm thick each one) were removed from the LD muscle at 12-13th rib at 24 h *post mortem*, vacuum packaged and aged for 10 days at 2-4 °C. Then, these steaks were cooked in a water bath at 70 °C during 1 h to an internal temperature of 70 °C and refrigerated overnight at 4 °C. Six cores (1.27 cm) were removed from the steaks. Shear force determinations (SF) were made on each core using a Warner Bratzler device.

Statistical Analyses: The analyses were conducted using SAS (2000). Simple Pearson correlations were estimated between carcass data and tenderness. Prediction equations were developed using stepwise regression analysis. Independent variables had to be significant ($P<0.10$) to remain in the model. Analysis of variance (GLM procedure) was considered to analyze the differences in tenderness explained by class variables (producer, PP and sex)

Results and Discussion

Table 1 shows the means, standard deviations (SD) and variation coefficient (VC) of the main variables of the study. The mean tenderness value was 2.67 kg for a 10 day aging period. Comparing to Koohmaraie et al. (1996) and Wheeler et al. (1994) studies who reported 3.34 kg for 7 days of aging and 3.1 kg for 14 days of aging respectively, our samples were more tender although they experienced bigger SD (1.2 kg). The aging T was similar among studies, There was difference ($P<0.05$) in tenderness between PP (2.94 kg vs 2.31 kg), that could be explained mainly by the significant difference ($P<0.05$) in T_3 (9.25 °C vs 15.70 °C, respectively), and pH_3 (6.37 vs 6.21, respectively). The results clearly show the influence of slaughter and chilling processes on tenderness between both commercial PP. When the effect of PP was deleted, producer variable was significant ($P<0.0001$) followed by breed ($P<0.05$). Sex was not significant in this tenderness predictive model, however we detected difference ($P<0.05$) between F (3 kg) and M (2.63 kg) due to T_3 (10 °C vs 12.6 °C, respectively). The pH determinations were concordant with the mentioned studies, being different the T values. These authors reported T_3 = 15.8 °C (SD=0.5) and T_u= 1 °C (SD=0.1). Our results showed more SD and this corresponded with the slaughter house variation. The rates of pH and T decline were similar to those reported in both studies of reference. The color parameters (Table 1) were in the ranges that are mentioned by Sañudo et al. (1998), who fed younger lambs than ours, with hay and concentrate, explaining the difference in the red color (a*= 13.36). The L* and b* values reported by Sañudo et al. (1998) were 37.65 and 6.37, respectively. **Correlation analysis**: Table 2 shows the correlation coefficients (r) between some of the measured variables with SF and T_3. T_3 was the variable with the highest negative r with SF (-0.5) followed by GR (-0.38). We assumed that the tenderness in this study is explained by the activity of the calpain-calpastatin enzymes (Koohmaraie and Goll, 1998) during the aging period. To know the sarcomere length will contribute to understand more about the variation in tenderness. The GR determinations at 12-13th rib is a measure of the tissue thickness and it is related to the regulation on the T rate decline, avoiding or reducing the cold shortening conditions. Hertzman et al. (1993) considered that fiber muscle shortening during rigor mortis depends on T due to the relationship between this variable and Ca^{++} presence in the muscle sarcoplasm. **Variable response**: It was observed a quadratic response (R^2=0.78) between GR and SF where tenderness increased with GR levels until 13 mm of thickness and then started to decrease. A curvilinear relationship (R^2=0.23) also was observed between pH_3 and SF, with steaks being tougher at pH 6.3-6.4. This is concordant with the results presented by Purchas et al. (1990) working with beef cattle, who found that carcasses with intermediate *postmortem* pH decline (pH_3=5.9-6.3) were more tender than those with fast and slow glycolysing carcasses. However, Marshall and Tatum (1991) cited by Shackelford et al. (1994) indicated that pH_3 was not highly effective in sorting carcasses according to mean differences in tenderness. Similar quadratic response (R^2= 0.12) was detected between pH_3 and GR, decreasing pH_3 until GR value of 13 mm. The relationship between T_3 and SF was exponential (R^2=0.53), increasing tenderness as T_3 decreased. **Regression Analysis:** It was conducted to better understand the relationships between tenderness and the measured variables in the lamb carcasses. This was also done to evaluate the ability to predict tenderness and to determine the most appropriate data collection. Table 3 shows the best models considering the first 4 variables entering in the model. The best regression model to predict tenderness considering the determination coefficient (R^2=0.40) included T_3, T_u, pH_3 and T_1(model 1). The main contributing variable was T_3 explaining 35% of tenderness variation. In this model all pH and T determinations and muscle color (L*, a* and b*) variables were considered. When T_3, T_1, pH_3, pH_1 and muscle color (model 2) were analyzed the R^2 of the model was 0.37 and the variables entering into it were T_3 (partial R^2 = 0.35), pH_3, a* and T_1.

Conclusions

This study is the first approach conducted in Uruguay trying to characterize the meat tenderness level of the Uruguayan lamb within the national heavy lamb program. The average SF value of 2.67 kg obtained with 10 days of aging, satisfied our expectations since it would allow to access demanding markets, as US market, and also it meets the New Zealand Beef and Lamb Quality Mark standards. The main variable to predict tenderness according to r and R^2 was T_3, which explained 35% of the tenderness variation.

The tenderness differences between PP implies the necessity to define protocols in slaughter and chilling processes and have more control over them. Further research would allow us studying models to segregate carcasses by tenderness with good accuracy, adding information to our meat products and implementing marketing strategies for export and domestic markets.

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Table 1: Mean and Standard Deviation of main variables

Variable	Mean	Std. Dev.	VC (%)
SF (kg)	2.67	1.22	46
pH_1	6.49	0.19	3
pH_3	6.30	0.18	3
pH_u	5.78	0.22	4
T_1 (°C)	22.01	3.57	16
T_3 (°C)	12.19	4.78	39
T_u (°C)	3.12	1.84	59
L*	34.43	2.70	8
a*	18.34	1.78	10
b*	7.02	1.55	22
GR (mm)	9.48	6.36	67
Hcw (kg)	19.34	3.9	20

Table 2: Correlation coeff. (r) between main variables and SF and T_3

Variable	SF	Sig. level	T3	Sig. level
pH_1	-0.02	0.77	-0.03	0.66
pH_3	0.17	0.0005	-0.41	<0.0001
pH_u	0.08	0.12	-0.11	0.05
T_1 (°C)	-0.45	<0.0001	0.73	<0.0001
T_3 (°C)	-0.50	<0.0001		
T_u (°C)	-0.44	<0.0001	0.41	<0.0001
L*	-0.18	0.0002	0.35	<0.0001
a*	-0.20	<0.0001	0.25	<0.0001
b*	-0.21	<0.0001	0.31	<0.0001
GR (mm)	-0.38	<0.0001	0.66	<0.0001
Hcw (kg)	-0.24	<0.0001	0.57	<0.0001

Table 3 Regression equations for predicting lamb tenderness using pH, temperature, muscle color and GR at different time during rigor mortis

		Partial regression coefficients					R^2
Dependent variable	Intercept	T_3	T_u	pH_3	T_1	a*	
SF							
Model 1							
1	4.56**	-0.15**					0.35
2	4.69**	-0.13**	-0.14**				0.38
3	9.59**	-0.14**	-0.14**	-0.75*			0.39
4	10.15**	-0.11**	-0.15**	-0.73*	-0.04		0.40
Model 2							
1	4.56**	-0.15**					0.35
2	9.19**	-0.17**		-0.71			0.36
3	10.98**	-0.16**		-0.80*		-0.07	0.37
4	11.82**	-0.13**		-0.79*	-0.05	-0.08*	0.37

** Significant variable (P<0.01) * Significant variable (P<0.05)