Effect of sex, age, and pre-slaughter conditioning on pH, temperature, tenderness and colour of indigenous South African goats

L. Simela[1], E.C. Webb[1#] and L. Frylinck[2]

[1]Department of Animal & Wildlife Sciences, University of Pretoria, Hatfield, Pretoria 0002, South Africa
[2]Meat Science Centre, ARC-Animal Nutrition & Products Institute, Private Bag X2, Irene 0062, South Africa

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Abstract

Sex, age and pre-slaughter conditioning effects on pH, temperature, colour and tenderness properties of *M. semimembranosus* (SM) of indigenous South African goats were investigated. Sex and age had no significant effect on pH. However, female goat carcasses cooled significantly slower than those of intact males. The carcasses of 2-teeth goats had the slowest and those of the 4–6-teeth goats the fastest cooling rates. The carcasses of pre-slaughter conditioned goats had higher temperatures and lower pH values than the non-conditioned goats at both three and 24 hours post-mortem. Of the meat quality traits, colour was affected mainly by sex and age. Intact males had lower 24-hour a* and chroma values than the females and castrates. Chevon from 2-teeth goats had higher 24-hour and 96-hour a* and 24-hour chroma values than that from the milk-, 4–6- and 8-teeth groups. The milk-teeth goats had a lighter colour (96-hour L* value) than the 8-teeth goats. Pre-slaughter conditioning resulted in longer sarcomeres, lower Warner-Bratzler shear force values and generally a better meat colour. Tenderness and colour properties of chevon were found to be highly dependent on post-mortem pH and temperature as well as the ultimate pH attained by the carcasses. Carcasses that chilled slowly and had a fast decline in pH yielded better quality chevon.

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Introduction

To a large extent, meat quality is affected by the rate of post-mortem carcass pH and temperature decline and the ultimate pH (pHu) attained (Watanabe *et al.*, 1996). Ideal pH and temperature profiles result in meat that is acceptably tender and has a normal colour. Any deviations result in abnormalities that may be reflected in post-slaughter myofibrillar changes, colorimetric values of the meat and meat tenderness. The aim of this study was to investigate the effects of sex, age and pre-slaughter conditioning of marketed indigenous South African goats on early post-mortem and ultimate pH and temperature, colour and tenderness related properties.

Materials and Methods

Samples of *M. semimembranosus* (SM) were taken from a flock of indigenous South African goats (N = 74) consisting of recently weaned kids to 4–6 teeth intact and castrated males and to full-mouthed females. The flock was purchased and kept at a farm on a maintenance diet of Silgro® ewe and lamb pelleted concentrate mix fed at *ca*. 3% of total animal weight per pen. Clean water and *Eragrostis curvula* hay were available *ad libitum*. The goats were slaughtered randomly within the non-conditioned (slaughtered within two months of purchase) and pre-slaughter conditioned (slaughtered between six to ten months of purchase) states. Chronological age was estimated from dentition.

All the goats were slaughtered at a research abattoir under conditions similar to those employed in the meat industry of South Africa. Goats designated for slaughter were randomly selected, weighed before feeding and then held in a separate enclosure with their daily ration of feed and water the day prior to slaughter. They were later transported to the abattoir (about 30 km/20 minutes drive) where they were held in lairage overnight for about 17 hours with clean water *ad libitum* but no feed. At slaughter, the goats were stunned using 300V of electricity. Temperature and pH (pH₃ and pHu, respectively) of the SM were recorded at three and 24 hours post-mortem. Both the left and right SM were cut from the carcasses 24 hours post-mortem for the determination of sarcomere lengths (SL), Warner-Bratzler shear force (WBS), colorimetric

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values L*, a*, b* and chroma values. Left SM samples were vacuum packed and immediately stored at –20 °C for the 24-hour determinations (i.e. SL24, WBS24, L*24 etc.). Samples from the SM muscles obtained from the right side of each carcass were aged for a further 72 hours at about 4 °C and then stored at -20 °C for 96-hour determinations (i.e. WBS96, L*96, a*96, etc.). The SL samples were prepared according to Hegarty & Naudé (1970) and SL were determined using light microscopy. Warner-Bratzler shear force was determined as outlined by Honikel (1998). Colour was measured using a Minolta colorimeter (Tokyo, Japan) on freshly cut surfaces that were wrapped in oxygen permeable polythene film and bloomed for three hours at 2–4 °C with light.

All data were analysed using SAS (1996) GLM procedures. Sex, age, pre-slaughter conditioning and the first order interaction effects were tested on all variables. First order interactions were predominantly not significant and hence results of the main effects only are presented. Spearman's correlations between the meat quality traits and pH_3 and pHu were computed. Where the correlation coefficients were significant, the data were then grouped into three pH_3 and pHu groups and the variations of the meat quality traits with each set of pH groups were analysed using GLM models.

Results

Sex and age of the goats had no effect on the pH_3 and pHu (P > 0.05) of the SM. However, female carcasses cooled more slowly than those of intact males so much so that their mean 3-hour temperature was 1.3 °C higher than the 15.3 ± 3.97 °C of the latter (P = 0.036). At three (P = 0.046) and 24 hours (P = 0.032) post-mortem the 2-teeth group had the highest (18.8 ± 3.42 °C and 6.3 ± 3.25 °C) and the 4-6 teeth group the lowest temperature readings (13.1 ± 1.85 °C and 0.6 ± 1.32 °C). Temperatures of the milk-teeth and 8-teeth groups were similar but differed from the two extremes (P < 0.05).

Mean pH_3 of SM of the non-conditioned goats (6.44 ± 0.23) was 0.27 (P = 0.008) units higher than that of the pre-slaughter conditioned group, but the pHu means of the two groups were similar. The means were 5.93 ± 0.13 and 5.95 ± 0.18, respectively. Both the 3-hour (13.5 ± 2.22 °C) and 24-hour SM temperatures (1.4 ± 1.70 °C) of the non-conditioned goats were lower (P < 0.0001) than those of the pre-slaughter conditioned group by 6.1 °C and 5.9 °C, respectively. The effects of sex, age, pre-slaughter conditioning on SL, WBS and colour quality traits are summarised in Table 1.

Table 1 Effects of sex, age and pre-slaughter conditioning on tenderness-related characteristics and colour co-ordinates (means ± s.d.) of chevon from indigenous South African goats

Characteristics	Mean ± s.d.	Min	Max	Sex	Age	Pre-slaughter conditioning
n	74					
Sarcomere length (μm) 24 hr[1]	1.72 ± 0.16	1.24	2.15	NS	NS	***
Shear force (N) 24 hr[1]	74.81 ± 17.70	38.37	119.96	NS	NS	***
Shear force (N) 96 hr[2]	66.94 ± 17.21	25.03	113.33	*	NS	***
L* 24 hr[1]	38.57 ± 2.42	32.71	43.81	NS	NS	*
a* 24 hr[1]	13.78 ± 2.37	4.00	19.32	**	**	*
b* 24 hr[1]	9.60 ± 1.52	5.69	12.77	NS	NS	NS
Chroma 24 hr[1]	16.88 ± 2.49	10.21	22.54	*	**	NS
L* 96 hr[2]	38.14 ± 2.29	32.97	43.22	NS	*	*
a* 96 hr[2]	14.30 ± 2.20	4.99	19.01	NS	NS	**
b* 96 hr[2]	9.72 ± 1.38	5.46	12.00	NS	NS	NS
Chroma 96 hr[2]	17.34 ± 2.35	12.08	22.42	NS	NS	*

NS – not significant; * Significant (P < 0.05); ** Significant (P < 0.01); *** Significant (P < 0.001).
[1]Chroma and colorimetric determinations were done on samples that were frozen 24 hours post-mortem
[2]Chroma and colorimetric determinations were done on samples that were frozen 96 hours post-mortem

Sex did not affect SL (P > 0.05), but castrates (mean WBS96 = 64.28 ± 17.09N) tended to have a 3.8N lower WBS96 (P = 0.052) compared to females and intact males. The 2-teeth group tended to have the

lowest WBS96 (mean = 59.87 ± 20.15N; P = 0.074) while SM of the 8-teeth group was the toughest (WBS96 of 77.39 ± 18.54N).

Mean SL24 of the SM of non-conditioned goats (1.59 ± 0.17 µm) was 0.73 µm shorter (P < 0.0001) than SL24 of the pre-slaughter conditioned goats. Mean WBS of the SM of non-conditioned goats were 82.41 ± 16.06N and 74.95 ± 16.76N at 24- and 96-hours post-mortem respectively, which were higher than those of the pre-slaughter conditioned group (P < 0.0001) in both ageing treatments. The mean a*24 value of intact males (12.34 ± 3.30) was 1.86 units lower (P = 0.003) than the average mean for females and castrates. In turn the mean chroma24 value (15.73 ± 2.90) was a significant 1.87 units lower (P = 0.002) than the mean chroma24 of the castrates. The a*24 value for the 2-teeth group (15.56 ± 2.36) was between 2.45 and 4.15 units higher than the values for the milk-, 4–6- and 8-teeth groups. Accordingly, the 2-teeth group had the highest chroma24 (P = 0.003) of the four age groups (18.49 ± 2.59 *vs.*15.65 ± 2.64). Chevon from the milk-teeth group was lighter in colour (mean L*96 = 38.96 ± 2.44) than that from the 8-teeth group by 2.10 units of L*96 (P = 0.039). L*24 of the non-conditioned goats (39.42 ± 2.35) was 1.83 units larger (P = 0.029) and a*24 (12.62 ± 2.97) was 2.52 units smaller (P = 0.048) than the corresponding values of the pre-slaughter conditioned group. At 96 hours post-mortem, the SM of non-conditioned goats had a mean L* (38.73 ± 2.26) that was 1.35 units lighter (P = 0.039) and a* (13.18 ± 2.22) that was 1.45 units less red, which explains the less vivid chroma96 (P = 0.034).

Only 16% of samples from the SM exhibited an acceptable rate of glycolysis to attain a $pH_3 < 6.1$ (Table 2). The faster glycolysing SM had a higher early post-mortem temperature (P < 0.001), the longest SL24 (P = 0.0004), and highest a*24 value (P = 0.006). The lowest values obtained for these traits were associated with carcasses that had a SM $pH_3 > 6.3$. These slow glycolysing carcasses comprised ca. 58% of the SM samples.

Table 2 Effect of early post-mortem pH (pH_3) on chevon tenderness and colour of the *M. semimembranosus* (means ± s.d.) of indigenous South African goats

	$pH_3 < 6.1$	$pH_3 = 6.1$ to 6.3	$pH_3 > 6.3$	P-value
n	12	19	43	
3-hr pH (pH_3)	5.90 ± 0.16[a]	6.20 ± 0.05[b]	6.49 ± 0.17[c]	< 0.0001
3-hr temperature (°C)	20.04 ± 2.43[b]	17.01 ± 4.25[ab]	14.86 ± 306[a]	0.0001
Sarcomere length (µm) 24 hr[1]	1.85 ± 0.20[b]	1.78 ± 0.20[b]	1.65 ± 0.19[a]	0.0004
Warner-Bratzler shear force (N) 24 hr[1]	67.05 ± 18.14	73.41 ± 16.48	77.67 ± 20.55	0.1311
a* 24 hr[1]	15.71 ± 1.99[b]	14.36 ± 2.80[ab]	12.96 ± 3.17[a]	0.0058
Chroma 24 hr[1]	18.39 ± 2.19	17.38 ± 2.72	16.25 ± 3.06	0.0691
a* 96hr[2]	15.50 ± 2.33	14.73 ± 2.09	13.86 ± 2.55	0.0531
Chroma 96 hr[2]	18.51 ± 2.32	17.34 ± 2.65	16.99 ± 2.44	0.0998

[a, b, c] Row means with common superscripts do not differ (P > 0.05)
[1]Chroma and colorimetric determinations were done on samples that were frozen 24 hours post-mortem
[2]Chroma and colorimetric determinations were done on samples that were frozen 96 hours post-mortem

Generally, the SM of carcasses with a pHu < 5.8 had the highest a*, b* and chroma (P < 0.01) values at both ageing times (Table 3). Moreover they had a mean WBS96 that was 18N (P = 0.005) less than the average of 70N obtained for samples of the SM with pHu > 5.8. Only 20% of the carcasses had a pHu < 5.8, while 45% had a pHu between 5.8 and 6.0 and the 35% a pHu > 6.0.

Discussion

The results indicate that tenderness and colour of chevon were affected by both the rate and extent of glycolysis such that chevon suffered less sarcomere shortening and attained lower WBS values if the decrease in carcass temperature was slow or the pHu was below 5.8. Samples from the 2-teeth group and the castrates, which chilled slowly, tended to have lower WBS96 and better colour quality than their contemporary groups. Likewise, carcasses of the pre-slaughter conditioned goats chilled slowly, had a fast pH decline and hence yielded more tender and redder chevon with a more vivid colour than the non-

conditioned goats. By contrast, carcasses which chilled fast and were glycolysing slowly, suffered sarcomere shortening and had a low a* value that tended towards the dark cutting (DFD) condition (Onyango *et al*., 1998). Carcasses with a low pHu had a better colour quality, while high pHu carcasses yielded chevon with a mean a* value approaching 12 and a low chroma value. Carcasses with such low a* and chroma values, tend have a dull appearance (Onyango *et al*., 1998) and a low shelf life (Wiklund *et al*., 2001).

Table 3 Effect of ultimate pH (pHu) on the tenderness and colour of the *M. semimembranosus* (means ± s.d.) of indigenous South African goats

	pHu < 5.8	pHu = 5.8 to 6.0	pHu > 6.0	P-value
n	15	33	26	
Ultimate pH	5.74 ± 0.03^a	5.90 ± 0.06^b	6.10 ± 0.08^c	< 0.0001
Warner-Bratzler shear force (N) 96 hr	52.57 ± 14.87^a	70.71 ± 18.91^b	69.88 ± 20.03^b	0.0048
L* 24 hr[1]	39.33 ± 1.67	38.78 ± 2.22	37.93 ± 3.10	0.2115
a* 24 hr[1]	15.83 ± 2.83^b	13.51 ± 2.99^a	12.98 ± 2.85^a	0.0071
b* 24 hr[1]	10.46 ± 0.90^b	9.90 ± 1.15^b	8.75 ± 1.70^a	0.0013
Chroma 24 hr[1]	19.01 ± 2.66^b	16.84 ± 2.71^a	15.75 ± 2.79^a	0.0026
L* 96 hr[2]	38.57 ± 2.05	38.58 ± 2.24	37.48 ± 2.61	0.2098
a* 96 hr[2]	16.46 ± 1.69^b	14.12 ± 2.24^a	13.46 ± 2.52^a	0.0004
b* 96 hr[2]	10.48 ± 0.96^b	9.91 ± 1.04^{ab}	9.19 ± 1.36^a	0.0094
Chroma 96 hr[2]	19.52 ± 1.88^b	17.23 ± 2.29^a	16.23 ± 2.33^a	0.0004

[a, b, c]Row means with common superscripts do not differ (P > 0.05)
[1]Chroma and colorimetric determinations were done on samples that were frozen 24 hours post-mortem
[2]Chroma and colorimetric determinations were done on samples that were frozen 96 hours post-mortem

Conclusion

Both the tenderness and colour properties of chevon are highly dependent on the post-mortem pH and temperature profiles. Better quality chevon could be obtained by handling the goats in such a way that they attain a low pHu coupled with appropriate chilling conditions that will allow a slow rate of carcass temperature decline, acceptable rate of post-mortem glycolysis and subsequent decrease in pH early post-mortem.

Acknowledgements

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