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Post-mortem metabolic status, pH and temperature of chevon from indigenous South African goats slaughtered under commercial conditions

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Abstract

The study was conducted to investigate the effects of sex, age and pre-slaughter conditioning on post-mortem pH, temperature and glycolytic metabolite concentrations in *M. longissimus thoracis* (LT) of indigenous South African goats. Three hours post-mortem, the 2-teeth group had the highest temperature and lowest pH values. The group had an ultimate pH (pHu) that was 0.15 units lower than that of the 8-teeth group. Pre-slaughter conditioning resulted in a higher post-mortem temperature but had no effect on pH values. Sex, age and pre-slaughter conditioning had a low impact on glycolytic metabolite concentrations. Overall the goats in this study had a high pHu, high initial lactate concentration and low glycolytic potential, which suggest that they suffered both chronic and acute stress during pre-slaughter handling.

Keywords: Glycolytic metabolites, glycogen, lactate, pH, temperature, age, sex, pre-slaughter conditioning
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Introduction

Although substantial research has been conducted on goat carcass and meat quality, little attention has been paid to the biochemical changes taking place in the meat immediately post-mortem. This is despite the fact that these changes are highly influential in determining the quality of the meat yielded from a carcass. The aim of this study was to investigate the effects of sex, age and pre-slaughter conditioning on immediate post-mortem metabolic status of chevon from indigenous South African goats that were slaughtered under commercial conditions.

Materials and Methods

A total of 74 South African indigenous goats consisting of recently weaned kids, 4–6 teeth intact and castrated males and full-mouthed females was used in the investigation. The goats were kept on a maintenance diet of a ewe and lamb pelleted concentrate mixture (Silgro®). They received the concentrate at *ca.* 3% of total animal weight per pen per day plus *Eragrostis curvula* hay *ad libitum*. Clean water was freely available. The goats were slaughtered randomly within the non-conditioned (slaughtered within two months of purchase) or pre-slaughter conditioned (slaughtered between six and 10 months of purchase) state. Chronological age was estimated from dentition. All the goats were slaughtered at a research abattoir under conditions similar to those employed by the meat industry of South Africa. The day prior to slaughter the 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. They were then transported to the abattoir (about 30 km/20 minutes drive) where they were held in lairage overnight for *ca.* 17 hours with free access to clean water, but without feed. At slaughter the goats were stunned using 300 V of electricity and exsanguinated.

Samples from the *M. longissimus thoracis* (LT) were collected *ca.* 15 minutes after slitting of the throat and frozen immediately at –70 °C. Glycolytic metabolites were extracted from the meat using the method of Dalrymple & Hamm (1973) and their concentrations were determined using the method of Keppler & Decker (1974) for glycogen, those of Lamprecht *et al*. (1974) for ATP, glucose-6-phosphate and creatine phosphate and that of Gutmann & Wahlefeld (1974) for lactate. The temperature and pH of the LT were recorded on the cold carcass at three (pH_3) and 24 hours (pHu) post-mortem. Glycolytic potential (GP) was calculated according to the Monin & Sellier (1985) formula:

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$$GP = 2([glycogen] + [glucose] + [glucose\text{-}6\text{-}phospahte]) + [lactate]$$

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. Spearman correlations were computed between the glycolytic metabolites and pH_3 and pHu. Where the correlation coefficients were significant, the data were grouped into three pH_3 and pHu groups and the variations in concentration of the glycolytic metabolites within each set of pH groups were analysed, using GLM models.

Results

There were no sex effects ($P > 0.05$) on pH and temperature readings of the carcasses. The 2-teeth group had the highest 3-hour temperature ($P = 0.01$) of all age groups (16.33 ± 4.05 °C *vs*. 11.05 ± 3.45 °C), but the final temperature did not differ ($P > 0.05$) between the four age groups (mean = 3.67 ± 3.58 °C). The mean pH_3 of the 2-teeth group (6.16 ± 0.25) was the lowest, and was 0.27 and 0.33 units lower than pH_3 means for the milk-teethed and 2–6 teeth groups, respectively. The mean pH_3 of the 8-teeth group (6.36 ± 0.29) did not differ from either extreme ($P > 0.05$). Only the mean pHu values of the 2-teeth (5.88 ± 0.12) and 8-teeth (6.03 ± 0.19) groups differed ($P < 0.05$), while means for the milk teeth (5.94 ± 0.10) and 4–6 teeth (5.94 ± 0.13) groups were similar and did not differ from either extreme. Three-hour (17.82 ± 1.78) and final (7.02 ± 2.32) temperatures of the pre-slaughter conditioned group were higher ($P < 0.0001$) than those of the non-conditioned group by 8.3 °C and 6.2 °C, respectively. There was a tendency ($P = 0.081$) for the mean pH_3 of the non-conditioned goats (6.45 ± 0.22) to be higher than that of the pre-slaughter conditioned group (6.16 ± 0.25). However, the pHu means were similar (5.93 ± 0.12 and 5.92 ± 0.16, respectively).

The overall means, minimum and maximum concentrations of the glycolytic metabolites, the main effects of sex, age and pre-slaughter conditioning on all the traits are presented in Table 1.

Table 1 Effects of sex, age, pre-slaughter conditioning and their first order interactions on glycolytic metabolite concentrations (mean ± s.d.) in *M. longissimus thoracis* of indigenous South African goats

	Mean ± s.d.	Min	Max	Sex	Age	Pre-slaughter conditioning
n	74					
Glycolytic potential (µmol/g)	101.74 ± 23.21	56.29	153.81	NS	NS	NS
Lactate (µmol/g)	30.19 ± 10.57	8.88	75.16	NS	NS	NS
Glycogen (µmol/g)	32.82 ± 11.39	8.84	59.75	NS	NS	NS
Lactate %	15.37 ± 5.57	6.04	31.07	NS	NS	NS
Glycogen %	31.60 ± 6.28	14.40	42.20	NS	NS	NS
Glucose (µmol/g)	1.70 ± 0.53	0.76	3.37	NS	NS	NS
Glucose-6-phosphate (µmol/g)	1.25 ± 0.69	0.29	4.00	*	NS	NS
ATP (µmol/g)	5.17 ± 0.74	2.36	6.75	NS	NS	NS
Creatine phosphate (µmol/g)	3.74 ± 1.16	1.86	9.73	NS	*	NS

NS – not significant; * Significant ($P < 0.05$)

Only glucose-6-phosphate concentrations were affected ($P = 0.029$) by the sex of the goats. The monosaccharide concentrations were the lowest in the LT of the females (mean = 1.01 ± 0.67 µmol/g) and 0.34 µmol/g and 0.60 µmol/g less than that in the LT of castrates and intact males, respectively. Age affected creatine phosphate concentration ($P = 0.03$) in the meat. The metabolite was lowest in the 4–6 teeth group (3.40 ± 1.05 µmol/g) and highest in the milk-teethed kids (4.04 ± 1.70 µmol/g). Creatine phosphate concentration was generally higher in pre-slaughter conditioned females and castrates and lower in pre-slaughter conditioned intact males but was unaffected by sex ($P > 0.05$) within the non-conditioned group.

Pre-slaughter conditioned intact males had the lowest ATP concentration (2.95 ± 0.37 µmol/g), which differed ($P < 0.05$) from the concentration in the females of the same group (4.34 ± 1.93 µmol/g). Means for all castrates, non-conditioned females and intact males did not differ from either extreme.

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Only 22% of the LT were glycolysing at a rate fast enough to attain a $pH_3 < 6.1$ (Table 2). Most of the LT (54%) were glycolysing so slowly that their pH_3 readings were above 6.3. The meat with a pH_3 of < 6.1 had a higher 3-hour temperature ($P < 0.0001$) and lower pHu ($P = 0.039$) than LT with a pH_3 of > 6.3. The group also had the highest initial lactate concentration ($P = 0.042$) and tended to have a lower creatine phosphate concentration ($P = 0.052$). This suggests a high rate of peri-mortem glycolytic activity.

Table 2 Effect of early post-mortem pH (pH_3) on glycolytic metabolite concentrations and ultimate pH (pHu) of the *M. longissimus thoracis* (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	16	18	40	
pH_3	5.94 ± 0.17^{a}	6.20 ± 0.07^{b}	6.52 ± 0.15^{c}	<0.0001
Ultimate pH	5.88 ± 0.08^{a}	5.89 ± 0.17^{ab}	5.96 ± 0.14^{b}	0.0394
3-hr temperature (°C)	16.38 ± 3.48^{b}	15.34 ± 4.19^{b}	11.21 ± 4.00^{a}	<0.0001
Lactate (µmol/g)	36.71 ± 13.48^{b}	28.25 ± 5.34^{ab}	27.81 ± 8.81^{a}	0.0420
Glucose (µmol/g)	1.96 ± 0.59	1.65 ± 0.42	1.59 ± 0.47	0.1083
Lactate %	17.13 ± 5.63	15.54 ± 5.99	14.44 ± 4.94	0.4824
Glycogen %	29.56 ± 6.19	31.47 ± 6.67	32.64 ± 5.65	0.3478
Creatine phosphate (µmol/g)	3.33 ± 0.71	3.44 ± 0.63	4.06 ± 1.62	0.0515

[a, b, c]Row means with common superscripts do not differ ($P > 0.05$)

A pHu of < 5.8 was attained in 16% of the LT while the majority (55%) was between 5.8 and 6.0 (Table 3). On average, carcasses with a pHu of > 6.0 showed a GP concentration 27.73 µmol/g lower, a glycogen concentration 11.5 µmol/g less and an ATP concentration 0.52 µmol/g less than carcasses with a pHu of ≤ 6.0 ($P < 0.05$).

Table 3 Effect of ultimate pH (pHu) on initial glycolytic metabolite concentrations in the *M. longissimus thoracis* (means ± s.d.) of indigenous South African goats

	pHu <5.8	pHu = 5.8 to 6.0	pHu >6.0	P-value
n	12	41	21	
Ultimate pH	5.76 ± 0.02^{a}	5.89 ± 0.06^{b}	6.10 ± 0.10^{c}	<0.0001
Glycolytic potential (µmol/g)	114.82 ± 15.89^{b}	105.18 ± 21.61^{ab}	87.09 ± 23.68^{a}	0.0041
Glycogen (µmol/g)	37.83 ± 9.90^{b}	34.60 ± 10.35^{ab}	26.36 ± 11.71^{a}	0.0057
ATP (µmol/g)	5.39 ± 0.81^{b}	5.26 ± 0.74^{ab}	4.87 ± 0.77^{a}	0.0329
Lactate %	14.59 ± 5.97	14.62 ± 4.00	17.27 ± 7.83	0.1822
Glycogen %	32.75 ± 6.40	32.47 ± 4.55	29.23 ± 7.83	0.0988

[a, b, c] Row means with common superscripts do not differ ($P > 0.05$)

Discussion

Of the three factors that were investigated, pre-slaughter conditioning had the greatest influence on post-mortem temperature, possibly due to the insulating effect of higher carcass weight and fat content. However, contrary to expectation, pre-slaughter conditioning did not improve peri-mortem glycogen reserves or post-mortem pH (Warner *et al.*, 1998) of the goats. If there were differences in glycogen reserves in the two groups prior to slaughter, then pre-slaughter conditioning did not improve the goats' tolerance for stress. Handling stress would nullify any differences in stored glycogen (Fernandez & Tornberg, 1991).

Sex, age and pre-slaughter conditioning had little impact on early post-mortem glycolytic metabolite concentrations. However, the generally high pHu, high initial lactate concentration and low GP in this study suggest that the goats suffered both chronic and acute stress during pre-slaughter handling. Low GP is

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associated with stress that occurs earlier in handling, such as during transportation, deprivation of food and lairage, and high lactate concentration immediately after slaughter is associated with acute pre-slaughter stress occurring during the handling between the lairage and the stunning area (Yambayamba *et al*., 1996). Goats have been shown to be highly susceptible to these stressors (Kannan *et al*., 2003).

High pHu values for goat muscles (pHu > 5.8) are prevalently reported (e.g. Kannan *et al*., 2003) but evidently not an inherent characteristic of chevon. Since such a high incidence of high pHu meat often occurs amongst temperamental animals such as young bulls (Lahucky *et al*., 1998), heifers on heat (Kenny & Tarrant, 1988) and boars (Fernandez & Tornberg, 1991), chevon pHu values suggest that goats are generally highly prone to stress caused by handling.

Conclusion

Age, sex and pre-slaughter conditioning were not the major determinants of glycolytic metabolite concentrations. High pHu is not an intrinsic characteristic of chevon but is a consequence of low peri-mortem GP possibly due to stressful peri-mortem handling.

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