CHANGES IN ANTIOXIDANT CONTENTS, QUALITY ATTRIBUTES AND MYOFIBRILLAR PROTEINS OF CHEVON DURING *POSTMORTEM* AGEING

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ABSTRACT

This study examined the effect of *postmortem* ageing on the changes in antioxidant contents, physicochemical properties and and myofibrillar proteins in *Psoas major* (PM) muscle in goats. The PM samples were excised from carcasses of ten Boer bucks on 0, 1, 4 and 8 d *postmortem*. Muscle glycogen and pH was greater on d 0 *postmortem* compared with those observed on other storage days. Ageing had no effect on antioxidant enzyme activities in PM muscle in goats. The relative density of myosin heavy chain and troponin T were stable until d 1 *postmortem* but declined ($P< 0.05$) afterwards. The drip loss, carbonyl, metmyoglobin and TBARS increased ($P< 0.05$) while the redness, shear force, free thiol, tocopherol, carotenoid, myoglobin and metmyoglobin reducing activity decreased ($P< 0.05$) over *postmortem* ageing. *Postmortem* ageing improved tenderness but reduced the oxidative stability of PM muscle in goats.

Keywords: Ageing, *postmortem*, carbonyl, TBARS, tocopherol, myoglobin, *Psoas Major*

INTRODUCTION

Postmortem ageing of meat is a common practice in the red meat industry where meat are held at refrigeration temperatures to enhance tenderness and to supply chilled meat to distant markets (Lawrie and Ledward, 2006). In spite of the merits of *postmortem* ageing, oxidative stability of meat could be compromised. The effect of *postmortem* ageing on the oxidative stability of beef and mutton have been documented (Astruc *et al*., 2007; Nieto *et al*., 2013). However, there is dearth of information on the oxidative stability of myofibrillar proteins in chevon during ageing. The spur for examining the effects of *postmortem* ageing on the quality of chevon is premised on the upsurge in its consumption since its quality attributes are concordant with the present day consumers' demands (Webb 2014). Thus, as part of attempts to characterize the quality attributes of chevon, it was considered worthwhile to examine the role of *postmortem* ageing on the antioxidant status of chevon. The objective of this study was to determine the effect of *postmortem* ageing on the physicochemical properties and oxidative stability of *Psoas major* muscle in goats.

MATERIALS AND METHODS

Ten Boer bucks, aged 8–9 months and weighing 34 ± 0.76 kg were fasted overnight with *ad libitum* access to water and slaughtered in accordance to the Halal procedure. After evisceration, each carcass was split down the vertebral column into two halves. On day 0, 80 g of PM was dissected, trimmed free of external fat and epimyseal connective tissue and divided into three parts. The first part (20 g) was snap frozen and pulverized in liquid nitrogen, and assigned for the determination of antioxidants, myoglobin, protein and lipid oxidation at day 0. The second part (20 g) was stored in a chiller at 4°C for the determination of drip loss. The third part (40 g) was assigned for the determination of color coordinates. The same samples used for color analysis were used for the determination of cooking loss and shear force. The carcasses were hung in the chiller at 4°C for subsequent sampling on day 1, 4 and 8 d *postmortem*. The muscle glycogen, pH, drip and cooking losses, shear force and color coordinates of PM muscle were determined as described by Salwani *et al*. (2016) and Sabow *et al*. (2016). The concentration of tocopherols, carotenoids, myoglobin and metmyoglobin, metmyoglobin reducing activity and antioxidant enzyme

activities were determined as described by Adeyemi *et al.* (2016). Protein thiol was quantified as described by Winterbourn (1990). The carbonyl content in muscles was determined using Cayman protein carbonyl colorimetric assay kit (10005020) following the manufacturer's procedure. The concentration of myofibrillar proteins were determined by sodium dodecyl sulphate polyacrylamide gel electrophoresis as described by Adeyemi *et al.* (2016). Data obtained were subjected to a repeated measure analysis using the GLM procedure of SAS. Means were separated by Tukey HSD test at $P< 0.05$

RESULTS AND DISCUSSION

The changes in muscle glycogen, pH, shear force, cooking and drip losses during *postmortem* ageing of PM muscle in goats are shown in Table 1. The muscle glycogen and pH observed on d 0 was greater ($P< 0.05$) than those observed on other storage days. This observation could be due to *postmortem* glycolysis, which necessitates the conversion of muscle glycogen to lactic acid that lowers muscle pH (Adeyemi and Sazili, 2014). There were no significant changes in muscle glycogen and pH beyond d 1 *postmortem*. This observation suggests that *postmortem* glycolysis was completed within the first 24 h *postmortem*. Similar observation was observed in mutton (Sazili *et al.*, 2008). The drip loss increased ($P< 0.05$) over *postmortem* ageing. This finding could be attributed to the *postmortem* acidification of muscle, which caused the degradation of myofibrillar proteins by endogenous proteinases (Lawrie and Ledward, 2006; Salwani *et al.*, 2015). This finding is consistent with the decline in the density of myofibrillar proteins. Cooking loss of meat is important because the remaining water in the cooked product is the main contributor to the sensation of juiciness (Warriss, 2010). *Postmortem* ageing had no effect ($P> 0.05$) on cooking loss in chevon. Similarly, ageing had no effect on cooking loss in mutton (Sazili *et al.*, 2008). *Postmortem* ageing influenced shear force. The decrease in shear force could be due to the weakening of myofibrillar structure by endogenous muscle proteinases (Lawrie and Ledward, 2006). During *postmortem*, the accumulation of Ca^{2+} into the muscle sarcoplasm leads to the activation of μ-calpain which in turn destabilises the intact myofibrillar structure by degrading myofibrillar proteins (Lomiwes *et al.*, 2014). This observation is consistent with the decrease in shear force observed during *postmortem* ageing of mutton (Sazili *et al.*, 2008) However, Kannan *et al.* (2006) did not observe changes in shear force during a 6 d ageing of *triceps brachii*, *semimembranosus* and *longisimus dorsi* in Spanish does. Meat redness (a*) and lightness (L*) decreased and increased respectively as storage progressed. These findings coincide with the decrease in myoglobin concentration and metmyoglobin reducing activity (MRA) and the increase in % metmyoglobin. These findings suggest a decline in antioxidant contents of PM as storage progressed. The improvement in L* and decrease in a* over storage is consistent with the findings in mutton (Bekhit *et al.*, 2001) and beef (Liu *et al.*, 2015). The decrease in the concentration of myoglobin over storage coincides with the increase in % metmyoglobin. This suggests that that the myoglobin was converted to metmyoglobin. Similarly, %metmyoglobin in beef patties increased during an 8 d (Liu *et al.*, 2015) and a 10 d (Bekhit *et al.*, 2003) refrigerated storage. The MRA decreased ($P< 0.05$) over storage. This finding is in tandem with that of Madhavi and Carpenter (1993) who observed a reduction in MRA of beef from 2-21 d *postmortem*. The concentration of tocopherols and carotenoid decreased ($P< 0.05$) over storage. This reflects breakdown of antioxidant defense system and explained the increase in lipid and protein oxidation as *postmortem* storage progressed. The decrease in tocopherol is in tandem with the report of Clausen *et al.* (2009) who observed a reduction in the concentration of vitamin E in beef as *postmortem* storage continued. *Postmortem* ageing had no effect on the antioxidant enzymes activities in PM muscle in goats. This observation is consistent with the findings of Renerre *et al.* (1996) who observed that the catalase and GPx activities in beef did not change over storage. The TBARS value increased ($P< 0.05$) over storage. This observation could be attributed to the decrease in the concentration of carotenoid and tocopherols

over storage. Similarly, the TBARS value increased in aged beef (Liu *et al.*, 2015) and broiler meat (Sola-Ojo *et al.*, 2014). Carbonyl and free thiol are important parameters for assessing the extent of protein oxidation in tissues (Nieto *et al.*, 2013). *Postmortem* ageing reduced free thiol and increased carbonyl concentration in PM muscle in goats. Similarly, Martinaud *et al.* (1997) observed a decrease in thiol in beef *longissimus lumborum* during a 10 d *postmortem* ageing. In addition, Astruc *et al.* (2007) observed that chill storage increased the carbonyl concentration in beef.

The density of myosin heavy chain fast and myosin heavy chain slow decreased ($P< 0.05$) over storage. Myosin constitutes about 45% of the total myofibrillar protein in the skeletal muscles of animals (Lefaucheur, 2010) and it is highly susceptible to oxidation (Morzel *et al.*, 2006; Lund *et al.*, 2011). In contrast, myosin heavy chain of beef *semimembranosus* was stable throughout a 28 d chill storage at 4 °C (Bandman and Zdanis, 1988). Unlike myosin heavy chain, the band intensity corresponding to actin underwent ($P> 0.05$) slight degradation as storage progressed. The high oxidative stability of actin was attributed to the masking of oxidation sites caused by the interaction of actin with myosin chain in myofibrillar suspensions (Xue *et al.*, 2012). Similarly, Gil *et al.* (2006) did not observe significant degradation of actin during *postmortem* ageing of rabbit meat for 7 d. The reflective density of troponin T reduced over storage. Similar findings were observed in beef (Martinuad *et al.* (1997).

CONCLUSION

The current results show that *postmortem* ageing of PM muscle in goats enhanced meat tenderness but induced oxidative deterioration.

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Table 1 Physicochemical properties and antioxidant status of *Psoas Major* muscle in goats during *postmortem* ageing.

Parameter	Ageing period (d)				SE	P value
	0	1	4	8		
Glycogen (mg/g)	1.72^{a}	0.65^{b}	0.66^{b}	0.65^{b}	0.01	0.021
pH	6.51^{a}	5.50^{b}	5.53^{b}	5.51^{b}	0.20	0.001
Drip loss	-	5.80^{c}	6.90^{b}	8.70^{a}	0.01	0.032
Cooking loss	30.11	32.30	34.12	32.67	0.01	0.134
Redness (a*)	12.00^{a}	11.09^{b}	9.70^{c}	8.30^{d}	0.12	0.020
Lightness (L*)	32.40^{d}	35.50^{c}	37.00^{b}	38. 98^{a}	0.40	0.034
Yellowness (b*)	13.40	16.20	14.09	13.10	0.90	0.093
Shear force (kg)	0.87^{a}	0. 80^{b}	0.74^{c}	0.59^{d}	0.03	0.016
Myoglobin (mg/g)	2.89^{a}	2.40^{b}	2.07^{c}	1.90^{d}	0.01	0.015
Metmyoglobin (%)	5.60^{d}	7.19^{c}	12.77^{b}	20.47^{a}	0.25	0.032
MRA (nmol/min/g)	201.22^{a}	189.45^{b}	180.45^{c}	167.00^{d}	3.40	0.001
α-tocopherol (mg/kg)	4.55^{a}	4.52^{a}	2.83^{b}	1.40^{c}	0.343	0.001
γ-tocopherol (mg/kg)	0.77^{a}	0.73^{b}	0.68^{c}	0.50^{d}	0.054	0.004
δ-tocopherol (mg/kg)	0.10^{a}	0.07^{b}	0.05^{c}	0.03^{d}	0.001	0.001
Total carotenoid (mg/kg)	0.37^{a}	0.37^{a}	0.24^{b}	0.13^{c}	0.041	0.046
Catalase[1]	1733.2	1834.3	1691.3	1784	20.34	0.123
Superoxide dismutase[2]	2.78	2.59	2.75	2.67	0.02	0.090
Glutathione peroxidase[3]	87.52	84.90	80.69	85.00	2.90	0.145
TBARS[4] (mg MDA/kg)	0.14^{c}	0.16^{c}	0.28^{b}	0.41^{a}	0.02	0.003
Carbonyl (mmol/mg protein)	0.93^{d}	1.57^{c}	4.74^{b}	7.09^{a}	0.092	<.001
Free thiol (mmol/mg protein)	58.20^{a}	54.71^{a}	45.56^{b}	36.65^{c}	0.291	0.006
Myosin heavy chain fast[4]	14.00^{a}	13.30^{a}	10.10^{b}	7.30^{c}	0.920	0.023
Myosin heavy chain slow[4]	90.88^{a}	90.67^{a}	86.07^{b}	70.21^{c}	4.67	0.012
Actin[4]	9.20	9.20	8.39	8.00	0.30	0.06
Troponin T[4]	8.76^{a}	8.14^{a}	6.70^{b}	5.00^{c}	0.60	0/031

$^{a, b, c, d}$ means having different superscripts along the same row are significantly different (P< 0.05). MRA=metmyoglobin reducing activity. [1]expressed as nmol.H_2O_2/min/mg protein. [2]expressed as Units /50% mg protein. [3]expressed as nmoles NADPH oxidized /min/mg protein. TBARS =Thiobarbituric reactive substance. [4]expressed as density/mm^2