Journal of Animal and Veterinary Advances 9 (24): 3039-3047, 2010
ISSN: 1680-5593

Meat Quality and Lipid Oxidation of Infraspinatus Muscle and Blood Plasma of Goats under Dietary Supplementation of Herbal Antioxidants

[1,3]M. Karami, [1]A.R. Alimon, [1]A.Q. Sazili and [2]Y.M. Goh
[1]Department of Animal Science, [2]Department of Veterinary Preclinical Sciences,
University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Department of Animal Science, Agriculture and Natural Resource Research Centre,
415, Shahrekord, Iran

Abstract: This study investigated the effect of different antioxidants of dietary supplementation with *Andrographis paniculata*, turmeric and α-tocopherol on lipid and color stability of Infraspinatous (IS) kacang crossbred goat kids muscle. Four treatments of eight animals each were randomly selected consisting of Control (CN), 400 mg kg^{-1} Vitamin E (VE), 0.5% kg^{-1} DMI Turmeric (TU) and 0.5% kg^{-1} DMI *Andrographis paniculata* (AP). After 100 days feeding period, goats were slaughtered and infraspinatous muscle was sampled. The muscle was vacuum-packaged and displayed for 0, 7 and 14 days in a chiller at 3-4°C. Percent of drip loss in the IS muscle were not significantly different among of dietary supplementation antioxidants (VE, TU and AP) with CN. Period of display did not affect ($p>0.05$) drip loss in IS muscle. Percent of cooking loss in the IS muscle were different among of dietary supplementation antioxidants (VE, TU and AP) and AP supplemented diet only decreased significantly ($p<0.05$) cooking loss with CN treatment. Increasing the aging time had not significant effects on percent cooking loss in the IS muscle. Warner-Bratzler shear force was not affected by dietary supplementation antioxidants in IS muscle. However, Increasing the aging time significantly ($p<0.05$) decreased Warner-Bratzler shear force value or improved tenderness of IS muscle in kacang male goat kids. Supplementation of dietary antioxidant turmeric improved the IS muscle L* (lightness), a* value (redness), b* (yellowness) values, Chroma, Hue angle values and E enhanced significantly ($p<0.05$). Dietary antioxidants supplementation decreased TBARS value however, VE significantly ($p<0.05$) decreased lipid oxidation in IS muscle of kacang crossbred goat kid. TBARS value increased during the first 7 days store in refrigerator but not significant ($p>0.05$). TBARS value high significantly increased in aging time at 14 days ($p<0.01$). Dietary antioxidants supplementation and sampling periods of blood plasma decreased ($p<0.05$) TBARS value of blood plasma of goats. In conclusion, feeding herbal antioxidants supplementation of male goat kids resulted in a general improvement of blood plasma and IS muscle oxidative stability as compared to feeding a control diet. Meat color deterioration, measured as changes of color descriptors aging (over) time was less pronounced in IS muscle from animals fed herbs (TU and AP) and VE diets than in IS muscle from CN-fed goats.

Key words: Antioxidants, *Andrographis paniculata*, turmeric, vitamin E, infraspinatous muscle, goat

INTRODUCTION

Several active components of herbs and spices can prevent lipid peroxidation through quenching free radicals or through activation of antioxidant enzymes like superoxide dismutase, catalase, glutathione peroxidase and glutathione reductase.

Main molecules responsible for the antioxidative properties of herbs and spices are phenolic substances (flavonoids, hydrolysable tannins, proanthocianidins, phenolic acids, phenolic terpenes) and some vitamins (E, C and A) (Frankic *et al*., 2009). Often used herbs rich in flavonoids such as *Andrographis paniculata* (Gupta *et al*., 1983), phenolics are turmeric (*Curcumin longa*) (Arunothayanun *et al*., 2005; Grinberg *et al*., 1996). Lipid oxidation is a major cause of chemical spoilage in meat and food. To avoid or delay this autoxidation process antioxidants have been utilized with the practice being carried out successfully for over 50 years. Addition of vitamin E to the feed increased α-tocopherol concentration in sarcosomes and thus significantly increased the stability of the lipids against

Corresponding Author: A.R. Alimon, Department of Animal Science, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

oxidation, it has been found to improve the quality of farm animal products (Armstrong, 2002; Pokorny *et al*., 2001). Lipid oxidation results in the production of free radicals which may lead to the oxidation of meat pigments and generation of rancid odors and flavors (Faustman and Cassens, 1990).

Meat color is another important parameter and the main factor affecting on judge of consumers use to the freshness and wholesomeness of meat (Insani *et al*., 2008). The bright red or cherry red color in meat has considerable effect on acceptability and purchasing decision at retail points (Lynch *et al*., 1999; Gatellier *et al*., 2005; Insani *et al*., 2008). Concentrations of endogenous antioxidants depend on animal species, muscle type and diet (Decker *et al*., 2000). Information on the effects of feeding on lipid oxidation of chevon quality is limited (Lee *et al*., 2008).

The color of meat depends of different factors such as a number of haeminic pigments and particularly of myoglobin, the physical characteristics of the meat, essentially pH and the chemical state of these pigments. Reduced (or deoxy) myoglobin is the purple pigment of deep muscle and of meat surface under vacuum (Gatellier *et al*., 2005). Although, consumers demand lean meat especially in developed countries with a high incidence of cardiovascular diseases (Banskalieva *et al*., 2000). Lipid oxidation in meat increased after 4 or 7 days of storage (Luciano *et al*., 2009; Morrisey *et al*., 1998); it results in deterioration of flavour, color, odour, quality and nutritive value. But skeletal muscle also contains antioxidants that may interfere with the reactions induced by free radicals. Tocopherols, carotenoids and ubiquinols constitute the main lipid soluble free radical scavengers in meat (Decker *et al*., 2000). Lipid oxidation can also be reduced by supplementing antioxidants to the diet of the animals (Coronado *et al*., 2002). Although, synthetic antioxidants are widely used in the meat industry the consumer concern over their safety and toxicity initiated search for natural sources of antioxidants (Nuala *et al*., 2006). Dietary antioxidants can be delivered to the muscle where, together with the native defense systems, they counteract the action of pro-oxidants (Descalzo and Sancho, 2008). Ruminant diets supplemented with antioxidants such as vitamin E have been extensively studied as means of improving meat oxidative stability. Natural antioxidants are found in almost all plants, microorganisms, fungi and even in animal tissues (Akarpat *et al*., 2008). In recent years, substances derived from the plants such as dried herbs and essential oils have been successfully used to reduce lipid oxidation in meat products (Estevez *et al*., 2005). Antioxidant properties of herbs/spices/plant and other food extracts are apparently related to their phenolic content suggesting that their antioxidant action is similar to that of synthetic phenolic antioxidants (Lai *et al*., 1991). Curcumin is a good antioxidant and inhibits lipid peroxidation in rat liver microsomes, erythrocyte membranes and brain homogenates (Reddy and Lokesh, 1994). It was suggested that the curcuma antioxidants are more potent compared to vitamin E (Miquel *et al*., 2002). They exhibit strong antioxidant activity comparable of that to vitamins C and E (Toda *et al*., 1985). Vitamin E might help to extend the shelf life of aged meat (Liu *et al*., 1996). Tenderness may be the most important eating quality parameter that determines consumer acceptability (Miller *et al*., 2001; Savell and Shackelford, 1992).

It was reported that significant improvement in chevon tenderness occurs within the first 4 days of refrigerated storage. Further improvements in Warner-Bratzler shear force were not as evident thereafter (Kannan *et al*., 2002). The objective of this study was to effect of different dietary antioxidants (vitamin E, Turmeric and *Andrographis paniculata* (AP)) on color stability of Biceps femoris muscle of goats under refrigerated retail display.

MATERIALS AND METHODS

Four treatments of eight animals each were randomly selected, consisting of Control (CN), 400 mg kg^{-1} Vitamin E (VE), 0.5% kg^{-1} DMI Turmeric (TU) and 0.5% kg^{-1} DMI *Andrographis paniculata* (AP) added to their daily feed intake. After 100 days feeding period, goats were slaughtered and biceps femoris muscle were sampled. The muscle were vacuum-packaged and displayed for 0, 7 and 14 days in a chiller at 3-4°C.

All animals were fed 30% roughage and 70% concentrate (CN group). For the feedlot treatments, the supplement was uniformly mixed into the dry ration. All diets were formulated to meet the nutritional requirements of growing goats and adjusted according to their bodyweights. Each animal was provided with 0.62 m^2 of floor space with *ad libitum* access to water.

Slaughter was done at experimental slaughterhouse in the Meat Science Laboratory, Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia. Goats were fasted for 12 h with free access to water and weighed immediately prior to slaughter. The animals were slaughtered according to the Halal methods where a throat cut was employed to sever carotid arteries and jugular veins.

Carcasses were dressed according to (Colomer-Rocher *et al*., 1992) and cut according to (Farid, 1991). IS muscle was sampled from left side carcasses. Samples were split to 3 part and vacuum-packed for display for 0, 7 and 14 days at 4°C. At the end of the

display period, samples were frozen at -80°C for the determination of meat quality parameters within a month (drip loss, cooking loss and color).

Lipid phase antioxidant activity (TBARS Method): Lipid oxidation was evaluated using the Thiobarbituric Acid Reactive Substances (TBARS) method. The TBARS assay was performed as described by Buege and Aust (1978) with modifications. The production of Thiobarbituric Acid Reactive Substances (TBARS) was measured spectrophotometrically at 535 nm during the 20 min of incubation at 80°C and expressed as concentration causing 50% inhibition (IC50). The ground muscles samples (1 g) was mixed with 5 mL of 0.375% thiobarbituric acid 15% trichloroacetic acid-0.25N HCl stock solution in a glass test tube. The mixture was heated for 10 min in a boiling water bath (100°C) to develop a pink color. The test tube was then cooled with tap water and then centrifuged at 5000 rpm for 15 min. Absorbance of supernatant was measured at 532 nm using a spectrophotometer (Spectronic® 20 Genesys™). The TBARS were calculated from a standard curve of 1, 1, 3, 3,-Tetraethoxypropane (TEP) and expressed as mg Malondealdehyde (MDA) kg^{-1} sample.

Meat color measurement: The color of IS muscle was measured using the ColorFlex® system (Hunterlab, Reston, VA) with illuminant D65 as the light source. The instrument was calibrated against black and white reference tile prior to use. The L*, a* and b* color coordinate values were measured on the cut surface of IS muscle chop from left side of each carcass after a 30 min bloom time at 4°C.

Colorimetric co-ordinates for goat meat have been reported by Babiker and Bello (1986), Babiker *et al.* (1990), Dhanda *et al.* (1999), Husain *et al.* (2000), Kannan *et al.* (2001), Simela *et al.* (2004), Webb *et al.* (2005). Three measurements were taken from each sample. The average of the three measurements was recorded as color coordinate value of the sample for days 0, 7 and 14. Hue angle was calculated as tan-1 $(b^*/a^*)\times(180/\pi)$, whereas saturation index or chroma (a measure of color vividness) was calculated as $(a^{*2}+b^{*2})1/2$ (Hunter and Harold, 1987). The color measurement was carried out on each sample using to enhance the fraction of redness relative to those of yellowness and lightness, the Enhanced redness (E*) was calculated using the following modified equation as described by (Liu *et al.*, 2003):

$$E^* = a/b+a/L$$

Water holding capacity: Water holding capacity of the IS muscle included measurement for drip loss and cooking loss. At 0, 7 and 14 days post mortem, IS sample was weighed (about 50 g) and put on a plastic hurdle. Then both items (meat samples on the plastic hurdle) were put into sealed polyethylene bags and hermetically closed to prevent surface evaporative loss. After a 24 h storage period at 4°C, the meat samples were removed from the bag and reweighed. The difference in the weight of the samples before and after storage, divided by the sample weight before storage×100 accounted for the % drip loss (Lanza *et al.*, 2003).

The measurement of cooking losses was conducted on the IS sample at three display period (days 0, 7 and 14). About 50 g of each sample was weighed and held in plastic bags and immersed in an 80°C water-bath until the internal temperature reached 78°C. Then, the bags were cooled under running tap water for 30 min and blotted dry with paper towels and reweighed. Cooking losses as percentages were then calculated from the difference between the weights (Lanza *et al.*, 2003; Sazili *et al.*, 2004). Cooking losses were calculated by applying the following equation:

$$\text{Percentage cooking loss} = (Wa/Wb)\times 100$$

Where:

Wa = Weight of muscle slice after cooking (g) in water-bath

Wb = Weight of muscle slice be fore cooking (g) in water-bath (Lee *et al.*, 2008)

Texture Analysis (TA): At the end of each storage time (0, 7 and 14 days) the IS muscle was frozen and stored at -80°C. Prior to the mechanical assessment of tenderness, the cuts were thawed at 4°C, placed on aluminum pans and covered with aluminum foil. The cuts were then cooked in water-both to an internal temperature of 78°C were maintained for a further 10 min. The internal temperature was measured in a representative cut from each chop using thermocouple thermometers placed in the geometric center of the muscle studied. After cooking, cuts were chilled overnight at 4°C before core removal. (Kannan *et al.*, 2002). Up to 3 cores (0.9 cm diameter) were removed as close to the longitudinal orientation of the muscle fibers as possible. Each core was placed on the base plate of a TA-HD plus-texture analyzer (Stable Micro Systems, UK) fitted with a Warner-Bratzler blade and sheared once in the centre and perpendicular to the longitudinal direction of the fibres. Warner- Bratzler shear force values were reported as the mean of all core values of samples. To standardize the temperature of the cores between samples, The instrument was set with a 30 kg load cell and a crosshead speed of 3 sec min^{-1} (Sazili *et al.*, 2005).

Statistical analysis: A 4×3 factorial design (diets* display days) with three replicates was employed for storage data (Drip loss, Cooking loss, Colour, Shear forse, TBARS)

with treatments and storage time as main effects using two-way Analysis of Variance (ANOVA). Analysis of variance was performed on all the variables using the General Linear Model (GLM) procedure of the SAS statistical package. Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

RESULTS AND DISCUSSION

Lipid oxidation in meat and plasma: In comparison with the CN treatment all three dietary antioxidant supplements (VE, TU and AP) in the present experiment decreased ($p<0.05$) the TBARS values and protected lipid oxidation of the IS muscle (Table 1). However, it is interesting to note that the TBARS value in IS muscle increased already at 7 days of refrigerated display storage for the CN treatment but significantly ($p<0.05$) increases occurred only after 14 days of display for the dietary antioxidant (VE, TU and AP) treatments. Therefore, the rate of oxidation was decreased by the dietary supplements of antioxidants. The effect of dietary antioxidants supplement were significant ($p<0.05$) on blood plasma as well as blood sampling periods at 4 weeks ($p<0.05$) and 8 and 14 weeks ($p<0.01$) (Table 2).

Intraction between dietary antioxidants supplement and blood plasma sampling periods (Table 3) were significant ($p<0.05$), special in AP and TU diets at third and final periods were highly significant ($p<0.01$). In agreement of the study, Galipalli *et al.* (2004) reported that the effects of diets supplementation on oxidative stability of goat meat (chevon) were not significant but TBARS increased over display time. Kannan *et al.* (2001) observed that lipid with increasing refrigerated display time in case-ready m cuts from oxidation increased Spanish goat carcasses. Concentrations of endogenous antioxidants depend on diet, muscle type and animal species (Decker *et al*., 2000; Sante-Lhoutellier *et al*., 2008). Results of research by other researchers are in agreement (Lynch *et al*., 1999; Mercier *et al*., 2004). As expected like the study, in a study, natural antioxidants protected beef against lipoperoxidation (Descalzo *et al*., 2005). Lipid oxidation results in the production of free radicals which may lead to the oxidation of meat pigments and generation of rancid odors and flavors (Faustman and Cassens, 1990).

Color: Meat color is the main factor affecting ruminant product acceptability at retail points of purchase (Liu *et al*., 1996). In terms of appearance, goat meat tends to have a slightly lower a* value than had been reported for sheep meat but indications are that the colour is acceptable to consumers (Webb *et al*., 2005). The color stabilities of the fresh and aged muscle (0, 7 and 14 days) are shown in Table 4. The dietary antioxidant supplementation treatments had significant influences on the IS muscle L* (lightness), a* value (redness), b* (yellowness) values and also Chroma, Hue angle and E enhanced ($p<0.05$). Turmeric had highly significant

Table 1: Effects of treatments: (1) basal diet-Control (CN), (2) basal+Vitamin E (VE), (3) basal+Turmeric (TU) and (4) basal+*Andrographis paniculata* (AP) and display day (0, 7 and 14) in IS muscle on antioxidant activity of the Thiobarbituric Acid Reactive Substances (TBARS) as units of Malondialdehyde (MDA) in chevon (mg MDA kg^{-1} chevon)

Parameters	Mean±SE
Treatment	
CN	1.69±0.16^{a}
VE	1.27±0.12^{b}
TU	1.41±0.18^{ab}
AP	1.30±0.11^{a}
Displsy day	
1	0.97±0.17^{a}
7	1.21±0.07^{a}
14	2.11±0.14^{b}
Treatments	*
Display day	*
Treats*day	*

$^{a-c}$Means within columns with different superscripts are different among different treatments and display days ($p<0.05$).*: $p<0.05$, **: $p<0.01$

Table 2: Effects of treatment: (1) basal diet-Control (CN), (2) basal+Vitamin E (VE), (3) basal+Turmeric (TU) and (4) basal+*Andrographis paniculata* (AP) and sampling time day on blood plasma lipid oxidation by TBARS (MDA) assay measurement in goat blood plasma (μmol MDA L^{-1} of plasma)

Parameters	Plasma Mean±SE
Treatments	
CN	1.35±0.07^{a}
VE	1.06±0.08^{b}
TU	1.08±0.08^{b}
AP	1.01±0.11^{b}
Blood sampling periods	
0 day	1.59±0.13^{a}
4 weeks	1.23±0.06^{b}
8 weeks	0.89±0.06^{c}
14 weeks	0.81±0.06^{c}
Treatments	*
Sampling periods	**
Treat* periods	**

$^{a-c}$Means within columns with different superscripts are different ($p<0.05$). *: $p<0.05$, **: $p<0.01$

Table 3: Effect of treatments: (1) basal diet-Control (CN), (2) basal+Vitamin E (VE), (3) basal+Turmeric (TU) and (4) basal+*Andrographis paniculata* (AP) on different blood plasma sampling lipid oxidation by TBARS (MDA) assay measurement in goat blood plasma (μmol MDA L^{-1} of plasma)

Parameters	Prestarting (0 day) Mean±SE	Second blood plasma sampling (4 weeks) Mean±SE	Third blood plasma sampling (8 weeks) Mean±SE	Final blood plasma sampling (14 weeks) Mean±SE
Treatments				
CN	2.03^{x}±0.20^{a}	1.97^{x}±0.16^{a}	1.81^{x}±0.07^{a}	1.69^{x}±0.06^{a}
VE	2.01^{x}±0.16^{a}	0.92^{y}±0.18^{b}	0.76^{y}±0.07^{b}	0.78^{y}±0.06^{b}
TU	2.02^{x}±0.16^{a}	1.37^{y}±0.17^{ab}	0.90^{z}±0.06^{ab}	0.88^{z}±0.05^{ab}
AP	2.06^{x}±0.16^{a}	1.16^{y}±0.16^{ab}	0.90^{y}±0.07^{ab}	0.76^{z}±0.06^{b}

$^{a-c}$Means within columns with different superscripts are different among treatments ($p<0.05$). $^{x-z}$ Means within rows with different superscripts are different among blood sampling periods ($p<0.05$)

Table 4: Percent least square means of Infraspinatus muscle color of goats in different treatments and different display days

	L*[1]	a*[2]	b*[3]	C*[4]	Hue[5]	E*[6]
Parameters	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
Treatments						
CN	32.60±0.47[a]	8.62±0.18[a]	7.93±0.21[a]	11.76±0.64[a]	42.53±0.52[a]	1.20±0.02[a]
VE	31.57±0.46[a]	8.82±0.18[a]	7.94±0.21[a]	11.89±0.65[a]	41.92±0.52[a]	1.18±0.02[a]
TU	36.10±0.47[b]	12.6±0.200[b]	14.0±0.230[b]	18.88±0.76[b]	48.11±0.64[b]	1.48±0.04[b]
AP	31.53±0.46[a]	9.55±0.19[c]	8.48±0.21[a]	12.82±0.67[c]	41.51±0.52[a]	1.20±0.02[a]
Display day						
0	33.22±0.44[a]	11.03±0.17[a]	9.29±0.19[a]	14.23±0.62[a]	41.10±0.073[a]	1.43±0.02[a]
7	32.31±0.43[a]	9.04±0.16[b]	9.49±0.19[ab]	12.88±0.61[ab]	43.71±0.74[b]	1.24±0.02[a]
14	33.32±0.44[a]	8.58±0.16[b]	9.99±0.19[b]	12.41±0.62[b]	44.23±0.76[b]	1.16±0.02[a]
Treatments	*	*	*	*	*	*
Display day	NS	*	*	*	*	NS
Treats*day	NS	*	*	*	*	NS

[a-c]Means within columns with different superscripts are different ($p<0.05$). [1]Measure of darkness to lightness (a greater value indicates a lighter color). [2]Greater value indicates redder color. [3]Greater value indicates more yellow color. [4]Chroma or saturation index is measure of the total color/vividness of color (greater value indicates greater total color/more vivid color). [5]Degree changes from the true red axis (larger number indicates greater shift from red to yellow) [6]Enhenced redness E = a/b+a/L. NS: Non-Significant *: $p<0.05$

Table 5: Percent least square means and standard errors of drip l oss, Cooking loss and Warner-Bratzler shear force value (kg cm^{-2}) in Infraspinatous muscle of goats in different treatments and display days

		Drip loss	Cooking loss	Tenderness
Treatment	No	Mean±SE	Mean±SE	Mean±SE
Control	8	2.42±0.32	31.8±1.42	4.26±0.33
Vitamin E	8	2.45±0.32	28.8±1.41	4.61±0.28
Turmeric	8	1.98±0.31	30.3±1.42	4.51±0.32
Andrographis paniculata	8	2.57±0.33	28.6±1.41	3.93±0.31
Display day				
0	32	2.27±0.27	30.5±1.32	5.03±0.24[a]
7	32	2.59±0.28	29.3±1.31	4.57±0.27[ab]
14	32	2.43±0.28	29.0±1.30	3.97±0.27[b]

[a,b]Means within columns with different superscripts are different ($p<0.05$)

($p<0.01$) effect on L*, a*, b*, chroma and E enhanced in IS muscle of goat meat. Aging time had significant effect on the a*, b* values, Chroma hue and E enhanced, special in 14 days ($p<0.05$) of IS muscle. Increasing the display time was lighter and for redness was vice versa ($p<0.05$).

Supplementation of pasture-fed cattle with vitamin E had no effect on meat redness (a* value) of fresh or 47 days aged meat when measured over a 7 days period of aerobic storage. In contrast with previous publications (Arnold *et al*., 1992; Descalzo *et al*., 2008; Lynch *et al*., 1999), supra-nutritional supplementation of grain fed cattle with vitamin E did not affect meat redness or stability compared with that from non-supplemented cattle, when viewed over a 7 days period of aerobic storage. Therefore, the differences in post-mortem time could have affected the efficacy of dietary vitamin E on improving color stability (Yang *et al*., 2002). The stability and improvement in meat color by vitamin E was principally due to its ability to prevent the oxidation of myoglobin and/or oxymyoglobin to metmyoglobin (Cheah *et al*., 1995). Color of meat depends upon several individual factor and their interactions. While the species of a meat animal has a remarkable effect on meat color, it is also greatly influenced by the chemical stability of the meat pigment, myoglobin (Faustman and Cassens, 1990).

Ageing had a significant influence on lightness (L*) and yellowness (b*) color of the selected muscles (Kadim *et al*., 2003). Chevon has been reported to have lower lightness and higher redness than lamb, mainly due to the lower intramuscular fat of goat carcasses (Babiker *et al*., 1990; Kannan *et al*., 2001).

Oman *et al*. (2000) reported that the lean color score and overall appearance decreased as surface discoloration increased during 4 days storage of goat rib chops in retail overwrap packaging at 2°C. Kannan *et al*. (2001) also found that although, shoulder cuts were reddest with the highest chroma and lowest hue, surface discoloration of all packaged cuts occurred within 4-8 days so the case-life of goat meat was similar to other red meat species. The mechanism for increased color stability of meat from vitamin E supplementation is not completely understood. However, it has been speculated that lipid oxidation products catalyze the oxidation of oxymyoglobin to metmyoglobin. The direct antioxidant action of α-tocopherol on membrane lipids may indirectly delay oxymyoglobin oxidation and thus meat discoloration (Morrisey *et al*., 1998). Goat meat tends to be darker red, have a coarser texture with a detectable different flavour and aroma from lamb and mutton (Schonfeldt *et al*., 1993a; Sheradin *et al*., 2003; Webb *et al*., 2005). However, studies on color stability and meat quality of goat meat with antioxidant supplementation are favorable and interesting.

Drip loss: The least square mean for the percent of drip loss in the IS muscle (Table 5) was not significantly different among of dietary supplementation antioxidants

(VE, TU and AP) with CN. Display day were not affected ($p>0.05$) in BF muscle on drip losing but in LD muscle with aging time (0-7 day or 14 days), drip losing increased 1.77-3.9 or 3.19% ($p<0.05$). Leheska *et al.* (2002) reported that dietary treatment did not influence drip loss and cooking loss in pork. Juiciness of meat is directly related to the intramuscular lipids and moisture content of the meat but the water remaining in the cooked product is the major contributor to the sensation of juiciness during eating, Chevon and its products are reportedly less juicy than lamb and lamb products, a quality attributed to the lower fat content of chevon (Lee *et al*., 2008).

Cooking loss: The percent of cooking loss in the BF muscle (Table 5) was not significantly different among of dietary supplementation antioxidants (VE, TU and AP) with CN. Increasing aging time had significant effects on percent cooking loss ($p<0.05$) in BF muscle whatever increased postmortem aged from 0 day (34.0%) to 14 days (28.7%) cooking loss decreased. Kannan *et al.* (2001) found that percent cooking loss was higher at 0 day than at 4, 8 or 12 days of display for goat steaks and they reported that the average cooking loss was high in leg cuts and low in loin cuts. According to Trout (1988) cooking loss is more dependent on ultimate pH, sarcomere length and cooking condition. Bouton *et al.* (1972) suggested that the myofibrillar protein structurally changes with ageing, resulting in significantly reduced cooking loss for 6 days rather than 1 day aged muscles. Ageing had a significant influence on percent cooking loss of the selected muscles (Kadim *et al*., 2003). In another study obtained dietary treatments did not have any effect on the cooking loss of c hevon chops (Lee *et al*., 2008).

Tenderness (Warner-Bratzler shear force): VE, TU and AP improved tenderness in IS muscle but not significant. Aging time improved chevon tenderness occurred in 7 days and significantly ($p<0.05$) in 14 days. Tenderness may be the most important eating quality parameter that determines consumer acceptability (Miller *et al*., 2001; Savell and Shackelford, 1992). The tenderness value of chevon is often in the acceptable range (Webb *et al*., 2005). Shear force values depend on factors such as the treatment of the animals prior to slaughter, postmortem methodologies, the sampled muscle and method of sample preparation (Webb *et al*., 2005). Kannan *et al.* (2002) reported that significant improvement in chevon tenderness occurs within the first 4 days of refrigerated storage and further improvements in Warner-Bratzler shear force were not as evident thereafter. Maximum tenderization of chevon occurs within the first 4 days of aging although, myofibril weakening and fragmentation continue to increase even after 8 days of aging.

The endomysium and perimysium of chevon did not weaken up to 12 days of aging as evidenced by shear force values and collagen solubility of intramuscular connective tissue. Other researcher reported muscle tenderness was significantly improved by ageing for 6 days at 1-3°C. Goat breeds may also differ in their meat quality.

In other experiments designed to improve tenderness, daily intramuscular injections of vitamin E were tried on lambs from 5 days after birth and for 25 days (Maiorano *et al*., 1999). Studies on extended aging periods, similar to those in beef may not be relevant for chevon because of its shorter shelf life than other types of red meat (Kannan *et al*., 2002). Several researchers have reported that chevon is less tender than other types of red meat (Griffin *et al*., 1992; Schonfeldt *et al*., 1993a, b).

The lower shear values observed in the present study may be due to the fact that the diameter of cores used in this study was 1 cm. This core diameter was chosen to facilitate removal of at least two cores from each cut. The longissimus muscle cross sectional area of goat carcasses is considerably smaller than carcasses of other traditional red meat animals and maximum tenderization of chevon occurs within the first 4 days of aging time (Kannan *et al*., 2002).

CONCLUSION

Based on the present results, it can be concluded that dietary antioxidants from natural herbs such as *Andrographis paniculata* have potential for improved antioxidant activity, color stability and tenderness of IS muscle as well as dietary herbal antioxidants protected lipid oxidation of blood plasma in goat.

REFERENCES

Akarpat, A., S. Turhan and N.S. Ustun, 2008. Effect of hot-water extracts from mytle, rosmary, nettle and lemon balm leaves on lipid oxidation and color of beed patties during frozen storage. J. Food Process Preserv., 32: 117-132.

Armstrong, D., 2002. Oxidative Stress Biomarkers and Antioxidant Protocols. Humana Press, Totowa, New Jersey, pp: 322.

Arnold, R.N., K.K. Scheller, S.C.Arp, N. Williams, D.R. Buege and D.M. Schaefer, 1992. Effect of long- or short-term feeding of a-tocopheryl acetate to Holstein and crossbred beef steers on performance, carcass characteristics and beef color stability. J. Anim. Sci., 70: 3055-3062.

Arunothayanun, P., P. Wirachwong, V. Burananon, C. Phisalphong and S. Hokputsa *et al*., 2005. Development of tetrahydrocurcuminoid liposomes as an ingredient for cosmetic products. Proceedings of the 7th ASCS Conference, (ASCSC'05), Bangkok, Thailand, pp: 51-57.

Babiker, S.A. and A. Bello, 1986. Hot cutting of goat carcases following early post-mortem temperature ageing. Meat Sci., 17: 111-120.

Babiker, S.A., I.A. El-Khider and S.A. Shafie, 1990. Chemical composition and quality attributes of goat meat and lamb. Meat Sci., 28: 273-277.

Banskalieva, V., T. Sahlu and A.L. Goetsch, 2000. Fatty acid copmosition of goat muscles and fat depots: A review. Small Rumin. Res., 37: 255-268.

Bouton, P.E., P.V. Harris and W.R. Shorthose, 1972. The effects of ultimate pH on ovine muscle: Water-holding capacity. J. Food Sci., 37: 351-355.

Buege, J.A. and S.D. Aust, 1978. Microsomal lipid peroxidation. Methods Enzymol., 52: 302-310.

Cheah, K.S., A.M. Cheah and D.I. Krausgrill, 1995. Effect of dietary supplementation of vitamin E on pig meat quality. Meat Sci., 39: 255-264.

Colomer-Rocher, F., A.H. Kirton, G.J.K. Merces and D.M. Duganzich, 1992. Carcass composition of New Zealand saanen goats slaughtered at different weights. Small Rumin. Res., 7: 161-173.

Coronado, S.A., G.R. Trout, F.R. Dunshea and N.P. Shah, 2002. Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. Meat Sci., 62: 217-224.

Decker, E.A., C. Faustman and C.J. Lopez-Bote, 2000. Antioxidants in Muscle Foods: Nutritional Strategies to Improve Quality. John Wiley and Sons Inc., New York.

Descalzo, A.M. and A.M. Sancho, 2008. A review of natural antioxidants and their effects on oxidative status, odor and quality of fresh beef produced in Argentina. Meat Sci., 79: 423-436.

Descalzo, A.M., E.M. Insani, A. Biolatto, A.M. Sancho, P.T. Garcia, N.A. Pensel and J.A. Josifovich, 2005. Influence of pasture or grain-based diets supplemented with vitamin E on antioxidant/oxidative balance of Argentine beef. Meat Sci., 70: 35-44.

Descalzo, A.M., L. Rossetti, A.M. Sancho, P.T. Garcia, A. Biolatto, F. Carduza and G.M. Grigioni, 2008. Antioxidant consumption and development of oxidation during ageing of buffalo meat produced in Argentina. Meat Sci., 79: 582-588.

Dhanda, J.S., D.G. Taylor, J.E. McCosker and P.J. Murray, 1999. The infuence of goat genotype on the production of Capretto and chevon carcasses 3. Dissected carcass composition. Meat Sci., 52: 369-374.

Estevez, M., S. Ventanas and R. Cava, 2005. Protein oxidation in frankfurters with increasing levels of added rosemary essential oil: Effect of color and texture deterioration. J. Food Sci., 70: c427-c432.

Farid, A., 1991. Carcass physical and chemical composition of three fat-tailed breeds of sheep. Meat Sci., 29: 109-120.

Faustman, C. and R.G. Cassens, 1990. The biochemical basis for discoloration in fresh meat: A review. J. Muscle Foods, 1: 217-243.

Frankic, T., M. Voljc, J. Salobir and V. Rezar, 2009. Use of herbs and spices and their extracts in animal nutrition. Acta Argic. Slovenica, 94: 95-102.

Galipalli, S., K.M. Gadiyaram, B. Kouakou, T.D. Pringle and G. Kannan, 2004. Oxidative stability of chevon as influenced by dietary Tasco supplementation in boer goat bucks. South Afr. J. Anim. Sci., 34: 201-203.

Gatellier, P., Y. Mercier, H. Juin and M. Renerre, 2005. Effect of finishing mode (pasture- or mixed-diet) on lipid composition, colour stability and lipid oxidation in meat from Charolais cattle. Meat Sci., 69: 175-186.

Griffin, C.L., M.W. Orcutt, R.R. Riley, G.C. Smith, J.W. Savell and M. Shelton, 1992. Evaluation of palatability of lamb, mutton and chevon by sensory panels of various cultural backgrounds. Small Rumin. Res., 8: 67-74.

Grinberg, L.N., O. Shalev, H.H. Tonessen and E.A. Rachmilewitz, 1996. Studies on curcumin and curcuminoids: Antioxidant effects of curcumin on the red blood cell membrane. Int. J. Pharmacol., 132: 251-257.

Gupta, K.K., S.C. Taneja, K.L. Dhar and C.K. Atal, 1983. Flavonoids of Anderographis Paniculata. Phytochem., 22: 314-315.

Hunter, R.S. and R.W. Harold, 1987. Uniform Color Scales. In: The Measurement of Appearance, 2nd Edn., Hunter, R.S. and R.W. Harold (Eds.). Hunter Associates Laboratory, Reston, VA., pp: 135-148.

Husain, M.H., P.J. Murray and D.G. Taylor, 2000. Meat quality of first and second cross capretto goat carcasses. Asian-Austr. J. Anim. Sci., 13: 174-177.

Insani, E.M., A. Eyherabide, G. Grigioni, A.M. Sancho, N.A. Pensel and A.M. Descalzo, 2008. Oxidative stability and its relationship with natural antioxidants during refrigerated retail display of beef produced in Argentina. Meat Sci., 79: 444-452.

Kadim, I.T., O. Mahgoub, D.S. Al-Ajmi, R.S. Al-Maqbaly and A.N.M. Al-Saqri, 2003. Ritchie an evaluation of the growth, carcass and meat quality characteristics of Omani goat breeds. Meat Sci., 66: 203-210.

Kannan, G., B. Kouakou and S. Gelaye, 2001. Color changes reflecting myoglobin and lipid oxidation in chevon cuts during refrigerated display. Small Rumin. Res., 42: 67-75.

Kannan, G., C.B. Chawan, B. Kouakou and S. Gelaye, 2002. Influence of packaging method and storage time on shear value and mechanical strength of intramuscular connective tissue of chevon. J. Anim. Sci., 80: 2383-2389.

Lai, S.M., J.I. Gray, D.M. Smith, A.M. Booren, R.L. Crackel and D.J. Buckley, 1991. Effects of oleoresin rosemary, Tertiary butylhydroquinone and sodium tripolyphosphate on the development of oxidative rancidity in restructured chicken nuggets. J. Food Sci., 56: 616-620.

Lanza, M., M.B.D. Barbagallo, V. Fasone, L. Finocchiaro and A. Priolo, 2003. Effect of partially or totally replacing soybean meal and maize by chickpeas (*Cicer arietinum* L.) in lamb diets: Growth performances, carcass and meat quality. Anim. Res., 52: 263-270.

Lee, J.H., B. Kouakou and G. Kannan, 2008. Chemical composition and quality characteristics of chevon from goats fed three different post-weaning diets. Small Rumin. Res., 75: 177-184.

Leheska, J.M., D.M. Wulf and R.L. Maddock, 2002. Effects of fasting and transportation on pork quality development and extent of postmortem metabolism. J. Anim. Sci., 80: 3194-3202.

Liu, Q., K.K. Scheller, S.C. Arp, D.M. Schaefer and M. Frigg, 1996. Color coordinates for assessment of dietary vitamin E effects on beef colour stability. J. Anim. Sci., 74: 106-116.

Liu, Y., X. Fan, Y.R. Chen and D.W. Thayer, 2003. Changes in structure and color characteristics of irradiated chicken breasts as a function of dosage and storage time. Meat Sci., 63: 301-307.

Luciano, G., F.J. Monahan, V. Vasta, P. Pennisi, M. Bella and A. Priolo, 2009. Lipid and colour stability of meat from lambs fed fresh herbage or concentrate. Meat Sci., 82: 193-199.

Lynch, M.P., J.P. Kerry, D.J. Buckley, C. Faustman and P.A. Morrissey, 1999. Effect of dietary vitamin E supplementation on the colour and lipid stability of fresh, frozen and vacuum-packaged beef. Meat Sci., 52: 95-99.

Maiorano, G., A. Manchisi, G. Salvatori, F. Filetti and G. Oriani, 1999. Influence of multiple injections of vitamin E on intramuscular collagen and bone characteristics in suckling lambs. J. Anim. Sci., 77: 2452-2457.

Mercier, Y., P. Gatellier and M. Renerreb, 2004. Lipid and protein oxidation *in vitro* and antioxidant potential in meat from Charolais cows finished on pasture or mixed diet. Meat Sci., 66: 467-473.

Miller, M.F., M.F. Carr, C.B. Ramsey, K.L. Crockett and L.C. Hoover, 2001. Consumer thresholds for establishing the value of beef tenderness. J. Anim. Sci., 79: 3062-3068.

Miquel, J., A. Bernd, J.M. Sempere, J. Diaz-Alperi and A. Ramirez, 2002. The curcuma antioxidants: Pharmacological effects and prospects for future clinical use. A review. Arch. Gerontol. Geriatrics, 34: 37-46.

Morrisey, P.A., P.J.A. Sheehy, K. Galvin, J.P. Kerry and D.J. Buckley, 1998. Lipid stability in meat and meat products. Meat Sci., 49: S73-S83.

Nuala, T.M., B. Sean, A. Hogan and J.P. Kerry, 2006. Comparative addition of rosemary extract and additives on sensory and antioxidant properties of retail packaged beef. Int. J. Food Sci. Technol., 42: 1201-1207.

Oman, J.S., D.F. Waldron, D.B. Griffin and J.W. Savell, 2000. Carcass traits and retail display-life of chops from different goat breed types. J. Anim. Sci., 78: 1262-1266.

Pokorny, J., N. Yanishlieva and M. Gordon, 2001. Antioxidants in Food Practical Applications. Woodhead Publishing Limited, Cambridge, pp: 381- 388.

Reddy, A.C.P. and B.R. Lokesh, 1994. Studies on the inhibitory effects of curcumin and eugenol on the formation of reactive oxygen species and the oxidation of ferrous iron. Mol. Cell. Biochem., 137: 1-8.

Sante-Lhoutellier, V., E. Engel and P. Gatellier, 2008. Assessment of the influence of diet on lamb meat oxidation. Food Chem., 109: 573-579.

Savell, J. and S.D. Shackelford, 1992. Significance of tenderness to the meat industry. Proc. Recip. Meat Conf., 45: 43-50.

Sazili, A.Q., G.K. Lee, T. Parr, P.L. Sensky, R.G. Bardsley and P.J. Buttery, 2004. The effect of altered growth rates on the calpain proteolytic system and meat tenderness in cattle. Meat Sci., 66: 195-201.

Sazili, A.Q., T. Parr, P.L. Sensky, S.W. Jones, R.G. Bardsley and P.J. Buttery, 2005. The relationship between slow and fast myosin heavy chain content, calpastatin and meat tenderness in different ovine skeletal muscles. Meat Sci., 69: 17-25.

Schonfeldt, H.C., R.T. Naude, W. Bok, S.M. van Heerden, R. Smit and E. Boshoff, 1993a. Flavour and tenderness related quality characteristics of goat and sheep meat. Meat Sci., 34: 363-379.

Schonfeldt, H.C., R.T. Naude, W. Bok, S.M. van Heerden, L. Swoden and E. Boshoff, 1993b. Cooking and juiciness related quality characteristics of goat and sheep meat. Meat Sci., 34: 381-394.

Sheradin, R., L.C. Hoffman and A.V. Ferreira, 2003. Meat quality of boer goat kids and mutton merino lambs 2. Sensory meat evaluation. Anim. Sci. J., 76: 73-79.

Simela, L., E.C. Webb and L. Frylinck, 2004. Post-mortem metabolic status, pH and temperature of chevon from South African indigenous goats slaughtered under commercial conditions. South Afr. J. Anim. Sci., 34: 204-207.

Toda, S., T. Miyase, H. Arichi, H. Tanizawa and Y. Takino, 1985. Natural antioxidants. III. Antioxidative components isolated from rhizome of *Curcuma longa* L. Chem. Pharm. Bull., 33: 1725-1728.

Trout, G.T.R., 1988. Techniques for measuring water-binding capacity in muscle foods: A review of methodology. Meat Sci., 23: 235-252.

Webb, E.C., N.J. Casey and L. Simela, 2005. Goat meat quality. Small Rumin. Res., 60: 153-166.

Yang, A., M.J. Brewster, M.C. Lanari and R.K. Tume, 2002. Lipid stability and meat colour of beef from pasture-fed and grain-fed cattle with or without vitamin E supplement. Meat Sci., 60: 41-50.