Effects of shade on welfare and meat quality of grazing sheep under high ambient temperature

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ABSTRACT: This study was conducted to evaluate the effects of providing shade on growth performance, welfare, and meat quality of grazing sheep under high ambient temperature. A total of 120 healthy male Ujumqin wool sheep (a local breed; BW = 18.7 ± 1.27 kg; 14 wk old) were randomly and equally divided into shaded and unshaded treatments with 3 pens per treatment. Sheep were grazed on an unshaded pastureland from 0600 to 1000 h and 1400 to 1800 h. During other times, sheep were confined in shaded or unshaded pens. Body weight was recorded on d 1 and 42 of the experiment. Rectal temperature and respiration rate were recorded on d 7, 14, 21, 28, 35, and 42. At end of the trial, sheep were blood sampled and slaughtered to collect meat samples. Respiration rate was greater (P < 0.05) in the unshaded sheep than shaded sheep on d 14, 21, 28, 35, and 42 of the trial whereas no significant differences were found on d 7. Moreover, no differences were observed in final BW, ADG, or rectal temperature throughout the trial. The pH at 24 h postmortem (pH24) and cooking loss were greater (P < 0.01) in unshaded than shaded sheep. On the contrary, lightness (L*), redness (a*) and yellowness (b*) values at 24 h postmortem were lower (P < 0.05) in unshaded versus shaded sheep. The sheep in the unshaded group had a greater (P < 0.05) cortisol concentration compared with the shaded group. Sheep in the shaded group had lower creatine kinase activity (P < 0.01) as well as observed for glucose (P < 0.05), triiodothyronine (P < 0.01), and thyroxine (P < 0.05) concentrations and white blood cell count (P < 0.05). Compared with the unshaded group, sheep in the shaded group had a greater lymphocytes (LYM) count (P < 0.05). In contrast, the opposite was true for neutrophils (NEU) count (P < 0.01) and NEU:LYM ratio (P < 0.01). In conclusion, the shade cloth, although not enhancing ADG, improved meat quality traits and certain stress parameters in grazing sheep reared under high ambient temperature.

Key words: meat quality, shade, sheep, welfare

INTRODUCTION

During summer, grazing sheep raised in China are exposed to high ambient temperatures, often exceeding their thermal neutral zone (5 to 25°C; Curtis, 1983; Sevi et al., 2001). When sheep are exposed to high ambient temperatures, compensatory physiological mechanisms are triggered, which allow the maintenance of vital functions by drastic changes in the biological functioning of the animals, such as increased respiration rate, reduction of feed intake, changes in the metabolism of water, protein, energy, and mineral balances, enzymatic reactions, and hormonal secretions (Marai et al., 2007). These changes in biological functions result in a decrease of BW and growth rate (Marai et al., 1995, 1997, 2000; Shelton, 2000; Abdel-Hafez, 2002). Thus, a high ambient temperature is a major constraint on grazing sheep production during hot summers in China.

Management and nutritional practices are the main strategies available for improving productivity in animals raised in hot climates (Beede and Collier, 1986). At present, most of the methods for protecting animals against high temperature (e.g., air conditioning, electric fans, sprinkling with water) are uneconomical and difficult to carry out for grazing sheep. However, providing shade seems to be a viable alternative for grazing sheep. Some researchers report that the provision of shaded areas during summer could facilitate maintenance of thermal balance and normal energy and mineral metabolism (Kotby

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et al., 1987; Tony et al., 1987; Sevi et al., 2001). However, these studies focused on confined sheep, and little information on grazing sheep is available. Moreover, Hassanin et al. (1996) reported that the type of construction materials used for shade during hot summer conditions could affect protection against solar radiation. Shades made of polyethylene material with UV stabilizers are popular in agriculture. These shades are lightweight, have high strength, can cover a large area, and allow good ventilation. Therefore, the aim of this study was to evaluate the effects of shade cloth on growth performance, welfare, and meat quality of grazing sheep under high ambient temperature.

**MATERIALS AND METHODS**

All procedures were approved by the Administration Office of Laboratory Animals, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences.

**Experimental Design and Animal Management**

The research was conducted at the Ecological Research Station for Grassland Farming, Chinese Academy of Sciences, Jilin, China (longitude 123°33′, latitude 44°31′, and altitude 145 m) during the summer (June and July) of 2011 and lasted 42 d.

A total of 120 healthy male Ujumqin wool sheep (a local breed; BW = 18.7 ± 1.27 kg; 14 wk old) were grazed on an unshaded pastureland during the experimental period. The pasture contained mainly *Chloris virgata* (Feather fingergrass). Sheep were randomly and equally divided among 6 pens (n = 20 per pen). The 2 treatments were shaded or unshaded, with 3 pens per treatment. Sheep were grazed between 0600 to 1000 h and 1400 to 1800 h. During other times, 60 sheep in the shaded treatment were confined in 3 shaded pens of 5 by 12 m with mesh-fence boundaries. Other sheep were confined in 3 unshaded pens of 5 by 12 m with mesh-fence boundaries. The shade was provided by a 7 by 14 m shade cloth (70% shading rate) above the pen. Shade cloth was secured to the ground with 4 wooden stakes. The height was 2 m. During the trial, ambient temperature and relative humidity in shaded and unshaded pens were monitored daily (1000 to 1400 h and 1800 to 0600 h) using a thermohygrograph (Chaney Instrument Co., Lake Geneva, WI) placed 1.5 m above the ground. Temperature–humidity index (THI) was calculated using the equation of Marai et al. (2001). Sheep had free access to water in pens via automatic drinking troughs.

**Growth Performance and Sample Collection**

Body weight was individually recorded on d 1 and 42 of the experiment to calculate the ADG. Ten sheep per pen were used to determine rectal temperature and respiration rate at each time point. Rectal temperature and respiration rate (breaths per minute) were recorded on d 7, 14, 21, 28, 35, and 42 at 1200 h by inserting a medical digital thermometer (RUICARE-6113; Wenzhou Kayi Hardware Co., Ltd., Zhejiang, China) into the rectum for 15 s and by counting flank movements per minute, respectively.

On d 42, 10 sheep per pen were randomly chosen and blood samples were collected by jugular venipuncture into evacuated tubes. Each sheep was sampled in less than 1 min to minimize handling stress. Blood (15 mL) from each sheep was collected into 2 vacutainer tubes containing coagulant (silicon dioxide). One tube was kept at 4°C for a maximum of 2 h before arriving at the laboratory for routine hematological measurements. The other tube was allowed to clot at room temperature (25°C) for 45 min and centrifuged (Himac CR22G2; Hitachi Koki Co., Ltd., Tokyo, Japan) at 300 × g for 15 min at 4°C. Separated serum was stored at −20°C for subsequent analysis.

After blood sampling, 10 sheep per pen were electrically stunned and humanely slaughtered by exsanguination under commercial procedures in accordance with policies of the Animal Ethics committee of Northeast Institute of Geography and Agroecology. The sheep were hung to remove the skin, head (at the occipito-atlantal joint), fore feet (at the carpal-metacarpal joint), hind feet (at the tarsal-metatarsal joint), gastrointestinal tract and other visceral organs. Hot carcasses were weighed and dressing percentage was calculated and expressed as a percentage of BW.

After 24 h of chilling (4 °C), the carcasses were halved into sides and the longissimus lumborum (LL) muscle was excised. The LL muscle taken from left side was divided into 2 parts. The fore part was used to measure cooking loss (CL), color, and pH; the hind part was frozen and used to measure shear force.

**Analysis of the Blood Constituents**

An automatic blood cell analyzer (Coulter LH 750; Beckman Coulter, Fullerton, CA) was used to analyze red blood cells (RBC), white blood cells (WBC), packed cell volume (PCV), neutrophils (NEU), and lymphocytes (LYM). The serum was used to determine total protein (TP) using an automatic biochemistry analyzer (Synchron CX5 PRO; Beckman Coulter). The concentration of glucose and the activity of creatine kinase (CK) in the serum samples were determined with a Multichannel Technicon Analyser (RA-500) and reagents from Bayer Diagnostics SA (Oise, France). Triiodothyronine (T₃), thyroxine (T₄), and cortisol concentrations in serum were measured using commercial kits (Jiancheng Biology Co., Nanjing, China) and a gamma
Meat Quality Analysis

pH Measurement. Meat pH was measured at 24 h postmortem (pH24) at the level of the 13th thoracic rib at 20°C and recorded with a Crison MicroPH 2001 (Cronin Instruments, Barcelona, Spain) using a combination electrode (Double Pore Slim; Hamilton Company, Bonaduz, Switzerland) penetrating to 3 mm (Ouhayoun and Dalle Zotte, 1996).

Color Measurements. After 1 h of blooming, meat color was measured on the freshly cut surface of the loin at the level of seventh lumbar vertebra at room temperature (20°C) using a Minolta chromameter (Minolta CR-300, Tokyo, Japan) with the D65 illuminant and an 8-mm aperture in the measuring head. Color measurements were reported in terms of lightness (L*), redness (a*), and yellowness (b*) in the (Commission Internationale de l’Éclairage Lab (CIELAB) color space model (CIE, 1976).

Cooking Loss. A sample of the left LL muscle of each sheep was weighed, vacuum packed in a plastic bag, and cooked at 80°C for 1 h by immersing in a water bath (Ramírez et al., 2004). Meat samples were then removed from the water bath and cooled in running water. The meat was then taken from the bag, blotted dry, and weighed. Cooking loss was the difference in weight between the precooked and blotted dry postcooked weights and was expressed as a percentage of the precooked weight.

Shear Force. The hind parts of the left LL muscle samples were thawed overnight (approximately 16 h) in a cooler at 4°C. At least 3 slices (1 by 1 by 3 cm) from each sample were cut parallel to the longitudinal orientation of the muscle fibers. The slices were sheared perpendicular to the muscle fibers orientation using an Instron 5543 (Canton, MA) with a Warner-Bratzler shear device and crosshead speed set at 200 mm/min (AMSA, 1995). The shear force was recorded in newtons.

Statistical Analyses

For meteorological data, descriptive data only were presented. Data relating to cortisol, CK, RBC, WBC, NEU, LYM, and the NEU:LYM ratio were log-transformed to normalize variances before the analysis. Data were analyzed by ANOVA using the GLM procedure (SPSS Inc., Chicago, IL). The model contained the fixed effects of shade and pen, with their interaction as a random error term. The pen effect and mean values were not reported in the tables because the effects were not significant. Individual sheep was considered the unit of replication for analysis. Means were compared by LSD test, and differences were declared at P < 0.05.

RESULTS

Meteorological Data

For the shaded group, daytime (from 1000 to 1400 h) mean ambient temperature ranged from 24.9 to 28.8°C and peaked during wk 3 and 4 (Figure 1A). Mean ambient temperature for the unshaded group ranged from 29.8 to 34.1°C. Thus, during the day, mean ambient temperature was 4.2 to 5.3°C higher for the unshaded group versus shaded group. Conversely, nighttime (from 1800 to 0600 h) mean ambient temperature ranged from 18.7 to 23.5°C and from 17.9 to 21.3°C in shaded and unshaded groups, respectively (Figure 1B). Thus, during the night, mean ambient temperature was 0.4 to 2.4°C higher for the shaded group than for the unshaded group.

Daytime average THI was over 28 throughout the study period for the unshaded group whereas averages ranged from 22.2 to 25.9 for the shaded group (Figure 2A). Moreover, values in both groups never exceeded 22 during the night (Figure 2B).
Body Weight, Rectal Temperature, and Respiration Rate

Respiration rate was greater \( (P < 0.05) \) in the unshaded sheep than shaded sheep at d 14, 21, 28, 35, and 42 of the trial whereas no differences \( (P > 0.05) \) were found at d 7 (Figure 3). Moreover, no differences \( (P > 0.05) \) were observed in final BW, ADG, or rectal temperature throughout the trial (Table 1; Figure 4).

Carcass and Meat Quality Traits

Table 2 summarizes data concerning carcass and meat traits. No differences \( (P > 0.05) \) were found in BW, HCW, or dressing percentage between the 2 groups. Noteworthy is the fact that pH\(_{24}\) and CL were greater \( (P < 0.01) \) in unshaded than shaded sheep. On the contrary, L\(_*\), a\(_*\), and b\(_*\) values at 24 h postmortem were less \( (P < 0.05) \) in unshaded sheep versus shaded sheep. In addition, shear force was similar \( (P > 0.05) \) between the 2 treatments.

Blood Constituents

Blood chemical variables are shown in Table 3. The sheep in the unshaded group had a greater \( (P < 0.05) \) cortisol concentration compared with the shaded group. Sheep in the shaded group had reduced CK activity \( (P < 0.01) \), as was also observed for glucose \( (P < 0.05) \), T\(_3\) \( (P < 0.01) \), and T\(_4\) \( (P < 0.05) \) concentrations and WBC count \( (P < 0.05) \). Compared with the unshaded group, sheep in the shaded group had a greater \( (P < 0.05) \) LYM count. In contrast, the opposite was true for NEU count \( (P < 0.01) \) and NEU:LYM ratio \( (P < 0.01) \). Moreover, no differences \( (P > 0.05) \) were found between the 2 groups in PCV and TP concentrations.

DISCUSSION

Meteorological Data

The THI, a variable widely used to describe heat load for humans, is a reliable indicator of stressful thermal climatic conditions (McDowell et al., 1976). Marai et al. (2007) defined 4 possible categories of heat stress in sheep, namely <22.2 = absence of heat stress, 22.2 to

Table 1. Effects of shade cloth on BW of sheep (n = 60 per treatment)

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>Shaded</td>
<td>18.80</td>
<td>0.37</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>Unshaded</td>
<td>18.65</td>
<td></td>
</tr>
<tr>
<td>ADG, g/d</td>
<td>Shaded</td>
<td>23.83</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Unshaded</td>
<td>23.34</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Effects of shade cloth on temperature–humidity index (± SE) during daytime (A) and nighttime (B).

Figure 3. Effects of shade cloth on respiration rate of sheep (± SE; n = 30 per treatment). a,bWithin a sampling time, means without a common letter differ \( (P < 0.05) \)

Figure 4. Effects of shade cloth on rectal temperature of sheep (± SE; n = 30 per treatment).
Table 2. Effects of shade cloth on carcass characteristics and meat quality in sheep (n = 30 per treatment)

<table>
<thead>
<tr>
<th>Item1</th>
<th>Shaded</th>
<th>Unshaded</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW, kg</td>
<td>23.3</td>
<td>22.8</td>
<td>0.23</td>
<td>0.873</td>
</tr>
<tr>
<td>HCW, kg</td>
<td>10.3</td>
<td>9.8</td>
<td>0.19</td>
<td>0.764</td>
</tr>
<tr>
<td>Dressing percentage, % BW</td>
<td>44.1</td>
<td>42.9</td>
<td>0.28</td>
<td>0.567</td>
</tr>
<tr>
<td>pH24</td>
<td>5.54</td>
<td>5.86</td>
<td>0.01</td>
<td>0.000</td>
</tr>
<tr>
<td>CL, %</td>
<td>45.8</td>
<td>49.3</td>
<td>0.31</td>
<td>0.007</td>
</tr>
<tr>
<td>Shear force, newtons</td>
<td>30.28</td>
<td>29.30</td>
<td>0.73</td>
<td>0.902</td>
</tr>
<tr>
<td>L*</td>
<td>39.09</td>
<td>36.23</td>
<td>0.30</td>
<td>0.034</td>
</tr>
<tr>
<td>a*</td>
<td>24.10</td>
<td>20.18</td>
<td>0.22</td>
<td>0.045</td>
</tr>
<tr>
<td>b*</td>
<td>4.38</td>
<td>3.04</td>
<td>0.04</td>
<td>0.031</td>
</tr>
</tbody>
</table>

*pH24 = pH at 24 h postmortem; CL = cooking loss. Color variables in meat: L* = lightness; a* = redness; b* = yellowness.

<23.3 = moderate heat stress, 23.3 to <25.6 = severe heat stress, and 25.6 and more = extremely severe heat stress.

In the present study, the daytime average THI were 24.4 and 28.1 for shaded and unshaded groups, respectively. Values in both groups never exceeded 22 during the night. These results indicated heat stress conditions during the day for both groups, but the severity of heat stress was greater for the unshaded group according to the standards in Marai et al. (2007). Moreover, sheep in both groups were not subjected to heat stress during the night. Similarly, Caroprese et al. (2010) observed a decreased daytime THI for areas with shade. Conversely, Hassanin et al. (1996) found that asbestos shading induced a higher THI for areas with shade. Moreover, sheep in both groups were not subjected to heat stress during the night. Ruhe and Sevi (2002) observed that asbestos shading decreased THI from 30.27 to 27.3. Additionally, Caroprese et al. (2010) observed a decreased daytime THI for areas with shade.

Table 3. Effects of shade cloth on blood biochemical variables of sheep (n = 30 per treatment)

<table>
<thead>
<tr>
<th>Item1</th>
<th>Shaded</th>
<th>Unshaded</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortisol, nmol/mL</td>
<td>0.87</td>
<td>1.31</td>
<td>0.12</td>
<td>0.021</td>
</tr>
<tr>
<td>CK, IU/L</td>
<td>132</td>
<td>186</td>
<td>10.48</td>
<td>0.000</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>2.09</td>
<td>2.86</td>
<td>0.07</td>
<td>0.025</td>
</tr>
<tr>
<td>T3, ng/mL</td>
<td>1.87</td>
<td>2.64</td>
<td>0.05</td>
<td>0.006</td>
</tr>
<tr>
<td>T4, ng/mL</td>
<td>101</td>
<td>129</td>
<td>2.98</td>
<td>0.042</td>
</tr>
<tr>
<td>PCV, %</td>
<td>23.8</td>
<td>24.4</td>
<td>1.84</td>
<td>0.715</td>
</tr>
<tr>
<td>TP, g/L</td>
<td>64.2</td>
<td>65.8</td>
<td>2.31</td>
<td>0.663</td>
</tr>
<tr>
<td>RBC, × 1012/L</td>
<td>10.11</td>
<td>10.26</td>
<td>0.11</td>
<td>0.892</td>
</tr>
<tr>
<td>WBC, × 109/L</td>
<td>9.58</td>
<td>13.21</td>
<td>0.75</td>
<td>0.041</td>
</tr>
<tr>
<td>NEU, × 109/L</td>
<td>4.67</td>
<td>7.45</td>
<td>0.51</td>
<td>0.037</td>
</tr>
<tr>
<td>LYM, × 109/L</td>
<td>5.78</td>
<td>3.41</td>
<td>0.35</td>
<td>0.039</td>
</tr>
<tr>
<td>NEU:LYM</td>
<td>0.81</td>
<td>2.18</td>
<td>0.12</td>
<td>0.028</td>
</tr>
</tbody>
</table>

1CK = creatine kinase; T3 = triiodothyronine; T4 = thyroxine; PCV = packed cell volume; TP = total protein; RBC = red blood cells; WBC = white blood cells; NEU = neutrophils; LYM = lymphocytes.

Body Weight, Rectal Temperature, and Respiration Rate

Body weight was not affected by shade. Similar results were observed by Silanikove (1987), who found that brick shade did not affect feed intake or BW of sheep under hot summer conditions. Conversely, brick shade increased ADG of sheep from d 0 to 21, but there was no effect from d 0 to 44 (Caroprese et al., 2010).

In accordance with results of the present experiment, wool sheep exposed to high ambient temperature have an elevated respiration rate, which is the principal means of heat dissipation because a wool coat prevents sweating (Kamal, 1975; Silanikove, 2000; Marai et al., 2007). The increased respiration rate is partly due to direct stimulation of peripheral temperature receptors that transmit nerve impulses to the heat center in the hypothalamus (Habeeb et al., 1992). Likewise, Sevi et al. (2001) observed that shade decreased the respiration rate of sheep under hot summer conditions. Silanikove (1987) also found that respiration rate (125 breaths per minute) in exposed sheep under summer Mediterranean conditions was 56% faster than in sheep with shade (80 breaths per minute) due to direct effect of solar radiation.

Rectal temperature is often used as a representative measurement of animal core temperature. According to McDowell (1972), an increase of 1°C in rectal temperature can reduce performance in most domestic livestock species. The lack of effect of shade on rectal temperature in the present study is in agreement with no treatment effect on ADG. Average rectal temperature near the upper normal limit of sheep (39.9°C) suggested that heat stress impacted ADG of sheep in both treatments. A previous study also reported that shade in a hot Mediterranean climate decreased respiration rate but did not affect rectal temperature of sheep (Silanikove, 1987).

Carcass and Meat Quality Traits

In the present study, greater carcass ultimate pH for sheep without shade may relate to a greater load of heat stress that increases glycolysis in skeletal muscle, thereby decreasing lactic acid formation during storage (Kreikemeier et al., 1998; Davis and Mader, 2001). In accordance, Kadim et al. (2008) reported that the ultimate meat pH of 5.78 in sheep reared under hot season was greater than the 5.65 in sheep reared under cool season. Moreover, Warriss and Brown (1987) reported that pH was the most important factor in determining CL in muscle of sheep in agreement with reduced CL for the shaded than unshaded treatment in the present experiment. Likewise, Lu et al. (2007) observed that Arbor Acres broilers reared under hot conditions had a greater CL than those reared under cool conditions.

Many factors influence the development of muscle color, such as myoglobin concentration, ultimate pH,
muscle fiber type, and cooling rate (Faustman and Cas-sens, 1990). Meat samples darkened at a decreasing rate in terms of L*, a*, and b* values as ultimate pH increased (MacDougall and Rhodes, 1972). In the present study, L*, a*, and b* values exhibited a negative correlation to ultimate pH. The observed color differences might be due to differences in relative mitochondrial respiration rate (Ashmore et al., 1972). Lawrie (1985) indicated that high temperatures increase oxygen consumption by sheep, in accordance with an increased respiration rate, and this decreases availability of oxygen in meat, which in turn increases the concentration of de-oxygenated myoglobin to elicit a dark color.

**Blood Constituents**

It is well known that animal welfare can be assessed by using physiological changes occurring in stressful situations, such as increased serum cortisol, hyperglycemia, leucocytosis with neutrophilia, lymphopaenia, and eosinopaenia (Dantzer and Mormède, 1979; Fraser and Broom, 1990). When animals are subjected to heat stress conditions, the hypothalamic-pituitary-adrenal axis is activated and glucocorticoids are released from the adrenal cortex (Klemcke et al., 1989). In our study, the reduced cortisol concentration with shade indicated an alleviation of heat stress.

In agreement with difference in glucose and cortisol concentrations in the present study, stress increased glycolgenolysis via increase in catecholamines and glucocorticoids (Shaw and Tume, 1992). Similar results were also observed by Caroprese et al. (2010), who found that sheep with shade had a lower plasma glucose concentration than that of an exposed group. Moreover, CK is an enzyme marker whose blood concentrations correlate with muscle cell permeability and damage (Duncan and Prasse, 1986). In the current study, sheep in the shaded group had greater serum CK activity than that of the unshaded group. Similar results were observed by Abdelatif and Modawi (1994), who reported that the plasma CK activity of rabbits showed a significant increase with rise in temperature, and cell permeability seemed to be sensitive to tissue temperature.

Thyroid hormones are thought to be involved in the maintenance of immune function in response to environmental stimuli and stress-mediated immunosuppression (Dorshkind and Horseman, 2000; Dorshkind and Horsemanelson, 2001). Therefore, decreased serum T₃ and T₄ concentrations of sheep with shade in the present study may indicate that shade modulated the immune system response of sheep under high ambient temperature.

According to Paull et al. (2008), increases in serum cortisol in response to stressors in livestock can influence hematological changes, including an increase in the NEU count and a decrease in LYM. The WBC count for the unshaded group exceeded the recognized upper clinical threshold of approximately 13 × 10⁹/L (Cissik et al., 1991). This was also the case for the NEU count for the unshaded group, which was greater than the reference range (0.7 to 6 × 10⁹/L) of sheep (Stelletta et al., 2004). The opposite was true for LYM counts, where all values were within the normal range (2 to 9 × 10⁹/L) of sheep (Stelletta et al., 2004). Moreover, shade decreased the NEU:LYM ratio. These findings for WBC, NEU, and LYM counts and the NEU:LYM ratio indicate that stress alleviation from shade can prevent immune suppression induced by high temperature, thereby lessening susceptibility to disease and pathogen shedding (Swanson and Morrow-Tesch, 2001; Marin et al., 2008).

**CONCLUSIONS**

The shade cloth, although not enhancing ADG, improved meat quality traits and certain stress parameters in grazing sheep reared under high ambient temperature. Further research needs to be carried out to identify the effects of vegetative shade (trees or shrubs) planted in grassland on grazing animal growth and welfare.

**LITERATURE CITED**


Dorshkind, K., and N. D. Horseman. 2000. The roles of prolactin,


