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Length of Feeding Periods on Mutton pH and Color of Highland (Arsi-Bale) and Lowland (Black Head Ogaden) Male Sheep of Ethiopia

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Abstract

Yearling sheep from highland (Arsi-Bale) and lowland (Black Head Ogaden) areas of Ethiopia were used to determine effects and interactions of breed and length of feeding period on mutton pH and color. Rams were purchased, transported, and handled in accordance with normal practices of abattoirs in Modjo Modern Export Abattoir. 18-20 sheep of each origin were subjected to feeding periods 2, 4, and 6 weeks in length, during which time grass hay was consumed *ad libitum* and concentrate supplement was provided at approximately 200 g/day per animal (DM basis). Mutton pH and color measurements were made at 45 min (day 0) and 1, 2, and 3 days post-slaughter, with storage at 4°C. The data were analyzed using the GLM of SAS. Average mutton pH of Arsi-Bale rams was similar to Black head Ogaden rams on the same day of post slaughters. Both linear and quadratic length of feeding period had significant influence in mutton pH on day 0, 1, 2, and 3 post slaughters ($P < 0.05$). Length of feeding periods had greater effect to reduce mutton pH. For both sheep breeds, mutton pH values were lowest among feeding period lengths for 6 weeks. Mutton pH decreased as post slaughter days increased, but considerably decreased between day 0 and 1 post slaughters and then after slightly decreased as post slaughter days increased. The average mutton lightness (L*) was greater ($P < 0.05$) for Black head Ogaden rams (L*=29.50, 39.68, 40.91 and 42.73) than Arsi-Bale rams (L*=27.89, 35.81, 36.67 and 38.04) on the same day of 0, 1, 2, and 3 day post slaughters, respectively. Mutton a* (as an index of redness) changed with increasing day post-slaughter. The results of this study revealed that mutton darkening of both sheep origins was not detected/ apparent from comparisons of mutton pH and color measures with values reported in different literatures.

Keywords: Color, Length of feeding period, Mutton, pH, Sheep

Introduction

Ethiopia is home to 77 million people; 32 million are classified as poor living on less than US $1 per day (FAOStat, 2010). With an annual human population growth rate of 2.4%, it will increase to about 149.3 million by the year 2040 (FAO, 2008). Ethiopia, with about 25.5 million sheep and 23.4

million goats (CSA, 2010), has a huge potential for meat production, but its contribution to national economy has been minimal. Domestic and export market demand for the small ruminant mutton is increasing and the export has been expanded to the Middle East countries. A factor limiting the potential quantity of small ruminants available for lucrative export markets and returns from exported animals is a problem of mutton short shelf life with highland animals compared with those from lowland or pastoralists areas. It is claimed that mutton of highland sheep often darkens within two or three days after slaughtering. Akililu *et al. (*2005) reported that almost none of the sheep breeds from the Ethiopia highlands are exported due to darkening of the mutton after slaughter.

On the other hand, the causes as well as possible remedies for this problem have not been well investigated. Thus, it is timely and an urgent needs to properly investigate and understand the underlying physiological cause of mutton darkening. For example, possible management practices like short length of feeding period after arrival to the abattoir and prior to slaughtering may have pertain impact on the problem. Therefore, the objectives of this experiment were to evaluate and determine the effects and interactions of sheep origins and short length of feeding periods after arrival to abattoir on slaughter measures, notably mutton pH and color of Arsi Bale and Black head Ogaden rams.

Material and Methods

Location of experiment site

Slaughter of the experimental sheep was conducted at Modjo Modern Export Abattoir (MMEA), which is a private company strategically located near Modjo town, approximately 70 km south east of Addis Ababa, Ethiopia. The study was carried out between late August and beginning of October 2007. Slaughter and associated measures were performed at facilities of the Modjo Modern Export Abattoir (MMEA). Feeding of the sheep was done at a private small ruminant feedlot facility located approximately 1 km from the Abattoir. The feedlot was consisted 12; 11 x 3.5 m pens that had roof cover, but open wall at the front gate and had an earthen floor.

Animal management and treatments

A total of 132 intact male sheep, 66 from highland (Arsi-Bale rams) and 66 from lowland (Black head Ogaden rams) were purchased and used for this study. The rams had an average initial live weight of 20±0.57 kg and were similar age group. Procurement, transportation and handling of the rams were performed following the procedures used by abattoirs in the area. An experienced person who routinely supplying lowland animals for the MMEA was employed and instructed to follow up the implementation of standard operating procedures. Because the MMEA does not slaughter highland sheep, a similar contractural arrangement was made with a supplier of highland animals for another abattoir approximately 25 km from the MMEA (Helimex Abattoir, Debre Zeit, Ethiopia). The 66 lowland (Black head Ogaden) rams were purchased from markets in Borana zone of the Negelle district, approximately 575 km South of Addis Ababa. Similarly, the 66 highland (Arsi-Bale) rams were obtained from markets in West Shewa zone of Ginchi district, approximately 75 km from Addis Ababa. After purchase, both Black head Ogaden and Arsi-Bale rams were handled in a similar manner.

Rams purchased from highland area (Ginchi district) are characterized as Arsi Bale sheep breed (fat tailed) whereas the rams from lowland area (Borana) are grouped as Black Head Ogaden (fat rumped) sheep breed (Solomon *et al*., 2007). The highland sheep chosen for the experiment is the one that has been thought as yielding mutton with short shelf life (Personal Communication, 2007). The rams were selected upon arrival based on initial live weight, by looking their dentition to judge the age and body conformation. Based on dentition, all sheep were approximately 1 year of age.

Six treatments of a factorial design combined with randomized complete block design (RCBD) entailed different lengths of feeding (i.e., 2, 4, and 6 weeks length of feeding period for each origin) of diet. From 6 treatments, 3 treatments were with highland sheep (Arsi Bale rams) and the other 3 treatments were with lowland sheep (Black Head Ogaden rams). The treatment arrangement was two animal origins (Highland vs. Lowland) and three feeding periods (2, 4, and 6 weeks) or (2*3) treatment arrangement.

The 66 highland sheep were randomly assigned to three holding pens and the other 66 lowland sheep were randomly assigned to the other three holding pens. Animals were randomly allocated to pens by origin, with 11 per pen and supplemented with the treatment diet for 2, 4, and 6 weeks after 5 days of adaptation period. The animals in each pen were allowed to group feeding and animals in each pen received supplemental concentrate. Grass hay from the same source was given to the animals ad libitum. The concentrate used as a supplement was composed of 20 % ground maize, 60 % wheat bran, 19.5 % noug (*Guizotia abyssinica*) cake, and 0.5% salt and it was offered at 200 g/day per animal at 08:00 and 14:00 h for feeding treatments. All animals used for the feeding experiment were drenched with an anthelmintic (half doze Albendazole).

Slaughter Procedures

Four or five animals were removed for slaughter from each pen at the end of the 2nd, 4th, and 6th weeks of feeding periods. Accordingly, after 2 weeks of feeding period, 20 highland and 20 lowland sheep (a total of 40 rams) were randomly chosen and taken to the Modjo Modern Export Abattoir, approximately about 1 km from feeding houses and slaughtered. Similarly, after 4 weeks of feeding period, 18 highland and 20 lowland sheep were randomly chosen from each origin and slaughtered. Finally, after 6 weeks the remaining 18 highland and 18 lowland sheep were taken and slaughtered.

Mutton pH and color measurements

Mutton pH and color measurements were made after 45 minutes (day 0) and 1, 2, and 3 days post-slaughter, with storage at 4°C. At each time any subcutaneous fat present and a thin layer of muscle were removed from a small area of the surface of the longissimus muscle on each side of the backbone, beginning at the 13th rib and moving forward each day to the 6th rib. After tissue removal, a 30-min 'bloom' time was allowed before measures. Instrumental color determinations were made objectively by digital chromometer of a Hunter MiniScan unit (Model XE Plus 45/0 LAV; Hunter Associates Laboratory, Inc., Reston, VA, USA). Commission Internationale de l'Eclairage (CIE, 1976) L*, and a* values were determined from the mean of four readings (two from each muscle). Immediately after color measurements, pH was determined, likewise from a total of four readings, with a handheld pH meter (Model IQ150; Handheld ph/mV/ Temperature Meter; IQ Scientific Instruments, Inc., Carlsbad, CA, USA).

The digital chromometer of a Hunter Miniscan unit was set to display L*, and a* values. Brief description of the color values are as follows:

L* depicts lightness. 100=white, 0=black. High values are lighter and low values are darker.

a* indicates redness. Positive values are red, with high values red.

Statistical Analysis

The data were analyzed using the General Linear Model of Statistical Analysis System (SAS, 1990). In order to compare feeding treatments, animal was considered as experimental unit. The six treatment means were separated by orthogonal contrasts. Observations of feeding treatments were analyzed separately, with use of contrasts for sheep origin, the linear effect of length of feeding, the quadratic effect of length of feeding, origin x linear effect of length of feeding, and origin x quadratic effect of length of feeding. SE was presented in tables for all data combined. In addition, linear and quadratic effects of day post-slaughter for mutton pH and color measures were tested separately for each treatment.

Results and Discussion

Mutton pH

Effects and interactions of sheep origin and length of feeding periods on mutton pH of highland (Arsi-Bale) and lowland (Black head Ogaden) rams are presented in Table 1. A key determinant of mutton quality is pH. Sheep origins had no significant ($P > 0.05$) effect on mutton pH on the same day of post slaughters. The average ultimate mutton pH (24 hrs post slaughter) of Arsi-Bale rams was similar to Black head Ogaden rams. In contrast to this finding, Abebe *et al* (2010) reported that Carcass pH at 15 min after slaughter was affected by two-way interactions between length of rest and species and animal origin ($P < 0.05$), but differences in values were fairly small. The authors also reflected that at 24 hrs post-slaughter, carcass pH ranked ($P<0.05$) lowland goats > lowland sheep > highland sheep, with the value for highland goats intermediate ($P>0.05$) to those for highland and lowland sheep. The variation might be due to differences in experimental methods.

Both linear and quadratic length of feeding period had significant effect in mutton pH on day 0, 1, 2, and 3 post slaughters ($P < 0.05$). Mutton pH quadratically decreased with increasing length of feeding period ($P < 0.05$), with an interaction between origin and the quadratic effect of feeding period length on day 1, 2, and 3 post slaughters ($P < 0.05$). For both sheep origins, mutton pH values were lowest among feeding period lengths for 6 weeks, indicates length of feeding period had greater and positive effect to reduce mutton pH and the desirable low pH has a bacteriostatic effect on the mutton. From the result, it can be suggested that the animals were accessed to adequate feeds and water for length of feeding period so that the glycogen levels in the muscle of the mutton was high enough to develop optimum level of lactic acid causing a fall in pH and there by improve the shelf life of the mutton.

Post slaughter day had an effect on mutton pH. Mutton pH decreased as post slaughter days increased, but considerably decreased between day 0 and 1 and then after slightly decreased as post slaughter days increased. For both sheep origins, the mutton pH values on days post slaughter were within the acceptable range of mutton pH and comparable with several findings (Archim`ede *et al*., 2008; Johnson *et al*., 2005; Priolo *et al*., 2005).

Table 1: Effects and interactions of sheep origin and length of feeding periods on mutton pH of highland (Arsi-Bale) and lowland (Black head Ogaden) sheep

Origin	Feeding (wk)	n	Day post-slaughter 0	1	2	3	Effect[1] (P value) Linear	Quadratic
Highland	2	20	7.05	5.92	5.99	6.05	0.0001	0.0001
Highland	4	18	6.93	6.37	6.27	6.07	0.0001	0.0385
Highland	6	18	6.05	5.67	5.72	5.62	0.0001	0.0022
Lowland	2	20	7.04	5.95	5.95	6.02	0.0001	0.0001
Lowland	4	20	6.86	6.12	5.99	5.85	0.0001	0.0001
Lowland	6	18	5.99	5.69	5.72	5.62	0.0001	0.0666
SE[2]			0.06	0.06	0.06	0.05		
Treatment contrast P values[3]								
Feeding treatments								
Origin			0.4158	0.1090	0.0452	0.0568		
Feeding length linear			0.0001	0.0001	0.0001	0.0001		
Feeding length quadratic			0.0001	0.0001	0.0001	0.0050		
Origin x feeding length linear			0.7007	0.9638	0.7221	0.7586		
Origin x feeding length quadratic			0.7317	0.0082	0.0219	0.0217		

[1]P values for linear and quadratic effects of day post-slaughter determined for each treatment.
[2]SE for the analysis of feeding treatments
[3]Orthogonal contrasts. Effects of origin and linear and quadratic effects of length of feeding and their interactions with origin were determined for feeding treatments.

Mutton lightness (L*)

Effects and interactions of sheep origin and length of feeding periods on mutton lightness (L*) of highland (Arsi-Bale) and lowland (Black head Ogaden) rams are indicated in Table 2. The average mutton lightness (L*) was greater (P < 0.05) for supplemented Black head Ogaden rams (L*=29.50, 39.68, 40.91 and 42.73) than Arsi-Bale rams (L*=27.89, 35.81, 36.67 and 38.04) on the same day of 0, 1, 2, and 3 post slaughters, respectively, which is due to origin effect, but L* values of both sheep origins supplemented for 2, 4, and 6 weeks were not significantly different within the respective origin (P > 0.05). Length of feeding period improved mutton lightness more with Black head Ogaden than Arsi-Bale rams and mutton lightness increased quadratically with increasing length of feeding, with greater values for 4 and 6 weeks than 2 weeks. The average mutton lightness of Black head Ogaden rams (L*=41.51) was greater (P < 0.05) than Arsi-Bale rams (L*=38.01), but the mutton lightness for Arsi-Bale rams was not much lower than most values in literatures. In agreement to these results, Abebe *et al* (2010) reported that on day 3 post-slaughter, the L* value was greater for lowland compared with highland sheep (P < 0.05) and was greater for feeding in 4 vs. 0 and 2 weeks (P < 0.05).

Different lengths of feeding periods had some and inconsistent effects on mutton lightness. The results of this study showed that mutton darkening of both sheep origins was not detected/ apparent from comparisons of mutton pH and lightness measures with values reported in different literatures. In accordance, L* values in this experiment are comparable with the mutton lightness in many sheep studies, such as the Scerra *et al*. (2001), Priolo *et al*. (2002), Santos-Silva *et al*. (2002), Johnson *et al*. (2005), Teixeira *et al*. (2005), and Archimède et al. (2008). For all except few treatments mutton lightness increased quadratically with increasing day post slaughter (P < 0.05). As for mutton pH, most L* values change occurred from day 0 to 1 post slaughters with relatively some change thereafter. The L* values were increased with increasing post slaughter days, indicating that mutton discoloration was not observed up to 3 days post slaughters, which was in agreement with Wulf *et al*. (1995).

Table 2: Effects and interactions of sheep origin and length of feeding periods on mutton lightness (L*) of highland (Arsi-Bale) and lowland (Black head Ogaden) sheep

Origin	Feeding (weeks)	n	Day post-slaughter 0	1	2	3	Effect[1] (P value) Linear	Quadratic
Highland	2	20	28.33	34.21	36.62	36.77	0.0001	0.0002
Highland	4	18	28.25	36.71	37.03	38.76	0.0001	0.0005
Highland	6	18	27.08	36.52	36.37	38.60	0.0001	0.0001
Lowland	2	20	29.29	37.45	40.89	41.58	0.0001	0.0001
Lowland	4	20	29.59	40.89	41.88	43.85	0.0001	0.0001
Lowland	6	18	28.72	40.71	39.95	42.76	0.0001	0.0001
SE[2]			0.72	0.75	0.74	0.72		
Treatment contrast P values[3]								
Feeding treatments								
Origin			0.0311	0.0001	0.0001	0.0001		
Feeding length linear			0.2184	0.0003	0.4278	0.0359		
Feeding length quadratic			0.3776	0.0164	0.1246	0.0270		
Origin x feeding length linear			0.6464	0.5278	0.6453	0.6411		
Origin x feeding length quadratic			0.9745	0.7195	0.4745	0.6190		

[1]P values for linear and quadratic effects of day post-slaughter determined for each treatment.
[2]SE for the analysis of feeding treatments
[3]Orthogonal contrasts. Effects of origin and its interactions with linear and quadratic effects of length of feeding were determined with feeding treatments.

Mutton redness (a*)

Sheep origin had significant effect on mutton redness and the average mutton redness was greater (P < 0.05) for supplemented Arsi-Bale rams (a*=14.21, 17.04, 17.15 and 16.82) than supplemented Black head Ogaden rams (13.51, 15.63, 15.25 and 14.69) on the same day 0 and 1 post slaughters, respectively. In reverse to this result, Abebe *et al* (2010) reported that on day 3 post slaughter, mutton redness (a*) was lower for highland than lowland sheep (P<0.05).

Linear length of feeding period had significant effect on mutton redness on 2 and 3 post slaughters (P < 0.05; Table 3), although mutton redness increased with increasing length of feeding period from 2 to 4 weeks but declined when length of feeding period was increased further from 4 to 6 weeks, which is due to the quadratic effect of length of feeding period. Interaction of origin with quadratic length of feeding period had significant effect on mutton redness on day 2 post slaughter (P < 0.05; Table 3). For Arsi-Bale rams, increasing length of feeding period had little effect on mutton redness, but for Black head Ogaden rams, increasing length of feeding period quadratically increased mutton redness. From this finding, it is postulated that stresses associated with sheep procurement, transportation, and handling were not particularly severe and it has a value to advice an appropriate animal management and harvest procedures.

Different lengths of feeding period had some and inconsistent effects on mutton redness on day post slaughters. The results of this finding revealed that there was no evidence of mutton short shelf life or early darkening of both sheep origins. On top of this, for both sheep origins, mutton redness values in this experiment were comparable with observations reported in many sheep studies, such as of Scerra *et al*. (2001); Priolo *et al*. (2002); Santos-Silva *et al*. (2002); Johnson *et al*. (2005); Teixeira *et al*. (2005); Sheridan *et al*. (2000); Santos *et al*. (2001); Santos-Silva *et al*. (2002) and Archimède *et al*. (2008).

Mutton redness changed with increasing day post-slaughter relatively lower than mutton lightness (Table 3). For most treatments there was linear increase in mutton redness with increasing time, typically with quadratic effects as well (P < 0.05). The increase in a* values with increasing post slaughter days agrees with the observation of Priolo *et al*. (2005) who reported that the intensity of more redness color (greater a*) of the muscle tissue remained relatively constant in the supplemented groups up to a storage time of 7–9 days.

Table 3. Effects and interactions of sheep origin and length of feeding periods on mutton redness (a*) of highland (Arsi-Bale) and lowland (Black head Ogaden) sheep

Origin	Feeding (weeks)	n	Day post-slaughter 0	1	2	3	Effect[1] (P value) Linear	Quadratic
Highland	2	20	13.48	16.30	17.29	17.57	0.0001	0.0001
Highland	4	18	14.96	18.33	17.13	16.03	0.2225	0.0001
Highland	6	18	13.54	16.50	17.02	16.86	0.0001	0.0001
Lowland	2	20	13.25	15.90	16.29	15.74	0.0001	0.0001
Lowland	4	20	13.95	16.39	14.44	13.64	0.0330	0.0001
Lowland	6	18	12.87	14.59	15.03	14.68	0.0001	0.0001
SE[2]			0.28	0.35	0.31	0.28		
Treatment contrast P values[3]								
Feeding treatments								
Origin			0.0053	0.0001	0.0001	0.0001		
Feeding length linear			0.5497	0.1360	0.0136	0.0026		
Feeding length quadratic			0.0001	0.0001	0.0200	0.0001		
Origin x feeding length linear			0.4248	0.0236	0.1062	0.5459		
Origin x feeding length quadratic			0.2472	0.2154	0.0250	0.4432		

[1]P values for linear and quadratic effects of day post-slaughter determined for each treatment.
[2]SE for the analysis of feeding treatments
[3]Orthogonal contrasts. Effects of origin and its interactions with linear and quadratic effects of length of feeding were determined with feeding treatments.

Conclusion

Yearling sheep from highland (Arsi-Bale) and lowland (Black Head Ogaden) areas of Ethiopia were used to determine effects and interactions of breed and length of feeding period on mutton pH and color. Average mutton pH of Arsi-Bale rams was similar to Black head Ogaden rams on the same day of post slaughters. Both linear and quadratic length of feeding period had significant influence in mutton pH on day 0, 1, 2, and 3 post slaughters ($P < 0.05$). For both sheep breeds, mutton pH values were lowest among feeding period lengths for 6 weeks. As expected standard, mutton pH changed with advancing time post slaughter with a significant decrease from day 0 to 1 post slaughter and relatively little change thereafter. The average mutton lightness (L*) was greater ($P < 0.05$) for Black head Ogaden rams (L*=29.50, 39.68, 40.91 and 42.73) than Arsi-Bale rams (L*=27.89, 35.81, 36.67 and 38.04) on the same day of 0, 1, 2, and 3 post slaughters, respectively. Length of feeding period improved mutton lightness more with Black head Ogaden than Arsi-Bale rams and mutton lightness increased quadratically with increasing length of feeding, with greater values for 4 and 6 weeks than 2 weeks. Sheep origin had significant effect on mutton redness and the average mutton redness was greater ($P < 0.05$) for supplemented Arsi-Bale rams (a*=14.21, 17.04, 17.15 and 16.82) than supplemented Black head Ogaden rams (13.51, 15.63, 15.25 and 14.69) on the same day 0 and 1 post slaughters, respectively. In conclusion, the results of this study revealed that mutton darkening of both sheep origins was not detected/ apparent from comparisons of mutton pH and color measures with values reported in different literatures. From some influences of length feeding treatments on mutton pH and color measurements, animal managements (like pre-slaughter short length of feeding periods at abattoirs) should be properly considered.

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