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Effect of supplementary feeding on the production traits, carcass and meat quality of Jamuna basin lambs

Abstract

This study aimed to identify the optimum level of supplementary feeds on the carcass traits and meat quality of Jamuna basin lambs. Forty selected lambs were divided into four treatments such as T_0 (no concentrate supplementation), T_1 (1% concentrate feed), T_2 (1.5% concentrate feed) and T_3 (2% concentrate feed) having ten lambs per treatment. The data were analyzed through Completely Randomized Design (CRD) with SAS software. Hot carcass, dressing percentage, head, leg, neck, loin, heart, and spleen weight were showed significantly (p<0.05) higher values with increasing concentrate feed. The crude protein (CP), ether extract (EE) and ash values were significantly increased (p<0.001) except T_2 treatment. The ultimate pH was significantly increased except T_2 and cooked pH was significantly decreased (p<0.001) except T_3 treatment. Drip loss and cooking loss (CL) % had significantly reduced (p<0.001) except T_3 treatment. The water holding capacity (WHC) % was significantly increased (p<0.001) except T_3 treatment. The score of color, juiciness and tenderness were significantly different (p<0.001). Flavor and overall acceptability score were significantly increased (p<0.05) in different treatments. The color values L^* and b^* had significantly changed (p<0.001) and a^* value was found significantly higher (p<0.05) in all treatments. Hence, 12 months of aged lambs with 1.5% concentrate feed showed better performances on carcass, nutritional, physicochemical, sensory and instrumental color values to increase the carcass and the meat quality of lambs.

Keywords (3 to 6): Carcass traits, Jamuna basis lambs, Meat quality, Production traits, Supplementary feeding

Introduction

Sheep is a vital ruminant farm animal of Bangladesh. It plays an important role regarding the income and food supply, as well as the socio-economic status of poor farmers [1]. The sheep in Bangladesh are less profitable because of lower birth weight, average daily gain (ADG) and slaughter weight. The profitability of lamb farming in Bangladesh is associated with inadequate and poor quality feeds [2]. Concentrate supplementation plays a vital role on the growth and lamb performance [3-5]. There is alternatives way to mitigate this problem by supplementing high-energy concentrate feeds before marketing of lambs. Indigenous lambs are resistance to high ambient temperature in tropical and sub-tropical environment [6]. The production performances of lamb, carcass and meat quality depends on feedlot conditions. Various factors enhance the production performances such as breed and age of lamb, types of feed supplied as well as the period of feeding [7]. Concentrate feed supplementation in adult sheep increased the marbling and the tenderness of mutton [8].

The energy and protein play a crucial role on affecting meat production in small ruminants by including dietary nutrients [9]. The ADG of Jamuna basin lamb was found 51-54g upto slaughter age at 9-12 months and the body wt. was found 17-20 kg at that time [10]. Several researchers studied on sheep rearing systems particularly grazing with different levels of concentrate supplementation on the meat quality of lambs [11-12]. They found a positive result of concentrate supplementation on intramuscular fat depositionin lamb compared to only grazed lamb. The natural antioxidants are present in green grass resulting in the effect of grazing system to minimize meat oxidation [13]. The influences of green grass on sensory attributes, meat instrumental color values and texture had been studied by another author with different findings [14]. There were many previous studies which compared pasture grazing with concentrate supplementation on growth performance and meat quality [15], color [16], sensory attributes [17] and WHC [18]. The lambs having only grazing leads leaner carcasses with lower dressing% whereas, lambs with concentrate feeding performed higher growth rates, better carcass traits, and lower ultimate pH [19]. The instrumental color of mutton influences the consumer purchasing decisions [20]. The red color is treated by consumers as good quality whereas pale, discolored meat is treated as poor quality meat [21]. The consumers choose lamb meat due to its better color but market fails due to the lacking of standardization and quality when it reaches to the consumers [22].

Only limited information on growth, carcass & meat quality of lambs through different levels of concentrate were available in Bangladesh. The carcass traits and meat quality such as nutritional, physicochemical, sensory and meat color of lamb meat have not been studied yet in Bangladesh. The production of lamb in Bangladesh is practised through traditional feeding and its genetic potential is lower [23]. Therefore, it needs to identify the growth performances, carcass & meat quality of finished lambs at different ages & body weights with different concentrate feeds supplementation with normal grazing. Supplementation can help to improve the quality of feed resources through enhancing the activity of rumen microbes [24]. Concentrate supplementation levels are responsible for fluctuating the carcass traits, meat quality and fat deposition [25]. From different literatures it was found that 1 to 6% concentrate supplementations used to increase carcass and meat quality of lamb according to size and body weight. Only limited research is reported of different levels of concentrate supplementation in lambs and kids to identify slaughter age and meat quality in Bangladesh [26-27). Bangladesh Livestock Research Institute (BLRI) conducted a basic research suppying 1, 1.5 and 2% concentrate feed to enhance the lamb production performances in their own research station [28]. From this point of view, 1, 1.5 and 2% of concentrate feeds were used to validate this research work at rural farming condition in Bangladesh. Hence, the study was undertaken to evaluate the production performances, carcass & meat quality of marketing age and live weights with concentrate supplementation for Jamuna basin lambs in Bangladesh.

Materials and Methods

Experimental animals and management

The study was carried out forty (40) castrated Jamuna basin lambs with same management, feeding and vaccination under four treatments such as T_0 (Control), T_1 (1% concentrate), T_2 (1.5% concentrate) and T_3 (2% concentrate) having ten lambs in each group. The lambs were grazed at 6-7 h in an open grazing field at the day time and kept in the shed at night. The supplied feed was uniform in all four treatments. Sufficient green grass and fresh water were supplied with 1, 1.5, and 2% concentrate feed that contain 18% CP and 12 MJME/kg DM. The ingredients of the formulated diet were crushed wheat (68%), soybean meal (30%), di-calcium phosphate (DCP) (0.5%), vitamin-mineral premix (0.5%) and iodine salt (1%) which were supplied to the lambs twice a day.

Slaughtering procedure and sampling of carcass

Forty castrated lambs were fasted and slaughtered with Halal or Muslim method for laboratory analyses after end of the growth & feeding trial. The fasted body weights of the lambs were recorded before slaughtering and individual hot carcass weights were recorded immediately after flaying and evisceration. Non-carcass components such as skin, head, liver, lung, spleen, heart, kidneys, shank, and viscera were removed and measured their respective weights to indentify dressing percentage and other carcass parts. The rumen ingesta and other gut contents and the post-ruminal tracts were removed and weighed. The obtained dressing percentage was calculated as hot carcass basis or without chilling. Finally, 100-120g sample was taken from Longissimus dorsi (LD) muscle for analyses of proximate component, physiocochemical traits, instrumental meat color and sensory evaluation.

Estimation of carcass traits of lambs

After slaughtering, complete bleeding was practiced. The following parameters *viz.* live wt, carcass wt, dressing percentage, blood wt, skin wt, viscera wt, head wt, half carcass wt, pluck wt, neck wt, shoulder wt, rack wt, loin wt, kidney wt, liver wt, heart wt, lung wt, spleen wt and shank weight were measured. Then, the weight of hot carcass was taken with a balance to calculate dressing percentage.

$$\text{Dressing percentage (DP\%)} = \frac{\text{(Warm carcass weight)}}{\text{Live weight}} \times 100$$

Similarly, the weight of liver, heart, lungs, kidney, and spleen were taken to determine the percentage of these organs accordingly.

Proximate components of lamb meat

The proximate components of lamb meat such as dry matter (DM), crude protein (CP), ether extract (EE), and ash were analysed according to AOAC [29].

Sensory evaluation of lamb

Different sensory attributes of Jamuna Basin lamb were performed in this study. All meat samples were examined by skilled 8-members evaluation panel. The sensory parameters were measured on a 5 point scale for the attributes such as tenderness, juiciness, color, flavor, and overall acceptability. There were eight training sessions were conducted for the judges to familiarize themselves with the attributes for evaluation [30-31]. All panelists participated in orientation sessions prior to sample evaluation might be due to familiarize with the scale attributes. All lamb samples were served in the petri dishes prior to evaluation.

Physicochemical traits estimation

Drip loss measurement

Drip loss (DL) was measured according to the principle followed by Rahman et al. [32]. For DL measurement approximately 30 g sample was hung with a wire and kept in an air tight plastic container for 24 h. After 24 h, the sample was weighed and calculated the difference. It was expressed as percentage.

$$\text{Drip loss (\%)} = \frac{(\text{Weight of hot carcass} - \text{weight of carcass after 24 hours chilling})}{\text{Weight of hot carcass}} \times 100$$

Cooking loss (CL) measurement

For CL% measurement, thirty (30) g lamb meat sample was taken in a poly bag and put it into a water bath having 71 °C temperatures. Then lamb meat was removed from the water bath after 30 minutes cooking and soaked its moisture with white tissue paper. Weight loss of the sample was measured through deducting the moisture loss during cooking of lamb meat. The CL was calculated using the following formula:

$$\text{Cooking loss (\%)} = \frac{(\text{Weight of sample} - \text{weight after cooking at } 71°\text{C for 30 min})}{\text{Weight of sample}} \times 100$$

Ultimate pH measurement of lamb

Lamb meat pH was measured after 24 h of slaughtering (ultimate pH) using a pH meter (Hanna HI 99163, USA). The pH was measured by inserting the electrode at three different locations of the lamb meat which was calibrated prior to use at pH 7.0. Triplicate measurements of pH were taken from on the medial portion of the lamb meat at one cm depth to get an average value.

pH of Cooked lamb meat

The lamb meat samples were cooked at 71℃ for 30 minutes and then the meat samples were taken out from the water bath. After cooling the samples, the pH was measured as described in the same procedure as of raw meat samples.

Water holding capacity of lamb meat

The Water holding capacity (WHC) of lamb meat was measured according to the principle described by Choi et al. [33]. One g thawed sample was wrapped by absorbent cotton and put it into a 1.5 ml eppendorf tube. The tubes with samples were then centrifuged in a centrifuge separator (H1650-W Tabletop high speed micro centrifuge) at 10,000 rpm for 10 min at 4° C temperature. After then the samples were weighed and calculated the WHC%. The WHC% of the sample was measured through the following formula:

$$\text{WHC (\%)} = \frac{(\text{Weight of lamb meat sample after centrifugation})}{(\text{Weight of lamb meat sample before centrifugation})} \times 100$$

Instrumental color measurement of lamb meat

Instrumental color was measured from longissimus muscle of lamb carcass. Color was measured from the chilled muscles kept at 4℃ temperature after 24 h of slaughtering using a Konica Minolta Chroma Meter (CR 410, Konica Minolta Sensing, Inc., Osaka, Japan). A Miniscan Spectro colorimeter programmed with the CIE Lab (International Commission on Illumination, France) was used to measure the value of CIE L^*, a^*, and b^*, where L^* represents lightness, a^* redness and b^* yellowness [34]. The values were determined from the medial surface of the lamb meat just after 24 h of post-mortem [32].

Statistical analysis

The data were analyzed through Completely Randomized Design (CRD) along with GLM procedure of SAS statistical package program. Duncan’s Multiple Range Test (DMRT) was used to determine the variations among treatments at 5% level of significance ($p<0.05$).

Results and Discussion

Effect of concentrate feeds on the carcass traits

Level of concentrate feeding showed a significant difference (p<0.01) on the final body weight and ADG in different treatments. A higher ADG was found in T_2 and T_3 but there was no statistical difference. It was found from the study that 1.5% concentrate feed (T_2 group) showed the highest ADG (58.85 g/d) and dressing weight (51.35%) than all other treatments (Table 1). Concentrate feed digested easily and utilized properly in ruminal environment that results higher muscle growth as well as meat quality. Tadesse et al. [35] stated that the ADG was higher in small ruminant at higher level of concentrate supplements. A similar ADG was found in the results of Hashem et al. and Hossain et al. [10, 36] in growing Jamuna basin lambs. Yirdaw et al. [37] also found a similar ADG and dressing % in bagait sheep through cottonseed meal feeding. Dressing percentage was found significantly higher (p<0.05) in T_2 compared to T_0, T_1 and T_3 treatments. Similar results were stated by Ayrle et al. and Worku et al. in case of dressing percentage [39-40]. Costa also found a significant (p>0.05) effect of hot carcass and dressing percentage which was very much similar with this study [38]. Melese et al. [41] stated that the sheep consuming higher level of concentrate supplements had significant heavier carcass than lower level of concentrate feed. These results supported the present study. The heavier carcass weight reported in T_3 might be reflacted the effect of higher feed consumption in that treatment. The hot carcass weight of lambs (6.36-7.73 kg) in this study was not higher to the Ethiopian indigenous sheep breeds might be due to the breed variation [40]. Moniruzzaman et al. showed that the age of animal had significant influence on dressing percentage and the quality of meat [7]. In case of head weight, no difference was found in T_0 and T_1 but there was a significant difference (p<0.05) was detected with T_2 and T_3 treatment. The leg weight was similar in T_0, T_1 and T_2 but found a significant different (p<0.05) with T_3. A similar neck weight was found in T_0 and T_1 which had significant different (p<0.05) with T_2 and T_3 treatment. The loin weight was significantly different at different treatments of concentrate suppementation along with control group. Heart and spleen weight were found significantly heavier (p>0.001) in T_1, T_2, and T_3 treatments, respectively but lungs didn't. Liver weight had significantly (p<0.05) increased with increasing concentrate feeds. Weight of edible by-products such as liver, heart, spleen weight was similar and the kidney weight was not similar with the findings of Adem et al. [42].

Effect of concentrate feeds on proximate components of lamb meat

The CP and EE percentage were 21.46, 22.41, 24.16, 25.57 and 0.97, 1.94, 3.56 and 6.58, respectively in T_0, T_1, T_2 and T_3 treatments (Table 2) which were significantly increased (p<0.001) with the increasing of concentrate supplementation. Ash percentage found significantly lower (p<0.001) in four treatments compared to control group. The amount of CP, EE and ash of lamb meat was found significantly higher (p<0.001) at different treatments (T_1, T_2 and T_3) than in T_0 treatment. The CP and EE percentage were found significantly higher (p<0.001) in concentrate supplemented groups and the increasing was proportional to the level of concentrate feed. Worku et al. [39] found higher CP and EE percentage with increasing level of concentrate feed for Washera sheep where CP percentage was not increased significantly (p>0.05) but the EE percentage was increased significantly (p<0.05). On the contrary, sheep fed higher concentrate showed the higher meat fat [42]. The higher rate of concentrate supplementation showed a positive result on the fat deposition in meat. These findings were very much similar with this present study. Supplementation of concentrate results a greater feed intake and growth as compared to the control group lambs grazed on low quality forages in this current study. Some other researcher also reported that there was a positive effect on the protein intake and the digestibility of feed ingredients [43]. Gashu et al. [44] reported a lower fat deposition in Washera sheep (2.61-2.62%) might be due to lower concentrate supplementation. Good quality of lamb meat contains 70% moisture and 18.5-23.40% protein along with sufficient marbling and subcuteneous fat content [45]. Ash percentage of their study was higher up to 2.00 for concentrate feed which was significantly different (p<0.001). The result of ash content was similar with the results of Tadesse et al. [35] where they showed a non significant (p>0.05) effect of ash with the increasing levels of concentrate feed.

Effect of concentrate feeds on the physicochemical traits of lamb meat

The values of cooked pH, ultimate pH, cooking loss, drip loss and the WHC at different treatments are shown in Table 3. The ultimate pH was found optimum level (5.95) in T_2 treatment as compared to T_0, T_1 and T_3 treatments which showed significantly different results (p<0.001). Hossain et al. [36] reported that ultimate pH was 5.95 which were very similar with the present study. The ultimate pH values of T_2 lamb meat in the present study ranges within the acceptable international values of meat pH (5.5-5.9) for international trade. The muscle glycogen is responsible to produce lactic acid results a lower pH that improve the shelf life of meat [46]. The optimum pH value observed in this study indicated that lambs were in sound health status that ensured enough glycogen reserve during slaughtering. The higher glycogen levels in the muscle help to developed optimum level of lactic acid resulting the reduced pH that improve the shelf life of meat [47]. Higher ultimate pH was found in T_0, T_1 and T_3 treatment groups as compared with T_2 treatment. Live lambs were transported to Bangladesh Agricultural University market before slaughtering from a 90 kilometer distant place might be the cause of higher pH. There was a reduced muscle glycogen resulting from longer time feed withdrawl and transportation stress. The symultaneous effect of feed withdrawl and transportation stress decreased the amount of glycogen in muscle during slaughtering. Cooked pH was significantly lower (p<0.001) in T_2 as compared with other treatment groups. Lower cooking loss and drip loss percentages were found in T_2 as compared with T_0, T_1 and T_3 treatments in which cooking loss and drip loss had significant effect (p<0.05 and p<0.001, respectively). A lower cooking loss value (20.33-21.63) and higher drip loss (3.80-4.89) was also reported by Costa et al. [38] which were not similar with this study might be due to the stress condition of the slaughterd lamb. The cooking loss values of meat of small ruminants showed an acceptable range (14-41%) which was corroborated with the present study [48]. The drip loss percentage from the present study was found within the optimum ranges (0-4%) with increasing levels of concentrate feeds. The WHC% was detected significantly higher (p<0.001) in T_2 as compared with T_0, T_1 and T_3 treatments. Drip loss is an important indicator of WHC of fresh meat which is resulted by the gravity force. The WHC percentage of the present study was not in accordance with the results of Costa et al. [38] where they showed that the WHC% was 72.55.

Effect of concentrate feeds on sensory attributes of lamb meat

The values for color, flavor, tenderness, juiciness and overall acceptability at different treatments were 3.85 to 4.51, 4.06 to 4.46, 4.25 to 4.63, 4.25 to 4.63 and 4.17 to 4.46, respectively (Table 4). The color and tenderness were observed significantly higher (p<0.001) in T_2 compared with other treatments. In case of flavor, there was no difference in T_0 and T_1 but there was a significant superior flavor (p<0.05) was detected with T_2 and T_3 treatment. Juiciness and the overall acceptability were also detected significantly higher (p<0.05) in T_2 compared to T_0, T_1 and T_3 treatments. The average score of flavor (4.42 in T_2 treatment) and juiciness (4.63 in T_2 treatments) of the present study were higher than the results of Zanzibar Chulayo and Muchenji for flavor (3.33) and juiciness (3.47) in sheep [49]. The flavor was significantly higher (p<0.001) in T_3 and overall acceptability also significantly higher (p<0.05) in T_2 treatment compared with other treatments. The reason of higher flavor in lamb's meat might be due to increase of fat deposition with increasing concentrate feeds for lambs. Worku et al. [40] found significantly higher (p<0.001) flavor, tenderness, juiciness and overall acceptability with increasing concentrate feeds which was supported by the present study.

Effect of concentrate feeds on instrumental color values of lamb meat

According to International Commission on Illumination (CIE) the values of *L**, *a**, *b**, hue angle and saturation index at different treatments were ranged at 42.03-51.81, 15.83-18.15, 9.27-12.71, 20.75-26.11 and 16.78-22.65, respectively at different treatments (Table 5). Color value is an important criterion of meat quality evaluation of lambs. This color value was observed variation in age, sex, breed, geographical location and management condition of lambs. The *L** value was observed significantly higher (p<0.001) in T_0 compared to T_1, T_2 and T_3 treatments. The higher *L** value in T_2 was due to the distribution of more intramuscular fat deposition which made the luminous of meat [44]. Muscle from heavier lambs showed lighter/higher (*L**) color than that of higher/lighter weight lambs. A significant higher (p<0.05) *a** value was found in T_2 compared with T_0, T_1 and T_3 treatments. Lower *b** value was also found in T_2 compared with T_0, T_1 and T_3 treatments which was significantly different (*p*<0.001). Worku et al. [40] found a non-significant higher CIE *L**, *a** and *b** results at higher levels of concentrate feeds. These results were not similar with the present study. Costa et al. [38] found that the CIE *L**, *a** and *b** values of unweaned lambs and supplemented weaned lambs were 41.67 & 43.17, 15.23 & 15.98 and 6.34 & 6.55, respectively. These values were much lower than the present stydy. The bright red color of meat is an important characteristic for meat quality that influenced the consumer's perception that indicates the freshness and wholesomeness of meat [50]. The higher hue angle and saturation index were found in control group than treatment groups. The higher hue angle and saturation index were detected significantly difference (*p*<0.01) among the all treatments groups. The hue angle and saturation index values were not influenced by the higher concentrate supplemented groups [51] which were not supported the present study.

Pearson's correlation between different parts of carcass traits of lambs

The correlations in different variables of carcass traits are shown in Table 6. There was found a strong positive correlation association (r>0.80) between initial body weight and the final body weight. Strong positive correlation (r>0.85) was found between final body weight and hot carcass. High positive correlation association (r>0.83) was also observed between liver, shoulder and rack weight. Also, a stronger positive correlation associations (r>0.80) were observed between spleen & heart, skin & head and heart & head weight, respectively. A comperative higher positive correlation association (r>0.79) was observed between shoulder and rack weight. Olawumi et al. [52] stated that all the carcass traits were good indicators of live weight which was similar with the present study [53]. The correlation of ADG and hot carcass between live weight was significantly differed ($p<0.01$ and $p<0.05$), respectively. The hot carcass yield was strongly correlated (r = 0.90) with the chilled carcass yield; therefore, with a high hot carcass yield and low losses during the chilling of the carcass, the chilled carcass yield increased. The correlation of these two variables permits estimations of the characteristics of the carcasses and the meat when specific and accurate equipment were not available [54-55]. The correlation between final body weight and hot carcass was significantly different ($p<0.05$). The correlation between spleen and heart, shoulder and rack withl iver were significantly different ($p<0.01$). The correlation between initial and final body weight, skin and head weight were also found significantly different ($p<0.01$). Costa observed a positive correlation between body condition and dressing% in lamb meat which was significantly ($p<0.05$) different [38].

Pearson's correlation between proximate and sensory attributes of lamb meat

The correlation between proximate component and sensory attributes of meat traits is presented in Table 7. There was found positive correlation association (r>0.60-0.79) between CP and EE, CP and flavor. Positive correlation association (r>0.50-0.56) was observed between EE and ash, EE and flavor, EE and tenderness, respectively. The positive correlation of fat content (EE) and flavor between CP was found significantly differed (p<0.01). The positive correlation of ash, flavor and tenderness between EE was found significantly differed (p<0.01). Yalcintan et al. [56] found significant positive correlation (p<0.01) on juiciness and overall acceptability between tenderness. These results were in accordance with the present study. They also found significantly different (p<0.01) of positive correlation between juiciness and overall acceptability. These findings did not corroborate with the present study.

Pearson's correlation between physicochemical and color values of lamb meat

The correlation between physiocochemical traits and color values of meat traits is presented in Table 8. Positive correlation association (r>0.71) was observed between cooked pH and ultimate pH. Positive correlation association (r>0.50-0.70) was observed between b^* value and ultimate pH, b^* value and cooked pH, respectively. On the contrary, negative correlation association (r>-0.51) was found between L^* and ultimate pH. The positive correlation between ultimate pH and cooked pH was found significantly differed (p<0.01). The positive correlation between b^* and ultimate pH, b^* and the cooked pH was found significantly different (p<0.01). The negative correlation between L^* and ultimate pH was found significantly differed (p<0.01). Rahman et al. [32] found positive and significant (p<0.01) correlation of ultimate pH and drip loss between L^* values. Their results were not similar with the present study.

Average daily gain (ADG)

The ADG is presented in Table 9. The mean square of initial live weight was 15.51, F value 0.54 which was non-significant. The mean square of level of concentrate feed was 1680.78, F value 58.53 which was significantly different (p<0.001). The root sqaure was 0.83 and adjusted root square was 0.82. The total sum of square was 92071.66 and degree of freedom 40. The corrected total was 6047.89 and degree of freedom was 39.

The following ANOVA model was used to justify the analysis of covariance of different levels of concentrate feeds on ADG:

$$Ý i=ß_1+ ß_2D_2i+ ß_3D_3i+ ß_4D_4i+ \mu i$$

D_2= 1 for 0% concentrate = 0 otherwise

D_3= 1 for 1% concentrate = 0 otherwise

D_4= 1 for 1.5% concentrate = 0 otherwise

The estimated regression model has been presented below:

Ý i= 55.69** + 23.61** D2i + 16.80** D3i + 3.16D4i

(1.68) (2.38) (2.38) (2.38)

F= 59.10** R sqrare = 0.82

To identify which feed is contributing mostly for ADG, the following analysis of variance (ANOVA) model has been estimated. Feeds 0 and 1% concentrate were found to have significantly negative impact on the increase of average daily gain and they were significantly different from other feeds. However, 1.5 and 2% concentrate feeds were found to have positive impact of increasing average daily gain and there was no different impacts of 1.5% concentrate feed as compared to 2% concentrate feed. That is, 1.5 and 2% concentrate feeds were significantly (*p*<0.001) better compared to control and 1% concentrates feed. A significant F value suggests that the model is well fitted to the data. The adjusted R square shows that 82% variation of average daily gain could be happened due to supplementation of concentrate feeds of Jamuna basin lambs.

Conclusions

It is concluded from the study that the 1.5% concentrate supplementation in Jamuna basin lamb up to 12 months of age showed better productive and meat quality on the basis of carcass traits, nutritional, physicochemical, sensory and instrumental color values. Further research is required to deterrmine the detail nutritional contents like omega-3, omega-6, amino acid profile, fatty acid profile and consumer’s acceptablity of lamb meat

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References (Vancouver or NLM style)

1. Hossain MA, Islam MA, Akhtar A, Islam MS, Rahman MF. Socio-economic status of sheep farmers and the management prctices of sheep at Gafargaon Upazila of Mymensingh district. Int. J. Nat. Soc. Sci. 2018a; 5:07-15.

2. Rahman MM, Akther S, Hossain MM. The availability of the livestock feeds and feeding practices followed by the farmers of some areas of Mymensingh District. Bangladesh J. Anim. Sci. 1998; 27:119-126.

3. Sarker AK, Amin MR, Hossain MA, Ali MS, Hashem MA. Present status of organic sheep production in Ramgoti Upazila of Lakshmipur district. J. Env. Sci. Nat. Res. 2017; 10:95–103.

4. Sun MA, Hossain MA, Islam T, Rahman MM, Hossain MM, Hashem MA. Different body measurement and body weight prediction of Jamuna basin sheep in Bangladesh. SAARC J. Agric. 2020; 18 (1):183-196.

5. Hossain MA, Akhtar A, Easin M, Maleque MA, Rahman MF, Islam MS. Women household livelihood improvement through sheep (*Ovis aries*) rearing in Sirajganj district of Bangladesh. Int. J. Nat. Soc. Sci. 2018b; 5:1-8.

6. Rashid MM, Hossain MM, Azad MAK, Hashem MA. Long term cyclic heat stress influences physiological responses and blood characteristics in indigenous sheep. Bangladesh J. Anim. Sci. 2013; 42:96-100.

7. Moniruzzaman M, Hashem MA, Akhter S, Hossain MM. Effect of different feeding systems on carcass and non-carcass parameters of Black Bengal goat. Asian-Austral. J. Anim. Sci. 2002; 15(1):61-65.

8. Nishimura T. The role of intramuscular connective tissue in meat texture. Anim. Sci. J. 2010; 81(1):21–27.

9. Sultana N, Hossain SMJ, Chowdhury SA, Hassan MR, Ershaduzzaman M. Effects of age on intake, growth, and nutrient utilization and carcass characteristics of castrated native sheep. The Bang. Vet. 2010; 27:62-73.

10. Hashem MA, Islam T, Hossain MA, Kamal MT, Sun MA, Rahman MM. Production performance of Jamuna basin lamb under semi-intensive management system in Bangladesh. J. Anim. Vet. Adv. 2020; 19:150-158.

11. Valvo MA, Lanza M, Bella M, Fasone V, Scerra, M, Biondi L, Priolo A. Effect of ewe feeding system (grass v. concentrate) on intramuscular fatty acids of lambs raised exclusively on maternal milk. Anim. Sci. 2005; 81(3):431–436.

12. Hajji H, Mahouachi M, Saidi MC, Hammouda MB, Atti N. Effect of sheep house or range land management on lamb meat quality of three North African breeds. Viandes et Produits Carnés, hors série. Clermont-Ferran. 2014; 155–156.

13. Wood JD, Richardson RI, Nute GR, Fisher AV, Campo MM, Kasapidou E, Sheard PR, Enser M. Effects of fatty acids on meat quality: A review. Meat Sci. 2004; 66(1):21-32.

14. Priolo A, Micol D, Agabriel J, Prache S, Dransfield E. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. Meat Sci. 2002; 62:179-185.

15. Haque MI, Sarder MJU, Islam MA, Hashem MA, Khaton R, Islam MH. Effect of slaughter age on carcass characteristics and meat quality of Barind lamb. Meat Res. 2022; 2, Article No. 11.

16. Ripoll G, Joy M, Muñoz F, Albertí P. Meat and fat colour as a tool to trace grass-feeding systems in light lamb production. Meat Sci. 2008; 80:239–248.

17. Duckett SK, Neel JP, Lewis RM, Fontenot JP, Clapham WM. Effects of forage species or concentrate finishing on animal performance, carcass and meat quality. J. Anim. Sci. 2013; 91:1454–1467.

18. Santos-Silva J, Mendes IA, Bessa RJB. The effect of genotype, feeding system and slaughter weight on the quality of light lambs: Growth, carcass composition and meat quality. Livest. Prod. Sci. 2002; 76:17–25.

19. Zervas G, Tsiplakou E. The effect of feeding systems on the characteristics of products from small ruminants. Small Rum. Res. 2011; 101:140–149.

20. Mancini R, Hunt M. Current research in meat color. Meat Sci. 2005; 71:100–121.

21. Hashem MA, Hossain MM, Rana MS, Islam MS, Saha NG. Effect of heat stress on blood parameter, carcass and meat quality of Black Bengal goat. Bang. J. Anim. Sci. 2013; 42:57-61.

22. Cirne LGA, da Silva Sobrinho AG, de Oliveira EA, Jardin RD, Junior ASV, de Carvalho GGP, Jaeger SMPL, Bagaldo AR, de Almeida FA, Endo V, Moreno GMB, de Lima Valenca R. Physicochemical and sensory characteristics of meat from lambs fed diets containing mulberry hay. Italian J. Anim. Sci. 2018; 17:621-627.

23. Hossain MA, Su MA, Islam T, Rahman MM, Rahman MW, Hashem MA. Socio-economic characteristics and present scenario of sheep farmers at sherpur district in Bangladesh. SAARC J. Agric. 2021a; 19:185-199.

24. Olfaz M, Ocak N, Erener G, Cam MA, Garipoglu AV. Growth, carcass and meat characteristics of Karayaka growing rams fed sugar beet pulp, partially substituting for grass hay as forage. Meat Sci. 2005; 70:7-14.

25. Majdoub L, Said B, Say A, Kraiem K. Effect of concentrate level and slaughter body weight on growth performances, carcass traits and meat quality of Barbarine lambs fed oat hay based diet. Meat Sci. 2013; 93:557-563.

26. Murshed HM, Sarker MAH, Rahman SME, Hashem MA. Comparison of carcass and meat quality of Black Bengal goat and Indigenous sheep of Bangladesh. Journal of Meat Science and Technol. 2014; 2:63-67.

27. Kawsar SM, Rahman MM, Rahman SME, Hossain MM, MA Huq. Growth, carcass and non-carcass traits of Black Bengal goats due to urea molasses block supplementation. International J. Bio-Resources. 2006; 2:1-5.

28. Ahmed S, Rakib MRH, Karim RA, Fouzder SK, Jahan N, Sultana N, Ershaduzzaman M. 2017. Pre and Post-natal Nutrition of Ewes on the Performances of Native Bengal Ewes and Their Lambs. Anim. Vet. Sci. 2017; 5(2): 33-38.

29. AOAC 2005. Association of Official Analytical Chemists, Official method of analysis, 18th Ed. Washington, D.C.

30. Jahan I, Haque MA, Hashem MA, Rima FJ, Akhter S, Hossain MA. Formulation of value added beef meatballs with Pomegranate (*Punica granatum*) extract as a source of natural antioxidant. J. Meat Sci. Tech. 2018; 6:12-18.

31. Saba NA, Hashem MA, Azad MAK, Hossain MA, Khan M. Effect of bottle gourd leaf (*Lagenaria siceraria*) extract on the quality of beef meatball. *Bangladesh* J. Anim. Sci. 2018; 47(2):105-113.

32. Rahman MF, Iqbal A, Hashem MA, Adedeji AA. Quality assessment of beef using Computer Vision Technology. Food Sci. Anim. Resou. 2020; 40:896-907.

33. Choi MJ, Abduzukhurov T, Park DH, Kim EJ, Hong GP. Effects of deep freezing temperature for long-term storage on quality characteristics and freshness of lamb meat. Korean J. Food Sci. Anim. Resou. 2018; 38:959-969.

34. CIE (International Commission on Illumination). A guide to understand color communication. 2014; Retrieved from www.x-rite.com

35. Tadesse D, Urge M, Animut G, Mekasha Y. Growth and carcass characteristics of three Ethiopian indigenous goats fed concentrate at different supplementation levels. Springer Plus. 2016; 5:414.

36. Hossain MA, Rahman MM, Rahman MW, Hossain MM, Hashem MA. Optimization of slaughter age of Jamuna basin lamb based on carcass traits and meat quality. SAARC J. Agric. 2021; 19(2): 257-270.

37. Yirdaw M, Mengistu A, Tamir B, Brhane G. Effect of feeding cotton seed cake, dried *Acacia saligna*, *Sesbania sesban* or unguiculata on growth and carcass parameters of begait sheep in North Ethiopia. Agricl. Forest. Fish. 2017; 6(6 5):149-154.

38. Costa G, de Macedo REF, Hentz F, Prado OR, da Silva CJA, Taconeli CA, Monteiro ALG. Feeding systems and the physicochemical and sensory quality of lamb meat. J. Agril. Studies. 2019; 7:176-195.

39. Ayele S, Urge M, Animut G, Yusuf M. Comparative slaughter performance and carcass quality of three fat tailed hair sheep supplemented two level of concentrate. Tropical Anim. Health Prod. 2018; 51:187-198.

40. Worku A, Urge M, Animut G, Asefa GG. Comparative slaughter performance and meat quality of Rutana, Gumuz and Washera sheep of Ethiopia supplemented with different levels of

concentrate. Open J. Anim. Sci. 2020; 10:48-63.

41. Melese G, Mengistu U, Getachew A, Dereje T. Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition. African J. Agril. Res. 2017; 12:3072-3080.

42. Adem WS, Yadete GK, Beyene WT. Growth and carcass characteristics of Afar lambs at two concentrate levels supplementation and slaughter weights fed Tef Straw basal diet. Int. J. Liv. Prod. 2019; 10:77-85. https://doi.org/10.5897/IJLP2018.0539

43. Claffey NA, Fahey AG, Karane VG, Moloney AP, Monahan FJ, Diskin MG. Effect of forage to concentrate ratio and duration of feeding on growth and feed conversion efficiency of male lambs. Trans. Anim. Sci. 2018; 2:419-427.

44. McDonald P, Edwards RA, Greenhalgh JFD. Animal Nutrition, 7th ed.; Longman: London, UK, 1995; p. 468.

45. Gashu M, Urge M, Animut G, Tadesse D. Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition. African J. Agril. Res. 2017; 12:3072-3080.

46. Girma A, Kannan G, Goetsch AL. Effects of small ruminant species and origin (High land and Low land) and length of rest and feeding period on harvest measurements in Ethiopia. African J. Agric. Res. 2010; 5:834-847.

47. Abebe G, Kannan G, Goetsch AI. Effect of small ruminant species and origin (high land and low land) and length of rest and feeding period on harvest measurement in Ethiopia. African J. Agricl. Res. 2010; 5(9):834-847.

48. Ayeb N, Ghrab A, Barmat A, Khorchani T. Chemical and tissue composition of meat from carcass cuts of local goats affected by different feeding in Tunisian arid lands. Turkish J. Vet. Anim. Sci. 2016; 40(1):95-101.

49. Chulayo A, Muchenji V. The effect of pre-slaughter stress and season on the activity of plasma creatinine kinase and mutton quality from different sheep breeds slaughtered at smallholder abattoir. Asian-Austral. J. Anim. Sci. 2013; 26:1762-1772.

50. Watkins PJ, Frank D, Singh TK, Young OA, Warner RD. Sheep meat flavor and the effect of different feeding systems: A Review. J. Agric. Food Chem. 2013; 61(15):3561-3579.

51. Gashu M, Urge M, Animut G, Tadesse D. Slaughter performance and meat quality of intact and castrated Washera sheep kept under feedlot condition. African Journal of Agricultural Research. 2017; 12: 3072-3080.

52. Olawumi SO. Phenotypic correlations between live body weight and carcass traits in arbor acre breed of broiler chicken. 2013; Int. J. Sci. Nat. 4(1):145-149.

53. Zewide TM, Wossen AM, Yadeta AT, Geesink GH. Carcass and meat quality characteristics of two hair type breed lambs fed tef (Eragrostistef) straw ensiled with effective micro-organisms and supplemented with concentrates. Inte. J. Livest. Produc. 2019; 10(4):110-121.

54. Uruglu M, Ekiz B,Teke B, Salman M, Akdag F, Kaya I. Meat quality traits of male Herik lambs raised under an intensive fattening system. Turkish J. Vet. Anim. Sci. 2017; 41(3): 425-430.

55. Ali MS, Kang GH, Joo ST. A Review: Influences of pre-slaughter stress on poultry meat quality. Asian-Austral. J. Anim. Sci. 2008; 21:912-916.

56. Yalcintan H, Ekiz B, Kocak O, Dogan N, Akin PD, Yilmaz A. Carcass and meat quality characteristics of lambs reared in different seasons. Archive Anim. Breed. 2017; 60:225–233.

Tables

Table 1. Effect of concentrate feeds on carcass traits of lamb

Parameters	Treatment (Mean± SE)				Level of significance
	T_0	T_1	T_2	T_3	
Initial body wt. (kg)	10.60^{b}± 0.48	12.49^{a}± 0.49	10.54^{b}± 0.28	11.86^{a}± 0.31	<0.0024
Final body wt.(kg)	13.40^{b}± 0.61	15.99^{a}± 0.05	15.80^{a}± 0.31	16.77^{a}± 0.34	<0.0001
ADG (g)	32.08^{c}± 2.14	38.89^{b}± 1.99	58.85^{a}± 1.26	55.69^{a}± 1.11	<0.0001
% of live weight basis					
Hot carcass wt. (%)	6.36^{b}± 0.30	7.33^{a}± 0.25	7.51^{a}± 0.29	7.73^{a}± 0.39	<0.0208
Dressing wt. (%)	45.75^{c}± 0.49	47.37^{bc}± 0.91	51.35^{a}± 1.07	49.06^{ab}±1.46	<0.0040
Blood wt. (%)	3.91^{a}± 0.18	4.12^{a}± 0.24	4.43^{a}± 0.46	5.03^{a}± 0.25	NS
Skin wt. (%)	10.37^{a}± 0.19	10.66^{a}± 0.36	10.68^{a}± 0.27	12.37^{a}± 1.05	NS
Viscera wt. (%)	21.84^{a}± 1.61	14.58^{b}± 0.42	14.54^{b}± 0.30	23.04^{a}± 0.81	<0.0001
Head wt. (%)	5.53^{b}± 0.11	5.60^{b}± 0.16	6.84^{a}± 0.28	7.44^{a}± 0.63	<0.0009
Leg wt. (%)	9.42^{b}± 0.89	10.34^{b}± 0.21	10.88^{b}± 0.31	12.55^{a}± 0.47	<0.0020
Half carcass wt (%)	3.18^{c}± 0.25	3.67^{bc}± 0.49	3.76^{a}± 0.54	3.87^{ab} ± 0.73	<0.0041
Pluck wt. (%)	6.53^{a}± 0.23	6.69^{a}± 0.36	7.14^{a}± 0.37	6.70^{a}± 0.27	NS
Neck wt. (%)	3.63^{b}± 0.06	3.69^{b}± 0.11	4.47^{a}± 0.32	4.25^{a}± 0.11	<0.0043
Shoulder wt. (%)	8.66^{a}± 0.17	8.76^{a}± 0.25	8.99^{a}± 0.42	8.97^{a}± 0.21	NS
Rack wt (%)	9.78^{a}± 0.19	9.91^{a}± 0.28	10.22^{a}± 0.44	10.81^{a}± 0.23	NS
Loin wt. (%)	3.42^{b}± 0.05	4.42^{b}± 0.05	5.09^{a}± 0.58	4.45^{b}± 0.04	<0.0001
Shank wt. (%)	1.72^{c}± 0.09	2.02^{b}± 0.13	2.09^{b}± 0.04	2.37^{a}± 0.07	<0.0001
% of hot carcass weight basis					
Kidney wt. (%)	1.72^{a}± 0.28	1.68^{a}± 0.06	1.72^{a}± 0.07	1.38^{a}± 0.10	NS
Liver wt. (%)	3.72^{b}± 0.13	3.81^{b}± 0.15	3.84^{b}± 0.19	4.28^{a}± 0.09	<0.0419
Heart wt. (%)	0.80^{c}± 0.03	0.81^{c}± 0.03	1.49^{a}± 0.10	1.01^{b}± 0.05	<0.0001
Lung wt. (%)	1.61^{a}± 0.07	2.06^{a}± 0.10	2.28^{a}± 0.12	2.93^{a}± 1.57	NS
Spleen wt. (%)	0.68^{b}± 0.05	0.72^{b}± 0.02	0.73^{b}± 0.03	1.07^{a}± 1.07	<0.0001

Mean in each row having different superscripts varies significantly at values ($p<0.05$), T_0= Control group, T_1= 1% Concentrate feed, T_2= 1.5% Concentrate feed, and T_3= 2% Concentrate feed, NS=Non-significant

Table 2. Effect of concentrate feeds on proximate components of lamb meat

Parameters (%)	Treatments (Mean ±SE)				Level of significance
	T_0	T_1	T_2	T_3	
DM	25.25^a±0.26	24.06^a±1.17	24.04^a±0.25	25.81^a±0.58	NS
CP	21.46^c±0.52	22.41^c±0.11	24.16^b±0.41	25.57^a±0.07	<0.0001
EE	0.97^d±0.07	1.94^c±0.12	3.56^b±0.20	6.58^a±0.37	<0.0001
Ash	1.67^a±0.16	1.17^b±0.04	0.76^c±0.06	1.09^b±0.03	<0.0001

Mean in each row having different superscripts varies significantly at values ($p<0.05$), T_0= Control group, T_1= 1% Concentrate feed, T_2= 1.5% Concentrate feed, and T_3= 2% Concentrate feed

Table 3. Effect of concentrate feeds on physicochemical traits of lamb meat

Parameters	Treatments				Level of significance
	T_0	**T_1**	**T_2**	**T_3**	
Ultimate pH	$6.30^{b}\pm0.06$	$6.41^{b}\pm0.04$	$5.95^{c}\pm0.05$	$6.64^{a}\pm0.05$	<0.0001
Cooked pH	$6.91^{a}\pm0.08$	$6.70^{b}\pm0.06$	$6.42^{c}\pm0.04$	$6.91^{a}\pm0.05$	<0.0001
Cooking loss (%)	$30.33^{a}\pm1.72$	$29.03^{a}\pm1.55$	$24.44^{b}\pm1.26$	$31.64^{a}\pm0.98$	<0.0055
Drip loss (%)	$2.83^{b}\pm0.09$	$2.64^{c}\pm0.11$	$2.59^{bc}\pm0.08$	$3.36^{a}\pm0.09$	<0.0001
WHC (%)	$86.43^{b}\pm1.72$	$86.57^{a}\pm0.88$	$87.42^{a}\pm1.35$	$84.91^{a}\pm0.87$	<0.0001

Mean in each row having different superscripts varies significantly at values ($p<0.05$), T_0= Control group, T_1= 1% Concentrate feed, T_2= 1.5% Concentrate feed, and T_3= 2% Concentrate feed

Table 4. Effect of concentrate feeds on sensory attributes of lamb meat

Parameters	Treatments (Mean±SE)				Level of significance
	T_0	T_1	T_2	T_3	
Color	$3.85^{c}\pm0.11$	$4.30^{ab}\pm0.04$	$4.51^{a}\pm0.06$	$4.12^{b}\pm0.07$	<0.0001
Flavor	$4.06^{c}\pm0.07$	$4.43^{b}\pm0.05$	$4.45^{a}\pm0.06$	$4.46^{a}\pm0.05$	<0.0001
Tenderness	$4.25^{b}\pm0.07$	$4.38^{b}\pm0.04$	$4.63^{a}\pm0.09$	$4.56^{a}\pm0.05$	<0.0001
Juiciness	$4.25^{b}\pm0.07$	$4.38^{b}\pm0.04$	$4.63^{a}\pm0.09$	$4.56^{a}\pm0.05$	<0.0248
Overall acceptability	$4.17^{b}\pm0.4$	$4.38^{a}\pm0.04$	$4.46^{a}\pm0.05$	$4.34^{ab}\pm0.10$	<0.0280

Mean in each row having different superscripts varies significantly at values ($p<0.05$), T_0= Control group, T_1= 1% concentrate feed, T_2= 1.5% Concentrate feed, and T_3= 2% Concentrate feed

Table 5. Effect of concentrate feeds on instrumental color values of lamb meat

Parameters	Treatment (Mean± SE)				Level of significance
	T_0	T_1	T_2	T_3	
L*	$51.81^{a}\pm1.11$	$45.41^{bc}\pm0.95$	$48.81^{ab}\pm2.03$	$42.03^{c}\pm0.21$	<0.0001
a*	$15.83^{b}\pm0.67$	$16.70^{b}\pm0.18$	$18.05^{a}\pm0.33$	$17.30^{a}\pm0.58$	<0.0188
b*	$12.71^{a}\pm0.18$	$12.51^{a}\pm0.32$	$9.27^{b}\pm0.44$	$12.18^{a}\pm0.21$	<0.0001
Hue angle	$26.11^{a}\pm1.43$	$22.59^{b}\pm0.92$	$20.75^{b}\pm1.04$	$25.59^{a}\pm0.59$	<0.0021
Saturation index	$22.65^{a}\pm0.70$	$21.65^{ab}\pm0.28$	$16.78^{c}\pm0.78$	$20.17^{b}\pm0.47$	<0.0001

Mean in each row having different superscripts varies significantly at values $p<0.05$, T_0= Control group, T_1= 1% Concentrate feed, T_2= 1.5% Concentrate feed, and T_3= 2% Concentrate feed

Table 6. Pearson's correlation between different parts of carcass traits of lamb

Traits	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
A	1.00	0.80**	-0.08	0.70**	-0.15	0.26	0.22	0.11	0.09	0.47	-0.14	0.56	0.23	0.52	0.57	-0.20	0.31	0.50	-0.08	0.30	-0.02	0.58
B		1.00	0.58**	0.85*	0.01	0.37	0.03	0.04	-0.06	0.61	0.01	0.47	0.08	0.43	0.54	-0.55	0.24	0.55	-0.33	0.13	-0.32	0.82
C			1.00	0.17	0.22	0.28	-0.18	-0.01	-0.17	0.48**	0.21	0.70**	0.03	0.05**	0.52**	0.40**	0.38	0.07	0.13	-0.03	0.14	-0.10
D				1.00	0.06	0.03	0.09	0.03	-0.09	0.48**	0.16	0.70**	0.03	0.50**	0.52**	-0.40*	0.38*	0.63**	-0.22	0.09	-0.07	0.62**
E					1.00	0.06	0.30**	0.12	0.23	0.06**	0.99	0.32**	-0.17	0.11**	-0.14**	0.03	0.03**	0.07	0.13	-0.08	0.14**	-0.10
F						1.00	-0.02	0.16	0.14	0.34*	0.07	0.04	0.04	0.18	0.18	0.23	0.23	-0.18	0.23	0.16	-0.16	0.37*
G							1.00	0.54**	0.80**	0.48**	0.31**	0.48**	0.43**	0.59**	0.54**	0.23	0.28	0.45**	0.67**	0.05	0.52**	-0.09
H								1.00	0.76**	0.44**	0.11	0.32**	0.45**	0.32**	0.47**	0.18	-0.09	0.45**	0.71**	0.03	0.30**	0.13
I									1.00	0.49**	0.23	0.30**	0.59**	0.60**	.05**	0.38*	-0.10	0.58**	0.80**	0.06	0.55**	0.03
J										1.00	0.06	0.27	0.18	0.50**	0.57**	-0.50**	0.05	0.66**	0.09	0.11	-0.09	0.57**
K											1.00	0.32**	-0.16	0.12	-0.13	0.03	0.04	0.08	0.13	-0.08	0.15	-0.10
L												1.00	0.37*	0.62**	0.52**	0.18	0.60**	0.58**	0.41**	0.07	0.52**	0.24
M													1.00	0.58**	0.70**	0.54**	0.24	0.55**	0.61**	0.10	0.51**	0.22
N														1.00	0.79**	0.24	0.17	0.83**	0.43**	0.15	0.48**	0.37*
O															1.00	0.07	0.32**	0.83**	0.39*	0.14	0.29	0.58**
P																1.00	-0.06	-0.001	0.63**	0.001	0.74**	-0.44**
Q																	1.00	0.16	0.19	0.03	0.30	0.15
R																		1.00	0.38	0.13	0.33	0.59
S																			1.00	0.03	0.80**	-0.19
T																				1.00	0.27	0.08
U																					1.00	0.02
V																						1.00

A= Initial wt(kg), B=Final wt(kg), C=Average daily gain(g/d), D= Hot carcass wt., E= Dressing %, F= Blood %, G=Skin %, H=Viscera %, I= Head %, J=Leg%, K= half carcass %, L= Pluck %, M=Neck %, N= Shoulder %, O= Rack %, P=Loin %, Q= Kidney %, R= Liver %, S= Heart %, T= Lung %, U= Spleen %, V= Shank %

Table 7. Pearson's correlation between proximate and sensory attributes of lamb meat

Traits	A	B	C	D	E	F	G	H	I
A	1.00	0.06	0.20	0.19	-0.23	0.05	0.05	-0.01	0.01
B		1.00	0.79**	0.45**	0.20	0.60**	0.42**	0.16	0.19
C			1.00	0.54**	0.22	0.56**	0.50**	0.12	0.20
D				1.00	-0.32**	0.35**	0.34**	0.08	-0.14
E					1.00	0.12	0.24	-0.17	0.22
F						1.00	0.44**	0.36**	0.44**
G							1.00	0.38**	0.10
H								1.00	0.21
I									1.00

A= DM, B=CP, C= EE, D= Ash, E=Color, F=Flavor, G= Tenderness, H=Juiciness,

I= Overall acceptability

Table 8. Pearson's correlation between physicochemical and color values of lamb meat

Traits	A	B	C	D	E	F	G	H
A	1.00	0.30*	0.42**	0.38*	-0.23	-0.31*	-0.05	0.19
B		1.00	0.40**	0.43**	-0.38	-0.17	-0.02	0.27
C			1.00	0.71**	0.01	-0.51**	0.26	0.57**
D				1.00	-0.29	-0.11	0.34*	0.54**
E					1.00	-0.25	0.29	-0.004
F						1.00	0.11	-0.35**
G							1.00	0.47**
H								1.00

A=Drip loss, B= Cooking loss, C=Raw pH, D=Cooked pH, E= Water holding capacity,

F= L* (Lightness), G= a* (Redness), H= b* (Yellowness)

Table 9. Dependent Variable: Average daily gain

Source	Type III Sum of Squares	df	Mean Square	F	Level of significance
Corrected Model	5042.720	4	1260.680	43.897	<0.000
Intercept	737.595	1	737.595	25.683	<0.000
Initial weight	15.512	1	15.512	.540	0.467
Level of concentrate feed	5042.353	3	1680.784	58.525	<0.000
Error	1005.171	35	28.719		
Total	92071.661	40			
Corrected Total	6047.891	39			

R Squared = .834 (Adjusted R Squared = .815)