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**Research Article**

# Influence of different level of concentrate feeding on the productive performances and meat quality attributes of indigenous lamb

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## Abstract

This study aimed to identify the optimum level of concentrate feeds on the productive performances and meat quality attributes of three genotypes of indigenous lambs of Bangladesh. Thirty-six selected lambs of three genotype were divided into four treatments such as $T_0$ (Without concentrate supplementation), $T_1$ (1% concentrate feed), $T_2$ (1.5% concentrate feed) and $T_3$ (2% concentrate feed) having three lambs per treatment of three genotypes. The data were analyzed through 4 × 3 factorial experiments in Completely Randomized Design (CRD) with SAS software. Initial body weight (IBW), average daily gain (ADG) and final body weight (FBW) showed significantly ($p<0.001$) higher values at different Genotype with increasing level of concentrate feed. Hot carcass weight (HCW) was significantly ($p<0.001$) increased in different treatments. The crude protein (CP) and ether extract (EE) values were significantly increased ($p<0.05$) among different treatments. Genotype had a significant ($p<0.001$) effect on proximate components of meat except ether extract (EE). The ultimate pH was significantly ($p<0.001$) high in $T_{0,}$ $T_1$ and $T_3$ Treatment. Cooked pH was significantly ($p<0.001$) optimum in case of BRL compared to CBL and JBL. Cooking loss (CL %) had insignificantly reduced except $T_3$ treatment. Drip loss was significantly different in different genotype. The score of color, flavor juiciness and overall acceptability were significantly different ($p<0.001$) in different genotype. Flavor and tenderness score were significantly increased ($p<0.001$) in different treatments except $T_2$. The color values L* and b* had significantly changed ($p<0.001$) and a* value was found insignificantly higher in all treatments. Hence, the study reflects the superiority of Coastal Belt lamb over Jamuna Basin lamb and Barind Region lamb in terms of overall productive performance. Meat quality traits largely varied in different concentrate level. Jamuna Basin lamb with 1.5% concentrate feed showed better performances in nutritional, physicochemical, sensory, and instrumental color values of lamb meat.

## Introduction

Sheep is one of the most important small ruminant species which is widely distributed throughout the world. This species is widely adapted to different climatic conditions and is found in all livestock production systems (Berihulay et al., 2019). Traditional lamb farmers, often with zero or minimum input system under extensive/semi-intensive system, fail to provide proper nourishment, which affects the productivity due to low intake of nutrients (Steinfeld et al., 2006; Sharma et al., 2009). Sheep rearing is directly involved with poverty alleviation, employment generation and good quality nutrient supply. Sheep are predominantly raised for meat production in Bangladesh and lamb is the sheep aging below one year of age which are best use for meat purpose (Islam et al., 2021; Mobin et al., 2022). According to DLS report "Livestock Economy at a Glance, 2021-22" sheep population is 3.752 million and contribution of livestock in Gross Domestic Product (GDP) (Constant Prices) is 1.44%. For humans, meat is the most essential source of animal protein. In Bangladesh 62.5 percent of total need of animal protein is from livestock. Sheep provided 1.15 percent of total meat in Bangladesh, with 12.02 thousand metric tons of meat produced annually (DLS, 2022). The lamb meat is one of the best options for consumers for which they are willing to pay high; however, it fails in gaining market space due to the lack of standardization and quality when it reaches to the consumer (Cirne et al., 2018). Meat quality and price are affected by physiochemical properties. It is vital to understand the various elements that can influence the primary qualities of meat and production performance in this context. Age, sex (Hashem et al., 2020; Horcada et al., 1998; Habib et al., 2001a and 2001b; Barone et al., 2007), breed (Moniruzzaman et al., 2002; Crouse et al., 1981), preservation techniques (Sadakuzzaman et al., 2021; Akter et al., 2009 and 2022; Akhter et al., 2009 and 2022) and feed type (Hopkins and Fogarty, 1998) have all been found to affect carcass weight, conformation, fat content, and pH, texture, instrumental color, and nutritional composition.

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 (Hossain et al., 2018). Sheep are important in Bangladesh, providing meat and wool (Hassan and Talukdar, 2011). The production performances of lamb, production 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 (Moniruzzaman et al., 2002). Several studies report differences in production and meat quality between lambs raised on concentrates and those raised on grass systems. The main differences are in subcutaneous fat color, carcass fatness and meat flavor (Priolo et al., 2001). Lamb meat coming from these production systems is characterized by a pale pink color and fatness degree between slight and average which meets consumer preferences in such areas (Carrasco et al., 2009).

Only limited information on growth, carcass & meat quality of lambs through different 3 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 practiced through traditional feeding and its genetic potential is lower (Hossain et al., 2021a). Therefore, it needs to identify the growth performances and meat quality of finished lambs at different genotypes 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 (Olfaz et al., 2005). Concentrate supplementation levels are responsible for fluctuating the carcass traits, meat quality and fat deposition (Majdoub et al., 2013). From different literatures it was found that 1 to 6% concentrate 18 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 genotype and meat quality in Bangladesh. Bangladesh Livestock Research Institute (BLRI) conducted basic research supplying 1, 1.5 and 2% concentrate feed to enhance the lamb production performances in their own research station (Ahmed et al., 2017). 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. So, it is essential to establish an appropriate genotype to perform better response and avoid expensive fat deposition and bad flavor in the carcass for the attraction of consumer and ensure real market price. Therefore, the present study was conducted to identify the effect of different level of concentrate feeding on production performance and meat quality attributes of three main native lambs of Bangladesh which will help to decide optimum genotype for maximizing lamb production ensuring desired meat quality.

## Materials and Methods

### Experimental animals and management

The study was carried out forty (12) castrated Jamuna basin lambs, (12) castrated Barind region lambs, (12) castrated Coastal belt 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 twelve 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% crude protein (CP) and 12 MJME/kg dry matter (DM). The ingredients of the formulated diet were crushed wheat, soybean meal, di-calcium phosphate (DCP), vitamin-mineral premix and iodine salt which were supplied to the lambs twice a day.

**Table 1.** Ingredients and their amount used for the diet

| Ingredients | Percentage (%) |
|---|---|
| Crushed wheat | 68 |
| Soybean meal | 30 |
| Vita-mineral premix | 0.5 |
| DCP | 0.5 |
| Salt | 1 |
| Total | 100 |

### Slaughtering procedure and sampling of carcass

Thirty-six 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. Before slaughter initial body weight average daily gain and final body weight were also recorded. Non-carcass components such as skin, head, liver, lung, spleen, heart, kidneys, shank, and viscera were removed. 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, 100–120 g sample was taken from Longissimus dorsi (LD) muscle for analyses of proximate component, physicochemical traits, instrumental meat colour and sensory evaluation.

### Estimation of carcass traits of lambs

After slaughtering, complete bleeding was practiced. The following parameters viz hot carcass (%) dressing (%) were measured. Then, the weight of hot carcass was taken with a balance to calculate dressing percentage.

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

### Proximate components of lamb meat

The proximate components of lamb meat such as DM, CP, ether extract (EE), and ash were analysed according to AOAC (AOAC International; 2005).

### Sensory evaluation of lamb

Different sensory attributes of different genotypes 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 (Saba et al., 2018). All panellists 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 was measured according to the principle followed by Rahman et al. (2020). For drip loss 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.

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

### Cooking loss measurement

For cooking loss % measurement, thirty 30g lamb meat sample was taken in a poly bag and put it into a water bath having 71℃ 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 cooking loss was calculated using the following formula

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

### Ultimate pH measurement of lamb

Lamb meat pH was measured after 24 h of slaughtering (ultimate pH) using a pH meter (Hanna HI 99163, Hanna, Woonsocket, RI, 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 WHC of lamb meat was measured according to the principle described by Choi et al. (2018). 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, LABO-HUB, Shanghai, China) at 10,000 rpm for 10 min at 4℃ temperatures. 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℃ temperatures after 24 h of slaughtering using a Konica Minolta Chroma Meter (CR 410, Konica Minolta Sensing, Osaka, Japan). A Miniscan Spectro colorimeter programmed with the International Commission on Illumination (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. The values were determined from the medial surface of the lamb meat just after 24h of post-mortem. Calculations was done by (Hossain et al., 2022)

### Statistical analysis

The data were analysed 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

### Comparison of productive performances of JBL, BRL and CBL at different level of concentrate

The initial mean body weight of lambs from Jamuna basin, Barind region and Coastal belt and mean body weight of four concentrate feed ($T_0$, $T_1$, $T_2$, $T_3$) were 11.37, 12.22, 15.31, and 11.63, 13.23, 14.14, 14.23kg respectively (Table 2) and had a significant effect ($p<0.001$). Here, CBL had the highest mean IBW and JRL had the lowest. The final mean body weight of lambs from three genotypes and of four concentrate treatments were 15.49, 16.08, 17.77 and 13.84, 16.09, 16.43, 19.16 kg respectively and showed a significant effect ($p<0.001$) too. Here, CRL had the highest mean FBW and JBL had the lowest. The initial and final mean body weight of Jamuna Basin lambs were 4.64, 9.78; 7.90, 13.25, and 10.57, 15.80 in three treatments respectively, had a significant effect ($p>0.001$) (Hossain et al., 2021). This is almost similar to the present study for only JBL part. However, ADG was significantly higher in JBL and CBL (46.25 and 62.65) g/day than BRL (34.28) g/day. Treatment, genotype, and T*G had significant effect on ADG ($p<0.001$). The ADG was 57.39, 59.80 and 58.15 g/d in all treatments of JBL respectively according to Hossain et al. (2021) which was close to present study in terms of JBL part. Level of concentrate feeding showed a significant difference ($p<0.0001$) on the final body weight and ADG in different treatments (Hossain et al., 2023; Barman et al., 2017; ). 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 (54.10 g/d) and 2% concentrate feed ($T_3$ group) showed the highest dressing weight (49.04%) than all other treatments. Treatments and T*G had significant effect on HCW having value 6.36, 7.04, 7.67 and 8.42 for $T_0$, $T_1$, $T_2$ and $T_3$ but insignificant in genotype having value 7.24, 7.75 and 7.13 for JBL, BRL and CBL respectively. Santos et al. (2007) observed that the effect of hot carcass weight (HCW) was significant for all carcass traits. The result was completely supported by present research except genotype. Treatment, Genotype and T*G had no significant effect on Dressing%. Here, JBL and CBL had the highest mean value 48.42% and 48.46% but BRL had the lowest 44.64%. While for different treatment it was similar. Dressing% was highest in $T_3$ and $T_2$ treatments (49.04 and 47.48%).

**Table 2.** Comparison of productive performances of JBL, BRL and CBL at different level of concentrate

| Parameters | Genotype | Level of concentrate | | | | Mean ± SE | Level of Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | | Treatments | Genotype | T*G |
| IBW (kg) | JBL | 10.60±0.27 | 12.49±0.28 | 10.54±0.16 | 11.86±0.17 | **11.37$^c$±0.24** | <.0001 | <.0001 | <.0001 |
| | BRL | 12.06±0.03 | 12.33±0.07 | 12.17±0.05 | 12.34±0.08 | **12.22$^b$±0.08** | | | |
| | CBL | 12.45±0.05 | 14.78±0.05 | 18.72±0.01 | 17.31±0.12 | **15.31$^a$±0.08** | | | |
| | **Mean ± SE** | **11.63$^d$±0.12** | **13.23$^c$±0.13** | **14.14$^b$±0.23** | **14.23$^a$±0.12** | | | | |
| FBW (kg) | JBL | 13.40±0.34 | 15.99±0.03 | 15.80±0.17 | 16.77±0.19 | **15.49$^c$±0.75** | <.0001 | <.0001 | <.0001 |
| | BRL | 13.86±0.43 | 15.21±0.69 | 16.13±0.71 | 19.12±0.68 | **16.08$^b$±0.84** | | | |
| | CBL | 14.36±0.17 | 16.96±0.02 | 17.38±0.01 | 21.60±0.28 | **17.77$^a$±0.16** | | | |
| | **Mean ± SE** | **13.84$^d$±0.31** | **16.09$^c$±0.25** | **16.43$^b$±0.03** | **19.16$^a$±0.38** | | | | |
| ADG (g/d) | JBL | 32.08±1.23 | 38.39±1.14 | 58.85±0.72 | 55.69±0.64 | **46.25$^b$±0.94** | <.0001 | <.0001 | <0.0207 |
| | BRL | 28.88±4.50 | 34.17±3.66 | 34.06±4.09 | 40.00±0.00 | **34.28$^c$±3.09** | | | |
| | CBL | 55.12±4.61 | 59.63±4.46 | 69.38±4.49 | 66.50±2.62 | **62.65$^a$±3.96** | | | |
| | **Mean ± SE** | **38.69$^c$±3.44** | **44.06$^b$±3.09** | **54.10$^a$±3.10** | **53.06$^a$±1.08** | | | | |
| HCW (kg) | JBL | 6.36±0.17 | 7.32±0.14 | 7.51±0.61 | 7.76±0.19 | **7.24±0.29** | <.0001 | NS | <0.0262 |
| | BRL | 6.31±0.20 | 7.15±0.67 | 7.61±0.33 | 9.91±0.69 | **7.75±0.56** | | | |
| | CBL | 6.43±0.04 | 6.64±0.04 | 7.79±0.68 | 7.58±0.50 | **7.13±0.34** | | | |
| | **Mean ± SE** | **6.36$^c$±0.15** | **7.04$^{bc}$±0.43** | **7.67$^b$±0.42** | **8.42$^a$±0.42** | | | | |
| Dressing % | JBL | 45.75±0.28 | 47.53±0.39 | 51.35±0.61 | 49.06±0.84 | **48.42±0.45** | NS | NS | NS |
| | BRL | 45.21±1.52 | 46.83±1.11 | 34.98±14.86 | 51.55±0.92 | **44.64±0.45** | | | |
| | CBL | 48.24±3.07 | 48.08±2.92 | 51.01±1.44 | 46.52±1.98 | **48.46±2.26** | | | |
| | **Mean ± SE** | **46.40±1.56** | **47.48±4.53** | **45.78±5.24** | **49.04±1.25** | | | | |

Superscripts of the same letter in each row and column did not differ significantly (p>0.05), $T_0$= Control feeding, $T_1$= 1% concentrate, $T_2$=1.5% concentrate and $T_3$=2% concentrate; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; IBW= Initial Body Weight, FBW= Final Body Weight, ADG= Average Daily Gain, HCW= Hot Carcass Weight, T*G= Level of significance for combined effect of genotype and concentrate feed.

### Effect of different level of concentrate on proximate components of indigenous lamb meat

Moisture and Dry matter percentage had no significant effect (p<0.001) in different Treatments $T_0$, $T_1$, $T_2$ and $T_3$ having almost similar mean value 73.25, 73.62, 73.46, 73.23 and 26.74, 26.12, 26.53, 26.70 respectively (Table 3). But both Genotype (JBL, BRL and CBL) and T*G value shows significant (p<0.001) effect having value 24.81, 28.81 and 26.13. DM percentage of BRL was higher than JBL and CBL. The CP percentage were non-significant effect in treatments and T*G having values 21.85, 22.42, 23.82 and 24.50 in $T_0$, $T_1$, $T_2$ and $T_3$ (Table 3) respectively. But CP% were significant (p<0.001) in different Treatment, Genotype and T*G having value 21.85, 22.42, 23.82, 24.50 and 23.40, 22.48, 23.57 respectively. Treatment, genotype, and T*G had significant (p<0.001) effect on EE%. Here, BRL had the lowest mean EE% and CBL and JBL had the lowest. According to Hossain et al. (2023) 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 which were significantly increased (p<0.001) with the increasing of concentrate supplementation. This is almost similar to the present study for different treatments. Ash percentage were insignificant in different treatments, genotype and T*G having value 1.19, 1.03, 0.89 and 1.04% in $T_0$, $T_1$, $T_2$ and $T_3$ and 1.17, 0.92 and 1.02 in JBL, BRL and CBL. Hossain et al. (2023) observed ash percentage found significantly lower (p<0.001) in four treatments compared to control group which were not similar with this study might be due to the stress condition.

**Table 3.** Effect of different level of concentrate on proximate components of indigenous lamb meat

| Parameters | Genotype | Level of concentrate | | | | Mean ± SE | Level of Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | | Treatments | Genotype | T*G |
| Moisture (%) | JBL | 74.74±0.14 | 75.86±0.61 | 75.95±0.14 | 74.19±0.33 | **75.19$^a$±0.47** | NS | <.0001 | <0.0078 |
| | BRL | 71.50±4.45 | 71.14±0.48 | 71.02±0.48 | 71.07±0.47 | **71.18$^c$±0.52** | | | |
| | CBL | 73.53±0.16 | 73.88±0.22 | 73.43±0.12 | 74.63±0.18 | **73.86$^b$±0.26** | | | |
| | **Mean ± SE** | **73.25±1.64** | **73.62±0.45** | **73.46±0.25** | **73.29±0.31** | | | | |
| DM (%) | JBL | 25.25±0.14 | 24.13±0.61 | 24.043.14 | 25.80±0.33 | **24.81$^c$±0.20** | NS | <.0001 | <0.0078 |
| | BRL | 28.50±4.50 | 28.86±0.48 | 28.98±0.48 | 28.92±0.47 | **28.81$^a$±2.09** | | | |
| | CBL | 26.47±0.16 | 26.12±0.22 | 26.57±0.12 | 25.37±0.18 | **26.13$^b$±0.24** | | | |
| | **Mean ± SE** | **26.74±1.36** | **26.37±0.48** | **26.53±0.48** | **26.70±0.64** | | | | |
| CP (%) | JBL | 21.46±0.30 | 22.41±0.06 | 24.16±0.23 | 25.57±0.04 | **23.40c±0.87** | <0.0065 | <.0001 | <0.0080 |
| | BRL | 21.97±0.48 | 22.64±0.47 | 22.75±0.49 | 22.56±0.48 | **22.48$^b$±0.45** | | | |
| | CBL | 22.13±0.60 | 22.23±0.62 | 24.55±0.73 | 25.38±0.50 | **23.57a±0.56** | | | |
| | **Mean ± SE** | **21.85$^b$±0.35** | **22.42$^b$±0.63** | **23.82$^a$±0.48** | **24.50$^a$±0.36** | | | | |
| EE (%) | JBL | 0.97±0.04 | 1.94±0.06 | 3.56±0.11 | 6.58±0.21 | **3.26$^b$±0.09** | <.0001 | <.0001 | <.0001 |
| | BRL | 3.95±0.48 | 4.05.45 | 4.04±0.48 | 4.08±0.47 | **4.03$^a$±0.47** | | | |
| | CBL | 1.33±0.39 | 1.54±0.38 | 4.26±0.64 | 5.22±0.70 | **3.08$^b$±0.56** | | | |
| | **Mean ± SE** | **2.08$^c$±0.26** | **2.51$^c$±0.24** | **3.95$^b$± 0.48** | **5.29$^c$±0.45** | | | | |
| Ash (%) | JBL | 1.16±0.09 | 1.11±0.02 | 0.76±0.034 | 1.09±0.01 | **1.17±0.05** | NS | NS | NS |
| | BRL | 0.91±0.48 | 0.92±0.48 | 0.92±0.51 | 0.95±0.48 | **0.92±0.46** | | | |
| | CBL | 1.01±0.01 | 1.00±0.00 | 1.00±0.02 | 1.08±0.04 | **1.02±0.03** | | | |
| | **Mean ± SE** | **1.19±0.23** | **1.03±0.08** | **0.89±0.21** | **1.04±0.25** | | | | |

Superscripts of the same letter in each row and column did not differ significantly (p>0.05), $T_0$= Control feeding, $T_1$= 1% concentrate, $T_2$=1.5%concentrate and $T_3$=2% concentrate; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; DM=Dry matter, CP= Crude protein, EE=Ether extract, T*G= Level of significance for combined effect of genotype and concentrate feed.

### Effect of different level of concentrate on the physicochemical traits of indigenous lamb meat

The values of cooked pH, ultimate pH, cooking loss, drip loss and the WHC at different treatments are shown in Table 4. The ultimate pH was found optimum level 5.58 in $T_2$ treatment and 5.73 in BRL as compared to $T_0$, $T_1$ and $T_3$ treatments and JBL and CBL which showed significantly different results (p<0.001). Hossain et al. (2021) reported that ultimate pH was 5.95 which were very similar with the present study. The ultimate pH values of BRL and $T_2$ 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 (Girma et al., 2010). 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 (Abebe et al., 2010). 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 withdrawal and transportation stress. The simultaneous effect of feed withdrawal and transportation stress decreased the amount of glycogen in muscle during slaughtering (Hossain et al., 2021). Cooked pH was significantly similar (p<0.001) in different Genotype groups having value 6.73, 5.95, and 6.35 respectively but insignificant in different Treatment. The cooked pH was found optimum level 5.95 in BRL compared to others. 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 no-significant effect on treatment. The mean value of cooking loss in different treatment $T_0$, $T_1$, $T_2$ and $T_3$ was 29.62, 28.76, 27.24, and 31.63 and drip loss in different treatment $T_0$, $T_1$, $T_2$ and $T_3$ was 2.44, 2.47, 2.33 and 2.72 respectively. BRL had the lowest drip loss 1.93% compared to JBL and CBL (2.85 and 2.68). A lower cooking loss value (20.33-21.63) and higher drip loss (3.80-4.89) was also reported by Costa et al. (2019) which were not similar with this study might be due to the stress condition of the slaughtered lamb. The cooking loss values of meat of small ruminants showed an acceptable range (14-41%) which was corroborated with the present study. 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 insignificantly higher in $T_2$ 87.58% 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. (2019) where they showed that the WHC% was 72.55. The values of cooked pH, drip loss and the WHC at different treatment were non-significant. There were no effect of Genotype, Treatment and T*G on WHC of lamb meat. Water, cooking loss, color and sensory quality were not affected by both concentrated and controlled factors (Hajjia et al., 2016).

**Table 4.** Effect of different level of concentrate on the physicochemical traits of indigenous lamb meat

| Parameters | Genotype | Level of concentrate | | | | Mean ± SE | Level of Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | | Treatments | Genotype | T*G |
| Ultimate pH | JBL | 6.30±0.03 | 6.41±0.02 | 5.95±0.02 | 6.64±0.02 | **6.32$^a$±0.02** | <.0001 | <0.0188 | <0.0017 |
| | BRL | 5.66±0.03 | 6.18±0.38 | 5.75±0.14 | 5.35±0.03 | **5.73$^c$±0.05** | | | |
| | CBL | 6.06±0.04 | 6.08±0.04 | 5.95±0.02 | 6.19±0.02 | **6.07$^b$±0.03** | | | |
| | **Mean ± SE** | **6.00$^{ab}$±0.03** | **6.22$^a$±0.07** | **5.58$^b$±0.08** | **6.06$^{ab}$±0.02** | | | | |
| Cooked pH | JBL | 6.91±0.04 | 6.70±0.03 | 5.32±0.02 | 6.91±0.02 | **6.73$^a$±0.03** | NS | <.0001 | NS |
| | BRL | 6.04±0.04 | 6.17±0.08 | 5.98±0.04 | 5.61±0.57 | **5.95$^c$±0.05** | | | |
| | CBL | 6.30±0.02 | 6.25±0.01 | 6.46±0.02 | 6.41±0.04 | **6.35$^b$±0.03** | | | |
| | **Mean ± SE** | **6.41±0.02** | **6.37±0.02** | **6.28±0.03** | **6.31±0.19** | | | | |
| Cooking Loss (%) | JBL | 30.33±0.99 | 29.03±0.89 | 24.44±0.72 | 31.64±0.56 | **28.86±0.78** | <.0001 | NS | <0.0331 |
| | BRL | 28.92±3.75 | 24.72±3.19 | 32.73±1.68 | 33.89±0.31 | **28.86±2.35** | | | |
| | CBL | 29.62±3.29 | 32.55±1.27 | 24.57±2.42 | 29.38±3.40 | **29.03±2.74** | | | |
| | **Mean ± SE** | **29.62$^{ab}$±2.65** | **28.76$^{ab}$±1.94** | **27.24$^b$±1.56** | **31.63$^a$±1.32** | | | | |
| Drip Loss (%) | JBL | 2.83±0.05 | 2.64±0.06 | 2.59±0.04 | 3.36±0.05 | **2.85$^a$±0.05** | NS | <0.0111 | NS |
| | BRL | 1.72±0.31 | 1.94±0.67 | 2.03±0.80 | 2.05±0.87 | **1.93$^b$±0.67** | | | |
| | CBL | 2.77±0.20 | 2.82±0.15 | 2.39±0.17 | 2.75±0.12 | **2.68$^a$±0.15** | | | |
| | **Mean ± SE** | **2.44±0.13** | **2.47±0.24** | **2.33±0.25** | **2.72±0.25** | | | | |
| WHC (%) | JBL | 86.43±0.99 | 86.57±0.50 | 87.75±0.51 | 84.91±0.50 | **86.41±0.65** | NS | NS | NS |
| | BRL | 85.55±0.44 | 86.78±0.03 | 89.42±0.77 | 86.22±0.46 | **86.99±0.45** | | | |
| | CBL | 83.50±3.86 | 83.69±3.63 | 85.57±2.45 | 84.61±1.84 | **84.34±2.64** | | | |
| | **Mean ± SE** | **85.16±1.34** | **85.68±1.34** | **87.58±1.013** | **85.24±0.97** | | | | |

Superscripts of the same letter in each row and column did not differ significantly (p>0.05), $T_0$= Control feeding, $T_1$= 1% concentrate, $T_2$=1.5%concentrate and $T_3$=2% concentrate; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; WHC=Water holding capacity, T*G= Level of significance for combined effect of genotype and concentrate feed.

### Effect of different level of concentrate on sensory attributes of indigenous 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 (Hossain et al., 2023). The color was observed significantly (p<0.001) similar value in different Genotype but insignificant in different treatments and T*G. In case of flavor, there was no difference in $T_0$ and $T_2$but there was a significant superior flavor (p<0.001) was detected compared with $T_1$ and $T_3$ treatment (Table 5). Juiciness and the overall acceptability were also detected significantly higher (p<0.001) in $T_1$, $T_3$ (4.29 & 4.38) and (4.22 & 4.40) compared to $T_{0,}$ $T_2$ (4.06 & 4.08) and (4.00 & 4.15) treatments. The average score of flavors (4.16 in $T_2$ treatment) and juiciness (4.08 in $T_2$ treatments) of the present study were higher than the results of Chulayo and Muchenji (2013) for flavor (3.33) and juiciness (3.47) in sheep. The flavor was significantly higher (p<0.001) in $T_3$ (4.55) and overall acceptability also significantly higher (p<0.001) in $T_3$ (4.40) 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. (2020) found significantly higher (p<0.001) flavor, juiciness and overall acceptability with increasing concentrate feeds which was supported by the present study. The mean value of tenderness 4.26, 4.36, 4.09 and 4.18 in $T_0$, $T_1$, $T_2$ and $T_3$ treatment was significantly higher (p<0.005) but within the range 4.25 to 4.63 except $T_2$ and $T_3$. Juiciness and overall acceptability had a significant (p<0.001) effect on different genotype. There was no significant effect of T*G on color, flavor, tenderness, juiciness, and overall acceptability. In case of JBL color value 6.94 was higher than BRL and CBL. CBL had the lowest value in color, flavor, tenderness, juiciness, and overall acceptability 4.17, 3.78, 3.80, 3.47 and 3.65 respectably. The reason of lowest color, flavor, tenderness, juiciness, and overall acceptability in CBL meat might be due to stress or decrease of fat deposition with increasing concentrate feeds for lambs.

**Table 5.** Effect of different level of concentrate on sensory attributes of indigenous lamb meat

| Parameters | Genotype | Level of concentrate | | | | Mean ± SE | Level of Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | | Treatments | Genotype | T*G |
| Color | JBL | 14.85±11.05 | 4.30±0.02 | 4.51±0.03 | 4.12±0.04 | **6.94$^a$±2.86** | NS | <.0001 | NS |
| | BRL | 4.00±0.24 | 4.00±0.24 | 4.22±0.13 | 4.55±0.23 | **4.19$^b$±0.23** | | | |
| | CBL | 4.20±0.40 | 4.50±0.28 | 3.80±0.34 | 4.20±0.34 | **4.17$^c$±0.34** | | | |
| | **Mean ± SE** | **7.68±0.43** | **4.26±0.14** | **4.17±0.14** | **4.29±0.15** | | | | |
| Flavor | JBL | 4.06±0.03 | 4.43±0.02 | 4.45±0.03 | 4.46±0.02 | **4.35$^b$±0.02** | <.0001 | <0.0380 | NS |
| | BRL | 4.45±0.25 | 5.00±0.00 | 4.44±0.23 | 5.00±0.00 | **4.72$^a$±0.01** | | | |
| | CBL | 3.68±0.30 | 3.65±0.30 | 3.60±0.28 | 4.20±0.34 | **3.78$^c$±0.34** | | | |
| | **Mean ± SE** | **4.16$^b$±0.17** | **4.36$^{ab}$±0.12** | **4.16$^b$±0.14** | **4.55$^a$±0.12** | | | | |
| Tenderness | JBL | 4.25±0.04 | 4.38±0.02 | 4.63±0.05 | 4.45±0.02 | **4.45$^a$±0.05** | <0.0027 | NS | NS |
| | BRL | 4.55±0.23 | 4.80±0.00 | 4.16±0.18 | 4.20±0.16 | **4.42$^a$±0.23** | | | |
| | CBL | 4.00±0.04 | 3.90±0.46 | 3.50±0.28 | 3.80±0.40 | **3.80$^b$±0.03** | | | |
| | **Mean ± SE** | **4.26±0.08** | **4.36±0.02** | **4.09±0.28** | **4.18±0.15** | | | | |
| Juiciness | JBL | 4.25±0.04 | 4.38±0.02 | 4.63±0.05 | 4.56±0.02 | **4.45$^a$±0.03** | NS | <.0001 | NS |
| | BRL | 4.45±0.17 | 5.00±0.00 | 4.32±0.31 | 5.00±0.00 | **4.69$^a$±0.12** | | | |
| | CBL | 3.50±0.40 | 3.50±0.40 | 3.30±0.23 | 3.60±0.46 | **3.47$^b$±0.34** | | | |
| | **Mean ± SE** | **4.06±0.06** | **4.29±0.02** | **4.08±0.03** | **4.38±0.03** | | | | |
| Overall Acceptability | JBL | 4.17±0.02 | 4.38±0.02 | 4.46±0.02 | 4.34±0.05 | **4.33$^a$±0.03** | NS | <.0001 | NS |
| | BRL | 4.35±0.25 | 4.80±0.00 | 4.40±0.11 | 4.88±0.12 | **4.60$^a$±0.15** | | | |
| | CBL | 3.50±0.40 | 3.50±0.40 | 3.60±0.28 | 4.00±0.34 | **3.65$^b$±0.06** | | | |
| | **Mean ± SE** | **4.00±0.14** | **4.22±0.13** | **4.15±0.13** | **4.40±1.35** | | | | |

Superscripts of the same letter in each row and column did not differ significantly (p>0.05), $T_0$= Control feeding, $T_1$= 1% concentrate, $T_2$=1.5%concentrate and $T_3$=2% concentrate; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb, T*G= Level of significance for combined effect of genotype and concentrate feed.

## Effect of different level of concentrate on instrumental color values of indigenous 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. 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 $T_0$, $T_1$and $T_2$ (48.71, 47.77 and 48.07) compared to $T_3$ (40.45) treatments (Table 6). The higher L* value in $T_2$ (48.07) was due to the distribution of more intramuscular fat deposition which made the luminous of meat McDonald et al. (1995). A non-significant a* value was found in $T_0$, $T_1$ $T_2$ and $T_3$ (16.92, 17.25 16.95 and 16.63) treatments where $T_1$ (17.25) was higher compared to $T_0$, $T_2$ and $T_3$. Lower b* value was also found in $T_2$ (9.30) compared with $T_0$, $T_1$ and $T_3$ treatments which was significantly different (p<0.001). Worku et al. (2020) 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 in case of L* and b*. Costa et al. (2019) found that the 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 study. 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 Watkins PJ et al. (2013). The higher hue angle and saturation index were found in $T_1$ (32.93 and 20.68) than other treatment groups in different treatment. The higher hue angle was detected significant effect (p<0.01) among the all-treatment groups but saturation index shows non-significant effect on it. The hue angle and saturation index values were not influenced by the higher concentrate supplemented groups Gashu et al. (2017). In case of hue angel, the study was not supported the present study. There was no significant effect of a*and saturation index (SI) at different Treatment and Genotype. In case of genotype BRL had the highest L* value (49.45) compared to JBL and CBL. a* value was almost similar in three genotype JBL, BRL and CBL (16.97, 17.32 and 16.52). b* value of BRL (8.56) was lower compared to JBL and CBL (11.67 and 11.39). Hue angle and saturation index of JBL (35.32 & 20.66) was higher compared to BRL and CBL. Hue angel value was higher compared to CIE range (20.75-26.11) due to stress or higher fat deposition influenced by the higher concentrate supplementation. So, it was not supported the present study.

**Table 6.** Effect of different level of concentrate on instrumental color values of indigenous lamb meat

| | Genotype | Level of concentrate | | | | Mean ± SE | Level of Significance | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | | Treatments | Genotype | T*G |
| L* | JBL | 47.81±0.64 | 45.41±0.54 | 48.81±1.17 | 42.03±0.12 | **46.01$^{a}$±0.78** | <.0001 | <.0001 | NS |
| | BRL | 49.37±0.61 | 50.34±0.41 | 49.91±1.09 | 48.21±0.91 | **49.45$^{ab}$±0.81** | | | |
| | CBL | 48.97±1.94 | 47.57±1.96 | 45.50±3.17 | 31.11±1.11 | **43.28$^{b}$±2.16** | | | |
| | **Mean ± SE** | **48.71$^{a}$±0.93** | **47.77$^{a}$±0.89** | **48.07$^{a}$±1.89** | **40.45$^{b}$±0.94** | | | | |
| a* | JBL | 15.83±0.38 | 16.70±0.10 | 18.05±0.19 | 17.31±0.32 | **16.97±0.05** | NS | NS | NS |
| | BRL | 17.32±0.57 | 17.74±0.93 | 17.34±0.64 | 16.88±0.55 | **17.32±0.73** | | | |
| | CBL | 17.61±0.80 | 17.31±0.63 | 15.47±3.17 | 15.72±1.15 | **16.52±1.36** | | | |
| | **Mean ± SE** | **16.92±0.45** | **17.25±0.56** | **16.95±1.93** | **16.63±0.79** | | | | |
| b* | JBL | 12.74±0.07 | 12.51±0.18 | 9.27±0.25 | 12.18±0.14 | **11.67$^{a}$±0.23** | <0.0109 | <.0001 | <0.0126 |
| | BRL | 8.17±0.75 | 8.80±1.28 | 9.73±0.67 | 7.54±1.45 | **8.56$^{b}$±0.83** | | | |
| | CBL | 13.05±0.03 | 12.51±0.28 | 8.90±0.98 | 11.13±1.09 | **11.39$^{a}$±0.62** | | | |
| | **Mean ± SE** | **11.32$^{a}$±0.06** | **11.27$^{a}$±0.95** | **9.30$^{b}$±0.61** | **10.28$^{ab}$±1.29** | | | | |
| HA | JBL | 38.84±0.52 | 36.82±0.23 | 30.50±3.67 | 35.13±0.23 | **35.32$^{a}$±1.22** | <.0001 | <.0001 | <0.0156 |
| | BRL | 25.15±1.38 | 26.09±2.17 | 29.22±0.79 | 23.65±3.44 | **26.03$^{b}$±2.45** | | | |
| | CBL | 36.61±1.18 | 35.87±0.37 | 29.85±0.24 | 35.26±0.61 | **34.40$^{a}$±0.52** | | | |
| | **Mean ± SE** | **33.53$^{a}$±1.25** | **32.93$^{a}$±1.27** | **29.86$^{b}$±1.43** | **31.35$^{ab}$±1.46** | | | | |
| SI | JBL | 20.32±0.34 | 20.86±0.19 | 20.29±0.28 | 21.16±0.33 | **20.66±0.23** | NS | NS | NS |
| | BRL | 19.16±0.83 | 19.83±1.40 | 19.88±0.89 | 18.55±1.09 | **19.35±0.43** | | | |
| | CBL | 21.92±0.66 | 21.35±0.68 | 17.84±1.84 | 19.26±1.57 | **20.09±0.53** | | | |
| | **Mean ± SE** | **20.47±0.64** | **20.68±0.89** | **19.34±0.98** | **19.66±1.04** | | | | |

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$), $T_0$= Control feeding, $T_1$= 1% concentrate, $T_2$=1.5% concentrate and $T_3$=2% concentrate; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb, L*=Lightness, a*=Redness, b*=Yellowness, HA=Hue angel, SI= Saturation index; T*G= Level of significance for combined effect of genotype and concentrate feed.

## Conclusion

From this study it can be concluded that the superiority of Coastal Belt lamb over Jamuna Basin lamb and Barind Region lamb in terms of overall productive performance. Meat quality trait parameters largely varied in different concentrate level. With 1.5% concentrate feed, Jamuna Basin lamb performed better in terms of the physicochemical, sensory, and instrumental color parameters of the lamb meat.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.


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