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Research Article

Influence of rearing system on the productive, carcass and meat quality attributes among three genotypes of native lambs in Bangladesh

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Abstract

The aim of this study was to evaluate the productive performance, carcass traits and meat quality of native lambs of Bangladesh under two rearing system. Total 30 animals were taken for productive, carcass and meat quality attributes evaluation from three regions (Jamuna Basin, Barind Region and Coastal Belt); and total 18 animals were considered for evaluating productive, carcass and meat quality parameters for two treatment groups (T_1= Grazing, T_2= Stall Feeding) from each of three regions. Statistical analysis was conducted by SAS where statistical model was 3*2 factorial experimental model in CRD. DMRT was conducted for mean comparison and 5% level of significance was considered for analyses. Both genotype and rearing system had significant effect ($p<0.05$) on body weight at different rearing systems. Among all genotypes grazing lambs had the highest body weight than stall feeding lambs where CBL shows higher body weight compared to JBL and BRL. The ADG of grazing lambs were found significantly ($p<0.01$) higher than stall feeding lambs. Dressing % (46.80) was higher in grazing lambs. Genotype and rearing system had significant effect ($p<0.05$) on blood, head, shoulder, loin wt.% except skin, viscera, leg, pluck, Neck, rack, and shank where only genotype had significant effect but effect of rearing system was non-significant ($p>0.05$). Genotype and rearing system had significant effect ($p<0.05$) on heart, and spleen weight%. CP%, EE% and Ash% were found higher in grazing lambs whereas DM was higher in stall feeding. DL, Ultimate pH, cooked pH and WHC% were higher in grazing lambs whereas CL% were higher in stall feeding. Grazing lambs showed higher tenderness, juiciness and overall acceptability whereas stall feeding lambs showed higher color and flavor. Instrumental color values L*, a*, b* and saturation index were found significantly ($p<0.05$) higher in grazing lambs. Superiority of JBL over CBL and BRL in terms of overall productive, carcass and meat quality attributes largely varied in different genotypes for different rearing systems. It may be concluded that grazing group had positive effects on productive performance, carcass traits, proximate components, physicochemical, sensory evaluation and instrumental color values in three genotypes of native lambs of Bangladesh where JBL performs better compared to CBL and BRL.

Introduction

Sheep is one of the most important small ruminant species which is widely distributed throughout the world (Hashem et al., 2023). Sheep rearing is an important economic activity in Bangladesh and contributes significantly to the country's Gross Domestic Product (GDP). According to the Department of Livestock Services (DLS) report on "Livestock Economy at a Glance, 2021-22," the sheep population in Bangladesh is 3.752 million, and sheep contribute 1.15% of total meat production in the country, producing 12.02 thousand metric tons of meat annually (DLS, 2022). Indigenous sheep breeds are the main source of lamb meat in Bangladesh, with few crossbreds. These sheep are capable of bi-annual lambing and multiple births, and they are divided into three types based on regional basis: Jamuna basin, Barind, and Coastal belt indigenous sheep (Rashid et al., 2013; Hossain et al., 2018). Sheep farming is an important source of income for rural households and plays a significant role in poverty alleviation and employment generation in Bangladesh (Hossain et al., 2023a, 2023b and 2023c). The rearing system of sheep plays a crucial role in determining the growth and carcass traits of the animals. Two of the most common rearing systems for sheep are stall feeding and grazing. Stall-fed animals are usually confined to pens or sheds and are fed a concentrate-based diet, while grazing animals are allowed to graze on natural pasturelands (Tariq et al., 2019). The traditional system of sheep rearing in Bangladesh is extensive grazing, where sheep feed on natural pasture throughout the year. However, with the increasing human population, land availability is decreasing, which is resulting in a decrease in grazing land for sheep. In recent years, stall feeding has become an alternative method for feeding sheep in Bangladesh. Stall feeding is a confined feeding system, where sheep are fed on concentrate feed and crop residues (Khan et al., 2014). The advantages of stall feeding over grazing are higher animal productivity, better animal health, and reduced grazing land requirement. The meat quality is affected by various factors, including breed, age, sex, feeding regime, and slaughtering age (Rahman et al., 2022; Barone et al., 2007; Hashem et al., 2021; Sarker et al., 2021). A previous study conducted by Fourie et al. (1970) found that lamb fat increases with weight, both in terms of carcass fat percentage and fat depths, and that those lambs reaching a higher mature weight will be less fat at any given weight because they are at a lower proportion of their mature weight. Therefore, it is important to determine the optimal feeding regime for sheep rearing that maximizes lamb production while maintaining desired carcass and meat quality traits. Several studies have reported the effects of rearing systems on the growth and carcass traits of sheep. For instance, it has been reported that stall-fed animals have a higher average daily gain, higher carcass weight, and better meat quality compared to grazing animals (Iqbal et al., 2018; Sun et al., 2020). In contrast, other studies have shown that grazing animals have a better feed conversion efficiency and produce meat with better flavor and nutritional value (Shalloof et al., 2003). No research has been conducted to compare the carcass and meat quality traits among three genotypes of indigenous sheep in Bangladesh which are reared under different rearing systems. Therefore, the present study will provide important insights into the effects of rearing systems on the growth and carcass traits of indigenous sheep in Bangladesh.

Materials and Methods

Experimental Site

The research was conducted in three regions of Bangladesh. Jamuna basin lambs from Nalitabari Upazilla of Sherpur district, Barind lambs from Paba Upazilla of Rajshahi district and Coastal lambs from Shubarnachar Upazilla of Noakhali district.

Animals and their Management

Number of animals: Ten (10) wethers from three regions (Jamuna Basin, Barind Region and Coastal Belt), total 30 wethers were taken for rearing where five wethers were selected for grazing and five were selected for stall feeding in each region. Again, three wethers for two treatment groups (T_1= Grazing, T_2= Stall Feeding) from three regions, total 18 wethers were considered for evaluating carcass traits and meat quality attributes. Wethers were selected based on similarity of their body weight both single born and twin born. All wethers were marked by ear-tagging.

Housing of animals: All the wethers were housed in well-ventilated slated floor. Four sides of the tin roofed house were encircled with wire made net. Rice straw was provided for ensuring extra cushion and warmth specially, during winter.

Management of lambs: All male lambs were castrated using rubber ring method before 2 weeks of age. All lambs were reared under common protocol in view of feeding. Every kid was allowed 20 g concentrate/day from 2 weeks of age each in a weekly increment of 10 g/lamb/day until 8 weeks of age. Weaning was applied at 8 weeks. From 2 weeks of age kids were allowed to graze 8 hours every day.

Feeding and Drinking Management: The diet was supplied uniformly for all lambs. In grazing (T_1 group), lambs were grazed for 6-7 h in grazing land for eating road side green grasses during the day and kept inside the shed at night. Cut and carry methods were applied for supplying green grass like road side grass for stall feeding (T_2 group). Leaves of tree viz., mango, jackfruit and banana leaves or chopped grass from cultivated land was fed during rainy season. Farmers used concentrate (crushed maize, soybean meal, wheat bran, rice polish, DCP, vitamin-mineral premix and iodine salt containing 18% CP and 12 MJME/kg DM) in morning and again in afternoon at the rate of 1.5% concentrate mixture on the basis of their live weight during the experimental periods (Table 1). Pure drinking water was supplied ad libitum for lambs.

Composition of concentrate feed

Table 1. Composition of concentrate feed

Ingredients	Percentage (%)
Crushed maize	40
Soybean meal	26
Wheat bran	22
Rice polish	10
Vita-mineral premix	0.5
DCP	0.5
Salt	1
Total	100

18% CP, 12 MJME/kg DM

De-worming and Vaccination

Before the starting of the experiment, the sheep were de-wormed against internal and external parasites at 1 month first with the injection of ivermectin as prescribed by the manufacturer and it was continued till to the end of the experiment giving 3 months interval. All lambs were vaccinated firstly for PPR disease at 2 months of age followed by booster dose at 6 months of age.

Slaughtering of experimental animals

At the end of the growth and feeding trial, eighteen lambs from two treatments were slaughtered in three regions having 6 lambs each region. All the selected lambs were fasted for 24 h and slaughtered according to the “Halal” method at Bangladesh Agricultural University slaughterhouse facilities. The fasted live weights of the lambs were measured before slaughtering and individual hot carcass weights were measured immediately after evisceration. Non-carcass components (skin, head, liver, spleen, lung, shank, heart, kidneys and viscera) were removed and measured weight. The digesta content of the stomach and intestines were removed and the empty tract was washed and weighed. Dressing% was calculated as hot carcass weight relative to fasted body weight. The 100-120g sample was taken from longissimus dorsi (LD) area for proximate, physicochemical, sensory and instrumental color value analyses in the Animal Science Meat Laboratory. Different parameters like live weight gain (LWG), carcass traits and meat quality of the lambs were recorded. Live weight of each lamb was recorded at the onset of the trial and later on monthly basis.

Collection of data

For growth performance study, live weight of each animal was collected every fortnightly up to 12 months using a hanging weight measuring machine. The weights of fresh non-carcass organs, the hot carcass and other parts of carcass were immediately recorded after slaughter for carcass traits study. Collected data were coded after ending of data collection and then compiled, tabulated and stored in MS Excel spreadsheet software for further statistical analysis.

Meat Quality Analysis

Proximate components

The proximate components regarding to dry matter (DM), ether extract (EE), crude protein (CP) and ash was measured according to AOAC (2005).

Physicochemical traits measurement

Drip loss (DL) measurement

Drip loss was measured following the procedure of Rahman et al. (2020). 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.

$$\mathrm{DL}\ (\%) = \frac{(\text{Weight of sample} - \text{weight after 24 hours chilling})}{\text{Weight of sample}} \times 100$$

Cooking loss (CL) measurement

The 30 g lamb meat sample was taken in a poly bag and heated it in water bath until the temperature rises to 71ºC in sample. Lamb meat with 71ºC was taken out from the water bath and soaked it with tissue paper. Weight loss of the sample was measured during cooking lamb meat. The CL was calculated using following formula:

$$\mathrm{CL}\ (\%) = \frac{(\text{Weight before cooking of sample} - \text{weight after cooking})}{\text{Weight before cooking of sample}} \times 100$$

Ultimate pH measurement

Meat pH value was measured 24 h after slaughter (ultimate pH) using a pH meter. The pH was measured by inserting electrode at three different points of the meat which was calibrated prior to use at pH 7.0 by pH meter (Hanna HI 99163). Triplicate measurements at 1 cm depth on the medial portion of meat were averaged.

Cooked pH

The samples were cooked to an internal temperature of 71°C for 30 minutes. Then the muscle samples were taken out after that cooled at room temperature. After cooling sample pH was measured as the same way of ultimate pH system.

Water holding capacity (WHC)

The WHC was measured according to the methodology of Choi et al. (2018). Thawed samples (1 g each) were wrapped in absorbent cotton and placed in a 1.5 ml centrifuge tube. The tubes with samples were centrifuged in a centrifuge separator (H1650-W Tabletop high speed micro centrifuge) at 10,000 rpm for 10 minutes at 4º C, following which the samples were weighed. The WHC % of the sample is expressed as the following formula:

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

Instrumental color measurement

Instrumental color measurement of lamb meat was identified from longissimus dorsi muscle obtained from eye muscle area of 12^{th} and 13^{th} rib cut. Instrumental color was measured at 24 hours post-slaughter using 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) L*, a*, and b* system, where L* represents lightness, a* redness and b* yellowness (CIELAB, 2014). The analysis was carried out on the medial surface (bone side) of the meat at 24 h post-mortem (Rahman et al., 2020).

Hue angle (HA) measurement

Hue angle is a measure of the color of an object that represents the direction of the color in a color space, usually measured in degrees. It is commonly used in colorimetry and spectrophotometry to describe the color of an object. The hue angle is determined by calculating the angle between a reference axis and the color vector that represents the color of the object in a particular color space. The reference axis is usually a line that represents the achromatic axis, which corresponds to the neutral colors of white, gray, and black.

In the CIE Lab* color space, for example, the hue angle can be calculated as the arctangent of the ratio of the b* (yellow-blue) and a* (green-red) color components, which yields a value between -90 and 90 degrees. This value can be converted to a hue angle in degrees by adding 180 degrees to the value if b* is negative, and adding 360 degrees if both a* and b* are positive. The HA was calculated using following formula:

$[(b^*/a^*)^{\tan^{-1}}]$

Saturation Index (SI)/ (Chroma) measurement

"Chroma" is a term used to indicate the intensity or purity of a color, also known as its saturation. Chroma is a quantitative measure of how much a color differs from gray at a given lightness, and it is often used to describe the vividness or richness of a color.

In the meat industry, Chroma measurement can be used to assess the color quality of meat. Meat color is an important quality parameter that influences consumer acceptance, as well as safety and shelf-life. The color of meat is affected by various factors, such as animal age, diet, processing conditions, and storage conditions. To measure Chroma in meat, a spectrophotometer is commonly used. A spectrophotometer can measure the reflectance of light from the surface of the meat at different wavelengths, allowing for the calculation of various color parameters, such as Chroma.

Chroma can be expressed in various ways, but the most common method is to use the CIELAB color space, which is a standard color model that describes colors based on three parameters: L*, a*, and b*. Chroma in the CIELAB color space is defined as the distance from the L* axis to the color point, with higher values indicating more saturated colors. The SI was calculated using following formula:

$[(a^{*2}+b^{*2})^{1/2}]$

Sensory evaluation

Different sensory attributes were examined in this study. Each meat sample was evaluated by a trained 8-members panel. The sensory questionnaires measured intensity on a 5-point balanced semantic scale for the attributes *viz.* color, flavor, tenderness, juiciness, and overall acceptability. Eight training sessions were held to familiarize the judges with the attributes to be evaluated and the scale to be used (Hashem et al., 2020). Before sample evaluation, all panelists participated in an orientation sessions to familiarize with the scale attributes (color, flavor, juiciness, tenderness, overall acceptability) of meat using intensity scale. All samples were supplied in the petri dishes.

Statistical analysis

Statistical analysis was conducted by SAS (previously “Statistical Analysis System”) which is a statistical software suite developed by SAS institute for data management, advanced analytics, multivariate analysis, business intelligence, criminal investigation and predictive analytics. Grazing and Stall-Feeding data were analyzed with unpaired t-test along with GLM procedure of SAS statistical package. Data was analyzed with (3×2) factorial experiment in CRD (Completely Randomized Design) by using SAS software. Duncan’s Multiple Range Test (DMRT) was used to determine the significant differences between two treatments means at values $p<0.05$.

Results and Discussion

Growth Performance

The initial mean body weight of lambs from Jamuna basin, Barind region and coastal belt and mean body weight of two rearing systems (T_1, T_2) were 11.07,10.61,15.46 and 12.55, 12.21 kg respectively (Table 2) and had a significant effect ($p<0.001$). Here, CBL had the highest mean IBW and BRL had the lowest. The final mean body weight of lambs from three regions and of two rearing systems were 16.62, 13.48, 20.49 and 17.12, 16.37 kg respectively and showed a significant effect ($p<0.001$) too. Here also, CBL had the highest mean FBW and BRL had the lowest. The initial and final mean body weight of Jamuna Basin lambs were 11.19, 10.94; and 16.73, 15.78 in two treatments respectively, had a significant effect ($p>0.001$) Hossain et al. (2022). This is almost similar to the present study for only JBL part. However, ADG was significantly higher in JBL and CBL (57.66 and 55. 96) g/day than BRL (51.86) g/day. Genotype, Rearing System and G*RS had significant effect on ADG ($p<0.0001$). The ADG was 57.66, and 61.55 g/d in all treatments of JBL respectively Hossain et al. (2022) which was close to present study in terms of JBL part. Kibria et al. (2017) compared the ADG of Jamuna basin lambs under stall-fed and grazing conditions. The results showed that the ADG of lambs under stall-fed conditions was significantly higher than that of lambs under grazing conditions which is not similar to the present study. The ADG of grazing lambs was found significantly ($p<0.01$) higher than stall feeding lambs (Hossain et al., 2022) which is similar to the present study. Both genotype and rearing system had significant effect ($p<0.001$) on HCW having 7.58, 6.79 and 7.55 values for JBL, BRL and CBL; and 7.73, and 6.88 values for T_1 and T_2 respectively. Santos-Silva & Portugal (2002) observed that the effect of hot carcass weight (HCW) was significant for all carcass traits. All variables showed linear relationships with HCW. The result was completely supported by present research. Rearing system and G*RS had no significant effect on Dressing% while for genotype it was similar. Dressing% was highest in grazing lambs then stall feeding (46.80 and 45.99) %.

Table 2. Comparison of growth performance and dressing% of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
IBW (kg)	$11.07^b±0.101$	$10.61^c±0.216$	$15.46^a±0.219$	$12.55^a±0.180$	$12.21^b±0.177$	<.0001	0.047	0.467
FBW (kg)	$16.26^b±0.113$	$13.48^c±0.204$	$20.49^a±0.260$	$17.12^a±0.214$	$16.37^b±0.170$	<.0001	.0007	0.510
ADG (g/d)	$55.96^b±0.713$	$51.86^c±0.397$	$57.66^a±0.129$	$50.82^a±0.481$	$46.17^b±0.344$	<.0001	<.0001	0.0006
HCW (kg)	$7.55^b±0.061$	$6.79^c±0.201$	$7.58^a±0.069$	$7.73^a±0.162$	$6.88^b±0.085$	0.0004	<.0001	0.0030
Dressing%	$46.62^b±0.156$	$45.64^c±0.252$	$46.94^a±0.865$	$46.80^a±0.403$	$45.99^b±0.445$	0.0791	0.0916	0.2717
Half CW (kg)	$3.79^b±0.246$	$3.38^c±0.109$	$4.46^a±0.376$	$4.17^a±0.330$	$3.71^b±0.157$	0.0030	0.0758	0.6004

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; 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, Half CW= Half Carcass Weight, G*R= Combined effect of Genotype and Rearing System.

Hot carcass wt (kg) and dressing% were found significantly ($p>0.001$) higher in grazing then stall feeding (7.33 and 46.80) which is similar to the result of Ahmed et al. (2018). Hot carcass (kg) was significantly higher ($p<0.05$) in grazing whereas, dressing% had no statistical significance ($p>0.05$) (Hossain et al., 2022) which is slightly different with the present study. In a study conducted by Hossain et al. (2019), the dressing percentage and carcass traits of Jamuna Basin lambs were evaluated. The study showed that grazing had a positive effect on the dressing percentage, carcass weight, and meat yield of Jamuna Basin lambs. Another study conducted by Akter et al. (2018) evaluated the carcass characteristics of Barind region lambs. The study reported that stall feeding had a positive effect on the carcass weight, dressing percentage, and meat yield of Barind region lambs. The authors also reported that the fat cover and marbling score of the lambs were significantly affected by the feeding system. In a study conducted by Hasan et al. (2020), the carcass traits of Coastal Belt lambs were evaluated. The study reported that grazing had a positive effect on the dressing percentage, carcass weight, and meat yield of Coastal Belt lambs which is similar to the present study.

Carcass Traits

JBL had the highest mean blood wt% (4.67) followed by BRL (4.49) and CBL (2.90); Grazing lambs (4.33) had highest blood wt% then stall Feeding (3.70). Both genotype and rearing system had significant effect ($p<0.001$) on Blood wt%. (Table 3). Genotype and rearing system had significant effect ($p<0.001$) on Skin wt%. It was highest in JBL (11.17) and lowest in CBL (7.45). BRL had the highest viscera% (14.83) and CBL the lowest (20.17). The mean value of viscera wt% is higher in grazing (19.72) then Stall Feeding (19.09). (Table 3). Head wt% is higher in BRL (7.52) and lowest in CBL (2.07) and the mean value is higher for grazing lambs. Leg wt % was highest in BRL (14.02) compared to JBL (11.03) and CBL (10.52) and highest in grazing (11.92) then stall feeding (11.79). Neck wt% was highest in BRL (4.76) followed by JBL (3.74) and CBL (3.57); and highest in grazing (4.15) then stall feeding (3.89). JBL (8.81)) had the highest shoulder wt% followed by BRL (8.22) and CBL (6.77); and highest in grazing (8.09) then Stall Feeding (7.77). Highest rack wt% in JBL (9.96) followed by BRL (9.24) and CBL (6.35); highest in stall feeding (13.66) then grazing (9.03). Loin wt% was higher in JBL (5.27) compared to BRL and CBL (3.39 and 4.53); and higher in grazing (4.91) then stall feeding (3.88). Shank wt% was higher in JBL (2.04) compared to BRL and CBL (1.76 and 1.71); and higher in grazing (1.87) then stall feeding (1.81). Genotype has significant effect ($p<0.001$) on viscera, head, neck leg, pluck and shoulder wt. but for rearing system skin, viscera, leg, pluck, neck and shoulder wt. differ significantly. In JBL Skin, viscera, head and neck% were found significantly ($p<0.05$) higher in grazing lambs than that of stall-feeding lambs. Pluck, heart, lung and spleen% were found significantly ($p<0.05$) higher in grazing lambs than that of stall-feeding lambs (Hossain et al., 2022) which is similar to the present study.

Table 3. Comparison of carcass traits (on live weight basis) of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
Blood wt %	4.67^a±0.067	4.49^b±0.191	2.90^c±0.134	4.33^a±0.187	3.70^b±0.050	<.0001	0.001	0.0176
Skin wt %	11.17^a±0.223	8.38^b±0.135	7.45^c±0.415	9.19^a±0.187	8.81^b±0.369	<.0001	0.1586	0.0092
Viscera wt %	14.83^b±0.084	28.75^a±0.564	14.66^c±0.336	19.72^a±0.280	19.09^b±0.375	<.0001	0.0739	0.7868
Head wt%	5.71^b±0.041	7.52^a±0.058	2.07^c±0.217	5.33^a±0.162	4.86^b±0.048	<.0001	0.0023	0.7602
Leg wt%	11.03^b±0.116	14.02^a±0.162	10.52^c±0.309	11.92^a±0.323	11.79^b±0.068	<.0001	0.5414	0.0378
Pluck wt%	6.85^b±0.061	4.57^c±0.049	6.96^a±0.329	6.26^a±0.169	5.99^b±0.123	<.0001	0.1207	0.0592
Neck wt%	3.74^b±0.029	4.76^a±0.087	3.57^c±0.337	4.15^a±0.177	3.89^b±0.125	0.0002	0.1440	0.6359
Shoulder wt%	8.81^a±0.104	8.22^b±0.109	6.77^c±0.224	8.09^a±0.171	7.77^b±0.119	<.0001	0.0351	0.0362
Rack wt%	9.96^a±0.087	9.24^b±0.182	6.35^c±0.179	9.03^b±0.235	13.66^a±0.063	0.6741	0.4176	0.3850
Loin wt%	5.27^a±0.024	3.39^c±0.111	4.53^b±0.107	4.91^a±0.066	3.88^b±0.094	<.0001	<.0001	0.0006
Shank wt%	2.04^a±0.038	1.76^b±0.063	1.71^c±0.148	1.87^a±0.090	1.81^b±0.076	0.0122	0.4432	0.3488

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; G*R= Combined effect of Genotype and Rearing System.

Kidney wt % was higher in JBL (1.64) compared to BRL (0.57) and CBL both (0.73) (Table 4) and it is higher in grazing (0.99) then stall feeding (0.96). Liver wt % was higher in CBL (3.95) compared to JBL (3.79) and BRL both (2.54) (Table 4), and it is higher in grazing (3.46) then stall feeding (3.39). Heart, lung, spleen all had comparatively higher wt% in JBL (0.91, 1.65, 0.79) than in BRL (0.44, 1.45, 0.33) and CBL (0.70, 1.62, 0.25) respectively. Heart and Spleen wt% are higher in grazing then stall feeding but lung wt is higher in stall feeding (1.58) then grazing (1.56). Genotype, had significant effect ($p<0.05$) on kidney, liver, heart, and spleen wt%. But the Rearing system and G*RS has no significant effect on kidney, liver and lung wt%. There was no any other proportionate of the carcass part varied significantly ($p>0.05$) among treatments Hossain et al. (2022); differed from the present study in case of lung only.

Table 4. Comparison of carcass traits (on hot carcass basis) of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
Kidney wt%	1.64^a±0.041	0.57^c±0.012	0.73^b±0.077	0.99^a±0.054	0.96^b±0.032	<.0001	0.5185	0.3512
Liver wt%	3.79^b±0.058	2.54^c±0.041	3.95^a±0.281	3.46^a±0.121	3.39^b±0.132	<.0001	0.6719	0.0941
Heart wt%	0.91^a±0.035	0.44^c±0.018	0.70^b±0.056	0.75^a±0.040	0.61^b±0.033	<.0001	0.0018	0.1283
Lung wt%	1.65^a±0.024	1.45^c±0.034	1.62^b±0.260	1.56^b±0.109	1.58^a±0.103	0.4010	0.8817	0.1686
Spleen wt%	0.79^a±0.015	0.33^b±0.008	0.25^c±0.035	0.48^a±0.028	0.43^b±0.010	<.0001	0.0248	0.0140

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; G*R= Combined effect of Genotype and Rearing System.

Proximate components

The DM was higher in Stall Feeding lambs (27.14) than Grazing lambs (26.48) (Table 5) which is not similar to the study of Islam et al. (2019). DM was higher in BRL (28.76) compared to JBL (26.35) and CBL both (25.32). The CP was higher in CBL (25.22) compared to JBL (24.29) and BRL (21.46) and highest in grazing lambs (24.03) than stall feeding lambs (23.28) which is similar to the study of Islam et al. (2019) in terms of JBL. Genotype and Rearing system had significant effect on DM and CP ($p<0.05$) but G*RS had insignificant effect on CP and significant effect on DM. The higher EE (4.22) and Ash (1.01) were found in grazing lambs compared to stall feeding lambs which is not similar to the study of (Mishra et al., 2019) in terms of EE but similar to the study in terms of Ash. Another study by Molino et al. (2017) and Mahgoub et al. (2005) found that grazing lambs had higher levels of intramuscular fat, which is associated with increased juiciness and flavor, compared to stall-fed lambs. Both EE and Ash were found higher in CBL (5.19, 1.23) compared to JBL (2.57, 1.04) and BRL (3.67, 0.83) respectively which is similar to the study of (Hossain et al., 2022) in terms of JBL. Genotype was found significant for EE and Ash ($p<0.05$) but rearing system and G*RS found insignificant in both except the rearing system for EE which is similar to the study of Nazir et al. (2016) in terms of Ash.

Table 5. Comparison of proximate component of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
DM%	$26.35^b±0.176$	$28.76^a±0.419$	$25.32^c±0.392$	$26.48^b±0.361$	$27.14^a±0.297$	<.0001	0.0404	0.0112
CP%	$24.29^b±0.084$	$21.46^c±0.211$	$25.22^a±0.494$	$24.03^a±0.259$	$23.28^b±0.266$	<.0001	0.0123	0.1969
EE%	$2.57^c±0.070$	$3.67^b±0.243$	$5.19^a±0.372$	$4.22^a±0.192$	$3.39^b±0.264$	<.0001	0.0029	0.1135
Ash%	$1.04^b±0.032$	$0.83^c±0.056$	$1.23^a±0.188$	$1.09^a±0.101$	$0.99^b±0.082$	0.0191	0.2780	0.9679

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; DM=Dry Matter, CP= Crude Protein, EE= Ether Extract; G*R= Combined effect of Genotype and Rearing System.

Physicochemical traits

The DL was higher in grazing (2.43) than stall feeding (2.42) (Table 6) which was similar to the study of (Hossain et al., 2022) in terms of JBL. DL was higher in CBL (3.08) than JBL (2.74) and BRL (1.45) respectively. CL was higher in BRL (32.28) compared to JBL (29.95) and CBL (29.94) and it was higher in stall feeding (31.04) than grazing lambs (30.04) which is similar to the study of Molino et al. (2017) and Mahgoub et al. (2005). They stated that the grazing lambs also had higher levels of myoglobin, which contributes to the meat's color, and a lower cooking loss, which indicates higher water-holding capacity. The Genotype, Rearing System and G*RS are significant for CL ($p<0.05$). The Genotype and G*RS had significant effect but Rearing System had insignificant ($p>0.05$) effect on DL. Ultimate pH, cooked pH and WHC were higher in grazing lambs (6.10, 6.34, 86.83) than stall feeding lambs (5.96, 6.23, 86.69) which is similar to the study of (Osman et al., 2020). Ultimate pH was higher in JBL (6.12) compared to CBL (6.01) and BRL (5.98). Cooked pH was higher in JBL (6.59) compared to CBL (6.29) and BRL (5.98). The rearing system had significant effect on both Ultimate pH and cooked pH. The genotype had significant effect on cooked pH but insignificant effect on Ultimate pH. The WHC was higher in JBL (87.59) compared to CBL (87.21) and BRL (85.47). The genotype had significant effect but Rearing System and G*RS had insignificant ($p>0.05$) effect on WHC. However, a study by Gürsoy et al. (2019) reported no significant differences in pH, water-holding capacity, cooking loss, or color parameters between the meat of grazing and stall-fed lambs which is not similar to the present study.

Table 6. Comparison of physicochemical traits of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
DL%	$2.74^b±0.087$	$1.45^c±0.075$	$3.08^a±0.140$	$2.43^a±0.096$	$2.42^b±0.104$	<.0001	0.9011	<.0001
CL%	$29.95^b±0.075$	$32.28^a±0.821$	$29.94^c±0.068$	$30.04^b±0.060$	$31.40^a±0.583$	0.0042	0.0226	0.0070
Ultimate pH	$6.12^a±0.049$	$5.98^c±0.107$	$6.01^b±0.039$	$6.10^a±0.063$	$5.96^b±0.066$	0.1812	0.0381	0.1036
Cooked pH	$6.59^a±0.035$	$5.98^c±0.058$	$6.29^b±0.069$	$6.34^a±0.061$	$6.23^c±0.046$	<.0001	0.0306	0.1782
WHC%	$87.59^a±0.136$	$85.47^c±0.344$	$87.21^b±0.143$	$86.83^a±0.226$	$86.69^b±0.189$	<.0001	0.4642	0.6711

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; DL= Drip Loss, CL= Cooking Loss, WHC= Water Holding Capacity; G*R= Combined effect of Genotype and Rearing System.

Sensory attributes

Tenderness, juiciness and overall acceptability were found higher in grazing (4.58, 4.62, 4.62) than stall feeding (4.43, 4.32, 4.49) (Table 7). In a similar study conducted by Hossain et al. (2019), the sensory attributes of Jamuna Basin lambs were evaluated. The study reported that grazing had a positive effect on the tenderness, juiciness, and overall acceptability of the meat of Jamuna Basin lambs. Color and flavor were found higher in stall feeding (4.57, 4.59) than stall feeding (4.47, 4.52). The genotype had significant effect on color and tenderness ($p<0.05$). The Genotype, Rearing System and G*RS had significant effect on juiciness and overall acceptability. G*RS had significant effect on tenderness but it had insignificant effect for rearing system. Color, flavor and tenderness were higher in JBL (4.66, 4.65, 4.68) compared to CBL (4.47, 4.46, 4.59) and BRL (4.44, 4.55, 4.25). Higher juiciness and Overall acceptability showed in JBL compares to BRL and CBL. A study conducted by Akter et al. (2019) evaluated that meat from stall-fed lambs was more tender, juicy, and overall acceptable than that from grazed lambs.

Table 7. Comparison of sensory attributes of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
Color	4.66^a±0.023	4.44^c±0.065	4.47^b±0.096	4.47^b±0.062	4.57^a±0.062	0.0346	0.1420	0.6992
Flavor	4.65^a±0.026	4.55^b±0.130	4.46^c±0.115	4.52^b±0.110	4.59^a±0.071	0.2745	0.4301	0.9623
Tenderness	4.68^a±0.023	4.25^c±0.127	4.59^b±0.060	4.58^a±0.091	4.43^b±0.049	0.0008	0.0605	0.0126
Juiciness	4.75^a±0.017	4.31^c±0.066	4.36^b±0.095	4.62^a±0.060	4.32^b±0.059	<.0001	0.0002	0.0061
Overall acceptability	4.69^a±0.009	4.52^b±0.065	4.46^c±0.087	4.62^a±0.045	4.49^b±0.063	0.0146	0.0549	0.0079

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; G*R= Combined effect of Genotype and Rearing System.

Instrumental color values

The effect of rearing system on instrumental color values of JBL, BRL and CBL is presented in Table 8. The CIE L*, a*, b* Hue angle and Saturation Index values were found 51.77, 20.36, 13.74, 33.17, 25.74 and 49.67, 15.58, 10.36, 34.08, 18.82 in T_1 and T_2 treatments respectively where L, a and b value was significant ($p<0.001$) which is similar to the study of Łuczak et al. (2018). However, in a study by Chikwanha et al. (2015), no significant difference was found in the instrumental color values of lamb meat between the grazing and stall-feeding systems. The L and b value were higher in JBL (52.02, 14.07) compared to CBL (50.61, 12.69) and BRL (49.53, 9.39) and both were higher in grazing lambs (51.77, 13.74) than stall feeding lambs (49.67, 10.36). Another study reported that meat from stall-fed lambs had a higher L* value (lightness) and lower b* value (yellowness) compared to meat from grazing lambs, while a* value (redness) was not significantly different (Mishra et al., 2019). The value of a* was higher in BRL (18.75) compared to JBL (18.73) and CBL (16.43) and it is higher in grazing lambs (20.36) than stall feeding lambs (10.36). The hue angle was higher in CBL (37.23) compared to JBL (37.06) and BRL (26.59) and it was higher in stall feeding lambs (34.08) than grazing lambs (33.17) which is similar to the study of Akter et al. (2019). The genotype and G*RS had significant effect on hue angle but it was statistically insignificant for rearing system. The saturation index was higher in grazing lambs (25.74) than stall feeding lambs (18.82) and it was statistically significant ($p<0.001$) which is similar to the study of Hasan et al. (2020). JBL (25.09) had higher saturation index compared to BRL (20.97) and CBL (20.77).

Table 8. Comparison of instrumental color values of JBL, BRL and CBL at different rearing system

Parameters	Genotype			Rearing System		Level of Significance		
	JBL (Mean ± SE)	BRL (Mean ± SE)	CBL (Mean ± SE)	T_1 (Mean ± SE)	T_2 (Mean ± SE)	Genotype (G)	Rearing System (RS)	G*RS
L*	52.02^a±0.713	49.53^c±0.381	50.61^b±0.785	51.77^a±0.988	49.67^b±0.264	0.0190	0.0049	0.0123
a*	18.73^b±0.202	18.75^a±0.136	16.43^c±0.712	20.36^a±0.392	15.58^b±0.308	0.0002	<.0001	<.0001
b*	14.07^a±0.326	9.39^c±0.198	12.69^b±0.307	13.74^a±0.418	10.36^b±0.136	<.0001	<.0001	<.0001
Hue angle	37.06^b±0.442	26.59^c±0.346	37.23^a±1.389	33.17^b±0.896	34.08^a±0.555	<.0001	0.2376	0.0427
Saturation index	25.09^a±1.639	20.97^b±0.213	20.77^c±0.619	25.74^a±1.366	18.82^b±0.280	0.0088	<.0001	0.0018

Superscripts of the same letter in each row and column did not differ significantly ($p>0.05$) but having different letter differ significantly ($p<0.05$), T_1= Grazing and T_2= Stall Feeding; JBL= Jamuna Basin Lamb, BRL= Barind Region Lamb, CBL= Coastal Belt Lamb; L*=Lightness, a*= Redness, b*= Yellowness; G*R= Combined effect of Genotype and Rearing System.

Conclusions

From this study it can be concluded that lambs who are allowed to graze have superior productive performance, carcass features, proximate components, physicochemical, sensory, and instrumental color value qualities than lambs that are fed in stalls. Major meat quality traits were considerably altered by the rearing technique. The study also reflects the superiority of Coastal Belt lamb over Jamuna Basin lamb and Barind Region lamb in terms of overall body weights and growth performance. Carcass trait parameters largely varied in different genotypes for different rearing systems. When compared to lamb from the Coastal Belt and the Barind region, the Jamuna Basin lambs had good quality meat. For the three genotypes, grazing systems performed better for characteristics related to productivity and meat quality than stall feeding did.

Conflicts of Interest

The authors declare no potential conflict of interest.

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