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Research Article

A study on productive performance of Garole sheep in Sundarban areas of West Bengal

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Abstract

The present study compared the productive performances viz., body weight, body measurement, reproductive traits, carcass characteristics, meat quality and acceptability of Garole sheep of Sundarbans delta region of West Bengal, India, reared under semi-intensive system and traditional system. Each group comprised 10 sheep (total n=20) and were evaluated for body weight and body measurements. At the age of 12 months, 6 healthier adult sheep from each rearing system (total n=12) were chosen and evaluated for the pre-and post-slaughter characteristics. Carcass characteristics varied significantly ($p<0.05$) between sheep reared under different management systems. The major primal cuts showed significant ($p<0.05$) differences among different groups of Garole sheep. Meat quality parameters like WHC showed significant ($p<0.05$) higher value in the semi-intensive system than that of the traditional rearing system, whereas pH, muscle fibre diameter and cooking yield showed non-significant ($p>0.05$) differences between the groups. The proximate analysis showed that meat protein and carbohydrate content were significantly ($p<0.05$) higher, whereas the moisture content was significantly ($p<0.05$) lower for mutton obtained from semi-intensive system. It was revealed from the sensory evaluation that colour, appearance, juiciness and flavour scores were significantly ($p<0.05$) higher for meat from semi-intensive system than that of traditional rearing system. However, this study concluded that Garole sheep meat, especially reared under semi-intensive system, served better-quality meat in terms of proximate composition as well as in organoleptic characteristics.

Keywords: Carcass characteristics, Garole sheep, Meat quality, Sundarban

Highlights

- This study evaluated the productive performance, meat quality and acceptability of Garole sheep reared under semi-intensive system and traditional system (free range system).
- Carcass characteristics varied significantly ($p<0.05$) between sheep reared under different management systems.
- Among the primal cuts, significant ($p<0.05$) differences were observed among different groups of Garole sheep.
- Meat quality parameters showed significant ($p<0.05$) higher value in semi-intensive system than that of traditional rearing system.
- Garole sheep meat, especially that reared under a semi-intensive system, is of the best quality in terms of nutritional as well as organoleptic characteristics.

INTRODUCTION

In India, the most common sources of meat are poultry, goat and sheep. Sheep meat or mutton, being a red meat, is considered a valuable source of dietary proteins and iron. In comparison with chevon, mutton is economically cheaper though having almost similar nutritive values. Mutton is such a kind of meat towards which there is no prejudice by any community in India, and identification of superior breeds for mutton production will have a great scope in the developing economy of India. The breeds of indigenous sheep differ widely in terms of their adaptation and productive performance across different regions. The specific micro-sheep breed, Garole sheep, is preferably reared in the Sundarban areas of North 24 Parganas and South 24-Parganas district, West Bengal, India.

The Garole sheep is a miniature sheep breed with a small body size. The head is straight, viewed as triangular

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from the front and is placed little higher than the body. The sheep breed possesses a straight nose and a pale cream or black muzzle. The eyes are typically black, the legs are thin, and the hooves are black. It has a long neck, and the neck is heavier in males. The chest and abdomen are barrel-like and heavier posteriorly in females (Pan *et al.*, 2004). The average adult body weight of Garole sheep at 12 months of age ranges from 14 to 14.5 kg with 1.87 mean litter size (Mishra *et al.*, 2007). Garole sheep breed has a very high prolificacy rate of 227% (Ghalsasi and Nimbkar, 1993). The sheep carry the Booroola gene (FecB) as a result of mutation in bone morphogenetic protein receptor-IB (BMPR-IB) (Wilson *et al.*, 2001), resulting in high prolificacy. Garole ewes exhibit high mothering instinct for their newly born lambs. Garole sheep are generally reared in small flock sizes (5-7 sheep) and are maintained mainly upon grazing on field boundaries, fallow land and on the verges of the road. These sheep are reared solely for meat and are neither sheared nor milked (Ghalsasi and Nimbkar, 1993).

Ali *et al.* (2022) studied the meat quality attributes of Abo-Deleek lambs managed under semi-intensive and intensive system of rearing in Egypt. Several researchers like Alhidary *et al.* (2016), Boughalmi and Araba (2016), Hamdi *et al.* (2016) and Frank *et al.* (2017) also studied the mutton and lamb characteristics of some sheep breeds under different feeding and management systems. Similarly, Islam *et al.* (2017) studied the growth performance, carcass and meat quality characteristics of two groups of Bangladeshi Garole sheep fed with two different rations.

Das *et al.* (2008) and Mule (2007) studied carcass characteristics of Muzaffarnagari lambs and Deccani sheep, respectively. Sen and Karim (2010) compared the carcass characteristics of Garole sheep, Malpura sheep and Malpura × Garole crossbreds. Similar studies were also conducted by Ghanekar *et al.* (1972) in Bannur lambs, Muthukumar *et al.* (2006) in Nellore lambs, Panneerselvam *et al.* (2009) in Coimbatore ram lambs, Appannavar *et al.* (2010) in Kenguri sheep, Banerjee (2011) in Shahabadi yearling ewes and Vinaya Babu (2013) in Macherla Brown sheep.

Garole sheep is basically reared as mutton sheep and is well known for its organoleptic characteristics among local consumers. Exploration of all the good characteristics of Garole can be used for crossbreeding purpose for increasing mutton production. Garole sheep meat can be popularized if quality and acceptability evaluation is properly done to attract the common people. Keen interest in the commercialization of Garole sheep meat has been taken by the government, non-government and other international development agencies in the recent past. However, the effect of rearing and management on productive performance, meat quality and acceptability of Garole sheep meat is rarely studied and documented in the previously published literatures. So, this study was undertaken to evaluate and compare the productive performance viz. body weight, body measurement, reproductive traits, carcass characteristics, meat quality and acceptability of Garole sheep of Sundarbans delta region of West Bengal, India, reared under semi-intensive system and traditional system (free range system).

MATERIALS AND METHODS

In the current study, Garole sheep from Sundarbans delta region of North-24-Paraganas district (Hingalganj block) of West Bengal (Fig. 1) were reared under two different management systems, like semi-intensive system and traditional system (free range system).

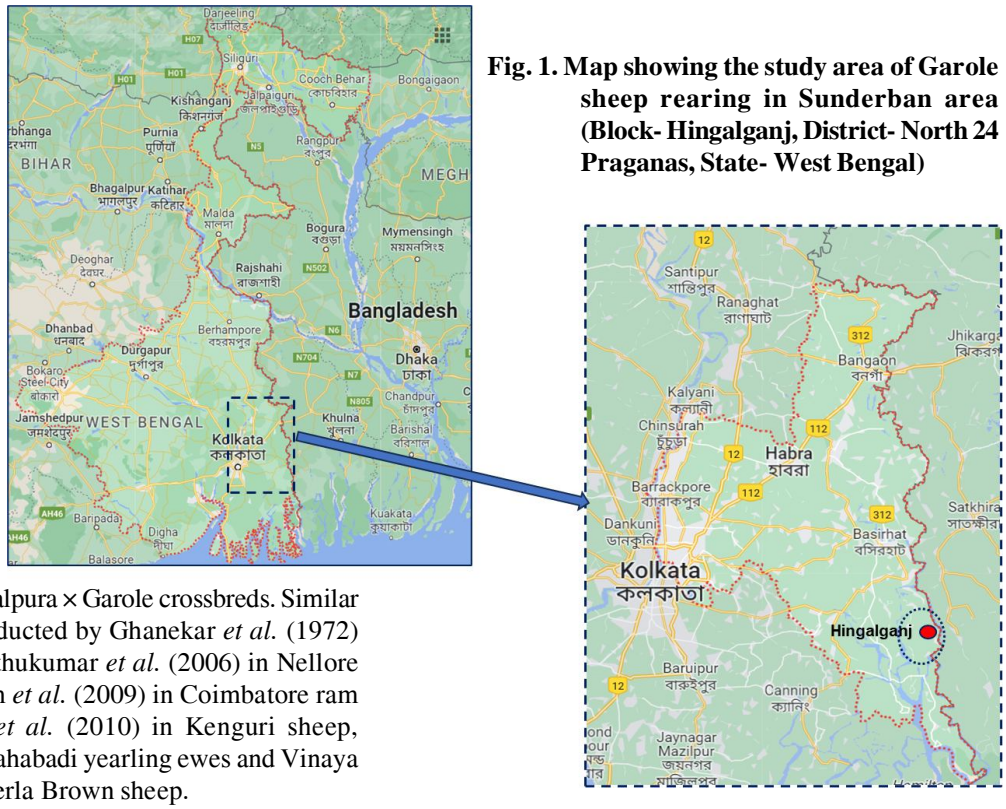

Fig. 1. Map showing the study area of Garole sheep rearing in Sunderban area (Block- Hingalganj, District- North 24 Praganas, State- West Bengal)

A total of 20 (n=20) healthy sheep of good grade were selected by multistage stratified random sampling technique and allotted to two groups (n=10 in each of the two rearing systems). Among the 10 sheep in each group, only the adult sheep (n=6 in each system, total n=12) were evaluated for pre- and post-slaughter characteristics as they attained the age of 12 months. The remaining sheep in each group below 12 months of age were not slaughtered; hence, slaughter traits and meat quality parameters were not studied for them. The group of sheep under semi-intensive system in this study were reared in an intermediate system between extensive and intensive systems, where animals were kept in extensive housing and management and stall-fed with a commercially available concentrate mixture but allowed for limited grazing. In contrast, the other group of sheep reared under free-range (traditional) system had no definite housing, management and feeding strategies, were solely left to thrive on grazing and were given night shelter only. The study on productive performance including body weight (0, 3, 6, 9 and 12 months age), body measurement (3, 6, 9 and 12 months age), carcass characteristics, meat quality and acceptability of Garole sheep of same age groups (i.e., 12 months) has been undertaken. The sheep of different groups were slaughtered at 12 months of age according to common procedures under federal inspection, and the meat samples were analyzed for different meat quality parameters. To ascertain the meat quality and carcass characteristics, measurement of cut-up portions, physico-chemical properties (pH, WHC, Fibre diameter), proximate composition (Moisture, Protein, Fat, Ash) and sensory quality attributes (Colour, Flavour, Tenderness, Juiciness, Overall acceptability) of the fresh mutton was done.

Productive performance

Live body weight and body measurements: The body weight of sheep was recorded in kilograms (kg) using a digital weighing balance at birth/0, 3, 6, 9, and 12 months of age. Body measurements, like length, height, and belly circumference, were measured in centimeters (cm) using a measuring tape.

Carcass characteristics and wholesale cuts: The weight of the whole carcass was recorded as hot carcass weight. Then, the carcass was cut into forequarter and hindquarter, and cuts like leg, loin, rack, neck and shoulder, breast, and foreshank were made as per the specification of ISI (1963), and their weights were recorded. The dressing percentage was calculated from the hot carcass weight, live weight before slaughter, and weight after removal of ingesta.

Physico-chemical analysis: The pH of the finely minced meat sample was determined by the method of Trout (1992). The Water Holding Capacity (WHC) was estimated based on the percentage of free water in meat, as per the method of Grau and Hamm (1953) and as modified by Pohja and Niinivaara (1957).

Muscle fibre diameter of Garole sheep meat sample was estimated as per the method of Jeremiah and Martin (1977).

Garole sheep meat (mutton) was uniformly cut into half square inches size and boiled in a pressure cooker for 15-20 minutes at 15 lb pressure. The cooking yield was determined as a % of the initial weight. After cooking, the cooked meat samples were drained of excess water, and the weight was taken. The cooking yield was calculated by the following formula:

Cooking yield (%) = Weight of cooked meat/ Weight of raw meat x 100

Proximate composition analysis: The proximate composition, such as protein, fat, moisture and ash percents of Garole sheep meat (mutton) samples, were analyzed by following the standard procedure of AOAC (1995).

Carbohydrate estimation in Garole sheep meat sample

The estimation of total carbohydrate content (%) in Garole sheep meat was done by colorimetric method given by AOAC. 100 g of meat sample was taken and oven-dried to remove moisture. Around 1-2 g of dried meat sample was placed in a container. 10 mL of 80% ethanol was added to the meat and refluxed for 30 minutes. The mixture was filtered to separate the extract. The filtrate was transferred to another container, and 10 mL of 2M sulfuric acid was added to it. The mixture was hydrolyzed by placing it in a boiling water bath for 2 hours. The hydrolysate was neutralized by adding 10N sodium hydroxide solution slowly dropwise until the pH reaches 6-7. A portion of the neutralized hydrolysate was diluted with distilled water. Phenol-sulfuric acid reagent was added to it and mixed thoroughly. The mixture was allowed to stand for 30 minutes, and the absorbance was taken spectrophotometrically at 490 nm. The carbohydrate content (%) per 100 g of meat was expressed by comparing the value obtained with the standard curve.

Sensory evaluation

Garole sheep meat (mutton) uniformly cut into half square inches and boiled in a pressure cooker for 15-20 minutes at 15 lb pressure, is allowed for sensory evaluation to a trained panel of 7 members amongst the

semi-trained members of the Faculty of Veterinary and Animal Sciences, Kolkata. No cooking ingredients like salt, spice, oil etc. were used. All the meat samples were evaluated for tenderness, colour, flavour, juiciness and overall acceptability by using a 9-point Hedonic scale as described by Ingham *et al.* (2002).

Statistical analysis

The data collected for various study parameters were analyzed by one-way ANOVA, and differences between groups were verified by Duncan's Multiple Range test using SPSS Statistics (Version 23) software. The results were expressed in terms of mean and standard error (SE) of mean. The $p<0.05$ is treated as significant, $p<0.01$ is noted as highly significant and $p>0.05$ is considered as non-significant. The samples were replicated twice, i.e., tested in duplicates for each parameter measurement, giving rise to n=10 for body weight and body measurements in each rearing system, total n=20; n=6 in each rearing system, total n=12 for carcass characteristics, wholesale cuts, physicochemical parameters and proximate composition; n=30 for sensory evaluation.

RESULTS

Productive performance

Body weight (kg): The mean values of the live body weight (kg) of Garole sheep in two different rearing/management groups are tabulated in Table 1. The average body weights in the two rearing systems at birth, 3, 6, 9 and 12 months of age were in the ranges 0.98-1.42 kg, 3.67-4.33 kg, 7.25-8.33 kg, 9.16-10.19 kg and 12.15-13.46 kg, respectively. The analysis of data revealed significant differences ($p<0.05$) in live body weight among different age groups in both the rearing systems. Significantly higher ($p<0.05$) body weights of Garole sheep were recorded in semi-intensive system as compared to the traditional rearing system at different ages. The average live weight (kg) was found to be 1.19±0.03, 4.00±0.06, 7.79±0.11, 9.68±0.14 and 12.81±0.139 kg at birth, 3, 6, 9 and 12 months age, respectively.

Body measurements: The mean values of live body measurements (cm) of Garole sheep in two different rearing/management groups are tabulated in Table 2. The average body lengths in the two rearing systems at 3, 6, 9 and 12 months of age were in the ranges of 50.80-52.21 cm, 53.34-54.36 cm, 58.42-59.29 cm and 66.37-67.29 cm, respectively. The average body height (cm) of Garole sheep at 3, 6, 9 and 12 months of age in the two-rearing system were in the ranges of 43.18-45.28 cm, 45.72-46.29 cm, 46.70-46.32 cm and 46.35-47.26 cm, respectively. Similarly, the belly circumference (cm) at 3, 6, 9 and 12 months of age in the two-rearing system

Table 1. Productive performance (Body wt.) of Garole Sheep

Management system / Age	Semi-intensive system		Traditional system (Free range system)		Overall	
	No.	Mean ± S.E.	No.	Mean ± S.E.	No.	Mean ± S.E.
Birth Weight	10	1.42±0.04^a	10	0.98±0.04^b	20	1.19±0.03
3 months	10	4.33±0.08^a	10	3.67±0.08^b	20	4.00±0.06
6 months	10	8.33±0.15^a	10	7.25±0.15^b	20	7.79±0.11
9 months	10	10.19±0.19^a	10	9.16±0.19^b	20	9.68±0.14
12 months	10	13.46±0.19^a	10	12.15±0.19^b	20	12.81±0.13

Mean ± S.E. bearing different superscripts (a, b …. row wise) differ significantly ($p<0.05$), n = 10 for each rearing system, total n = 20

Table 2. Productive performance (Body measurements) of Garole sheep

Management system / Age	Semi-intensive system			Traditional system (Free range system)		
	Body length (cm)	Body height (cm)	Belly circumference (cm)	Body length (cm)	Body height (cm)	Belly circumference (cm)
3 months	52.21±0.80	45.28±0.75	16.16±0.32	50.80±0.85	43.18±0.75	15.24±0.22
6 months	54.36±1.01	46.29±0.71	22.10±0.48^a	53.34±1.09	45.72±0.74	20.32±0.45^b
9 months	59.29±1.07	46.32±0.72	27.20±0.58^a	58.42±1.03	46.70± 0.72	25.42±0.88^b
12 months	67.29±0.86	46.35±0.74	28.40±0.67^a	66.37±0.69	47.26± 0.44	26.02±0.75^b

Mean ± S.E. bearing different superscripts (a, b …. row wise) differ significantly ($p<0.05$), n = 10 for each rearing system, total n = 20

were in the ranges of 15.24-16.16 cm, 20.32-22.1 cm, 25.42-27.2 cm and 26.02-28.40 cm, respectively. Significantly higher belly circumference was noticed at 6, 9 and 12 months of age in sheep rearing under semi-intensive system than the traditional system.

Carcass characteristics

Live weight (kg) prior to slaughter and dressed carcass weight (kg): The mean values of live and dressed body weight (kg) after the humane method of slaughtering Garole sheep in two different management groups are tabulated in Table 3. The analysis of data revealed a significant difference ($p<0.05$) in pre-slaughter weight as well as post-slaughter dressed weight between the two groups. The average live weight (kg) and dressed carcass weight (kg) of sheep were found to be significantly ($p<0.05$) higher in the semi-intensive system as compared to the traditional system.

Dressing percentage (%): The mean values of dressing percentage of Garole sheep of two different rearing groups are tabulated in Table 3. The analysis of data revealed a significant difference ($p<0.05$) in dressing percentage (%) among different groups of sheep. The average dressing percentage (%) was found to be higher for sheep reared under semi-intensive system than that of traditional system.

Forequarter (kg) and hindquarter (kg): The mean values of forequarter (kg) and hindquarter (kg) after the humane method of slaughtering Garole sheep reared under two different management systems are tabulated in Table 3.

The analysis of data revealed a significant difference ($p<0.05$) in post-slaughter weight of forequarter (kg) and hindquarter (kg) among different age groups. The average forequarter (kg) and hindquarter (kg) weight of Garole sheep were found to be significantly ($p<0.05$) higher in sheep reared semi-intensive system as compared to the traditional system.

Yield of primal cuts: Primal cuts of two different groups of Garole sheep reared under different rearing conditions at 12 months of age included hind legs, loin, flank, rack, neck and shoulder, foreshank and breast as per ISI (1963) specifications. The yield (%) of all the standard cut portions of the slaughtered Garole sheep at 12 months of age reared under two different rearing systems are represented in Table 4.

Neck and shoulder- The analysis of data revealed a non-significant difference ($p>0.05$) of neck and shoulder percentage among sheep reared in different management systems. The average neck and shoulder percentage were found to be higher for sheep reared under traditional system than that of semi-intensive system.

Table 3. Carcass characteristics of Garole Sheep

Management system / Slaughter traits	Semi-intensive system	Traditional system (Free range system)
	12 months age	12 months age
	Mean ± S.E.	Mean ± S.E.
Live wt. prior to slaughter (kg)	12.00±0.29[a]	10.50±0.29[b]
Dressed wt. (kg)	6.70±0.17[a]	5.25±0.17[b]
Dressing (%)	55.77±0.57[a]	49.97±0.57[b]
Fore quarter (kg)	3.59±0.07[a]	2.73±0.07[b]
Hind quarter (kg)	3.09±0.07[a]	2.68±0.07[b]

Mean ± S.E. bearing different superscripts (a, b …. row wise) differ significantly ($p<0.05$), n = 6 for each rearing system, total n = 12

Table 4. Wholesale cuts or standard primal cuts (ISI, 1963) of Garole sheep carcass

Management system / Wholesale cuts	Semi-intensive system	Traditional system (Free range system)
	12 months age	12 months age
	Mean ± S.E.	Mean ± S.E.
Neck and shoulder (%)	27.00±0.54	28.17±0.54
Foreshank and breast (%)	14.18±0.25[b]	16.05±0.25[a]
Rack (%)	11.93±0.27	11.15±0.27
Loin (%)	11.93±0.28	11.17±0.28
Hind legs (%)	32.00±0.23[a]	31.03±0.23[b]
Flank (%)	3.03±0.09	3.12±0.09

Mean ± S.E. bearing different superscripts (a, b ... row-wise) differ significantly ($p<0.05$), n = 6 in each rearing system, total n = 12

Fore shank and breast- The average fore shank and breast percentage were found to be significantly ($p<0.05$) higher for sheep reared under traditional system than that of semi-intensive system. These results indicated that the foreshank and breast percentage of Garole sheep were influenced by the rearing/management system, body weight and dressing percentage.

Rack- The average rack percentage was found to be higher for sheep reared under semi-intensive system than that of traditional system. The analysis of data revealed a non-significant difference ($p>0.05$) in terms of rack percentage among different rearing groups.

Loin- The average loin percentage was found to be higher for sheep reared under semi-intensive system than that of traditional system. The analysis of data revealed a non-significant difference ($p>0.05$) in terms of loin percentage among different management/rearing groups. These results indicated that the loin percentage of Garole sheep was not much influenced by the rearing/ management system, body weight and dressing percentage.

Hind legs- The average hind legs percentage was found to be significantly ($p<0.05$) higher for sheep reared under semi-intensive system than that of traditional system.

Flank- The average flank percentage was found to be higher for sheep reared under traditional system than semi-intensive system. The analysis of variance revealed a non-significant difference ($p>0.05$) in terms of flank percentage among different rearing groups.

Physico-chemical properties of mutton

The mean values of pH, Water Holding Capacity (WHC) %, fibre diameter (ìm) and cooking yield (%) of fresh Garole sheep meat of two different groups under different rearing conditions at 12 months of age are tabulated in Table 5.

pH: The average pH value was found to be slightly higher for meat obtained from sheep reared under traditional system than that of semi-intensive system. The analysis of data revealed non-significant differences ($p>0.05$) of pH value of mutton obtained from different rearing systems.

Water Holding Capacity (WHC) %: The WHC % is responsible for the appearance and juiciness of the meat and can also have the potential to prevent the bacterial load, hence aiding in increasing the shelf life of meat (Watt and Merrill, 1963). In this study, the average WHC

Table 5. Physico-chemical parameters, proximate composition and sensory attributes of sheep meat (mutton)

Management system / Parameters	Semi-intensive system	Traditional system (Free range system)
	12 months age	12 months age
	Mean ± S.E.	Mean ± S.E.
Physico-chemical parameters		
pH	5.91±0.04	6.02±0.04
WHC	31.26±0.25^{a}	28.09±0.25^{b}
Muscle fibre diameter (µm)	27.66±0.27^{b}	28.89±0.27^{a}
Cooking yield (%)	71.99±0.31^{a}	70.03±0.31^{b}
Proximate composition		
Moisture (%)	74.07±0.26^{b}	75.88±0.65^{a}
Protein (%)	18.10±0.15^{a}	17.467±0.19^{b}
Fat (%)	3.34±0.11	3.23±0.11
Ash (%)	1.61±0.07	1.55±0.02
Carbohydrate (%)	1.85±0.09^{a}	1.57±0.06^{b}
Sensory attributes		
Colour	7.48±0.18	7.18±0.18
Appearance	7.44±0.20	7.16±0.20
Tenderness	7.33±0.20	7.15±0.20
Juiciness	7.30±0.14	6.99±0.14
Flavour	7.26±0.16	7.04±0.16
Overall acceptability	7.49±0.21	7.37±0.21

Mean ± S.E. bearing different superscripts (a, b … row wise) differ significantly ($p<0.05$), n = 6 in each rearing system, total n = 12 for physico-chemical parameters and proximate composition, n = 30 for sensory evaluation

% was found to be significantly higher ($p<0.05$) for meat obtained from sheep reared under semi-intensive system than traditional system.

Fibre diameter (μm): The average fibre diameter (μm) was found to be significantly more ($p<0.05$) for meat obtained from sheep reared under traditional system than that of semi-intensive system.

Cooking yield (%): The average cooking yield (%) was found to be significantly higher ($p<0.05$) for meat obtained from sheep reared under semi-intensive system than that of traditional system.

Proximate composition

The mean values of moisture, protein, fat, ash and carbohydrate percentage of fresh Garole sheep meat under two different management groups are tabulated in Table 5.

Moisture %: The moisture content (%) was significantly higher ($p<0.05$) in the meat of sheep reared under traditional system as compared to that of semi-intensive system.

Protein %: The analysis of data revealed that the protein content (%) was significantly higher ($p<0.05$) in the meat of sheep reared under semi-intensive system as compared to that of traditional system.

Fat %: The analysis of data revealed a non-significant ($p>0.05$) difference in terms of fat % in the meat of two different groups of Garole sheep. But it was slightly higher in the meat of sheep reared under semi-intensive system as compared to that of traditional system.

Ash %: The ash content (%) was slightly higher in the meat of sheep reared under semi-intensive system as compared to that of traditional system, but the difference was non-significant ($p>0.05$).

Carbohydrate %: The carbohydrate content (%) was significantly higher ($p<0.05$) in the meat of sheep reared under semi-intensive system as compared to that of traditional system, which could have been affected by the diet and feeding practices.

Sensory evaluation

The comparative appraisals of the effect of different rearing systems on sensory scores for colour, flavour, tenderness and juiciness of fresh Garole sheep meat slaughtered at 12 months of age are presented in Table 5. On the basis of the sensory scores, the variations in eating qualities due to different age groups have been estimated to know the acceptability of Garole sheep meat. Non-significant ($p>0.05$) were observed in terms of colour, flavour, tenderness, juiciness and overall acceptability scores between the two rearing systems. However, slightly higher ($p>0.05$) sensory scores were noticed for meat obtained from sheep reared under semi-intensive system than that of traditional system.

DISCUSSION

Productive performance

Body weight (kg): These results indicated that the body weight of Garole sheep gradually increased with the advancement of age in both systems, and the system of rearing had a significant ($p<0.05$) effect on the body weight of Garole sheep. The average live body weight observed in the present study was more or less similar as reported by Pan *et al*. (2004) and Pan and Sahoo (2009) in Garole sheep. Das *et al.* (2008) also reported that under intensive management system like feeding, deworming, and vaccination, the live body weight of Muzaffarnagari lambs grows rapidly with age. Alhidary *et al.* (2016), in their experiment on growing Naemi lambs, also noticed that supplementation of Alfalfa hay in the ration increased the body weight at slaughter as compared to control lambs.

Body measurements (cm): There was a gradual increase in body length (cm), body height (cm) and belly circumference (cm) with increasing age. Non-significant ($p>0.05$) differences were observed for body length (cm) and body height (cm) at 3, 6, 9 and 12 months of age between sheep reared under two different rearing systems. Moreover, a significantly higher ($p<0.05$) belly circumference (cm) of sheep at 6, 9 and 12 months of age was observed in sheep under semi-intensive system. The higher values of belly circumference (cm) of sheep under semi-intensive system can be related to comparatively higher body length, height and weight than those reared under traditional system. These findings are corroborated with the values of body measurements by Sahana *et al.* (2001) in their study on Garole sheep.

Carcass characteristics

Live weight (kg) prior to slaughter and dressed carcass weight (kg): The system of rearing and management affected the live weight and dressed weight of Garole sheep.

The average live weight and dressed weight observed in the present study of Garole sheep bear similarity with the study conducted by Banerjee *et al.* (2009) and Pan *et al.* (2004). Comparatively higher

values of dressed carcass weights were recorded by Das *et al*. (2008) in Muzaffarnagari lambs, Sen *et al.* (2000, 2004) in yearling sheep and finisher lambs, Latif and Owen (1980) in Suffolk and Taxel lambs and Mule (2007) in Deccani lambs which can be attributed to the breed differences. Similarly, Alhidary *et al.* (2016) observed higher dressed weight and better carcass characteristics in lambs supplemented with alfalfa hay as compared to control lambs.

Dressing percentage (%): The results of the study indicated that the system of rearing and management influences the dressed weight of Garole sheep. The average dressing percentage of Garole sheep in the present study agrees with the findings of Banerjee *et al.* (2009) and Pan and Sahoo (2009). Similar values of dressing percentage were also observed in Muzaffarnagari sheep as reported by Khan *et al.* (1981). Comparatively lower values of dressing percentage were recorded by Ghanekar *et al.* (1972) in Bannur lambs, Muthukumar *et al.* (2006) in Nellore lambs, Sen *et al.* (2004) in yearling lambs and Mule (2007) in Deccani lambs, which may be due to the breed differences. Hamdi *et al.* (2016) and Alhidary *et al.* (2016) in their studies also observed a higher dressing % of lambs supplemented with oilcakes and alfalfa hay, respectively.

Forequarter (kg) and hindquarter (kg): These results indicated that the forequarter (kg) and hind quarter (kg) weight of Garole sheep were affected by the system of rearing/management and are directly related to live weight prior to slaughter, dressed weight and dressing %.

Yield of primal cuts: Neck and shoulder- The results of our study indicated that the neck and shoulder percentages of Garole sheep were influenced by the rearing/management system, body weight and dressing percentage. The findings of this study were in agreement with the findings of Mule (2007) in Deccani sheep. The findings in the present study were close to that of the Garole sheep recorded by Sen and Karim (2010), but lower values were reported in the Malpura breed and Malpura × Garole crossbreds at 10 months of age. Lower values were recorded in Muzaffarnagari sheep by Das *et al.* (2008) and in Shahabadi yearling ewes by Banerjee (2011). Hamdi *et al.* (2016) also reported a higher yield of primal cuts except neck and thorax in grazing and feedlot lambs receiving olive cake.

Foreshank and breast- The results of our study bear similarity with the findings of Mule (2007) in Deccani sheep at 9 to 12 months of age kept on feedlot studies. Similar results were also obtained by Banerjee (2007) in Garole sheep and Das *et al.* (2008) in Muzaffarnagari sheep. More or less similar observations were recorded by Sen and Karim (2010) in Garole sheep, but comparatively higher values were recorded in Malpura breed and Malpura × Garole crossbreds at 10 months of age. Mule (2007) observed similar values in Deccani sheep. Comparatively lower values were recorded in Muzaffarnagari sheep by Das *et al.* (2008) at 6 to 9 months of age reared under intensive and semi-intensive management system.

Rack- The results of our study indicated that the loin % of Garole sheep was not much influenced by the rearing and management system, body weight and dressing %. These findings were in agreement with the findings of Banerjee (2007) in Garole lambs. The current findings were close to the results of Sen and Karim (2010) in Garole sheep, but comparatively higher values were recorded in the Malpura breed and Malpura × Garole crossbreds at 10 months of age. Comparatively higher values were also recorded by Das *et al.* (2008), Banerjee (2011) and Mule (2007) in Muzaffarnagari sheep at 6 to 9 months of age, Shahabadi yearling ewes and Deccani lambs, respectively.

Loin- The result of our study is in congruence with the findings of Banerjee (2007) and Das *et al.* (2008) in Garole lambs and Muzaffarnagari lambs, respectively. Sen and Karim (2010) observed similar values in Garole sheep, but comparatively lower values were recorded in the Malpura breed and Malpura × Garole crossbreds at 10 months of age. Mule (2007) reported that in Deccani sheep, the proportion of loin significantly ($p<0.01$) increased as the age increased from 9 to 12 months.

Hind legs- These results indicated that the hind legs % of Garole sheep was influenced by the rearing and management system, body weight and dressing %. Similar observations were recorded by Sen and Karim (2010) in Garole sheep, but higher values in Malpura and lower values in Malpura × Garole crossbreds at 10 months of age. This was in congruence with the results of Das *et al.* (2008) and Mule (2007) in 6 to 9 months old Muzaffarnagari lambs and 4, 6, 9 and 12 months old Deccani sheep, respectively. Moreover, hind leg % recorded the highest primal cut value among all the standard cuts.

Flank- These results indicated that the flank % of Garole sheep was not much influenced by the rearing/ management system, body weight and dressing %. This result was in congruence with the findings of Banerjee (2007) and Das *et al.* (2008) in Garole and Muzaffarnagari lambs, respectively.

Physico-chemical properties of mutton

pH: The results of our study for pH bear similarity with the findings of Banerjee (2007) in Garole lambs and of Das *et al.* (2008) in Muzaffarnagari lambs. Similar results

were obtained by Banerjee (2011) in Shahabadi sheep meat, but comparatively higher values were recorded in Garole sheep meat by Pan and Sahoo (2009) at 12 months old age. Comparatively lower values were recorded by Sen *et al.* (2004) in yearling sheep in semi-arid regions and by Sanudo *et al.* (2012) in suckling lambs. Alhidary *et al.* (2016), in their experiment on growing Naemi lambs, also observed that supplementation of Alfalfa hay in the ration did not affect the pH of meat.

Water Holding Capacity (WHC) %: The values for WHC % in the present study were close to the results of Pan and Sahoo (2009) in 12 months old Garole sheep meat. Comparatively higher values were recorded in 8 to 12 months old Garole sheep meat by Banerjee *et al.* (2009). Much lower values were reported by Das *et al*. (2008) in the meat of Muzaffarnagari sheep at 6 to 9 months of age reared under intensive and semi-intensive management system. No correlation between the moisture content and WHC of meat could be established here. Some other factors (protein content or sample presentation) than moisture content could have affected the WHC. The possible reason for lower WHC might be less protein content in the meat of non-intensively managed lambs, as protein is responsible for water binding. The trends of the current study were also in accordance with the findings of Rajkumar and Agnihotri (2005). Contrastingly, Boughalmi and Araba (2016) in their study observed higher WHC in the meat of pasture-grazed Timahdite lambs as compared to that of concentrate-fed lambs.

Fibre diameter (μm): Regular physical activity and more body height (Table 2) could be the possible reasons for longer muscle fibre diameter in sheep reared under traditional system. Regular physical activity and exercise can stimulate muscle growth and hypertrophy. Sheep engaged in more movement and grazing activity may develop larger muscle fibres due to muscle stress and adaptation. This result was in congruence with the findings of Banerjee (2007) in Garole lamb meat and of Das *et al.* (2008) in Muzaffarnagari lamb meat. More or less similar results were obtained by Banerjee (2011) in 8 to 12 months old Shahabadi sheep meat, but comparatively lower values were recorded by Pan and Sahoo (2009) in 12 months old Garole sheep meat. The lower fibre diameter of sheep meat from semi-intensive system signifies tenderness of meat which plays most important role in the acceptability of meat.

Cooking yield (%): These results indicated that the cooking yield (%) of Garole sheep meat was influenced by the rearing or management system. The sheep meat from semi-intensive system showed comparatively higher cooking yield (%) than that of traditional system. Similar results for cooking yield (%) were obtained by Pan and Sahoo (2009) in 12 months old Garole sheep meat, in 8 to 12 months old Garole sheep meat by Banerjee *et al.* (2009) and by Das *et al*. (2008) in meat of Muzaffarnagari sheep at 6 to 9 months of age reared under intensive and semi-intensive management system.

Proximate composition

Moisture %: A similar result was reported by Muthukumar *et al.* (2006), who found that there was a significant ($p<0.05$) decrease in moisture % as the slaughter weight of Nellore sheep increased. These values agree with the results of Das *et al.* (2008) in Muzaffarnagari lambs, Mhaske (2010) in Madgyal lambs and Panneerselvam *et al.* (2009) in Coimbatore lambs. Similar results were also obtained by Banerjee *et al.* (2009) in 8 to 12 months old Garole sheep meat. Comparatively lower values were recorded by Pan and Sahoo (2009) at 12 months old Garole lambs and Murshed *et al*. (2014) in Bangladesh local sheep, but higher values were recorded by Mohanty and Mishra (1992) in Ganjam and Bolangir sheep breeds at 12 months of age and by Dani *et al.*, (1985) in Bannur ram lambs at 9-12 months of age. Moisture % is inversely related to the fat content. In the present study, similar relation is reflected, and Garole sheep meat with higher moisture content showed a lower fat % in the same group of sheep. However, the rearing, feeding practices, and individual variations could have affected the fat contents and moisture contents in two different groups of sheep in the present study. In a similar experiment, Islam *et al.* (2017) did not find any significant differences in proximate composition in terms of moisture % between two groups of Bangladeshi Garole sheep fed with different rations.

Protein %: More or less similar results were obtained by Banerjee *et al.* (2009), Mhaske (2010) and Appannavar *et al.* (2010) in 8 to 12 months old Garole sheep, 6 months old Madgyal sheep and adult Kenguri sheep, respectively. Comparatively lower values were reported by Pan and Sahoo (2009) in Garole sheep at 8 to 12 months of age, Dani *et al.* (1985) in Bannur lambs at the age of 10 months and Farid (1991) in adult fat-tailed Iranian sheep breeds. Higher protein % was recorded by Murshed *et al.* (2014) in Bangladesh local sheep breed, Mohanty and Mishra (1992) in Ganjam and Bolangir sheep at the age of 10 months, Das *et al.* (2008) in Muzaffarnagari lambs at 9 months of age under intensive management and Panneerselvam *et al.* (2009) in Coimbatore ram lambs at 6 to 9 months of age. In the present study, significantly ($p<0.05$) lower level of protein content was noted in

Garole sheep meat under traditional system. It might be due to lower nutritional content in their feed under traditional management system.

Fat %: The reason for non-significant ($p>0.05$) higher fat % in sheep meat under semi-intensive system as compared to traditional system might be due to high nutrient content of diet and less physical exercise in semi-intensive system. Additionally, these results agree with the fact that fat % is inversely proportional to moisture % of meat. This finding was in congruence with the results of Muthukumar *et al.* (2006) in Nellore sheep, Das *et al.* (2008) in Muzaffarnagari sheep, Mhaske (2010) in Madgyal sheep and Vinaya Babu (2013) in old Macherla brown sheep. More or less similar results were also obtained by Sen and Karim (2010) in Garole sheep at 10 to 12 months of age. Comparatively higher fat % was recorded by Pan and Sahoo (2009) in Garole sheep at 12 months of age, Sen and Karim (2010) in Malpura and Malpura × Garole crossbred lambs at 10 months of age, Latif and Owen (1980) in Suffolk ram lambs at an age of 4 months and Tahir *et al.* (1985) in Arabian adult lambs. Comparatively lower fat % was reported by Banerjee *et al.* (2009) in Garole sheep at 8 to 12 months of age, Murshed *et al.* (2014) in Bangladesh local sheep meat, Appannavar *et al*. (2010) in Kenguri sheep and Panneerselvam *et al*. (2009) in Coimbatore sheep at the age of 9 months. Animal fat is a source of cholesterol which can affect heart and cause circulatory disorders in terms of human consumption (Lawrie, 1998). Due to this reason, people prefer to consume meat with low fat content. From this study, it can be suggested that Garole meat can be advantageous for human consumption as compared to other red meat due to its lower fat content.

Ash %: The reason for non-significant ($p>0.05$) higher ash% in sheep meat under semi-intensive system as compared to traditional system might be due to high nutrient content of diet in semi-intensive system. This result was in accordance with the results of Das *et al.* (2008) in Muzaffarnagari ram lambs, Mule (2007) in Deccani sheep and Mhaske (2010) in Madgyal sheep. Similar results were obtained by Banerjee *et al.* (2009) in 8 to 12 months age of Garole sheep, Mohanty and Mishra (1992) in Bolangir and Ganjam adult sheep and Vinaya Babu (2013) in Macherla brown old sheep. Comparatively lower fat % was recorded by Pan and Sahoo. (2009) in 12 months age old Garole sheep, Murshed *et al.* (2014) in Bangladesh local sheep, Panneerselvam *et al.* (2009) in Coimbatore ram lambs at 9 months of age and Muthukumar *et al.* (2006) in Nellore sheep at the weight of 10-15 kg and 15-25 kg, whereas higher ash % was reported by Appannavar *et al.* (2010) in Kenguri sheep. Furthermore, in the present study, a higher value of ash content was observed in Garole sheep meat as compared to other recognized breeds. The higher mineral content in Garole meat might be due to its adaptation in native coastal saline track of the Sundarban delta region.

Carbohydrate %: More or less similar results were obtained by Banerjee *et al.* (2009), Mhaske (2010) and Appannavar *et al.* (2010) in 8 to 12 months old Garole sheep, 6 months old Madgyal sheep and adult Kenguri sheep, respectively. Similar results were reported by Pan and Sahoo (2009) in Garole sheep at 8 to 12 months of age and Dani *et al.* (1985) in Bannur lambs at an age of 10 months.

Sensory evaluation

Colour: The average score for colour was found to be non-significantly ($p>0.05$) higher in semi-intensive system than traditional rearing system. Similar result was observed in colour of Macherla brown sheep meat (Vinaya Babu, 2013), but these results were higher than culled sheep meat as reported by Mendiratta *et al.* (2008). Similarly, Boughalmi and Araba (2016) noticed a lighter colour of meat in pasture-grazed Timahdite lambs as compared to that of concentrate-fed lambs.

Flavour: The average score for flavour was found to be non-significantly ($p>0.05$) higher in semi-intensive system than traditional rearing system. More or less similar trend was reported in Deccani sheep at 9 and 12 months (Mule, 2007) and in Macherla brown sheep (Vinaya Babu, 2013). Asghar *et al*. (1979) reported slightly lower flavour scores than the current study. Hamdi *et al.* (2016) also found higher values of flavor in grazing lambs than in feedlot lambs.

Tenderness: The average score for tenderness was found to be non-significantly ($p>0.05$) higher in semi-intensive system than traditional rearing system. Similar value of tenderness was reported in Deccani sheep at 9 and 12 months (Mule, 2007), in Macherla brown sheep at 9 months and 12 months of age (Vinaya Babu, 2013) and in Garole sheep at the age of 10 months (Sen and Karim, 2010).

Juiciness: The average score for juiciness was found to be non-significantly ($p>0.05$) higher in semi-intensive system than traditional rearing system. This result bears more or less similarity with the findings of Mule (2007) in Deccani sheep between 9 and 12 months of age, Sen and Karim (2010) in Garole sheep at the age of 10 months and Vinaya Babu (2013) in Macherla brown sheep at 9

months and 12 months of age. In another study, Hamdi *et al.* (2016) found higher values of juiciness in grazing and feedlot lambs receiving olive cake.

Overall acceptability: The average scores for overall acceptability were found to be non-significantly ($p>0.05$) higher in semi-intensive system than traditional rearing system. In a similar study by Ali *et al*. (2022), it was also noticed that the lamb meat from semi-intensive system fetched significantly higher sensory acceptability scores than that of other systems. Similarly, Frank *et al.* (2017) in their study found that the meat from lambs finished on a lucerne-based diet yielded better sensory acceptability than that of rye-grass-fed lambs. Our finding was in congruence with the results of Sen and Karim (2010) in Garole sheep at 10 months of age, Mule (2007) in Deccani sheep at 9 to 12 months of age and Vinaya Babu (2013) in Macherla brown sheep. Almost all mean values of different parameters of sensory evaluation in respect of Garole sheep meat were in positive aspect of acceptance. So, Garole sheep reared under semi-intensive and traditional system can be used for production of good quality and tasty mutton.

The productive performance in terms of body measurements, mutton quality and sensory acceptability of Garole sheep was studied in two different rearing systems in the current study. This study showed that Garole sheep could be described as a well acceptable mutton breed with low fat content red meat. From the above comparative study, it can be concluded that the Garole sheep meat, reared under semi-intensive system, had better-quality meat in terms of proximate composition as well as organoleptic characteristics. The sheep slaughtered at the age of 12 months age in this study displayed good meat quality and acceptability traits. This study, in a nutshell, provides a better understanding about the effect of the rearing system of Garole sheep on productive performance, meat quality, proximate composition and consumer acceptability of mutton.

Conflict of interest: The authors disclose no conflict of interest.

Author's contribution: KM: Conducted the work; JKC, GP: Planned and supervised the work; AD, MR: Prepared the manuscript and analyzed the data.

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REFERENCES

Alhidary IA, Abdelrahman M, Alyemni AH, Khan RU, Alsaiady M *et al.*, 2016. Effect of alfalfa hay on growth performance, carcass characteristics, and meat quality of growing lambs with ad libitum access to total mixed rations. Rev Bras Zootec. 45(6): 302-308, doi: 10.1590/S1806-92902016000600004

Ali IZM, Mohamdy M, Shehata MF and Ghanem N, 2022. Transcriptional profile and meat quality attributes of Abo-Deleek lambs managed under intensive and semi-intensive production systems of Egypt. Adv Anim Vet Sci, 10(6): 1362-1370, doi: 10.17582/journal.aavs/2022/10.6.1362.1370

AOAC (Association of Official Analytical Chemist), 1995. Official Methods of Analysis, 16th edn. Virginia, USA

Appannavar MM, Ashok P, Ramachandra B, Tandle MK and Kumar GSN, 2010. Study on meat characteristics of Kenguri breed of sheep. Indian Vet J, 87(1): 83

Asghar A and Yeates NTM, 1979. Muscle characteristics and meat quality of lambs, grown on different nutritional planes. II. Chemical and biochemical effects on muscle. Agric Biol Chem, 43(3): 437-444, doi: 10.1080/00021369.1979. 10863491

Banerjee R, Mandal PK, Bose S, Banerjee M and Manna B, 2009. Quality evaluation of meat, skin and wool from Garole sheep- A promising breed from India. Asian J Anim Sci, 3(2): 39-46, doi: 10.3923/ajas.2009.39.46

Banerjee S, 2007. Carcass composition of Garole sheep. Indian Vet J, 84(10): 1072-1084

Banerjee S, 2011. Carcass composition of Shahabadi sheep reared on natural pastures in hot and humid climate of Eastern India. World Appl Sci J, 14(4): 506-509

Boughalmi A and Araba A, 2016. Effect of feeding management from grass to concentrate feed on growth, carcass characteristics, meat quality and fatty acid profile of Timahdite lamb breed. Small Rumin Res, 144: 158-163, doi: 10.1016/j.smallrumres.2016.09.013

Dani NP, Rajalakshmi D, Indira CB, Dhanaraj S, Rao DN *et al.*, 1985. Meat quality in Bannur ram lambs. Indian J Anim Sci, 55(12): 1094-1099

Das AK, Das G and Singh NP, 2008. Growth, carcass characteristics and meat quality of Muzaffarnagari lambs at various stages under intensive and semi-intensive management. Indian J Anim Sci, 78(5): 541-546

Farid A, 1991. Carcass physical and chemical composition of three fat-tailed breeds of sheep. Meat Sci, 29(2): 109-120, doi: 10.1016/0309-1740(91)90058-X

Frank D, Raeside M, Behrendt R, Krishnamurty R, Piyasiri U *et al.*, 2017. An integrated sensory, consumer and olfactometry study evaluating the effects of rearing system and diet on flavour characteristics of Australian lamb. Anim Prod Sci, 57(2): 347-362, doi: 10.1071/AN15006

Ghalsasi PM and Nimbkar BV, 1993. The "Garole"- microsheep of Bengal, India. Anim Genet Resour, 12: 69-75, doi: 10.1017/S1014233900003412

Ghanekar VM, Soman BV and Bhatawadekar SD, 1972. A note on some vital meat characteristics in Bannur Sheep. Indian J Anim Sci, 42(8): 584-586

Grau R and Hamm R, 1953. A simple method for the determination of water binding in muscles. Naturwissenschaften, 40(1): 29-30

Hamdi H, Majdoub-Mathlouthi L, Picard B, Listrat A, Durand D *et al*., 2016. Carcass traits, contractile muscle properties and meat quality of grazing and feedlot Barbarine lamb receiving or not olive cake. Small Rumin Res, 145: 85-93, doi: 10.1016/j.smallrumres.2016.10.028

Ingham SC and Schoeller NP, 2002. Acceptability of a multi-step intervention system to improve apple cider safety. Food Res Int, 35(7): 611-618, doi: 10.1016/S0963-9969(01)00162-4

ISI, 1963. Indian standard specification for mutton and goat flesh. Fresh, chilled and frozen. IS 2536. Bureau of Indian Standard Institution, New Delhi, India

Islam R, Redoy MRA, Shuvo AAS, Sarker MAH, Akbar MA *et al*., 2017. Effect of pellet from total mixed ration on growth performance, blood metabolomics, carcass and meat characteristics of Bangladeshi garole sheep. Progress Agric, 28(3): 222-229, doi: 10.3329/pa.v28i3.34659

Jeremiah LE and Martin AH, 1977. The influence of sex, within breed-of-sire groups, upon the histological properties of bovine longissimusdorsi muscle during postmortem aging. Canadian J Anim Sci, 57(1): 7-14, doi: 10.4141/cjas77-002

Khan BV, Bhat PN and Bisht GS, 1981. Carcass traits in Muzaffarnagari sheep and its Corriedale half breeds. Indian J Anim Sci, 51(11): 1062-1066

Latif MGA and Owen E, 1980. A note on the growth, performance and carcass composition of Texel and Suffolk sired-lambs in an intensive feeding system. Anim Prod, 30(2): 311-314, doi: 10.1017/S0003356100024120

Lawrie RA, 1998. Lawrie's Meat Science. 6th edn. Pergamon Press Plc, Headington Hill Hall, Oxford, England

Mendiratta SK, Kondaiah N, Anjaneyulu ASR and Sharma BD, 2008. Comparisons of handling practices of culled sheep meat for production of mutton curry. Asian-Australas J Anim Sci, 21(5): 738-744, doi: 10.5713/ajas.2008.70511

Mhaske PS, 2010. M.Sc. Thesis on Madgyal sheep submitted to Mhatma Phule Krishi Vidyapeeth, Rahuri. Ahemadnagar, Maharastra, India

Mishra AK, Arora AL, Kumar S, Kumar S and Singh VK, 2007. Improving productivity of Malpura breed by crossbreeding with prolific Garole sheep in India. Small Rumin Res, 70(2): 159-164, doi: 10.1016/j.smallrumres.2006.02.004

Mohanty SC and Mishra M, 1992. Yield, quality and palatability of mutton in Ganjam and Bolangir sheep. Indian J Anim Prod Mgmt, 8(3): 206-209

Mule AD, 2007. M. Sc. Thesis on Deccani sheep submitted to Mhatma Phule Krishi Vidyapeeth, Rahuri, Ahemadnagar, Maharastra, India

Murshed HM, Sarkerb MAH, Rahman SME and Hashem MA, 2014. Comparison of carcass and meat quality of Black Bengal goat and Indigenous sheep of Bangladesh. J Meat Sci Technol, 2(3): 63-67

Muthukumar M, Naveena BM, Babji Y and Sen AR, 2006. Effect of slaughter weight and sex on carcass composition and mutton quality of Nellore sheep. Indian J Anim Sci, 76(5): 413-415

Pan S and Sahoo AK, 2009. The Garole sheep: history, management, production and current status. Use of the FecB (Booroola) gene in sheep-breeding programs, ACIAR Proceedings, pp 32-43

Pan S, Sahoo AK, Tantia MS and Ahlawat SPS, 2004. Garole sheep NATP (MM) on Animal Genetic Resource Biodiversity. West Bengal University of Animal and Fisheries Sciences, Mohanpur and Kolkata, West Bengal and NBAGR, Karnal, Haryana, India

Panneerselvam S, Chandrasekharan V, Devendran P and Kandaswamy N, 2009. Carcass characteristics of Coimbatore sheep. Indian Vet J, 86(8): 810-812

Pohja MS and Niinivaara FP, 1957. Die Bestimmung der Wasserbindung des Fleisches mittels der Konstantdrückmethode. Fleischwirtschaft, 9: 193-195

Rajkumar V and Agnihotri MK, 2005. Carcass and meat quality attributes of Muzaffarnagari lambs reared under intensive and semi-intensive management system. Indian J Anim Sci, 75(10): 1196-1198

Sahana G, Gupta SC and Nivsarkar AE, 2001. Garole: The prolific sheep of India. Anim Genet Resour, 31: 55-63, doi: 10.1017/S1014233900001486

Sanudo AC, Campo MM, Muela E, Olleta JL, Delfa R *et al*., 2012. Carcass characteristics and instrumental meat quality of suckling kids and lambs. Span J Agril Res, 10(3): 690-700, doi: 10.5424/sjar/2012103-670-11

Sen AR and Karim SA, 2010. Carcass and meat quality characteristics of designated indigenous sheep breeds of India. Indian J Anim Sci, 80(4): 362-365

Sen AR, Karim SA and Santra A, 2000. Carcass characteristics of finisher lambs maintained on grazing with concentrate supplementation. Indian J Anim Sci, 70(9): 988-990

Sen AR, Santra A and Karim SA, 2004. Carcass yield, composition and meat quality attributes of sheep and goat under semi-arid conditions. Meat Sci, 66(4): 757-763, doi: 10.1016/S0309-1740(03)00035-4

Tahir MAH, Al-Amin SK and Kadim T, 1985. Carcass characteristics of Arabi ram's slaughtered at different age. Indian J Anim Sci, 55(12): 1099-1103

Trout GR, Thomson BC and Hanrahan BG, 2000. Tenderness of commercially produced Australian emu meat: effect of temperature and pH decline rate. Food Aust, 52 (5): 170-172

Vinaya Babu P, 2013. Evaluation of carcass composition and meat quality characteristics of Local Macherla Brown Sheep. M.V.Sc. Thesis submitted to Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh, India

Watt BK and Merrill AL, 1993. Composition of foods: raw, processed, prepared. Agriculture handbook No 8, U.S. Department of Agriculture: Beltsville, MD, USA

Wilson T, Wu XY, Juengel JL, Ross IK, Lumsden JM *et al*., 2001. Highly prolific Booroola sheep have a mutation in the intracellular kinase domain of bone morphogenetic protein IB receptor (ALK-6) that is expressed in both oocytes and granulosa cells. Biol Reprod, 64(4): 1225-1235, doi: 10.1095/biolreprod64.4.1225

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