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Effect of Feeding Complete Rations with Variable Protein and Energy Levels Prepared Using By-products of Pulses and Oilseeds on Carcass Characteristics, Meat and Meat Ball Quality of Goats

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ABSTRACT : Thirty six pre-weaned Barbari kids at 4 months age were reared on four rations computed using coarse cereal grains and by-products of pulses and oil seeds with Crude Protein (CP) and Total Digestible Nutrients (TDN) of 12 and 55% (Low protein Low energy); 12 and 60% (Low protein High energy); 14 and 55% (High protein Low energy); and 14 and 60% (High protein High energy), respectively. After 180 days on feed, male animals (4×5 = 20) were slaughtered to study the effect of diet on carcass characteristics and meat quality. To asses the effect, if any, of such diet on product quality, meat balls were prepared and evaluated for quality changes when fresh as well as during storage (-20±1°C). Feeding a ration with CP12 and TDN 60% (LH) to kids produced animals with highest slaughter weight (20.3 kg) yielding higher carcass weight and dressing percentage, lean (65.6%) and fat (6.6%) contents with low bone and trim losses. Although total variety meat yield was markedly higher in HL, the non-carcass fat deposition was relatively higher in LH carcasses. The water activity (a_w) of fresh goat meat ranged from 0.994-0.995 and total cholesterol 72.8-90.5 mg/100 g meat. The pH was high in HL and HH meat resulting in decreased ($p\leq0.05$) extract release volume (ERV). Meat balls were prepared using meat obtained from goats fed different rations (treatments) and stored at -20±1°C. They were evaluated on day 0 and months 1, 2, 3, 4 for physicochemical, microbiological and organoleptic changes. Overall moisture (%), a_w, TBA number and pH value were 67.9, 0.987, 0.17, 6.6 respectively and were not affected by treatments except pH that was significantly ($p\leq0.01$) lower on LH. As the storage period advanced moisture, pH, a_w and TBA number increased irrespective of treatments. Feeding various diets had no marked effect on microbial load of meat balls but with increasing storage period Standard Plate Count (SPC) and psychrotrophs declined ($p\leq0.01$). Treatment LL and LH produced meat balls with better flavour. (**Key Words :** Goats, Complete Ration, Carcass Characteristics, Meat Balls and Quality)

INTRODUCTION

Goats in India are reared on the concept of "zero input" by browsing/grazing on community lands, pastures, barren lands and harvested crop field with little or no supplementation. Prevailing management practices do not ensure adequate growth rate and slaughter weight. Kids of large frame size breed's like Jamunapari and Beetal seldom achieve 25 kg live weight at 9-12 months of age when they are marketed for slaughter. The carcass weight varies from 6-12 kg, majority falling below 10 kg (Agnihotri and Rajkumar, 2001) as against 14-16 kg in Boer, Angora and Feral goat crosses (Dhanda et al., 1999a). Average daily gain improves in response to increase in intake of either protein or energy (Bhuyan et al., 1996). In spite of the fact that country is endowed with 123 million goats, second highest to China in the World, goats (FAO, 2000) contribute little over 11.0% (0.48 millions tones) to total meat production. Major contribution (73%) of meat comes from cattle, buffalo, pigs and for that preference is limited due to socio-religious factors. In the recent past demand for goat meat and its products has increased, as it is the major source to produce preferred meat. Domestic market price of chevon ranges from Indian National Rupees (INR) 90-100/kg and is spiraling up continuously (Kumar et al., 2002).

There are 20 defined breeds of goat in India (Acharya, 1992). The importance of goat farming has increased due to their fast economic return. Goats provide more meat and milk per unit live weight per year than cattle, sheep and camels. Barbari goats are one of the most promising

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Table 1. Ingredients composition of different treatment rations and design of experiment

Ingredients (%)	CP (%)**	TDN (%)***	LL	LH	HL	HH
Maize (*Zea mays*)	11.1	89.0	-	7.2	-	4.8
Pearl millet (*Pennisetum typhoids*)	11.8	87.0	3.2	8.0	-	-
Sorghum (*Sorghum bicolor*)	15.1	86.0	-	-	2.8	6.8
Mustard (*Brassica compestris*) cake	37.1	69.0	5.2	-	8.0	-
Sesame (*Saesamum indicum*) cake	37.7	77.0	-	6.0	-	9.2
Linseed (*Linum usitalissimum*) cake	41.2	75.0	-	4.8	8.0	10.0
Pigeon pea (*Cajanus cajan*) chips	14.5	64.3	8.8	3.6	10.4	8.0
Bengal gram (*Cicer arietinum*) chips	11.8	61.3	6.8	3.2	-	-
Wheat bran	10.2	62.0	14.8	2.0	9.6	-
Rice polish	7.1	70.0	-	4.0	-	-
Mineral/vitamin mix*			0.8	0.8	0.8	0.8
Common salt			0.4	0.4	0.4	0.4
Pigeon pea straw	10.1	45.0	60	60	60	60
Total	-	-	100	100	100	100
CP %	-	-	12.0	12.0	14.0	14.0
TDN %	-	-	55.4 = 55	59.9 = 60	56.6 = 55	59.9 = 60
Number of kids			9(5♂+4♀)	9(5♂+4♀)	9(5♂+4♀)	9(5♂+4♀)
Age (days)			122±3.6	125±3.1	119±3.6	122±2.2
Initial body weight (kg)			9.1±0.5	9.3±0.7	9.3±0.7	9.2±0.5
Average daily gain (ADG) (g)			53.6±4.3	57.9±5.1	57.1±3.8	62.9±5.1

* Each kg of mineral/vitamin mix consisted of: copper (312 mg), cobalt (45 mg), magnesium (6 g), iron (1.5 g), zinc (2.13 g), iodine (156 mg), selenium (10 mg), manganese (1.2 g), calcium (247.34 g), phosphorous (114.68 g), sulphur (12.20 g), sodium (5.8 mg), potassium (48.05 mg), vitamin A (6,25,000 IU), vitamin D_3 (62,500 IU), vitamin E (250 mg) and nicotinamide (1 g).
** CP% estimated as per AOAC (1984) by Kjeldhal method.
*** TDN% calculated values.

indigenous meat goat breeds (Agnihotri and Pal, 1997) because it is very prolific, attains early maturity, has low kidding interval and better growth rate than other Indian breeds (Paramasivam et al., 2002). It is gaining popularity country wide for meat production as it performs well under stall-fed conditions. Nutrition and management are considered crucial in determining the quantity, quality and economics of meat production. Need has been felt to develop goat rations that promote higher growth rate; are economical and ingredients used are less competitive with large ruminant feeds (Dutta et al., 2004). One such possibility is utilizing locally available crop by-products.

High concentrate feeding of sheep has been shown to shorten the time to slaughter, increased dressing percentage and improve carcass quality and sensory panel tenderness evaluations (McClure et al., 1994). Few studies have reported on the effect of concentrate feeding of goats. Shahjalal et al. (1992) observed that high-energy diets increased carcass weight, dressing percentage, *longissimus* area, dissected lean and chemical fat weight of British Angora goats. Diet/ Management treatment had no influence on sensory panel evaluation of roasted loins and Warner-Bratzler shear evaluation of grilled leg slices of goat (Johnson and McGowan, 1998).

Main objective of this study was therefore, to asses, how feeding densified ration computed using by-products of pulses, oil seeds along with coarse cereal grains having different protein and energy ratio can influence the attributes of meat produced from Barbari male kids under intensive system and meat balls processed thereof.

MATERIALS AND METHODS

Location of the study

The study was conducted at Central Institute for Research on Goats located in Makhdoom village of Mathura District, Utter Pradesh, India (27°10’ N, 78°02’ E and 169 m above MSL). Geologically the Institute land comes under Jamuna alluvial soil category. The climate is semi-arid. Temperature ranges between 6°C in winter to as high 45°C in summer. Annual average rainfall is 750 mm and spread over a period of 50-60 days. Monsoon arrives in mid July and remains active till mid -September. Deep tube wells provide saline water.

Animals and rearing

Thirty six purebred Barbari goat kids born during October were weaned at the age of three months and kept under general feeding for another one month. For experiment kids were divided into four groups and kept under intensive management system on four dietary regimens:

Low protein low energy (LL) with CP 12%, TDN 55%;
Low protein high energy (LH) with CP 12%, TDN 60%;
High protein low energy (HL) with CP 14%, TDN 55%, and

Table 2. Composition of dry spices mixture

Spices	Composition (%)
Clove	5
Black pepper	25
Large cardamom seeds	20
Cinnamon bark	5
Small cardamom seeds	5
Cumin seeds	10
Shia zira (*Carum carvi*) seeds	10
Red pepper powder	20
Total	100

High protein high energy (HH) with CP 14%, TDN 60%. The ingredient composition along with CP % and TDN % of rations (mash) used for feeding is given in Table 1. Pigeon pea and Bengal gram chips and *Cajanus* straw were the basal material in these rations. Concentrate mixture in the form of mash was offered at 2% of the body weight along with *Cajanus* straw *ad libitum* and fixed quantity of seasonal green fodder (350 g/day) to prevent vitamin-A deficiency. Roughage to concentrate ratio was maintained at a minimum of 60:40 in the composite ration. Body dimensions, carcass measurements, carcass and non carcass traits, carcass physical and meat chemical compositions were recorded to study the effect of different CP and TDN levels on these traits with ultimate aim to asses meat production potential of the animals.

Slaughtering

After 180 days on feed, five male animals were slaughtered from each group (4×5 = 20), after 16-18 h fasting and free access to potable drinking water. Weight of the animals was recorded prior to slaughter. Body measurements of the animals were also recorded following standard procedures (Prasad and Sinha, 1991). Bleeding, skinning and evisceration were done as per the standard commercial procedures. Post-fasted live animal measurements and carcass measurements after dressing were taken as per Prasad and Agnihotri (1992). Warm carcass weights with kidneys, pelvic and kidney fat removed were collected and weighed to the nearest of 1 g. Weight of edible and inedible offal's to the nearest of 1 g, hot carcass weight, empty body weight to the nearest of 5 g, and dressing percentage were recorded as described by Dhanda et al. (1999a).

Carcass characteristics

Immediately after dressing chest circumference (across the posterior to the scapula -humerus joint), carcass length (measured from the point of the hock to the point of the shoulder, anterior to the scapula-humerus joint) and leg circumference (across the stifle area of the right leg) of carcasses hanging with achilles tendon were recorded using a measuring tape to the nearest of 1mm. After taking measurements carcasses were washed thoroughly using tap water. Eye muscle area was recorded on the cut surface of *longissimus* muscle at the interface of 12th and 13th rib on either side of the carcass divided into fore and hindquarters after tracing on tracing paper. Traced area was measured using compensating planimeter (Fuji Corona, 027, Japan) with optical tracer and reported in cm^2. GR measurement was taken 11 cm from midline on 12th rib (Prasad and Agnihotri, 1992). The dressed carcasses were split along the mid-line manually and left halves were jointed into five primal cuts: leg, loin, rack, neck and shoulder, breast and shank as per the specifications of Indian Standards Institution as reported by Prasad (1981). The weight of individual cuts followed by dissection within 2.5 h after slaughter into lean, bone and total fat was recorded to the nearest of 1 g and reported as percentage. Right side of the carcass was trimmed, chopped and packed in HDPE 500 g packets for sale. Total trim and packed meat weight were recorded and subtracted with right side total cut weight to get the loss through evaporation and reported as percentage.

Analyses of meat samples

The separated thoracic portion of *longismus thoracis* 130-150 g from each carcass was collected, minced and used after 24 h of storage (-15±2°C) for analysis of moisture, protein, fat and ash (AOAC, 1984). Water holding capacity was determined taking 0.2-0.4 g of minced meat using the filter paper (Whatman filter paper No.1) press method (Trout, 1988). The extract release volume (ERV), pH, titrable acidity (pH_t) and thiobarbituric acid (TBA) number of meat were estimated as per the method described by Strange et al. (1977).

Cholesterol content of minced meat was determined using cholesterol test kit (Span Diagnostics Ltd., India) except that instead of blood serum, lipid extract was used (Rajkumar et al., 2004).

Storage of meat

Knife separated lean, packed in high-density polyethylene (HDPE, WVTR 5 g/m^2 per 24 h at 38°C and 90% RH) bags was stored at -20±2°C till further use. Partially thawed meat on the day of experiment was minced using automatic meat mincer by passing through five mm plates (Talleres Ramon Make P-22, Barcelona) before use.

Dry and green spices mixture

Dry spices mixture was prepared (Table 2) and filled in stainless steel jars. It was stored in cool and dry place and used within two weeks. For preparation of green spices mixture, peeled and washed onion, ginger and garlic in ratio of 3:1:1 were finely chopped and ground. Mixture thus obtained was packed in HDPE and stored at -20±2°C and

Table 3. Body and carcass measurements (means±SE) of buck kids of Barbari goats fed complete rations varying in energy and protein levels

Traits	LL	LH	HL	HH
Slaughter weight (kg)	18.5±1.9	20.3±2.1	18.8±1.8	17.3±1.2
Body measurements (cm)				
Body length	58.6±2.8	59.7±2.0	59.6±2.3	56.2±1.9
Height	57.2±2.4	58.4±1.8	55.9±2.1	55.8±1.9
Heart girth	56.7±2.2	59.6±2.0	58.3±1.6	56.2±1.5
Paunch girth	59.0±2.6	60.4±1.0	60.4±3.6	57.6±2.8
Loin width	11.3±0.6	12.1±0.5	11.7±0.5	11.6±0.4
Leg circumference	25.8±1.3	27.8±1.1	26.2±1.1	25.0±2.8
Carcass measurements				
Carcass loin width (cm)	9.9±0.5	10.48±0.5	10.0±0.3	10.2±0.4
Chest circumference (cm)	53.4±2.2	57.5±1.7	55.8±1.5	52.2±1.6
Leg circumference (cm)	21.6±0.8	25.7±1.2	23.8±1.0	22.8±2.6
Eye muscle area (cm^2)	8.1±0.8	11.0±1.0	8.4±1.2	7.6±0.7
GR measurement (mm)*	2.3±0.3^{a}	2.4±0.4^{a}	1.8±0.4^{a,b}	1.4±0.2^{b}
Fat thickness**				
Back fat (mm)	1.7±0.2	1.6±0.2	1.7±0.4	1.5±0.1
Breast fat (cm)	2.0±0.1	2.2±0.1	2.2±0.2	2.1±0.5

Means±SE bearing uncommon superscripts within rows differ (p≤0.05).
* GR measurement is the soft tissue thickness, measured 11 cm from midline on 12th rib of the carcass using vernier caliper.
** Fat thickness measured with vernier caliper.

used within two weeks.

Recipe and preparation of meat balls

The separated lean obtained from the carcasses of 4 groups of animals was packed in HDPE bags and stored at -15±2°C till used for meat balls preparation. Before use meat was thawed overnight at 4±1°C. The meat balls using already standardized recipe and processing techniques was prepared from all four treatments and evaluated on day 0 and month 1, 2, 3, 4 for physicochemical, microbiological and organoleptic changes.

Meat balls were prepared using standard recipe (Agnihotri, 2002) except, instead of 5.0% vegetable oil 2.5% goat fat was used. To minced meat, 2.5% minced goat fat, 1.5% common salt, 6.0% green spices, 1.5% dry spices mixture, 3.0% refined wheat flour, 0.01% sodium nitrite, 0.3% TSPP and 20.0% chilled water were added. Firstly minced meat with common salt was chopped (Model type K 20, Seydelmann, Germany) for 2 min using 6 cutters knives. Sodium nitrite, tetra sodium pyrophosphate (TSPP) were dissolved in 70 ml lukewarm water and mixed, followed by addition of other ingredients and chopped for 3 min. Raw meat balls of about 40.0 g were hand molded wearing gloves and cooked in boiling water in stain less steel vessel till started floating (internal temperature of 80±2°C). Weight of raw and cooked cooled meat balls was recorded to calculate percent cooking yield. Meat balls (average weight 39 g) were packed and heat-sealed in HDPE (WVTR 5 g/m^2 per 24 h at 38°C and 90% RH) bags aerobically 8-10 meat balls in each and stored (-20±1°C) for further study.

Analyses of meat balls

Changes in physico-chemical, microbiological and sensory traits of meat balls on day 0 and months 1, 2, 3 and 4 of storage were studied. Each time one packet from each treatment was randomly taken out. Samples from each packet were taken for microbiological examination first, followed by physico-chemical traits. Remaining parts of samples were used for sensory evaluation. Evaluation of freshly prepared meat balls was done and taken as day 0 value.

Physico-chemical characteristics

Moisture content in balls was determined (Konecko, 1979). Water activity (a_w) of meat balls was directly estimated using water activity meter (AquaLab, Model CX-3TE, Decagone Devices, Inc., USA). Final readings were recorded when three consecutive readings were same. The pH was determined (Agnihotri and Pal, 1997) by triturating 10.0 g of samples with 90 ml of distilled water and recorded by digital pH meter (Systronics, μ pH system 361). Thiobarbituric acid (TBA) number was estimated as per the method described by Strange et al. (1977). The OD at 532 nm was taken using UV visible spectrophotometer (Model Cintra - 5, GBC equipment, Australia) and reported as TBA number. Cholesterol content of fresh cooked meat balls was determined using cholesterol test kit (Span Diagnostics Ltd., India) as described earlier.

Microbiological analyses

For microbiological analyses, a representative 10 g mashed meat balls sample was withdrawn and homogenized

Table 4. Carcass characteristics, composition and carcass components of (means±SE) of buck kids of Barbari goats fed rations with varying energy and protein levels

Traits	LL	LH	HL	HH
Carcass traits				
Hot carcass weight (kg)	8.0±0.9	9.4±1.0	8.1±1.1	7.8±0.6
Fore quarter % (Based on slaughter weight)	23.9±0.7	26.0±0.5	22.9±2.2	24.5±0.7
Hind quarter % (Based on slaughter weight)	19.1±0.6	20.3±0.3	19.6±0.6	20.3±0.8
Dressing percentage based on empty body weight	52.5±1.1	54.6±0.6	53.1±1.8	53.1±2.0
Based on slaughter weight	42.9±0.9	46.3±0.5	45.2±0.6	44.7±0.9
Carcass physical composition (%)				
Meat	64.0±1.1	65.6±0.6	65.8±0.7	64.5±2.6
Fat	6.6±1.4	6.6±1.6	5.7±1.3	5.4±0.7
Bone	25.2±0.4	23.5±1.0	24.9±1.1	25.0±1.0
Trim	1.2±0.2	1.0±0.3	1.1±0.2	1.9±1.0
Evaporative weight loss	3.0±0.4	2.6±0.3	2.5±0.2	2.2±0.2
Carcass components (% slaughter weight)				
Blood	3.8±0.1	4.0±0.2	3.9±0.3	4.1±0.1
Head	6.6±0.2	6.7±0.3	7.4±0.6	7.0±0.3
Fore cannons	1.4±0.04	1.3±0.03	1.3±0.06	1.3±0.05
Hind cannons	1.0±0.03	1.0±0.04	1.0±0.02	1.0±0.08
Skin	6.5±0.3	7.3±0.2	6.4±0.4	7.2±0.7
Lungs and trachea	1.4±0.1	1.2±0.1	1.3±0.1	1.3±0.1
Uro-genital tract	0.7±0.1	0.5±0.1	0.4±0.1	0.7±0.1
Gastro-intestinal tract (empty)*	8.7±0.3	7.4±0.8	8.1±0.7	7.9±0.9
Ingesta	18.2±1.1	15.3±0.4	18.5±1.3	17.7±1.6
Variety meat (g)				
Testes	145.2±22.3	155.0±15.7	138.0±17.9	137.0±7.0
Pancreas	23.0±2.0	21.6±5.3	26.0±4.0	24.0±2.9
Spleen	19.0±1.9	19.0±4.6	21.0±3.7	21.0±3.3
Kidneys	57.0±5.1	51.0±5.1	56.0±4.1	51.0±5.6
Liver	308.0±31.9	312.0±25.8	346.0±26.9	326.0±19.1
Heart	76.0±8.9	66.0±6.8	86.0±12.6	75.0±4.5
Fat (g)				
Inguinal (cod)	70.0±14.9	69.0±15.8	70.0±13.7	47.0±7.7
Omental	196.0±30.4	217.0±63.6	129.0±55.8	168.0±31.6
Kidney (perinephric)	145.0±26.6	155.0±50.8	106.0±47.2	114.0±22.3
Mesenteric	107±17.9	116.0±13.7	125.0±9.7	114.0±5.3

No significant difference between treatments ($p \geq 0.05$).

* Gastro-intestinal tract (empty), weighed after emptying the stomach and intestinal contents.

(Model, PT-MR-2100, Kinematica AG, Switzerland) aseptically using 90 ml 0.1% sterile peptone water (Agnihotri and Pal, 2000) and serial dilutions were made using 0.1% sterile peptone water. Standard Plate Counts (SPC) were enumerated on duplicate pour plates of plate count agar (PCA, Hi-Media Laboratories, M 091, Mumbai, India) which were incubated at 37°C for 48 h; psychrotrophic bacteria counts on pour plates of plate count agar (PCA, Hi-Media, M 091) which were incubated at 5±1°C for 10-12 days; coliforms bacteria counts on pour plate of Violet Red Bile Agar (VRBA, Hi-Media, M 049) which were incubated at 37°C for 48 h. Freshly prepared acidified potato dextrose agar was used to determine yeast and mould counts by incubating plates at 25±2°C for 7-8 days. Colonies were counted and expressed as $\log_{10}$ CFU/g of meat balls. The enumeration procedures as described in ICMSF (1978) were followed.

Sensory evaluation

Meat balls were subjected to organoleptic evaluation by minimum of 6 semi-trained panelists using 9 point hedonic scale (9 = like extremely; 1 = dislike extremely) (Pal and Agnihotri, 1996). Meat balls at a temperature of 30-35°C were assessed under incandescent light for their appearance, color, flavour, juiciness, texture and overall acceptability. Drinking water was provided after tasting each sample to cleanse the palate.

Statistical analysis

Analyses of variance was done to find the effect of

Table 5. Saleable meat yield, retailing loss and carcass primal cuts composition

Parameters	LL	LH	HL	HH
Saleable meat (%)	91.3±1.1	93.0±0.8	90.3±1.0	92.2±0.4
Retailing loss (%)				
Trim	6.1±1.0	4.7±0.5	6.9±0.7	6.1±0.4
Evaporation	2.7±0.3	2.3±0.4	2.9±0.2	1.7±0.4
Primal cuts weight and composition*				
Leg				
Cut weight	1.2±0.1	1.4±0.1	1.2±0.2	1.2±0.1
Lean	69.7±0.9	70.9±0.4	70.9±1.1	71.4±1.0
Bone	24.0±0.5	22.5±0.7	24.7±0.9	25.1±1.8
Total fat	3.6±0.6	4.4±0.3	2.3±0.7	3.6±0.2
Loin				
Cut weight	0.6±0.1	0.7±0.1	0.6±0.1	0.5±0.1
Lean	69.5±3.2	66.8±2.8	69.9±2.8	74.8±3.2
Bone	19.9±1.4	18.5±1.8	17.9±1.3	16.1±1.5
Total fat	7.4±1.8	13.1±4.0	8.0±2.8	11.0±5.9
Rack				
Cut weight	0.6±0.1	0.7±0.1	0.5±0.1	0.6±0.0
Lean	65.7±2.3	64.3±1.0	65.0±2.9	62.7±0.6
Bone	22.7±1.8	24.8±2.3	27.8±1.6	27.4±1.0
Total fat	8.7±4.0	6.4±1.3	3.1±1.3	6.6±1.9
Neck and shoulder				
Cut weight	1.1±0.2	1.3±0.1	1.0±0.1	1.0±0.1
Lean	58.4±2.6	64.8±1.2	63.0±2.0	61.8±1.7
Bone	25.1±0.7	22.6±1.1	24.7±1.4	25.5±2.1
Total fat	8.8±1.6	7.41±1.2	7.05±0.5	7.83±0.7
Breast and shank				
Cut weight	0.8±0.1	0.9±0.1	0.7±0.1	0.7±0.1
Lean	57.8±0.9	62.1±2.1	61.5±0.9	64.1±1.2
Bone	31.9±1.8	27.1±1.2	30.4±1.7	30.8±1.6
Total fat	7.7±1.6	8.9±3.2	3.5±1.1	1.9±0.7

No significant difference between treatments ($p\geq0.05$).

* Except cut weight, which is in kg, lean, bone and total fat (subcutaneous+intermuscular) are in percentages.

treatments on carcass and meat quality traits including effect of storage period and their interactions on various quality traits of meat balls. Differences between means were tested by critical difference (Snedecor and Cochran, 1968).

RESULTS

Influence of feeding varying levels of protein and energy on body and carcass measurements

The means and standard errors for the influence of feeding varying levels of energy and protein on body and carcass measurements are presented in Table 3. Slaughter weight varied from 17.3 to 20.3 kg. Among the 4 treatments, LH kids produced non-significantly higher slaughter weight and body frame size. Protein and energy levels in diet did not significantly affect any of the carcass measurements studied except LH kids that after slaughter produced carcass with more eye muscle area, with the exception of GR measurement. LH kids deposited more soft tissue as revealed by higher ($p\leq0.05$) GR measurements than HH (Craddock et al., 1974). Kids under LH attained highest slaughter weight (20.3 kg) having higher body dimensions. Lowest values for the corresponding traits, though not significant ($p\geq0.05$), were recorded in kids under HH.

Influence of feeding varying levels of protein and energy on carcass traits, variety meat, fat deposition and saleable meat yield

Feeding varying levels of protein and energy did not influence hot carcass weight. Hot carcass weight varied from 7.8 to 9.4 kg (Table 4). There were no significant differences between treatments for carcass traits, dressing percentage, carcass physical composition, variety meat yield and fat deposition. However, LH kids produced highest hot carcass weight (9.4 kg), fore quarter (26%) and hind quarter (20.3%) yield on slaughter weight basis. Similar trend was observed for dressing percentage both on

Table 6. The chemical composition and physico-chemical properties of longismus thoracis muscle (means±SE) of buck kids as affected by dietary treatments

Parameters	LL	LH	HL	HH
Chemical composition[1]				
Moisture	75.4±1.3	73.0±1.4	74.8±0.6	72.6±0.8
Ether extract	04.6±0.3	05.5±0.9	04.0±0.4	05.4±0.8
Crude protein	18.7V0.5	20.0±0.3	18.8±0.4	19.6±0.4
Ash	01.2±0.5	01.3±0.1	01.3±0.1	01.2±0.1
Total cholesterol (mg/100 g)	89.3±6.8	90.5±7.6	72.8±7.1	86.4±6.3
Physico-chemical properties				
Water activity (aw)	0.995±0.0	0.994±0.0	0.995±0.0	0.994±0.0
ERV* (ml)	37.1±3.5^{a,b}	27.9±3.8^{a}	28.8±5.3^{a,b}	38.3±2.3^{b}
pH	05.4±0.1^{a}	05.5±0.1^{a,b}	05.6±0.0^{b}	05.2±0.1^{c}
pHt**	03.9±0.1	03.8±0.1	03.9±0.2	03.86±0.2
WHC*** (%)	64.6±3.7	65.8±2.0	67.3±4.2	68.6±3.8

Means±SE bearing uncommon superscripts within rows differ (p≤0.05).
[1] Chemical composition expressed as percentage of fresh muscle weight.
* Extract release volume. ** Titrable acidity. *** Water holding capacity.

Table 7. Cooking yield and cholesterol content of goat meat balls

Traits	Cooked meat balls			
	LL	LH	HL	HH
Batter				
pH	6.5±0.04	6.4±0.01	6.5±0.02	6.4±0.03
Moisture	68.1±0.2	68.5±0.3	67.7±0.1	66.8±0.2
Ether extract	12.3±1.4	10.0±0.3	11.0±0.2	11.5±0.2
Meat balls				
Cooking yield (%)*	94.7±0.2	97.2±0.3	98.4±0.1	97.8±0.2
Ether extract	10.1±1.5	10.0±0.6	11.0±0.2	12.2±0.2
Ash	2.7±0.1	2.2±0.3	2.3±0.1	2.3±0.1
Total cholesterol (mg/100 g) **	75.0±6.1	80.6±5.9	81.2±4.2	89.6±7.8

No significant difference between treatments (p≥0.05).
* Individual weights of 50 meat balls both raw, after cooking were recorded to calculate percent yield.
** Five samples from each treatment were analysed.

empty body weight (54.6 kg) and slaughter weight basis (46.3 kg). LH kids produced carcass with more lean (65.6%) and fat (6.6%) with minimum bone content and trim losses. Less carcass fat deposition was observed in the HL and HH group. HL kids produced highest total variety meat (673 g). Liver contributed more for variety meat yield of HL and HH than for LL and LH bucks. Whereas, non-carcass fat (557 g) deposition was relatively more in LH carcasses. Omental and perinephric fat contributed more for non-carcass fat deposition of LH carcasses. As evident from Table 5, saleable meat yield was non-significantly more from the carcasses of LH due to comparatively low trim (4.7%). Irrespective of the cuts, primal cuts weight of LH kids was more with lowest bone content. The fat percentage in cuts also revealed increasing trend.

Influence of feeding varying levels of protein and energy on carcass chemical composition and meat physico-chemical properties

The means and standard errors for the effect of varying energy and protein level on chemical composition and physico-chemical properties of *longismus thoracis* muscle are presented in Table 6. There were no significant differences between dietary treatments in muscle chemical composition. Total cholesterol of meat ranged from 72.8 to 90.5 mg/100 g meat. HL produced meat with lower extractable fat (4.0%) and total cholesterol (72.8 mg). However, LH produced meat with higher ether extract (5.5%) and total cholesterol (90.5 mg). Barring ERV and muscle pH no significant effect of diet having different protein and energy level was observed on physico-chemical properties. The meat from kids of HH revealed significantly higher (p≤0.05) ERV (ml) due to significantly lower pH (p≤0.05) value. The a_w of meat ranged from 0.994 to 0.995. Higher WHC (%) was observed in the meat obtained from the bucks fed with HH and HL diet and lower from LL and LH kids (Enfalt et al., 1997).

Influence of feeding varying levels of protein and energy on cooked meat balls

Cooked meat balls prepared using meat from the kids fed different diets having varying protein and energy level

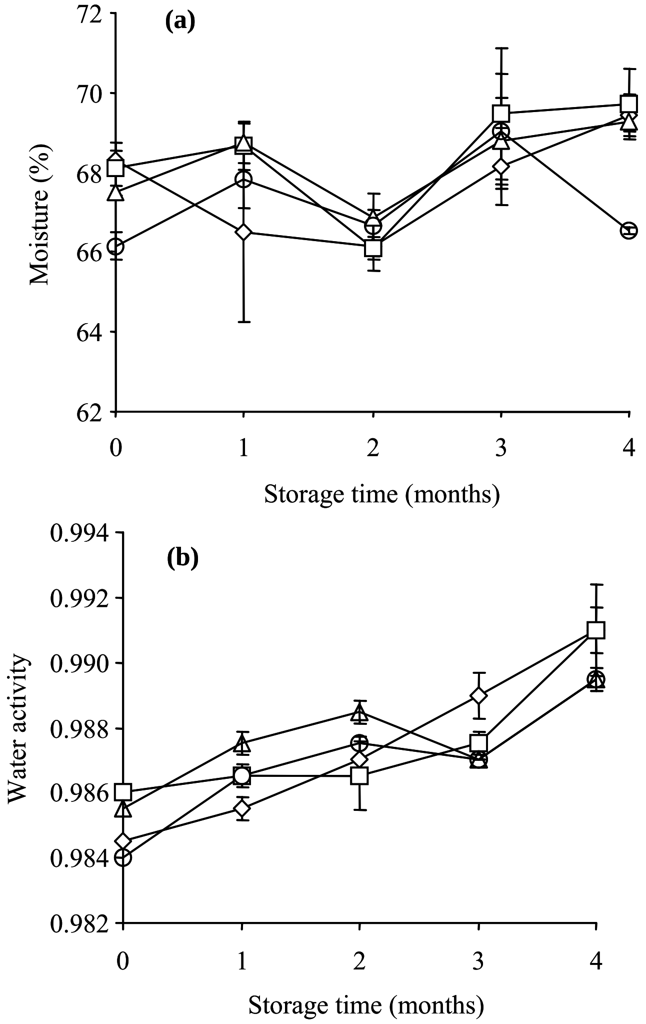

Figure 1. Changes in (a) moisture (%) and (b) water activity (a_w) of meat balls prepared from goat meat fed rations containing 12 CP% and 55 TDN% (LL) (◇), 12 CP% and 60 TDN% (LH) (□), 14 CP% and 55 TDN% (HL) (△), 14 CP% and 60 TDN% (HH) (O) and stored (-20±1°C) for four months. Mean values±SE for two analysis performed in duplicate.

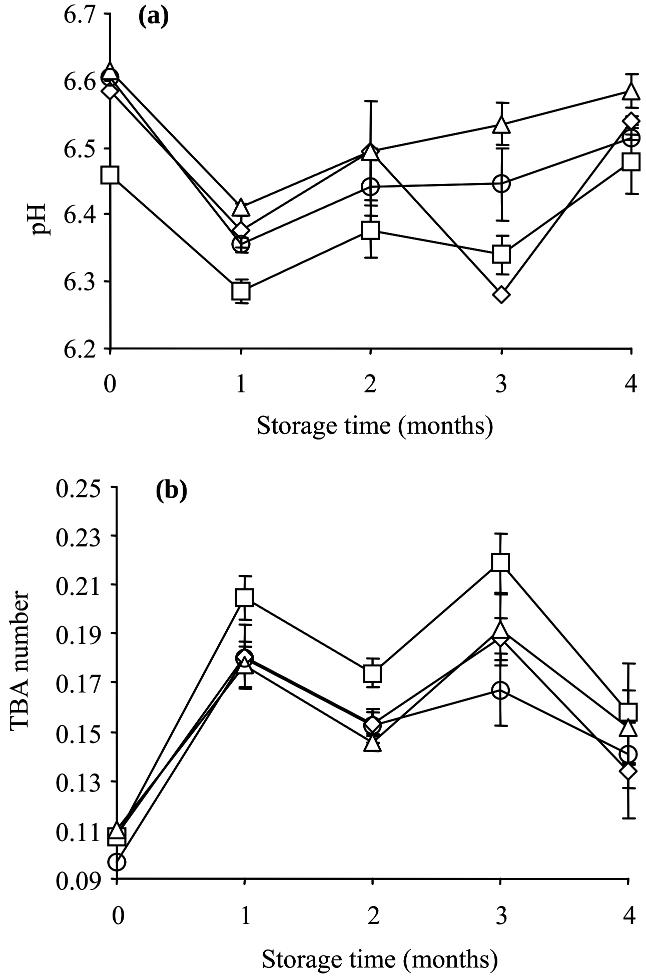

Figure 2. Changes in (a) pH and (b) TBA number of meat balls prepared from goat meat fed rations containing 12 CP% and 55 TDN% (LL) (◇), 12 CP% and 60 TDN% (LH) (□), 14 CP% and 55 TDN% (HL) (△), 14 CP% and 60 TDN% (HH) (○) and stored (-20±1°C) for four months. Mean values±SE for two analysis performed in duplicate.

revealed percent cooking yield ranging from 94.7 to 98.4 and total cholesterol from 75.0 to 89.6 mg/100 g of the product (Table 7). Meat obtained from HH and HL kids, having higher WHC produced meat balls with higher cooking yield. No consistent correlation was observed for meat cholesterol and meat balls cholesterol content prepared under different dietary treatments. Meat balls packed by heat sealing in HDPE bags, stored at -20±1°C were evaluated on day 0 and month 1, 2, 3, 4 for physico-chemical, microbiological and organoleptic changes. Meat balls evaluated on day 0 and month 1, 2, 3, 4 for physico-chemical changes revealed overall moisture (%), a_w, TBA number and pH value 67.9, 0.987, 0.17, 6.6 respectively. Treatment had no significant effect ($p\leq0.05$) on moisture, a_w and TBA number of meat balls. The storage periods affected moisture, a_w and TBA number. As the storage period advanced, values for moisture, a_w and TBA number increased (Figures 1 and 2). The pH value was affected by both, treatments and storage periods and was significantly ($p\leq0.01$) lower (6.34) for LH. Treatment had no significant effect on microbial load of meat balls however, as the storage period advanced, standard plates count (SPC) and psychrotrophs revealed significant decline (Figure 3). The yeast and mould counts that ranged from log 0.3 to 1.6 CFU g^{-1} were not affected due to treatment and period of storage applied in this experiment. Coliforms were not detected in any of the meat ball samples.

Treatment had no significant effect on general appearance, juiciness and overall acceptability of the product but product from HL and HH meat revealed significantly lower ($p\leq0.01$) scores for flavour (6.5) than LL and LH, which revealed little over 7.0 score (Table 8). On

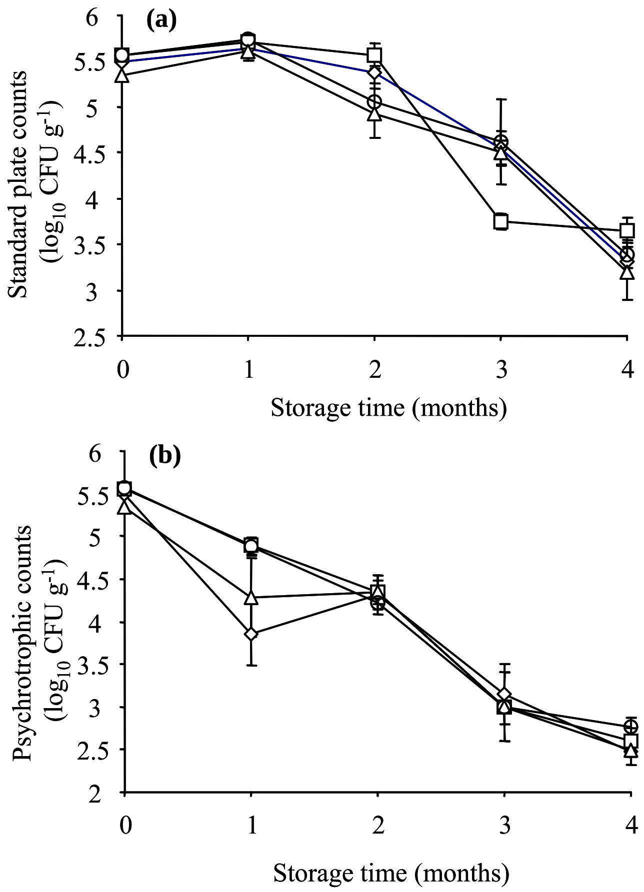

Figure 3. Changes in (a) standard plate counts and (b) psychrotrophic counts of meat balls prepared from goat meat fed rations containing 12 CP% and 55 TDN% (LL) (◇), 12 CP% and 60 TDN% (LH) (□), 14 CP% and 55 TDN% (HL) (△), 14 CP% and 60 TDN% (HH) (○) and stored (-20±1°C) for four months. Mean values±SE for two analysis performed in duplicate.

storage flavour, juiciness and overall acceptability did not reveal significant change barring general appearance, which showed decline ($p\leq0.05$) in scores with the progress of storage.

DISCUSSION

Influence of feeding varying levels of protein and energy on body and carcass measurements

Plane of nutrition affects chevon production and carcass characteristics of goats (Bhuyan et al., 1996). In the present study, feeding low protein and high energy showed positive response to slaughter weight and carcass measurements. Bhuyan et al. (1996) were also of the same opinion that feeding high energy diet increases the body weight in the kids of Beetal and Assam local cross. Reduced energy intake had detrimental effect on slaughter weight, carcass weight, *longissmus* muscle area and yield of both wholesale and retail cuts (Jacobs et al., 1973). In the present study, LH kids had higher body length, height, heart girth, paunch girth, loin width and leg circumference. Consequently, carcass measurements were also recorded to be higher. Low protein diet had produced carcasses with more GR measurement, which is the indication of soft tissue thickness. Craddock et al. (1974) reported that carcass measurements, quality factors and chemical composition of carcass were not affected by changes in protein and energy levels. They also reported that protein measures with low energy in the diets of lambs increased the fat measures. No consistent pattern was observed for fat thickness of kid's carcasses in the present study. Observations of the study were similar to those reported for ram lambs received different energy levels in the diet (Crouse et al., 1978).

Influence of feeding varying levels of protein and energy on carcass traits, variety meat, fat deposition and saleable meat yield

Carcass characteristics, variety meat yield, fat deposition and saleable meat yield are in general agreement with the results reported for same breed except separated fat, which was higher in LL and LH kids but not significant (Agnihotri and Pal, 1997; Pal and Agnihotri, 1999). Increasing energy levels in the diet of lambs usually result in greater fat deposition (Craddock et al., 1974). They also reported that carcass traits, quality factors and chemical composition of carcass were not affected by changes in protein and energy levels. However, higher carcass weight for LH could be due to higher energy in the ration. Similar trend could be attributed to percent knife separable meat physical composition. High concentrate feeding of sheep has been shown to shorten the time to slaughter, increased dressing percentage and improve carcass quality (McClure et al., 1994). Shahjalal et al. (1992) observed that high-energy diets increased carcass weight, dressing percentage, longissimus area, dissected lean and chemical fat weight of British Angora goats. Total variety meat yield of 673 g was recovered from HL kids, which may be due high protein in the diet. As protein level increases with low protein in the diet total fat deposition in the body decreases (Craddock et al., 1974). In the present study, total non carcass yield was higher (557 g) for LH and lower (430 g) for HL kids, which also been demonstrated by other workers for lambs (Craddock et al., 1974). The result of the present study confirms that feeding varying levels of protein and energy had no significant effect on percent contributions of visceral organs. Genotype also had no significant effect (Dhanda et al., 1999), but breed type as a proportion of live weight (Gibb et al., 1993) had significant influence on percent visceral organs of goats. Feeding varying levels of protein and energy also had no significant effect on saleable meat yield, retailing loss and primal cuts composition.

Table 8. Organoleptic scores (mean±SE) of goat meat balls as influenced by treatment and storage period

Traits	Storage months	LL	LH	HL	HH	Storage period mean±SE
General appearance	0	7.7	7.6	7.9	7.7	7.7±0.1^{ac}
	1	7.4	6.9	7.2	6.4	7.0±0.2^{ab}
	2	6.0	6.9	6.6	7.0	6.6±0.2^{b}
	3	7.1	7.0	7.2	7.1	7.1±0.1^{ab}
	4	7.0	7.2	7.9	7.1	7.3±0.2^{ab}
	Treatment mean±SE	7.04±0.71	7.11±0.29	7.36±0.13	7.07±0.25	7.14*
Flavour	0	7.22	7.56	7.33	6.44	7.14±0.24
	1	7.33	7.22	6.33	6.78	6.92±0.23
	2	6.89	6.89	6.33	6.00	6.53±0.22
	3	7.00	7.00	6.11	6.33	6.61±0.23
	4	6.78	6.78	6.33	6.78	6.67±0.11
	Treatment mean±SE	7.04±0.71^{A}	7.09±0.10^{A}	6.49±0.14^{B}	6.47±0.22^{B}	6.77*
Juiciness	0	7.33	7.56	6.67	6.89	7.11±0.20
	1	7.11	6.33	6.44	6.33	6.56±0.19
	2	5.89	6.78	7.44	6.44	6.64±.33
	3	6.89	7.00	6.56	6.11	6.64±0.20
	4	6.56	6.44	6.44	6.22	6.42±0.07
	Treatment mean±SE	6.76±0.71	6.82±0.25	6.71±0.22	6.40±0.19	6.67*
Overall acceptability	0	7.00	7.22	7.00	6.78	7.00±0.09
	1	7.56	6.89	6.78	6.89	7.03±0.18
	2	6.89	7.22	7.22	6.89	7.06±0.10
	3	7.22	7.11	6.33	6.33	6.75±0.24
	4	6.89	7.22	6.89	7.22	7.06±0.10
	Treatment mean±SE	7.11±0.71	7.13±0.13	6.84±0.06	6.82±0.15	6.98*

Means±SE bearing a common superscript in a column (small letters) for general appearance ($p \le 0.05$) and in a row (capital letters) for flavour do not differ ($p \le 0.01$).
* Overall mean for a particular trait.

Influence of feeding varying levels of protein and energy on carcass chemical composition and meat physico-chemical properties

The observation of proximate chemical composition of the present study was similar to that reported by Dhanda et al. (1999b) in various New Zealand cross breed goat kids at similar carcass weights. In the present study, LH (5.5%) and HH (5.4%) group muscle had higher extractable fat than LL (4.6%) and HL (4.0%) group. In general extractable fat of *longismus thoracis* muscle was higher than reported by other workers for different goat breeds (Hogg et al., 1992; Dhanda et al., 1999b). The difference might be due to different breeds studied by different workers. In this study, feeding variable protein and energy had no significant effect on proximate composition of muscle. Total cholesterol of *longismus thoracis* muscle ranged from 72.8 to 90.5 mg /100 g meat. Cholesterol content of muscle was higher than the goat *l. dorsi* and *B. femoris* muscle, which was 57.80 and 69.50 respectively as reported by Park et al. (1991). This difference might be due to the different breed used for the study. The water activity of muscle ranged from 0.994 to 0.995 and did not differ significantly. In fresh sheep muscle similar values have been reported by Rao and Sreenivasamurthy (1986). In the present study, muscle pH was in the range of 5.2-5.6. There was significant difference in muscle pH and ERV. The pH of meat influences both ERV and WHC. Higher the pH lesser is ERV and more is WHC of meat (Enfalt et al., 1997). Higher WHC of meat generally reduces the cooking loss in meat products prepared using such meat. Lower WHC of LL group produced meat balls with lower cooking yield and vice versa.

Influence of feeding varying levels of protein and energy on cooked meat balls

The percent cooking yield of meat balls prepared using meat from the bucks fed different diets having varying protein and energy level was in the range of 94.7-98.4. Padda et al. (1989) found a cooking yield of 83-94% for meat balls containing varying levels of vegetable extenders in the composition. Variation in the yields might be due to level of extenders used in the composition of meat balls. In the present study, meat balls prepared using meat of LL group had lowest percent cooking yield. The cooking yield of meat balls is in general agreement with findings on other goat meat products as reported by Agnihotri and Pal (1997), Pal and Agnihotri (2000). Total cholesterol content of meat balls varied from 75.0 to 89.6 mg/100 g and is in the range reported for cooked goat meat leg slice and lower than cooked goat carcass composite (Johnson and McGowan, 1998). Rajkumar et al. (2004) reported, 134.84 mg/100 g total cholesterol in goat meat patties. Variation in the total cholesterol content might be due to type of cooking method and product used for the study.

Quality changes under storage of less than -10°C are of biochemical origin like drying and oxidation (Laack, 1994). Overall mean moisture (%), a_w, TBA number and pH of the product was 67.89, 0.987, 0.166 and 6.46. In the present study, as the storage period advanced moisture and a_w of meat balls increased except a slight decline in the second month of storage for moisture. Fresh goat meat patties had a_w, moisture (%), pH and TBA number of 0.983, 63.27, 6.36 and 0.148 (Rajkumar et al., 2004). Lower values might be due to oven (dry heat) cooking for goat meat patties as against simmering (moist heat) adopted for cooking of meat balls. Frazier and Westhoff (1997) reported a_w 0.98 in processed meat products like fermented sausage. Feeding treatment had no significant effect on product moisture and a_w but storage period had effect on them. As storage period advanced TBA number increased but were in acceptable limits. Consistent pattern was not observed for TBA number, which is the main indicator for oxidative rancidity. Spices used in the formulation might have influenced oxidative rancidity. Spices such as clove (Jayathilakan et al., 1997), mustard (Shahidi et al., 1996), ginger (Masuda and Jitoe, 1994) and red pepper (Palic et al., 1993) were reported to have antioxidant properties. The pH value was affected by both, treatments and storage periods. Rajkumar et al. (2004) reported that packaging method like vacuum packaging significantly affected pH values of goat meat patties.

Freshly prepared meat balls had mean SPC and yeast and mould counts of log 5.49 and 0.77 CFU g^{-1}. The microbial counts in the freshly prepared product were within the maximum permissible limits of 5×10^4 to 1×10^6 for APC and 1×10^3 for yeast and mould count in processed meats (Shapton and Shapton, 1991). Maca et al. (1997) reported that initial APC of log 5.7 CFU g^{-1} in ground beef patties. Cooked goat meat sausage had initial SPC of log 4.25 CFU g^{-1} (Agnihotri and Pal, 2000). Lower values might be due to type of product used for the study. Treatment had no effect on microbial load of meat balls however, as the storage period advanced, standard plates count (SPC) and psychrotrophs revealed significant decline. The yeast and mould counts were well within the acceptable limits. Overall mean SPC, psychrotrophs and yeast and mould counts were log 4.83, 3.95 and 0.85 CFU g^{-1}. Coliforms were not detected in any of the meat ball samples. Overall mean scores for general appearance, flavour, juiciness and overall acceptability were 7.14, 6.77, 6.67 and 6.98. Organoleptic scores were well within the acceptable limits throughout the storage period. Treatment had no significant effect on organoleptic characteristics of the product but product from HL and HH meat revealed significantly lower scores for flavour than LL and LH. Low protein diet tend to decrease fat measures of the carcass (Crouse et al., 1978). This also might be due to lower pH of the product in the LL and LH group products. Diet/ Management treatment had no influence on sensory panel evaluation of roasted loins and Warner-Bratzler shear evaluation of grilled leg slices of goat (Johnson and McGowan, 1998). On storage flavour, juiciness and overall acceptability did not reveal significant change barring general appearance, which showed decline in scores with the progress of storage. High concentrate feeding of sheep improve sensory panel tenderness evaluations (McClure et al., 1994).

CONCLUSION

It is inferred that under the present set of experimental conditions, diet with 12% CP % and 60% TDN (LH) was better for higher meat production from intact Barbari males. Good quality meat balls could be prepared from all the treatments and safely stored for 4 months without significant loss in eating quality except in general appearance. Treatment LL and LH produced meat balls with better flavour. The practicality of the intensive system for rearing goats and the corresponding improved yield would depend on the production cost.

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