Indian Journal of Animal Sciences **93** (1): 82–89, January 2023/Article
https://doi.org/10.56093/ijans.v93i1.127288

Effect of different levels of concentrate supplementation on feed intake, growth performance, carcass traits and composition in finisher Barbari kids reared under intensive system

T K DUTTA[1✉], MAMTA[2], A CHATTERJEE[1], C BHAKAT[1], D K MANDAL[1], S RAI[1], A MOHAMMAD[1], D SATPATHY[1], SUSHIL KR YADAV[1], ANIL[1] and ARUN K DAS[3]

ICAR-Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh 281 122 India

Received: 24 August 2022; Accepted: 16 November 2022

ABSTRACT

Thirty-two weaned male Barbari kids (av. age, 144.65 days; weight, 9.43±0.24 kg), reared under intensive system of feeding, were divided equally into four groups (T_1, T_2, T_3 and T_4) to investigate the effect of supplementation of different levels of concentrate mixture on voluntary intake, growth performance, carcass traits and quality. All kids were fed with Bengal gram straw *ad lib.* + green fodder *ad lib.* as basal ration and supplemented with barley grain @ 0.7% of body weight in T_1 and concentrate mixture @ 0.7, 1.4, and 2.1% of body weight in T_2, T_3, and T_4, respectively. Dry Matter Intake (DMI, g)/kg $W^{0.75}$ increased significantly in T_1 and T_4 than T_2 and T_3. Average daily weight gain (ADG) (g/d/kid) was enhanced significantly with each gradual increase in concentrate level. Slaughter weight and empty body weight were greatest in T_4 compared with other treatments. Significantly greater dressing percentage and yield of separated lean meat was observed in kids under T_3 and T_4 than other two groups. But, meat:bone ratio and separated carcass fat yield was significantly higher only in kids under T_4. Meat protein content (%) increased in T_2, T_3, and T_4 as compared to control T_1. Meat fat content increased linearly due to a gradual increase in the level of concentrate mixture supplementation to the finisher kids. Whereas, meat moisture and ash per cent remained unaltered due to different levels of concentrate supplementation to kids. Therefore, it may be concluded that supplementation of concentrate mixture @ 2.1% of the body weight in the roughage-based diet increased DMI in finisher Barbari kids with greater energy and protein values, which attributed to enhanced ADG in such kids by 408.3% over the control (supplemented with barley grain only), and also improved feed conversion ratio, carcass yield, carcass traits, and meat quality.

Keywords: Carcass traits, Concentrate, Growth, Intake, Kids, Meat quality, Supplementation

Goat farming is an economically demanding activity due to the higher consumers' acceptance of meat (chevon), milk and skin; and plays a vital role in the livelihood security of the small and marginal farmers, and landless labourers in India. However, lower body weight and poor carcass quality remained a regular threat to pasture-based goat production (Mushi *et al.* 2009). Hence, balanced feeding in terms of energy and protein optimized growth and feed conversion efficiency (FCE) in goats (Shahjalal *et al.* 2000, Hossain *et al*. 2003, Dutta *et al.* 2009).

Supplementation of concentrate is generally done to increase voluntary intake, growth performance, meat production and maximize economic efficiency in small ruminants. Das (2010) reported maximum ADG in kids when supplemented with concentrate mixture @ 1.5 of the body weight. Similarly, addition of concentrate in the diet enhanced body weight gain, daily DM intake, DM, and ADF digestibility in lambs and kids (Chaturvedi *et al*. 2000, Das and Ghosh 2007, Jatta, *et al.* 2022). Feeding a higher ratio of concentrate: roughage (80:20) and (70:30) improved body weight gain, and vigour of newborn lambs, and reproductive performance of ewes (Omar *et al.* 2019). Increased dietary concentrate levels improved the growth performance in Tibetan sheep (Liu *et al.* 2019). A positive response to a higher level of starch-based concentrate (grains) on methane reduction has also been reported by Beauchemin and McGinn (2005). Nutritional constraints limit the potential for the availability of goat meat to fulfill the increased domestic and export market demands (Hozza *et al*. 2013). On-farm supplementation of concentrate pellets at 1.5% of the live weight of growing kids improved growth performance, carcass traits, and provided leaner carcass (Chaudhary *et al*. 2015). Higher level of concentrate feeding to goats increased overall carcass yields, dressing percentage, crude protein, and fat contents in meat (Kim

Present address: [1]ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, Nadia, West Bengal. [2]ICAR-Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh. [3]ICAR-Indian Veterinary Research Institute, Eastern Regional Station, West Bengal. ✉Corresponding author email: tkdcirg@gmail.com, Tapas.Dutta@icar.gov.in

et al. 2014, Bambou *et al*. 2021); also affected carcass traits, serum biochemical indexes, and fatty acid profiles in different muscles of female Hu lambs fed with high energy (Wang *et al.* 2020).

Progressive farmers and entrepreneurs are increasingly interested in rearing goats as a component of agribusiness under the intensive system of management; which is mainly due to gradual shrinkage of the community pasture land/rangeland in India. Therefore, the present experiment was designed to investigate the effect of supplementation of different levels of concentrate mixture on voluntary intake, growth performance, carcass traits and quality in weaned Barbari kids reared under intensive system of feeding.

MATERIALS AND METHODS

Study site: The experiment was conducted in the experimental unit of Nutrition, Feed Resource and Products Technology Division, ICAR-Central Institute for Research on Goats (CIRG), Makhdoom, Farah, Mathura (Uttar Pradesh) as per approval of Dr. Bhim Rao Ambedkar University, Agra, Uttar Pradesh and ICAR-Central Institute for Research on Goats (India) and all standard Institutional ethical protocol was followed during the entire experimental period. Makhdoom is situated at 27°10'N latitude and 70°02'E longitude and at an altitude of 169 m MSL in the semi-arid region of Indo-Gangetic plain.

Experimental animals and diets: Thirty-two weaned male Barbari kids (av. age, 144.65 days; weight, 9.43±0.24 kg) were divided equally into four groups (T_1, T_2, T_3 and T_4) having eight kids in each group. The animals were dewormed at the beginning of the experiment. The kids were vaccinated against PPR, goat pox, enterotoxaemia, FMD, and HS as per standard Institute's schedule. The feeding schedules followed during the entire experimental period (up to slaughter study) were, T_1 (control) : Bengal gram straw *ad lib.* + green fodder *ad lib.* + barley grain @ 0.7% of body weight (synchronized control feeding schedule as practiced by some farmers in the semi-arid zone of Indo-Gangetic plain); T_2: Bengal gram straw *ad lib.* + green fodder *ad lib.* + concentrate pellet* @ 0.7% of body weight; T_3: Bengal gram straw *ad lib.* + green fodder *ad lib.* + concentrate pellet* @ 1.4% of body weight and T_4: Bengal gram straw *ad lib.* + green fodder *ad lib.* + concentrate pellet* @ 2.1% of body weight.

Seasonal green fodder was given to all kids (initial one month with berseem fodder followed by cowpea fodder up to the end of the experiment). Concentrate pellet* in the pelleted form (CP 18% and TDN 70%) was prepared as per the composition given in Table 1.

Evaluation of intake and growth performance: The experimental kids in each group were allowed feeding for 6 months by following the respective feeding schedule. Growth performance and intake of nutrients were evaluated during the experimental period following the standard procedure. Clean water was freely available to all the animals throughout the experimental period. Intake of diets was measured daily using a double pan balance (Avery, India). Live weight was recorded at the fortnight interval for the individual kid in the morning before feeding (08.00-09.00 h) throughout the experiment period using spring balance (Salter, India) to determine weight gain. Samples of feeds offered and residues left were analyzed for proximate (AOAC 1995) and cell wall composition (Van Soest *et al.* 1991). Mineral composition (Ca, Mg, Mn, Zn, Cu, Co and Fe) of different feeds and fodders were estimated using Atomic Absorption Spectrophotometer (GBC Avanta, Australia). Na and K of such samples were estimated using Flame Photometer. P content in these feeds and fodders were evaluated by following the method of (Ward and Johnson 1962). The chemical compositions of different feeds and fodder used during the growth experiment is mentioned in Table 1. The composition of different minerals (Ca, P, Mg, Na, K, Cu, Mn, Zn, Fe, Co) of different feed ingredients used during the animal feeding trial is mentioned in Table 2.

Carcass evaluation of finisher kids: Finisher kids were slaughtered after the completion of the feeding experiment (av. age, 378.22 days) to evaluate the carcass traits and chemical composition of meat. Kids were fasted for 16–18 h with free access to water and were slaughtered by the standard Halal method. Post-fasted live animal measurements and carcass measurements after dressing

Table 1. Chemical composition (% on DM basis) of feeds used for kids during growth trial

Feed	CP	EE	TCHO	OM	Ash	NDF	ADF	Hemi-cellulose	Cellulose	Lignin
Bengal gram straw	7.52	1.61	79.50	88.65	11.35	69.22	46.09	23.13	35.85	9.24
Cowpea fodder	17.28	5.28	64.00	86.58	13.42	53.78	22.59	31.19	13.46	8.13
Berseem fodder	19.17	4.99	64.75	88.93	11.07	39.81	25.00	14.81	16.29	8.01
Barley grain	11.76	5.29	79.83	96.88	3.12	22.67	10.46	12.21	9.03	1.24
Concentrate pellet*	17.44	4.66	71.70	93.82	6.18	44.10	20.55	23.55	15.63	2.92

Barley, *Hordium vulgare*; Bengal gram, *Cicer arietinum*; Cowpea, *Vigna sinensis*; Pearl millet, *Pennisetum typhoides*; Barseem, *Trifolium alexandrinum.* OM, Organic matter; CP, crude protein; EE, ether extract; TCHO, total carbohydrate; NDF, neutral detergent fibre; ADF, acid detergent fibre.*Concentrate pellet prepared with barley grain (*Hordium vulgare*) 40%, linseed cake (*Linum usitatissimum*) 25%, wheat bran (*Triticum aestivum*) 16%, Bengal gram chunni (*Cicer arietinum*, milling by-products of Bengal gram pulse containing husk, epicarp and fine particles of this pulse grains) 16%, mineral mixture** 2% and common salt 1%. **Composition (per kg basis) of mineral mixture (Agrimin Forte, Sunder Chemicals Pvt. Ltd., Chennai, India): Calcium 25.5%, Phosphorus 12.75%, Sulphur 0.72%, Magnesium 6000 mg, Potassium 100 mg, Sodium 5.9 mg, Cobalt 150 mg, Copper 1200 mg, Iodine 325 mg, Iron 1500 mg, Zinc 9600 mg, Manganese 1500, Vitamin A 700000 IU, Vitamin D_3 70000 IU, Vitamin E 250 mg, DL Methionine 1000 mg.

Table 2. Mineral composition (on DM basis) of different feed ingredients used for feeding to experimental kids under different groups

Feed ingredient	Ca%	P%	Mg%	Na%	K%	Mn (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Co (ppm)
Barley grain	0.15	0.45	0.05	0.06	0.34	22.81	606.24	42.79	23.89	1.12
Linseed cake	0.48	0.52	0.06	0.03	0.43	48.08	194.78	30.46	15.59	0.95
Wheat bran	0.28	0.46	0.05	0.04	0.33	27.05	273.58	34.20	12.98	0.09
Bengal gram chuni	0.37	0.38	0.03	0.03	0.38	15.13	86.73	21.04	12.79	ND
Bengal gram straw	1.01	0.21	0.05	0.25	0.50	54.53	764.41	44.60	80.60	7.58
Cowpea fodder	1.00	0.29	0.08	0.21	0.51	154.39	597.65	20.91	14.85	ND
Berseem fodder	1.17	0.32	0.06	0.47	0.72	50.91	508.83	71.57	50.88	7.39

ND, Non detected.

were also recorded (Das and Rajkumar 2010). Empty live weight (ELW) was calculated as the difference between slaughter weight and weight of digestive content (ingesta). Immediately after dressing, chest and leg circumferences of the carcass hanged with Achilles tendon were recorded. The hot carcass was split into fore and hindquarters and the loin eye area was recorded on the cut surface of the *Longissimus dorsi* muscle between 12th and 13th ribs on both sides of the carcass and was expressed as cm^2. Backfat thickness was the average of 2 measurements at the mid-length of the *Longissimus dorsi* muscle on either side of the midline. The dressed carcasses were split along the midline manually and left halves were split into 5 primal cuts and right half of each carcass was dissected into lean, fat, and bone (Das *et al.* 2008). Results were expressed on a carcass weight basis. Breast fat thickness, hot carcass weight (minus kidneys, kidney, and pelvic fat), edible and inedible offal's yield, and dressing percentage were also measured. Total visceral fat (%) comprised of omental, perinephric (kidney), inguinal, and mesenteric fat. The weight of empty compartments of the stomach (rumen, reticulum, omasum, and abomasum) of each animal was also recorded. *Longissimus dorsi* muscle of either side from the carcasses was separated and kept in a polyethylene bag at 4±1^{0}C for 24 h for further analysis of moisture, protein, fat, and ash (AOAC 1995).

Statistical analysis: Data of growth, voluntary intake, and carcass parameters were analyzed with one-way ANOVA using randomized complete block design (Snedecor and Cochran 1994) with eight replications (kids) in each group during animal experimentation. Polynomial regression equations with R^2 values were developed using the data of fortnightly growth and ADG of kids under each treatment group. Computerized IBM SPSS 20.0 package was used for the analysis of variance. Tukey's test was done to measure the differences of means.

RESULTS AND DISCUSSION

Feed intake: The DM intake (g/d/kid) through dry fodder and green fodder ranged from 356.60 (T_3) to 401.00 (T_1) and 79.01 (T_4) to 92.48 (T_1), respectively; however, the variations were statistically non-significant (Table 3). But, kids under T_4 consumed the greatest ($P<0.001$) amount (g/d/kid) of concentrate mixture (pelleted form) followed by T_3, T_2 and T_1. Total DMI (g/d/kid) was statistically higher ($P<0.001$) in T_4 than in T_1, T_2, and T_3; however, DMI (kg)/100kg body weight was greater ($P<0.01$) in T_1 and T_4 than T_2 and T_3. DMI (g)/kg $W^{0.75}$ was increased significantly ($P<0.01$) in T_1 (102.51) and T_4 (103.78) than T_2 (89.51) and T_3 (91.26). The variation in the ratio of roughage to concentrate was mainly due to gradual increase in the level of concentrate

Table 3. Voluntary intake and growth performance as affected by different levels of concentrate in kids

Parameter	T_1	T_2	T_3	T_4	SEM	Significance
Voluntary intake (DM basis)						
Green fodder (g/day/kid)	92.48	91.06	80.39	79.01	2.62	NS
Concentrate mixture (g/day/kid)	35.33^d	82.75^c	171.27^b	308.08^a	16.98	P<0.001
Gram straw (g/day/kid)	401.00	385.82	356.60	381.44	10.84	NS
Rough: concentrate ratio	93.32:6.68	85.21:14.79	71.84:28.16	59.91:40.08	-	-
DMI (g/day/ kid)	528.82^c	559.63^{bc}	608.27^b	768.54^a	20.43	P<0.001
DMI (kg/100 kg BW)	5.31^a	4.85^b	4.82^b	5.36^a	0.12	P<0.01
DMI (g)/$W^{0.75}$	102.51^a	89.51^b	91.26^b	103.78^a	1.94	P<0.01
Weight gain						
Initial wt. (kg)	9.25	9.42	9.56	9.49	0.24	NS
Final wt. (kg)	11.40^c	14.32^{bc}	17.03^b	20.40^a	0.77	P<0.001
Weight gain (kg)	2.15^d	4.90^c	7.46^b	10.91^a	0.67	P<0.001
ADG (g)	12.27^d	28.00^c	42.66^b	62.37^a	3.84	P<0.001
FCR (kg feed/kg gain)	52.0^a	29.90^b	15.12^c	12.46^c	3.95	P<0.01

Means in the same row with the different superscripts (a, b, c and d) are significantly different. ADG, Average daily weight gain; DMI, Dry matter intake; FCR, Feed conversion ratio.

supplementation in the diet of weaned Barbari kids.

Results depicted that supplementation of a higher level of concentrate mixture in the roughage-based diet balanced energy and protein mainly; thereby, improved intake in weaned kids under the intensive system of management. Although, total DMI (g/d/kid) increased linearly due to gradual increase in the level of concentration supplementation, but kids under T_1 consumed higher amount of DM per unit body weight (per 100 kg BW or per kg $W^{0.75}$) in order to fulfill the requirement of different essential nutrients for maintaining growth. Still growth rate was minimum in this group (T_1) due to deficiency of some major nutrients. Hence, there should be a proper balance of roughage and concentrate in the diet to have the optimum benefit from a diet. The results of the present study corroborated the findings of earlier researchers. The incorporation of concentrate into ruminant diets enhances dietary energy, proteins, minerals, and vitamins; hence, may optimize the efficiency of feed utilization (Morand-Fehr and Sauvant 1987). Concentrate supplementation is required to fulfill the nutrient requirements of livestock and can be supplemented up to 30% of required DM to obtain the best result (Ferdous *et al.* 2012). Goats should be grazed and supplemented with 353 g concentrate/day for satisfactory fattening performance and higher economic return (Hozza *et al.* 2013). Jatta *et al.* (2022) revealed that daily DM intake increased linearly with an increase in concentrate percentage from 0 to 40% in the ration of lambs; which was mainly due greater digestibility of dry matter and acid detergent fibre.

Growth performance: Final weight (kg) of kids was greatest ($P<0.001$) in T_4 (20.40) supplemented with concentrate @ 2.1% of their body weight compared to other treatments (T_1, 11.40; T_2, 14.32; T_3, 17.03) (Table 3). Average total weight gain (kg/kid) was highest ($P<0.001$) in T_4 followed by T_3, T_2 and T_1. Average daily weight gain (ADG) (g/d/kid) also enhanced significantly ($P<0.001$) due to gradual increase in concentrate level in finisher kids, the values (g/d) ranged from 12.27 (T_1) to 62.37 (T_4). The final weight of kids was increased by 25.61%, 49.39%, and 78.95% in T_1, T_2 and T_3 over control T_1. Similarly, average daily weight gain (ADG) was increased by 128.20%, 247.68%, and 408.31% in kids under T_1, T_2 and T_3 over control T_1. Marked differences were observed on the weight gain pattern of kids at fortnight intervals due to gradual increase of concentrate supplementation in the diets (Fig. 1). Based on the ADG pattern at fortnight intervals, it could be interpreted that finisher kids gained uniformly (R^2 value in T_3= 0.6386 and T_4 = 0.5324) higher up to 180 days of experimental feeding or at 11th month of age in T_3 and T_4 (Fig. 2). The weight gain pattern at fortnightly intervals, was much lower in kids under T_1 and T_2. Polynomial regression equations with R^2 values were developed for each treatment group (Fig. 1 and Fig. 2). Feed conversion ratio (FCR) was statistically higher ($P<0.01$) in T_1 (52.00) than T_2 (29.90), T_3 (15.12) and T_4 (12.46). Hence, FCR was most efficient in finisher Barbari kids under T_3 and T_4.

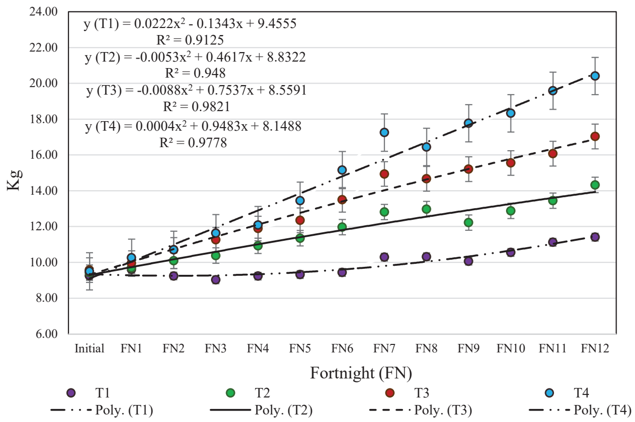

Fig. 1. Effect of different level of concentrate on body weight gain.

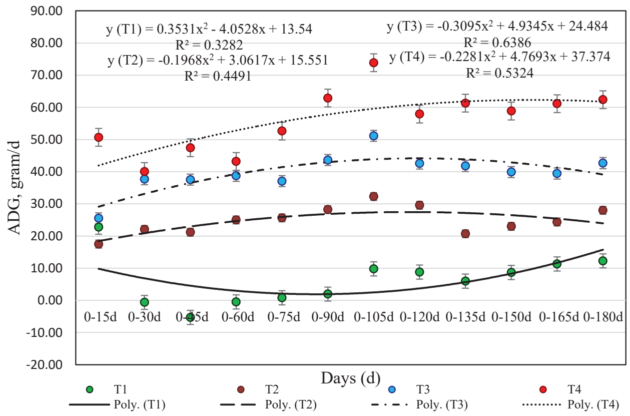

Fig. 2. Effect of different level of concentrate on ADG (g/d/kid) at different time period.

The results of the present study corroborated the findings of earlier workers. It was well established that supplementation of concentrate mixture in the roughage-based diet balances protein, energy, and minerals for ruminants; therefore, a positive response was found in terms of weight gain and feed conversion efficiency. The high energy content of the ration had a positive effect on the body weight gain of goats (Shahjalal *et al.* 1992, Saikia *et al.* 1995, Hossain *et al.* 2003). Providing larger quantity of concentrated feed in the diet increases the energy density of the diet which may improve feed efficiency and animal performance (Missio *et al.* 2010). Concentrate: roughage ratio is an important factor to be considered for improving feed efficiency. In the present study, weight gain and feed efficiency were maximized when roughage to concentrate ratio was maintained at 60:40 (T_4). Similarly, ADG was enhanced with increasing levels of concentrate supplementation in the diet of lambs and kids (Chaturvedi *et al.* 2000, Das and Ghosh 2007, Tripathi *et al.* 2007). Shahjalal *et al.* (2000) observed that the increase in energy and protein intakes resulted in increased feed conversion efficiency in goats. Concentrate mixture can be supplemented up to 30% of required DM to fulfill the nutrient requirements and to obtain the best performance in goats (Ferdous *et al*. 2012). Feeding higher concentrate to roughage ratio (80%C: 20%R) and (70%C:

30%R) improved body weight, and vigour of newborn lambs (Omar *et al*. 2019). Tibetan sheep fed diet with 45% concentrate obtained better growth performance (Liu *et al.* 2019). Lambs fed hay supplemented with concentrate @ 20% had better feed conversion ratio compared to other treatments (Jatta *et al.* 2022). Similarly, lambs fed with high concentrate (55%) diet had higher ADG (g/d) and DM digestibility (Jin and Jhou 2022). Goats should be grazed and supplemented with 353 g concentrate/day for satisfactory fattening performance and higher economic return on investment (Hozza *et al*. 2013). ADG of lambs increased linearly with increasing dietary ME levels, being highest in E4 (10.41 Mcal/kg of feed) group (Wang *et al.* 2020).

Carcass traits, quality, and meat composition: Slaughter weight ($P<0.001$) and empty body weight ($P<0.01$) were recorded greatest in finisher kids supplemented with concentrate mixture @ 2.1% of body weight (T_4) when compared with control (T_1) and other treatments (T_2, T_3) supplemented with a lower level of barley grain (T_1) or concentrate mixture (Table 4). The values of slaughter weight (kg) and empty body weight (kg) ranged from 11.64 (T_1) to 23.30 (T_4) and 8.98 (T_1) to 19.78 (T_4), respectively. Similarly, body measurements (height, body length, heart girth, punch girth, loin width, and leg circumference) were also measured highest ($P<0.05$) in T_4 than T_1 and T_2 treatments. Carcass measurements (leg circumference, chest circumference, and loin eye area) were also increased ($P<0.05$) in kids under T_4 than T_1 and T_2. Carcass weight (kg) was greatest ($P<0.01$) in kids under T_4 (10.71) compared to T_1 (4.48), T_2 (6.33), and T_3 (8.29). However, supplementation of concentrate mixture @ 1.7% and 2.1% of body weight resulted significantly ($P<0.05$) higher dressing percentage in kids under T_3 (44.04%) and T_4 (45.86%) than T_1 (37.65%) and T_2 (39.99%). The greater yield of forequarter ($P<0.01$) and hindquarter ($P<0.001$) were obtained in T_4 than other treatments. But, supplementation of higher level of concentrate mixture increased backfat thickness ($P<0.05$), breast fat thickness ($P<0.05$), and fat depots (cod fat, kidney fat, omental fat, and mesenteric fat) in kids under T_3 and T_4 compared to T_1 and T_2 (Table 4).

Weight of all non-carcass components (blood, skin, head, and GI tract) significantly increased ($P<0.05$) in T_4 than other treatments (Table 5). Similarly, the yield of most of the organs (kidney, liver, heart, and pancreas) in

Table 4. Effect of different levels of concentrate supplementation on carcass traits in kids

Trait	T_1	T_2	T_3	T_4	SEM	P value
Slaughter weight (kg)	11.64^d	15.46^c	19.10^b	23.30^a	0.90	P<0.001
Empty body weight (kg)	8.98^d	11.99^c	15.81^b	19.78^a	0.85	P<0.01
Body measurements (cm)						
Height	47.38^b	53.88^a	55.63^a	57.63^a	1.04	P<0.05
Body length	50.00^c	56.75^b	57.63^{ab}	61.88^a	1.09	P<0.05
Heart girth	53.00^c	56.38^{bc}	60.50^{ab}	63.63^a	1.05	P<0.05
Paunch girth	53.75^c	56.50^{bc}	61.12^{ab}	63.78^a	1.20	P<0.05
Loin width	9.65^c	11.25^b	12.00^{ab}	13.28^a	0.32	P<0.05
Leg circumference	23.78^b	25.43^b	30.22^a	30.34^a	0.77	P<0.05
Carcass measurements						
Chest circumference (cm)	49.09^c	53.90^b	57.72^a	60.94^a	0.99	P<0.05
Loin width (cm)	9.36	10.33	10.25	11.25	0.61	NS
Leg circumference (cm)	19.59^c	23.40^b	27.94^a	27.84^a	0.87	P<0.05
GR measurement# (mm)	1.02	1.46	1.73	2.40	0.32	NS
Loin eye area (cm^2)	6.03^d	7.16^c	8.25^b	9.35^a	0.22	P<0.05
Carcass traits						
Carcass weight (kg)	4.48^d	6.33^c	8.29^b	10.71^a	0.49	P<0.01
Dressing %	37.65^b	39.99^b	44.04^a	45.86^a	0.81	P<0.05
Fore quarter (Kg)	2.49^d	3.53^c	4.84^b	6.13^a	0.29	P<0.01
Hind quarter (Kg)	1.98^d	2.79^c	3.61^b	4.59^a	0.21	P<0.001
Fat thickness##						
Back fat thickness (mm)	0.92^b	1.12^b	1.29^{ab}	1.54^a	0.41	P<0.05
Breast fat thickness (cm)	1.22^b	1.74^{ab}	2.02^{ab}	2.07^a	0.44	P<0.05
Fat distribution (g)						
Cod fat	19.38^b	$25.63b^b$	42.50^a	56.25^a	4.00	P<0.01
Omental fat	77.50^c	78.75^c	151.88^b	216.25^a	18.43	P<0.01
Kidney fat	76.88^b	71.25^b	111.88^{ab}	152.50^a	59.57	P<0.05
Mesentric fat	95.38^b	110.37^b	162.00^a	205.75^a	11.18	P<0.05

Mean bearing different superscripts (a, b, c) in a row differ significantly. #GR measurement is the soft tissue thickness, measured 11 cm from midline on 12th rib of the carcass. ##Fat thickness measured with digital Vernier caliper.

Table 5. Effect of different levels of concentrate supplementation on non-carcass components, organ yields and chemical composition of meat in kids.

Trait	T_1	T_2	T_3	T_4	SEM	P value
Non carcass component (kg)						
Blood	0.57^{c}	0.63^{c}	0.79^{b}	0.91^{a}	0.03	P<0.05
Head	0.89^{d}	1.15^{c}	1.38^{b}	1.60^{a}	0.06	P<0.05
Skin	0.81^{d}	1.09^{c}	1.45^{b}	1.91^{a}	0.09	P<0.05
GI tract	1.22^{c}	1.39^{c}	1.61^{b}	1.92^{a}	0.05	P<0.05
Organ yield (g)						
Testes	81.88^{c}	110.00^{bc}	135.00^{ab}	160.63^{a}	8.01	P<0.05
Pancreas	21.88^{b}	28.13^{b}	32.50^{b}	33.75^{a}	1.31	P<0.05
Spleen	19.38^{c}	$23.13b^{c}$	32.50^{ab}	41.88^{a}	0.09	P<0.05
Kidney	37.50^{d}	45.63^{c}	53.13^{b}	60.63^{a}	1.81	P<0.05
Liver	236.25^{c}	281.25^{b}	319.37^{b}	429.38^{a}	14.79	P<0.05
Heart	58.75^{c}	$61.88b^{c}$	77.50^{b}	97.50^{a}	3.77	P<0.05
Digestive compartment (empty weight, g)						
Rumen	267.50^{c}	347.62^{b}	336.20^{b}	414.88^{a}	13.37	P<0.05
Reticulum	50.00^{b}	57.25^{b}	81.88^{a}	83.50^{a}	6.17	P<0.05
Omasum	60.00^{b}	65.87^{b}	73.13^{b}	97.00^{a}	4.48	P<0.05
Abomasum	77.75	81.62	81.13	81.13	2.28	NS
Cut – up parts (kg)- left side of the carcass						
Leg	0.71^{d}	0.97^{c}	1.27^{b}	1.61^{a}	0.07	P<0.05
Loin	0.34^{d}	0.47^{c}	0.60^{b}	0.75^{a}	0.03	P<0.05
Rack	0.33^{b}	0.42^{b}	0.61^{b}	1.04^{a}	0.08	P<0.05
Neck and Shoulder	0.66^{c}	0.78^{c}	1.11^{b}	1.47^{a}	0.07	P<0.05
Breast and Shank	0.44^{c}	0.64^{b}	0.83^{ab}	0.97^{a}	0.05	P<0.05
Carcass composition (left half carcass)						
Separated lean (kg)	2.09^{b}	2.51^{b}	3.06^{a}	3.48^{a}	0.76	P<0.05
Fat (g)	167.50^{c}	194.00^{b}	219.00^{b}	324.83^{a}	23.62	P<0.05
Bone (kg)	0.81^{c}	0.95^{bc}	1.15^{ab}	1.32^{a}	0.05	P<0.05
Meat: Bone	2.63^{b}	2.69^{b}	2.68^{b}	2.91^{a}	0.06	P<0.05
Meat composition (%)						
Moisture	76.35	75.33	74.86	74.92	0.24	NS
Protein	18.23^{b}	19.42^{a}	19.54^{a}	20.21^{a}	0.16	P<0.05
Fat	1.56^{c}	1.86^{b}	1.95^{ab}	2.06^{a}	0.23	P<0.05
Ash	1.02	1.12	1.32	1.21	0.08	NS

Mean bearing different superscripts (a, b, c) in a row differ significantly.

kids under T_4 was greater (P<0.05) than other treatments. The yield of organs weight was lowest in T_1. Interestingly, maximum (P<0.05) weight of empty rumen was obtained in T_4 than other treatments; indicating a higher volume of the rumen to occupy a greater amount of feeds for microbial digestion. A similar trend was also recorded for empty omasum weight. However, the weight of reticulum was enhanced (P<0.05) in kids under T_3 and T_4 supplemented with a higher level of concentrate mixture when compared with T_1 and T_2. The weight of abomasum was statistically non-significant among various treatments. Weights of different cut-up parts of the left half carcass (leg, loin, rack, neck, and shoulder) increased (P<0.05) in T_4 than other treatments (T_1, T_2 and T_3). The yield of separated lean meat was greater (P<0.05) in finisher kids under T_3 and T_4 than T_1 and T_2. But, meat: bone ratio was increased (P<0.05) only in kids under T_4. Similarly, separated carcass fat yield was also highest (P<0.05) in T_4. Meat protein content (%) increased (P<0.05) in T_2 (19.42), T_3 (19.54), and T_4 (20.21) compared to control T_1 (18.23). Meat fat content also increased (P<0.05) linearly due to a gradual increase in the level of concentrate mixture supplementation to the finisher kids. Whereas, meat moisture (%) and meat ash (%) remained unaltered due to different levels of concentrate supplementation to kids.

The results of the present study corroborated the findings of earlier workers. Low carcass weight and yield from goats are mainly due to nutritional constraints that limit the potential for the availability of meat (Hozza *et al.* 2013). On-farm supplementation of concentrate pellets at 1.5% of live weight improved growth performance, carcass traits, the weight of carcass and primal cuts, and provided leaner carcass in growing kids (Chaudhary *et al*. 2015). Strategic supplementation of concentrate feeds increased carcass quantity and quality in goats reared under pasture-based production systems (Priolo *et al.* 2002, Mushi *et al.* 2009, Safari *et al.* 2009). Supplementation of concentrate mixture @ 2% of the body weight increased growth and meat production potential without any change in meat composition in kids reared under the intensive and semi-intensive system (Dutta *et al.* 2020). In the present study, higher fat deposition was observed in finisher Barbari kids due to a greater level of concentrate supplementation. However, meat fat content in T_3 and T_4 was within the acceptable level. Shahjalal *et al.* (1992) reported that higher energy diets increased carcass weight particularly that of the shoulder and hind barrel. Concentrate feeding at the rate of 1.5% body weight resulted in heavier final body and carcass weight (Tadesse *et al.* 2016). High concentrate feeding increased overall carcass yields, crude protein, and fat contents in goats (Kim *et al.* 2014). In sheep, high concentrate feeding could increase the dressing percentage and improve carcass quality and tenderness of meat (McClure *et al.* 1994). The by-products of pulses (straw + chuni) based complete pelleted feed (R:C=60:40, CP:TDN=12:60) gave a better growth rate (ADG 51.11 g, FCE 7.63%) with a higher quality of meat in finisher Barbari kids (Dutta *et al.* 2009). The early growing Malabari male kids could double the net live weight with higher dressing percent when supplemented with finely ground concentrate feed mixed with equal quantity of rice gruel compared to natural suckling system, and the chevon produced was tender with less cooking loss (Prasad *et al.* 2022). Similarly, lambs fed with higher concentrate (55%) had greater dressing percentages, leg proportions, intramuscular fat (IMF) contents compared with lower concentrate supplementation (Jin and Jhou 2022).

Moreover, adjusting energy levels in a diet to produce high-quality goat carcasses could be beneficial to the producers, especially if they satisfy the demand of consumers (Abdullah and Musallam 2007). Traditional farmers in the Indo-Gangetic plain of the semi-arid region of India rear their goats under grazing in the community pasture land without or with supplementation of little quantity of grain. The area under community pasture land is gradually shrinking in India due to different social and economic reasons. Under this situation, the potential of higher goat carcass yield and quality of meat is very limited, and this may not be a profitable business opportunity for the farmers. Supplementation of concentrate mixture @ 2.1% of body weight increased growth potential of finisher Barbari kids and enhanced carcass yield with better quality meat composition in the present study; therefore, farmers may adopt the supplementation strategy to increase the meat production potential in finisher kids reared under intensive system of management.

Supplementation of concentrate mixture @ 2.1% (or 40.08% of total DMI) of the body weight in the roughage-based diet balanced the dietary energy and protein levels, and hence increased DM intake in finisher Barbari kids reared under intensive system of feeding management. This attributed to enhanced ADG in such kids by 408.3% over the control (supplemented with barley grain only); and also improved the feed conversion ratio, carcass yield, carcass traits, and meat quality. Therefore, progressive farmers and entrepreneurs may follow such type of feeding schedule for quantitative and qualitative enhancement of goat meat; and may get desirable carcass weight in finisher kids at a shorter duration of nutritional management.

ACKNOWLEDGEMENTS

The study was supported and funded by ICAR-Central Institute for Research on Goats, Makhdoom, Farah, Mathura, Uttar Pradesh (India).

REFERENCES

Abdullah A Y and Musallam H S. 2007. Effect of different levels of energy on carcass composition and meat quality of male black goats kids. *Livestock Science* **107**: 70–80.

AOAC. 1995. *Official Methods of Analysis* (16th ed.). Association of Official Analytical Chemists, Washington, DC.

Beauchemin K A and McGinn S M. 2005. Methane emissions from feedlot cattle fed barley or corn diets. *Journal of Animal Science* **83**: 653–61.

Bambou J C, Cériac S, Liméa L, Arquet R, Bocage B and Alexandre G. 2021. Impact of diet supplementation and age at slaughter on carcass characteristics of creole goats. *Frontiers in Veterinary Science* **8**: Article no. 671948.

Chaturvedi O, Mishra A, Karim S and Jakhmola R. 2000. Effect of supplementary feeding on growth performance of lambs under field condition. *Indian Journal of Small Ruminants* **6**: 110–12.

Chaudhary U B, Das A K, Tripathi P and Tripathi M K. 2015. Effect of concentrate supplementation on growth performance, carcass traits and meat composition of Sirohi kids under field condition. *Animal Nutrition and Feed Technology* **15**: 251–60.

Das A. 2010. Effect of different levels of concentrate supplementation on performance of Sikkim local kids fed mixed jungle grass based diet. *Animal Nutrition and Feed Technology* **10**: 87–97.

Das A and Ghosh S K. 2007. Effect of partial replacement of concentrates with jackfruit (*Artocarpus heterophyllus*) leaves on growth performance of kids grazing on native pasture of Tripura, India. *Small Ruminant Research* **67**: 36–44.

Das A K, Dass G and Singh N P. 2008. Growth, carcass characteristics and meat quality of Muzaffarnagari lambs at various stages under intensive and semi-intensive management. *Indian Journal of Animal Science* **78**: 541–46.

Das A K and Rajkumar V. 2010. Comparative study on carcass characteristics and meat quality of three Indian goat breeds. *Indian Journal of Animal Sciences* **80**: 1014–18.

Dutta T K, Agnihotri M K, Sahoo P K, Rajkumar V and Das A K. 2009. Effect of different protein-energy ratio in pulse by-products and residue based pelleted feeds on growth, rumen fermentation, carcass and sausage quality in Barbari kids. *Small Ruminant Research* **85**: 34–41.

Dutta T K, Das A K, Prabhat T and Dular R K. 2020. Effect of concentrate supplementation on growth, nutrient availability, carcass traits and meat quality in Barbari kids reared under semi-intensive and intensive systems. *Animal Nutrition and*

Feed Technology **20**: 267–78.

Ferdous M, Khan M, Rashid M and Kamruzzaman M. 2012. Effect of different levels of concentrate supplementation on the performance of Black Bengal goat. *Bangladesh Journal of Animal Science* **40**: 40–45.

Hossain M E, Shahjalal M, Khan M J and Hasanat M S. 2003. Effect of dietary energy supplementation on feed intake, growth and reproductive performance of goats under grazing condition. *Pakistan Journal of Nutrition* **2**: 159–63.

Hozza W A, Kifaro G C, Safari J G and Mushi D E. 2013. Effect of concentrate supplementation levels on growth and slaughter characteristics of SEA and SEA × Norwegian goats under on-farm conditions. *Tropical Animal Health and Production* **45**: 1789–94.

Jatta K, Chishti M F A, Rahman M A, Khan S, Riaz M, Bila Q and Sharif M. 2022. Effect of different dietary levels of concentrate and roughage for optimum growth performance in Thalli lambs. *Pakistan Journal of Agricultural Science* **59**: 503–10.

Jin Y and Zhou Y. 2022. Effects of concentrate level and chromium methionine supplementation on the performance, nutrient digestibility, rumen fermentation, blood metabolites, and meat quality of Tan lambs. *Animal Bioscience* **00**: 1-13.

Kim S W, Park S B, Kim M J, Kim D H and Yim D G. 2014. Effects of different levels of concentrate in the diet on physicochemical traits of korean native black goat meats. *Korean Journal of Food Science and Animal Resources* **34**: 457–463.

Liu H, Xu T, Xu S, Ma L, Han X, Wang X, Zhang X, Hu L, Zhao N, Chen Y, Pi L and Zhao X. 2019. Effect of dietary concentrate to forage ratio on growth performance, rumen fermentation and bacterial diversity of Tibetan sheep under barn feeding on the Qinghai-Tibetan plateau. *PeerJ* **7**: e7462.

McClure K E, Van Keuren R W and Althouse P G. 1994. Performance and carcass characteristics of weaned lambs either grazed on orchardgrass, ryegrass, or alfalfa or fed all-concentrate diets in drylot. *Journal of Animal Science* **72**: 3230–37.

Missio R L, Brondani I L, Filho D C A, da Silveira M F, Freitas L da S and Restle J. 2010. Comportamento ingestivo de tourinhos terminados em confinamento, alimentados com diferentes níveis de concentrado na dieta. *Revista Brasileira de Zootecnia* **39**: 1571–78.

Morand-Fehr P and Sauvant D. 1987. Feeding strategies in goats, pp. 1275–03. (Eds) Santana O P, de Silva A G and Foote W. 4th International Conference on Goats. Brasilia, Brazil.

Mushi D E, Safari J, Mtenga L A, Kifaro G C and Eik L O. 2009. Effects of concentrate levels on fattening performance, carcass and meat quality attributes of Small East African × Norwegian crossbred goats fed low quality grass hay. *Livestock Science* **124**: 148–55.

Omar A E, Gharib H S and Said E N. 2019. Effect of feeding different concentrate roughage ratio on growth, reproductive performance and behaviour of sheep. *Slovakian Veterinary Research* **56**: 433–43.

Prasad C K, Abraham J, Chinnappan B, Jose R A, Murugan S, Banakar P and Barman D. 2022. Carcass traits and meat quality characteristics of Malabari male kids reared under different production system. *Indian Journal of Animal Research* **56**: 116–20.

Priolo A, Micol D, Agabriel J, Prache S and Dransfield E. 2002. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. *Meat Science* **62**: 179–85.

Safari J, Mushi D E, Mtenga L A, Kifaro G C and Eik L O. 2009. Effects of concentrate supplementation on carcass and meat quality attributes of feedlot finished Small East African goats. *Livestock Science* **125**: 266–74.

Saikia G, Baruah K K, Buragohain S C, Saikia B N and Pathak N N. 1995. Feed intake, utilization of nutrients and growth of Assamese × Beetal goats fed three levels of energy. *Small Ruminant Research* **15**: 279–82.

Shahjalal M, Bishwas M A A, Tareque A M M and Dohi H. 2000. Growth and carcass characteristics of goats given diets varying protein concentration and feeding level. *Asian Australasian Journal Animal Science* **13**: 613–18.

Shahjalal M D, Galbraith H and Topps J H. 1992. The effect of changes in dietary protein and energy on growth, body composition and mohair fibre characteristics of British Angora goats. *Animal Production* **54**: 405–12.

Snedecor G W and Cochran W G. 1994. *Statistical Methods*. Oxford and IBH Publishing Co. New Delhi.

Tadesse D, Urge M, Animut G and Mekasha Y. 2016. Growth and carcass characteristics of three Ethiopian indigenous goats fed concentrate at different supplementation levels. *Springer Plus* **5**: 414–22.

Tripathi M K, Chaturvedi O H, Karim S A, Singh V K and Sisodiya S L. 2007. Effect of different levels of concentrate allowances on rumen fluid pH, nutrient digestion, nitrogen retention and growth performance of weaner lambs. *Small Ruminant Research* **72**: 178–86.

Van Soest P J, Robertson J B and Lewis B A. 1991. Methods for dietary fibre, neutral detergent fibre, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* **74**: 3583–97.

Wang Y, Wang Q, Dai C, Li J, Huang P, Li Y, Ding X, Huang J, Hussain T and Yang H. 2020. Effects of dietary energy on growth performance, carcass characteristics, serum biochemical index, and meat quality of female Hu lambs. *Animal Nutrition* **6**: 499–06.

Ward G and Johnson F B. 1962. *Chemical Method of Plant Analysis*. Research Branch, Department of Agriculture, Canada, pp. 1065.