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Nutrient digestibility and feedlot performance of lambs fed diets varying protein and energy contents

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Abstract Thirty-six Thalli male growing lambs were used in a completely randomized design with 2×2 factorial arrangement of treatments to evaluate the effect of varying levels of energy and protein on nutrient intake, digestibility, weight gain, and gain to feed ratio. Four experimental diets, i.e., low energy–low protein (LE-LP), low energy–high protein (LE-HP), high energy–low protein (HE-LP), and high energy–high protein (HE-HP) were formulated. The low- and high-energy diets contained 2.3 and 2.7 MJ/kg dry matter (DM) with 12% and 14% of crude protein. The lambs were fed ad libitum. Dietary energy and protein levels and their interactions influenced the nutrient intake. Maximum dry matter intake was noted in animals fed LE-HP diet followed by LE-LP, HE-HP, and HE-LP diets. Digestibility of DM and N increased ($P<0.01$) and that of neutral detergent fiber decreased ($P<0.01$) linearly with increasing levels of dietary energy and protein. Digestibility of N was only affected by protein level and interaction between energy and protein levels. Average daily gain was higher ($P<0.01$) in lambs fed HE-HP diet followed by LE-HP, LE-LP, and HE-LP diets. Dietary energy and protein levels and their interaction had significant effect ($P<0.01$) on gain to feed ratio.

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Introduction

Crop residues are integral part of ruminant diet in developing countries. Crop residues like wheat straw, rice straw, and corncobs are rich in fiber and represent a significant reservoir of energy for ruminants. Digestibility of these crop residues is low due to deficiency of fermentable carbohydrates and proteins, which limit ruminal fermentation. This results to decrease intake as well as digestibility of feed with subsequent decrease in availability of energy and metabolizable protein to ruminants. Low energy and metabolizable protein hamper the productivity of growing animals (Schroeder and Titgemeyer 2008).

Feeding high protein and energy diets improve the feedlot performance of growing animals and potential benefit of feeding diets varying in protein and energy on feed intake, and feed lot performance in steers is established (Sultan et al. 1991). Enzose (corn dextrose), corn steep liquor, maize bran, maize oil cake, and maize gluten 30% are the products of maize industry and are potential sources of protein and energy for ruminants (Nisa et al. 2004; Sarwar et al. 2004; Javaid et al. 2008) and are generally used in fattening ruminants. Supplementation of these sources not only enhances the protein and energy contents of diet but also results into increased nutritional worth of corncobs (Sarwar et al. 2004). In addition, these cheap sources lead to cost-effective ration formulation resulting economical meat production.

Supplementation of protein and readily available energy diets stimulates ruminal microbial protein synthesis as well as ruminal fermentation and subsequently increases the digestibility of feed. This results to increase of the supply of metabolizable protein and improves energy status (Cadorniga and Satter 1993). The digestibility of dry matter (DM), crude protein (CP), and neutral detergent fiber (NDF) was improved when corncobs were supplemented with readily available carbohydrates and ruminally degradable N (Doyle and Panday 1990). However, limited information is available in the literature regarding manipulation of protein and energy to optimize nutrient requirements of native sheep breeds for their optimal growth. Additionally, little work has been conducted to explore the potential of supplementation of corncobs by corn byproducts in a single study. Therefore, the present study was designed to explore the effect of protein or energy supplementation with corncobs based diets on nutrient intake, nutrient digestion, and weight gain in lambs.

Materials and methods

Animals feeding regimen

Thirty-six Thalli male growing lambs with an average weight of 20.7±2 kg were used in a completely randomized design with 2×2 factorial arrangement of treatments to determine the effect of varying levels of energy and protein on nutrient intake, digestibility, weight gain, and gain to feed ratio. The animals were randomly allotted to four rations having nine lambs each. Four experimental diets varying in energy and protein contents, i.e., low energy–low protein (LE-LP), low energy–high protein (LE-HP), high energy–low protein (HE-LP), and high energy–high protein (HE-HP) were formulated (Table 1). The low- and high-energy (ME) diets contained 2.3 and 2.7 MJ/kg DM with 12% and 14% of CP in each energy level. The lambs were fed ad libitum (twice daily) for 70 days. Initial 10 days were given as adjustment period and the rest of the 60 days for collection of data regarding nutrient intake, digestibility, and weight gain. Fresh and clean water was made available round the clock. The lambs were weighed on two consecutive days fortnightly. Individual fecal samples were collected on day 25, 40, and 55. Acid insoluble ash was used as an internal marker for the determination of nutrient digestion. Daily intake of DM, N, NDF, average daily gain (ADG), and gain to feed ratio were measured during growth trial.

Laboratory analyses

Feed and fecal samples were analyzed for DM, organic matter, and N (AOAC 1990). The NDF and acid insoluble ash were determined by methods of Van Soest et al. (1991). The total weight gain was calculated on the basis of difference between initial body weight and final body weight of the animals. Gain to feed ratio was calculated on the basis of total weight gain divided by total feed consumed by each group of experimental animals fed different diets.

Statistical analysis

Data regarding feed intake, digestibility, gain to feed ratio, and ADG were analyzed using analysis of variance techniques under completely randomized design. Treatment means were compared using least significant difference test (Steel and Torrie 1980). Diet sum of squares was partitioned to test for effects of energy level, protein level, and energy×protein interactions.

Results and discussion

Nutrient intake

DMI was higher ($P<0.05$) in lambs fed LE-HP than those fed other diets (Table 2). Increasing dietary energy contents from 2.3 to 2.7 MJ/kg resulted in decreased ($P<0.01$) DMI from 1,271 to 1,137 g/day. The DMI is regulated by dietary energy density (Lu and Potchoiba 1990). The decrease in DMI in animals fed high-energy diets was because of inverse relationship between dietary energy density and DMI. The DMI increased ($P<0.01$) from 1,160 to 1,248 g/day by increasing dietary protein contents from12% to 14% (Table 2). The DMI was 7.4% greater by the animals fed high-protein (14%) diet than those fed low-protein

Table 1 Ingredient and nutrient composition of experimental rations (on dry matter basis)

	Experimental diets			
	LE-LP	LE-HP	HE-LP	HE-HP
Ingredients				
Corn cobs	40.0	35.0	23.0	20.0
Maize gluten meal (30%)	3.0	13.0	17.0	27.0
Maize bran	30.0	30.0	20.0	20.0
Maize oil cake	20.0	15.0	18.0	13.0
Corn steep liquor	5.0	5.0	–	–
Enzose (corn dextrose)	–	–	20.0	18.0
Dicalcium phosphate	1.48	1.48	1.48	1.48
Mineral mixture	0.5	0.5	0.5	0.5
Vitamin A	0.02	0.02	0.02	0.02
Total	100	100	100	100
Chemical composition				
Dry matter	86.40	87.10	82.90	81.90
Organic matter	95.95	95.41	95.78	95.12
Crude protein	12.06	14.06	12.01	14.02
Neutral detergent fiber	35.30	31.75	24.56	22.96
Acid detergent fiber	15.05	13.78	9.65	8.54
Acid detergent lignin	4.63	4.59	2.44	2.42
Metabolizable energy (MJ/kg)	2.26	2.27	2.71	2.73

LE-LP low energy–low protein, *LE-HP* low energy–high protein, *HE-LP* high energy–low protein, *HE-HP* high energy–high protein

(12%) diets. An increase in CP level might be resulted in increased ruminal ammonia N (NH_3-N) concentration. Increased DMI with increased in dietary CP level might be due to high concentration of ruminal NH_3-N that led to increased ruminal microbial proliferation, fermentation, and digestibility, and thus, enhanced nutrient intake (Javaid et al. 2008). The DMI was also influenced ($P<0.05$) by interaction between energy and protein. The animals fed LE-HP diet consumed maximum DMI, while minimum DMI was consumed by the animals fed HE-LP diet.

Similar trend was observed in N intake as in DMI (Table 2). Dietary energy concentration reflected negative impact ($P<0.01$) on N intake. The N intake in animals fed low-energy diet was higher (26.5 g/day) than those (23.7 g/day) fed high-energy diet. The reduction in N intake by the animals fed high-energy rations was about 10.6%, which showed that the effect

Table 2 Nutrient intake and digestibility in lambs fed varying energy and protein level

Energy level	LE		HE		Effects $p<$		
Protein level	LP	HP	LP	HP	Energy	Protein	E×P
DM intake (g/day)	1201^{b}	1342^{a}	1120^{c}	$1155^{b,c}$	0.001	0.01	0.01
N intake (g/day)	22.9^{c}	30.2^{a}	21.5^{d}	25.9^{b}	0.001	NS	NS
NDF intake (g/day)	424.0^{a}	426.0^{a}	274.7^{b}	265.0^{b}	0.001	NS	NS
DM digestibility (%)	63.5	65.6	71.4	73.6	0.001	0.001	NS
N digestibility (%)	57.9^{c}	63.2^{b}	57.3^{c}	65.3^{a}	NS	0.001	0.01
NDF digestibility (%)	65.5	64.5	58.4	57.1	NS	0.04	NS

Values within the same parameter having different superscripts differ significantly ($P<0.05$)

LE low energy, *HE* high energy, *LP* low protein, *HP* high protein, *E× P* energy and protein interaction of dietary energy level on N intake was consistent with its effect on DMI. Increasing level of dietary protein from 12% to 14% resulted in increased ($P<0.01$) N intake from 22.2 to 28.0 g/day. This increase in N intake with increasing dietary protein level was due to increase in DMI (Hoffman et al. 2001). The combined effect of energy and protein on N intake was also observed.

The NDF intake was higher ($P<0.05$) in animals fed LE-LP and LE-HP diets than those fed HE-LP and HE-HP diets (Table 2). The NDF intake was affected ($P<0.01$) by dietary energy density. The NDF intake was higher (425.0 g/day) in animals fed low-energy diet than those (269.8 g/day) fed high-energy diet. Higher NDF intake in animals fed low energy was due to their higher DMI and proportionally higher of NDF contents in low-energy diets. There was no interaction between energy and protein regarding NDF intake.

Nutrient digestibility

The DM digestibility increased ($P<0.01$) from 64.6% to 72.5% with increasing the dietary energy density from 2.3 to 2.7 MJ/kg (Table 2). High-energy diets contained more nonstructural carbohydrates which were utilized more by ruminal microbes. It promoted ruminal fermentation, which eventually increased DM digestibility. The low DM digestibility in animals fed low-energy diets might be due to their high DMI because there is negative correlation between DMI and DM digestibility. The low DM digestibility in lambs fed low-energy diets might be due to higher level of lignin in their diets. Increasing the level of dietary protein increased ($P<0.01$) the DM digestibility (Table 3). Increasing dietary protein level might have improved ruminal NH_3-N status for ruminal microbes. Improvement in microbial activity resulted in greater DM digestibility (Griswold et al. 2003). Similar findings were reported by Hoffman et al. (2001) in Holstein heifers. There was no interaction between energy and protein.

The N digestibility was higher ($P<0.05$) in lambs fed HE-HP diet than those fed other diets. Dietary energy level did not affect N digestibility. Karim and Santra (2003) reported that CP digestibility did not differ among various dietary energy levels. Increased protein concentration from 12% to 14% resulted in increased ($P<0.01$) N digestibility from 57.6% to 64.3%. The N digestibility was also influenced ($P<0.05$) by interaction between energy and protein levels. Maximum N digestibility (65.3%) was noticed in animals fed HE-HP diet.

Increasing dietary energy contents decreased ($P<0.001$) NDF digestibility. The NDF digestibility was higher (65.0%) in animal fed low-energy diet than those (57.8%) fed high-energy diets (Table 2). Energy supplementation might cause a depression in ruminal pH. The low NDF digestibility in lambs fed high-energy diets might be attributed to their low ruminal pH because reduced ruminal pH is known to depress fiber digestion (Javaid et al. 2008). Firkins et al. (1986) reported that when roughage based diets high in energy content were fed; ruminal pH was reduced resulting in decreased NDF digestibility. The NDF digestibility decreased ($P<0.05$) from 62.0% to 60.8% as the level of dietary protein was increased from 12% to 14%. More protein might have caused more ruminal fermentation and increased the volatile fatty acids that might have caused reduced ruminal pH and ultimately reduced the NDF digestibility. There was no interaction between energy and protein levels regarding NDF digestibility.

Table 3 Growth performance and economics of lambs fed different levels of energy and protein

Energy level	LE		HE		Effects $p<$		
Protein level	LP	HP	LP	HP	Energy	Protein	E×P
Average daily gain (g)	126.0	152.0	125.0	154.0	NS	0.001	NS
Gain to feed ratio	0.105^{c}	0.113^{b}	0.112^{b}	0.133^{a}	0.004	0.001	0.04
Cost per kilogram weight gain (Rs.)	99.3	91.5	98.5	81.5	–	–	–

Values within the same parameter having different superscripts differ significantly ($P<0.05$)

LE low energy, *HE* high energy, *LP* low protein, *HP* high protein, *E× P* energy and protein interaction

Average daily gain

The ADG was 126.0, 152.0, 125.0, and 154.0 g/day in animals fed LE-LP, LE-HP, HE-LP, and HE-HP diets, respectively (Table 3). Increasing dietary energy level did not affect the ADG. Similarly, Lu and Potchoiba (1990) reported nonsignificant effect of different energy levels on weight gain in goats. The ADG was increased ($P<0.01$) with increasing dietary CP level from 12% to 14%. Sultan et al. (1991) reported a positive effect of dietary protein on weight gain of steers. There was no combined effect of energy and protein on weight gain of experimental animals.

Gain to feed ratio

Gain to feed ratio was not different between the lambs fed LE-HP and HE-LP diets, however, it was lower ($P<0.05$) than those fed HE-HP diet and higher ($P<0.05$) than those fed LE-LP diet (Table 3). Increasing the dietary energy contents increased ($P<0.01$) the gain to feed ratio. Similar trend was noted in gain to feed ratio with increasing protein contents. The feed to gain ratio was also affected ($P<0.05$) by interaction between energy and protein levels. Increasing energy supply increases the efficiency of protein utilization resulting greater N retention (Schroeder et al. 2006a; Schroeder et al. 2006b) and improved feed to gain ratio in sheep fed high energy and high protein might be due to increased efficiency of protein utilization. Low-energy diets were rich in NDF contents. High fibrous diets having less energy content might have increased heat increment, which resulted into reduced efficiency of energy utilization. Khan (1993) reported that energy and protein interaction had a significant effect on the feed efficiency of Nili–Ravi buffalo male calves.

Economics

The lambs fed HE-HP diet produced economical mutton than those fed other diets.

Conclusion

Based upon the findings of the present study, it is concluded that sheep gained more weight when fed diet high in protein and energy. It is hypothesized that efficient N and energy coupling at cellular level helped in higher gain in weight and improved gain to feed ratio in dry lot situation.

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