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Effect of Different Levels of Dietary Fat on Nutrient Utilization in Small Ruminants

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ABSTRACT. *An experiment was conducted to evaluate the effect of different levels of dietary fat on nutrient intake and digestibility. Fifteen male sheep were allotted to five dietary treatments. The basal concentrate diet consisted of molasses, dicalcium phosphate, salt, coconut poonac and rice bran. Experimental diet was prepared by adding 0%, 2.5%, 5%, 7.5% and 10% of dietary fat to the basal diet. "Guinea A" grass and water were provided ad libitum. This study consisted of 10 day transition, 10 day adaptation and 7 day collection period. Feed offered, refusals, fecal and urine samples were collected during total collection period and analyzed. Rumen fluid and blood samples were collected on the last day of the collection period. Rumen fluid was analyzed for pH, rumen ammonia-nitrogen (RAN), total volatile fatty acids (TVFA) and soluble protein (SP). Blood samples were analyzed for blood urea nitrogen (BUN), albumin (Ab), globulin (Gb) and total serum protein (TSP). Rumen pH, Ab, TSP, Gb and albumin/globulin ratios (Ab/Gb) were not affected by treatments. Dry matter intake (DMI), ether extract intake (EEI) and ether extract digestibility (EED) were not significantly ($P>0.05$) affected by the level of dietary fat. Organic matter intake (OMI), crude protein (CP), acid detergent fiber intake (ADFI), nutrient digestibility (ND), and rumen ammonia-nitrogen decreased significantly ($P<0.05$) with high level of dietary fat in the diet. Blood urea nitrogen and body weight gain were not significantly affected ($P<0.05$) by the level of dietary fat. Total volatile fatty acid increased significantly ($P<0.05$) with increasing fat levels added. Body weight gain and soluble protein in the rumen fluid were higher in the treatment containing 2.5% dietary fat. These findings suggest that fat supplementation at 2.5% of total diet can improve the nutrient digestibility in small ruminants.*

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INTRODUCTION

During late pregnancy and early lactation, higher levels of dietary energy are required by high producing small ruminants for milk synthesis. However, during this period, energy intake is frequently insufficient to meet energy requirements. This negative energy balance may cause suboptimal milk yields (Palmquist and Jenkins, 1980). Maximizing energy intake by increasing energy density of the diet is a logical feeding strategy for such periods. Excessive feeding of energy rich concentrates increase energy density of the diet, but it can cause undesirable rumen fermentation leading to many metabolic disorders. In addition, it may not be economical to feed expensive energy rich concentrates if a substantial return is not possible. On the other hand, severe competition exists between ruminant and non–ruminant livestock for such feed ingredients, since their level of production mainly depends on the availability. Dietary fat is a less exploited source of energy in livestock feeding and very little emphasis has been given in ruminant nutrition. There are numerous sources of edible fats that are not utilized for human consumption and hence under utilized. Therefore, dietary fat can be used as a partial supplement to improve energy nutrition of the ruminant livestock. If dietary fat does not alter dry matter intake excessively, this can be used satisfactorily to partially fulfil the energy requirement more economically. This effect depends on the level of fat fed to the animal.

Dietary fat added at 3–5% to common feeds appear to be tolerated by rumen microorganisms (Palmquist, 1984). It will increase DMI, ADFI and TVFA in the rumen (Lu, 1993). Higher levels of dietary fat can cause adverse effects on rumen function, and exert deleterious effects on fiber digestion through inhibition of rumen microbial activity. It could decrease dry matter intake and total volatile fatty acids (Beaulieu and Palmquist, 1995). Diets with high dietary fat increased ether extract and crude protein digestibility (Palmquist and Conrad, 1978). The, *et al.* (1994), reported that high level of dietary fat does not affect ruminal pH but decreases the body weight gain.

Saturated fatty acids in diet do not interfere with fermentation characteristics by ruminal microorganisms (Jenkins and Palmquist, 1984). Therefore, in this study Sediment Residue of Coconut Oil (SRCO) industry was used as a source of saturated dietary fat. SRCO is a by product of the Coconut Oil industry resulting during the purification process and has little economic importance and is being under–utilized. This study was conducted to investigate the effects of different levels of dietary fat on digestibility of the nutrients, rumen and blood parameters of small ruminants.

MATERIALS AND METHODS

The study was carried out at the Department of Animal Science, University of Peradeniya, Sri Lanka. Twenty (20) castrated male sheep (Dorset × Bikenary) were allotted to 5 dietary treatments in a randomized complete block design balanced by body weight. The study consisted of 10 day transition and 10 day adaptation and seven day of total collection period. Sheep were fed with medium quality (12% CP) "Guinea A" grass *ad-libitum*. The feed ingredient composition and chemical composition of experimental diets and guinea grass (basal diet) are given in Table 1. The basal concentrate was used to prepare the test diets by adding dietary fat (SRCO as a source) at the rate of 0% (T_0), 2.5% (T_1), 5.0% (T_2), 7.5% (T_3) and 10% (T_4). Concentrate diets were fed daily at the rate of 30 g/kg body weight. Daily ration was divided into two equal portions to be fed at 0800 hrs and at 1600 hrs. Three hours after each concentrate feeding, refusals of the concentrates were collected.

Grass and concentrate feeds offered and refused were measured daily. Samples of feeds and refusals were obtained daily and composited at the end of the collection period. A grab sample of the composited samples of feed and refusals were dried in an oven at 60°C until a constant weight was obtained. During the collection period daily faecal output was collected and weighed. 50 g of each faecal output was dried in a oven at 60°C till a constant weight was obtained. The samples at the end of the collection period were ground using a laboratory grinder to pass a 2 mm sieve and stored for chemical analysis. The feed and faecal sample were analyzed for DM, OM, Total Ash, CP and EE (AOAC, 1990). Acid detergent fiber was determined by the method of Goering and Van soest (1970). Apparent digestibility of diets were estimated on percent dry matter basis.

Urine was collected in a plastic container containing 25 ml of concentrated hydrochloric acid during the collection period and weighed daily. Ten percent of the daily total urine output was stored at 4°C until further analysis.

Body weight of the animals were recorded prior to and after the experimental period. At the end of the experiment, blood samples were obtained from the jugular vein of each animal 3 h post feeding of the concentrate diet in the morning. Part of the blood was coagulated with taungstic acid for the determination of blood urea nitrogen. The rest was centrifuged at 3000 g for ten min and the serum was separated and stored

Table 1. Feed ingredients and chemical composition of different concentrate diets fed to sheep.

COMPOSITION	Experimental diet				
	T_0	T_1	T_2	T_3	T_4
Feed Ingredients:	(% of DM)				
SRCO *	0. 0	2.5	5.0	7.5	10.0
Molasses	10.0	10.0	10.0	10.0	10.0
Salt	3.0	3.0	3.0	3.0	3.0
Dicalcium phosphate	2.0	2.0	2.0	2.0	2.0
Coconut poonac	20.0	20.0	20.0	20.0	20.0
Rice bran	5.0	62.5	60.0	7.5	55.0
Chemical Composition of Diet:					
Dry matter	94.1	95.8	96.8	92.6	93.0
Ash	14.4	14.5	17.6	14.0	16.8
Crude Protein	14.2	13.1	12.2	13.1	12.8
Ether extract	10.7	12.3	14.6	16.8	18.0
Acid detergent fiber	30.0	27.8	26.3	24.7	22.4

SRCO = Sediment Residue of Coconut Oil * adjusted to Crude Fat in SRCO

at -20°C until analyzed. Total protein and albumin were estimated in serum by standard enzymatic and colorimetric methods using the International Atomic Energy Agency (IAEA) nutritional metabolic kits (Anonymous, 1993).

Ruminal fluid was collected by using a stomach tube, 4 h post feeding of concentrate diets during the last day of the collection period. Rumen fluid samples were filtered through double layered Cheese cloth and pH was

determined electrometrically. Samples were acidified with concentrated sulphuric acid and centrifuged at 3000 g for 10 min and the supernatant was used to analyze rumen ammonia, soluble protein and total volatile fatty acid (Markham, 1942).

Data were statistically analyzed using analysis of variance (Snedecor and Cochran, 1979) and means were separated by Duncan's multiple range test (DMRT) using SAS package (SAS, 1985).

RESULTS AND DISCUSSION

Average daily intake of dry matter, organic matter, crude protein, ether extract and acid detergent fiber of sheep are given in Table 2. The different levels of dietary fat did not significantly affect the intake dry matter and ether extract. This result is in agreement with Grummer (1988) for cows. However,

Table 2. Daily intake of dry matter, organic matter, crude protein, ether extract and acid detergent fiber of sheep fed with concentrate diets containing different levels of dietary fat.

Constituents	Treatments					
	T_0	T_1	T_2	T_3	T_4	SE±
Intake (g/d):						
Dry Matter	912.9	935.2	869.8	909.6	786.9	21.6
Organic Matter	797.9^{ab}	869.5^{a}	748.5^{ab}	799.7^{ab}	697.7^{b}	20.3
Ether Extract	101.0	106.9	97.8	101.3	94.9	1.8
Crude Protein	110.6^{ab}	120.6^{a}	103.8^{ab}	98.9^{b}	78.2^{c}	4.3
Acid Detergent Fiber	275.0^{ab}	315.9^{a}	291.1^{a}	261.6^{ab}	211.9^{b}	11.7

Values in the same row with the same superscripts are not significantly different (P<0.05).

Johnson *et al.* (1988) reported a substantial reduction in dry matter intake with increased level of dietary fat. The reduced feed intake was associated with decreased palatability of the diet. Another reason could be that fat containing concentrate is only a part of the total diet and it may not have much influence on the total roughage intake.

Organic matter intake and acid detergent fiber intake decreased significantly in T_4. Chalupa *et al.* (1984) have also observed a depression in the intake of organic matter and acid detergent fiber when feeding unprotected fats to ruminants. The depression may be related to the level of incorporated fat in the diet (Kowalczyk *et al.*, 1977), physical form of the fat (Mcleod and Buchunan-Smith, 1972), and the type of fat (Free/complex; saturated/unsaturated) in the diet (Devendra and Lewis, 1974).

Crude Protein intake was decreased significantly ($P<0.05$) in T_3 and T_4. This may be due to the depression of nitrogen digestion in the rumen with higher level (6-9%) of dietary fat (The *et al.*, 1994). Many suggested the deleterious effect of dietary fat on the rumen microbes and their physiology. Chalupa *et al.* (1984), suggested that not only the level of fat in the diet but also the source of fat can influence the rumen microbes and their activity.

Digestibility of all nutrients, except EE were significantly decreased, as the level of dietary fat increased ($P<0.05$) than T_1 dietary level (Table 3). Chalupa *et al.* (1984), reported a depression in organic matter digestibility when rumen unprotected fat is incorporated in the diet. This depression effect of dietary fat may be brought about by physical coating of fat on feed particles in the rumen and by the inhibitory effect of fatty acid on rumen microbes, resulting in low microbial activity leading to low fiber digestion. However, several others have observed little or no adverse effects of dietary fat on nutrient digestibility in dairy cattle, when dietary fats were included in the diet (Jenkins and Palmquist, 1984; Jenkins and Jenny, 1992).

Crude protein digestibility (Table 3) was decreased significantly ($P<0.05$) than the control, except in T_1 and T_2 level. This was accompanied with lower dry matter intake or less efficient synthesis of microbial protein. High dietary fat (6-9%) inhibited the growth of protozoa, which constitutes a futile cycle of microbial nitrogen in the rumen (The *et al.*, 1994). These results contradict the findings reported by Palmquist and Conrad (1978) on crude protein digestibility in the presence of dietary fat. Their findings suggested that the addition of dietary fat to a ration improved crude protein digestibility and even better results were observed at higher levels of dietary fat. Compared

Table 3. Apparent digestibility of dietary nutrient when concentrate was fed with different levels of dietary fat.

Constituents	Treatments					
	T_0	T_1	T_2	T_3	T_4	SE±
Dry Matter	64.2^{c}	70.2^{a}	68.6^{ab}	65.6^{bc}	66.1^{bc}	0.7
Organic Matter	67.8^{b}	74.9^{a}	71.3^{ab}	69.1^{b}	69.6^{b}	0.8
Crude Protein	45.6^{abc}	55.0^{a}	53.1^{ab}	43.4b^{c}	38.6^{c}	2.1
Ether Extract	85.2	86.4	88.7	86.1	88.6	0.7

Values in the same row with same superscripts are not significantly different (P<0.05).

to other nutrients, the EE (lipid) digestibility was higher in all dietary fat supplemented diets. This suggested that the added fat was more digestible than the EE (lipid) component of the basal diet or that dietary fat supplementation impede the endogenous lipid secretions resulting in a more accurate estimate of true lipid digestibility (Grummer, 1988).

The body weight gain was not significantly (P<0.05) affected (Table 4) in the present study. But the actual body weight gain was higher in T_2 dietary fat level and thereafter decreased as the level of dietary fat increased in the diet. This may be due to the effect of high dietary fat in the diet resulting in reduction of nutrient intake and low nutrient digestibility, caused by the physiological and microbiological changes in the rumen. Similar observations were reported by The *et al.* (1994) in goats fed with diets containing high levels of dietary fats (6 - 9%).

Ruminal pH was not affected (Table 4) by the level of dietary fat, indicating a low influence of dietary fat on solubility of nitrogen in the rumen. These results were in agreement with the results of The *et al.* (1994) reported for goats. The SRCO has long chain fatty acids and its effect on ruminal fermentation was not very severe. In contrast to many suggestions made by others (Khorasani *et al*, 1992), in this study, the TVFA's were increased significantly with increasing levels of dietary fat (Table 4). The fatty acids present in SRCO are mainly long chained saturated fatty acids (stearic and

Table 4. Rumen parameters and body weight gain of sheep fed with concentrate diets with different levels of dietary fat.

Constituents	Treatments					
	T_0	T_1	T_2	T_3	T_4	±SE
Ruminal pH	7.33	7.23	7.00	7.10	7.13	0.09
Ammonia (mg/dl)	9.26^{b}	11.21^{ab}	12.87^{a}	9.33^{b}	8.13^{b}	0.56
Total VFA (mmol/l)	32.75^{b}	38.92^{b}	42.00^{ab}	57.33^{a}	59.91^{a}	3.58
Soluble Protein (mg/dl)	17.33	10.00	11.00	7.42	8.92	1.38
BWG (g/day)	120.10	127.10	107.60	105.10	90.58	7.46

VFA = Volatile Fatty Acids BWG = Body weight
Values in the same row with same superscripts are not significantly different (P<0.05).

palmitic acids) and their effect on rumen microbes is less than many unsaturated short chained fatty acids present in dietary fats. This could be one of the reasons for low influence of dietary fat on rumen fermentation characteristics. The dietary fat sources, composition of fatty acids and the degree of saturation of the fatty acids in reported studies may be different to the present study, leading to contrasting results observed in this study. However, much extensive and in depth investigations are required to confirm certain characteristics observed in the present study.

Rumen ammonia concentration was decreased significantly (P<0.05) in diets containing fats than in the control except for T_1 and T_2 (Table 4). This may be due to an inhibitory effect of dietary fat on the rumen microbes resulting in low crude protein digestion (Jenkins and Palmquist, 1982). In addition, presence of certain fats have shown to lower the solubility of soluble fraction of the dietary proteins through the formation of soap like substances.

The constituents of blood serum are presented in Table 5. Total serum protein, albumin, globulin and albumin/globulin ratio and blood urea nitrogen

Table 5. Blood parameters of sheep fed with concentrate diets with different levels of dietary fat.

Constituent	Treatment					
	T_0	T_1	T_2	T_3	T_4	±SE
BUN (g/dl)	1.80	2.08	1.57	1.08	1.19	0.28
Total Protein (g/dl)	7.54	7.47	7.44	7.23	7.49	0.09
Albumin (g/dl)	4.07	4.05	3.82	3.86	3.96	0.09
Globulin (g/dl)	3.48	3.41	3.59	3.38	3.54	0.08
Ab/Gb ratio	1.19	1.19	1.05	1.15	1.12	0.05

BUN = Blood urea ni rogen Ab/Gb = Albumin : Globulin Ratio

were not affected by the level of dietary fat. In this study, animals used were not in a high nutritional demand, since they were not in production. These result are not in agreement with the finding of Palmquist (1993) in dairy cattle. However, Palmquist (1993) reported that blood urea nitrogen increased with dietary fat, but total protein, albumin, globulin, and albumin/globulin ratio decreased with high dietary fat. However, if this study was carried out with lactating dairy cattle, different observations could have been made.

CONCLUSIONS

Results of this study suggest that a diet containing 2.5% of dietary fat fed to small ruminants can improve nutrient intake, digestibility, and body weight gain without altering rumen pH and blood metabolites. High fat (10%) in the diet reduced only the CP intake and the digestibility of the other nutrients were not effected. Therefore, dietary fat can be successfully incorporated into small ruminant diets as a source of energy.

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