Effects of Levels of Feed Intake and Inclusion of Corn on Rumen Environment, Nutrient Digestibility, Methane Emission and Energy and Protein Utilization by Goats Fed Alfalfa Pellets

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ABSTRACT : The effect of high and low level of feed intakes on nutrient digestibility, nutrient losses through methane, energy and protein utilization by goats fed on alfalfa (*Medicago sativa* L.) pellets based diets was investigated in this study. Twelve castrated Japanese goats were employed in two subsequent digestion and metabolism trials. The goats were divided into three groups, offered three diets. Diet 1 consisted of 100% alfalfa pellet, Diet 2 was 70% alfalfa pellet and 30% corn, and Diet 3 was 40% alfalfa pellet and 60% corn. The two intake levels were high (1.6 times) and low (0.9 times) the maintenance requirement of total digestible nutrients (TDN). Rumen ammonia nitrogen (NH_3-N) level of Diet 1 was lower ($p<0.001$) compared to Diets 2 and 3, but the values were always above the critical level (150 mg/liter). The pH values of rumen liquor ranged from 6.02 to 7.30. Apparent digestibility of nutrient components did not show differences ($p>0.05$) between the two intake levels but inclusion of corn significantly altered the nutrient digestibility. Diet 3 had highest ($p<0.001$) dry matter (DM), organic matter (OM), ether extract (EE) and nitrogen fee extract (NFE) digestibility followed by the Diet 2 and Diet 1. The crude protein (CP) digestibility values among the three diets were in a narrow range (70.1 to 70.8%). Crude fiber (CF) digestibility for Diet 3 was slight higher ($p>0.05$) than that for other two diets. When alfalfa was replaced by corn, there were highly significant ($p<0.001$) increases in DM, OM, EE and NFE apparent digestibility and a slight increase in the CF digestibility ($p>0.05$). There were no differences ($p>0.05$) in energy losses as methane (CH_4) and heat production among the diets but energy loss through urine was higher for the Diet 1. The total energy loss as CH_4 and heat production were higher for the high intake level but the energy loss as CH_4 per gram DM intake were same (0.305 kcal/g) between the high and low intake level. Retained energy (RE) was higher for Diet 3 and Diet 2. Nitrogen (N) losses through feces and urine were higher ($p<0.001$) for Diet 1. Consequently, N retention was lower ($p>0.05$) for Diet 1 and higher in Diets 3 and 2. It is concluded that inclusion of corn with alfalfa increased the metabolizable energy (ME) and RE, and retained N through reducing the energy and N losses. The high level of intake reduced the rate of nutrient losses through feces and urine. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 7 : 948-956*)

Key Words : Goat, Intake Level, Corn, Alfalfa, Rumen Environment, Methane, Energy Metabolism and Nitrogen Metabolism

INTRODUCTION

Increased animal production through dietary manipulation has been given much attention. Increase in dietary feed intake as well as nutrient intake is one of the ways to increase efficiency of animal production. High feed intake may affect rumen environment as well as fiber digestion. The intake level accounted for 60% of the total variation in digestibility (Tyrell and Moe, 1972). Supplementation with concentrate improves animal performance through a more uniform pattern of fermentation in the rumen (Gibson, 1981). Such information is limited for goats. Their energy and protein requirements have been obtained by feeding trials (Rajpoot, 1979; Aguilera et al., 1984) but balance measurements in respiration chambers are very limited. Energy and protein utilization (Terada et al., 1985) and the requirement for maintenance of castrated Japanese goats (Itoh et al., 1978) has been reported earlier, but at a high level of intake the energy and N utilization by goat are little known. Khan et al. (1998) studied the effect of protein supplement on energy and nitrogen balance in goats, but study on the effect of different intake levels and energy source supplement on the rumen environment, nutrient digestibility, and energy and nitrogen utilization is needed. The objectives of this study were to determine the effects of high and low feed intake levels and inclusion of corn on the nutrient digestibility of alfalfa, and the energy and nitrogen partitions in goats.

MATERIAL AND METHODS

Diets

Three diets were prepared using alfalfa (blooming stage) and corn in different ratios. Diet 1 consisted of 100% alfalfa pellet, Diet 2 was 70% alfalfa pellet and 30% corn, and Diet 3 was 40% alfalfa pellet and 60% corn. The two intake levels based on the TDN requirement for metabolic body weight ($W^{0.75}$) of Japanese goat were, low (0.9 times) and high (1.6 times) the maintenance level obtained from Itoh et al. (1978).

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Animals

Twelve adult male Japanese goats of mean live weight 32.1 kg were employed for two subsequent digestion and metabolism trials. Animals were randomly allotted into three groups, with mean body weights of 33.3, 31.0 and 32.2 kg. The diets were given at high intake level in trial 1 and at the low level in trial 2.

Metabolism trial

Metabolism trial for each diet was conducted for 7 days with a week of adjustment period and a week of preliminary period prior to the trials. The required amounts of feed were equally proportioned and offered to the goats. Total feces and urine were collected for 7 days, which included 3 consecutive days for measurement of gas exchange. The required amounts of feeds were supplied to the animal once in the morning at 08:30 h and refusals, if any, were collected and measured before the next feeding. During the collection periods, representative samples of feeds and refusals were taken, oven dried (60℃ for 24 h) and ground to pass through a 1mm sieve for chemical analysis. Total feces and urine from each goat were collected and measured prior to next feeding. All feces and 10% of the urine were preserved daily. Urine was collected in a bucket where 25 ml (1% of urine volume) of 20% H_2SO_4 was placed before the collection. After total collection, feces and urine were mixed thoroughly and sub-sampled for N determination. For further analysis, fecal samples were oven dried (60℃ for 48 h) and then ground similarly. In a polyethylene film 20 ml of urine were weighed and freeze-dried for determination of GE using the method described by Itoh and Tano (1977).

Respiration chambers

The calculation of energy balance, metabolizability and partition was undertaken using quantitative collections of feces and urine. Total air flow, consumption of oxygen (O_2), the concentration of methane (CH_4) and carbon dioxide (CO_2) were measured for 3 consecutive days by direct measurement of gaseous output using open circuit respiration chambers, details of which are as outlined by Iwasaki et al. (1982). The chamber was maintained under controlled conditions of temperature at 20℃ and relative humidity at 60% throughout the measurement period.

Nutrient analyses

Analyses of DM, OM, EE, CF, NFE and CP of feeds, feces and urine were carried out using the methods described by AOAC (1984).

Collection and analyses of rumen liquor

Rumen liquors were collected from individual goats at 0 and 3 h post-feeding using a stomach tube. The pH was measured immediately. Samples were then preserved in the freezer at 30℃. The ammonia N of rumen liquor was determined following the method described by Weatherburn (1967). The volatile fatty acids were analyzed using the Gas Chromatograph (YHP 5830A).

Energy balance measurement

The energy values of feed, feces and urine were used to calculate energy balance. Gross energy content of feed, feces and urine were determined using a bomb calorimeter (Shimadzu, CA3P). Digestible energy (DE) was calculated as the difference between GE intake and energy loss as fecal output. Metabolizable energy (ME) was calculated as the difference between DE intake and energy loss as urine and CH_4 output. Methane gas volume was converted to energy and mass values using the conversion factors 9.45 kcal/l and 0.716 g/l. Heat production (HP) was calculated from the gaseous exchange (l/d) and urine excretion (g/d) with the equation of Brouwer (1965) :

$$HP\ (kcal/d) = 3.866\ O_2 + 1.200\ CO_2 - 0.518\ CH_4 - 1.431\ N$$

Retained energy (kcal/day) was calculated as (ME-HP).

Statistical analyses

Statistical significance was determined by analysis of variances with the dietary intake levels and diets as factors in a 2×3 factorial analysis. In the event of significant differences being established, the difference between the diets and intake levels were investigated using Duncans new multiple range test. All the statistical analyses were carried out using SAS (1994).

RESULTS

Feed composition

The feed composition results are given in table 1. The corn contained higher GE, EE and NFE but lower CP compared to the alfalfa. Alfalfa contained higher CF than that for corn. Intakes of total dry matter intake (DMI) per metabolic body weight ($W^{0.75}$) were highest ($p<0.01$) for goats on Diet 1 followed by Diet 2 and Diet 3 (table 2).

Rumen environment

The pH values of rumen liquor for goats on the diets at two intake levels were in between 6.3 to 7.3 (table 3). Irrespective of diets, the pH of rumen liquor at the high level of intake was slightly higher ($p>0.05$) than that at low intake level; values were a little higher ($p>0.05$) for Diets 1 and 2 than 3. Inclusion of corn reduced the rumen pH slightly, and

Table 1. Chemical composition (g/kg DM) and energy value of alfalfa and corn used in the diets

Feeds	DM (g/kg)	Ash	CP	EE	CF	NFE	GE (kcal/kg DM)
Alfalfa	883	88	171	21	242	472	4,530
Corn	862	13	86	39	18	844	4,550

Table 2. Dry matter (DM) intakes of goats fed different diets based on corn and alfalfa at two intake levels

	Intake levels	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
Total DM intake (g/day/animal)	High	988.8	815.0	729.7	854.9[a]	34.51	42.26	59.77
	Low	494.3	410.3	364.8	423.1[b]	0.001	0.001	0.32
	Mean	741.5[a]	612.6[b]	521.1[c]				
DM intake ($g/day/kg^{0.75}$)	High	71.37	62.11	53.95	63.25[a]	1.17	1.32	1.87
	Low	37.45	31.84	28.75	32.68[b]	0.001	0.001	0.001
	Mean	54.4[a]	47.0[b]	39.6[c]				

Means with different superscripts in rows differ significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

Table 3. Rumen pH, NH_3-N and volatile fatty acid components at 0 and 3 h (post-feeding) of goats fed on different diets based on corn and alfalfa at two intake levels

	Intake levels	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
pH	High	7.15	7.12	6.65	7.00	0.110	0.138	0.195
	Low	6.83	6.75	6.77	6.78	0.077	0.201	0.203
	Mean	6.99	6.93	6.72				
NH_3-N (mg/liter)	High	177.3	213.5	356.5	239.3[a]	15.96	19.55	27.65
	Low	157.6	158.8	175.9	164.1[b]	0.001	0.001	0.002
	Mean	169.9[b]	182.9[b]	236.7[a]				
Total volatile fatty acids (mmol/dl)	High	8.50	6.71	6.92	7.42[a]	0.557	0.681	0.964
	Low	7.09	5.00	3.90	5.33[b]	0.001	0.006	0.506
	Mean	4.80[a]	5.85[b]	5.20[b]				
Acetic acid (mol%)	High	69.85	61.69	58.38	63.76[b]	2.18	2.67	3.77
	Low	70.74	69.13	68.18	69.35[a]	0.022	0.064	0.269
	Mean	70.29[a]	65.41[ab]	63.98[b]				
Propionic acid (mol%)	High	20.49	18.08	18.45	19.06	2.11	2.59	3.66
	Low	20.40	16.48	17.83	18.23	0.709	0.469	0.957
	Mean	20.44	17.28	18.09				
Butyric acid (mol%)	High	7.81	16.85	20.65	14.60[a]	0.834	1.02	1.45
	Low	6.54	10.86	11.19	9.53[b]	0.001	0.001	0.004
	Mean	7.17[b]	13.85[a]	15.28[a]				

Means with different superscripts in rows differs significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

the pH for low intake level was lower than that for high intake level. Ammonia nitrogen of rumen liquor for the diets at two intake levels ranged between 152 to 364 (mg/l). The mean NH_3-N of rumen liquor for the high intake level was higher ($p<0.001$) than that for low intake considering all the diets and irrespective of intake levels; Diet 3 produced higher ($p<0.001$) NH_3-N (table 3). The NH_3-N level increased ($p<0.001$) with increase in corn level on the diets and the high intake level produced higher rumen NH_3-N. The mean acetic acid production in rumen liquor was higher when goats consumed low DM. Among diets slightly higher acetate proportion was on Diet 1 followed by Diet 2 and 3 ($p>0.05$). Propionic acid levels were in a narrow range among the diets and intake level ($p>0.05$). Butyric acid proportion was higher ($p<0.001$) at high level intake and on Diets 2 and 3. Diet 1 produced lower butyric acid concen-

Table 4. Apparent digestibility (%) of different diets based on corn and alfalfa at two intake levels

	Intake level	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
DM	High	57.8	68.7	78.5	67.4	1.38	1.69	2.40
	Low	58.4	68.1	76.5	67.6	0.812	0.001	0.57
	Mean	58.1[c]	68.4[b]	77.3[a]				
OM	High	58.4	70.0	80.3	68.5	0.942	1.16	1.63
	Low	59.4	69.5	77.9	68.9	0.672	0.001	0.439
	Mean	58.9[c]	69.8[b]	78.8[a]				
CP	High	69.6	71.2	70.9	70.6	1.46	1.79	2.53
	Low	71.1	70.5	69.6	70.4	0.910	0.928	0.728
	Mean	70.4	70.8	70.1				
EE	High	42.3	65.6	79.2	61.1	0.912	1.12	1.58
	Low	42.3	65.7	80.3	62.8	0.078	0.001	0.830
	Mean	42.7[c]	65.7[b]	79.8[a]				
CF	High	33.3	36.3	40.9	36.4	1.52	1.86	2.63
	Low	34.4	35.0	35.4	34.9	0.335	0.138	0.247
	Mean	33.8	35.6	37.7				
NFE	High	71.1	82.8	89.6	80.4	0.773	0.947	1.34
	Low	71.7	82.5	87.7	80.6	0.754	0.001	0.454
	Mean	71.4[c]	82.6[b]	88.5[a]				

Means with different superscripts in rows differs significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

tration that other diets at both the intake levels. The mean of total volatile fatty acid (VFA, mg/dl) was higher ($p<0.001$) for Diet 1 than that for Diets 2 and 3, and high intake level produced higher total VFA Concentration (table 3).

Diet apparent digestibility

Apparent digestibility of the nutrients did not differ ($p>0.05$) between the two intake levels (table 4). Irrespective of the intake levels, inclusion of corn in the diets significantly increased the nutrient digestibility. Dry matter, OM, EE and NFE digestibilit- ies on Diet 3 were the highest ($p<0.001$) followed by those on Diet 2 and Diet 1. Mean CP digestibility values for the three diets were in a narrow range (70.1 to 70.8%). Diet 3 showed slightly higher ($p>0.05$) CF digestibility than that for the other two diets. When alfalfa was replaced by corn in Diet 2 and Diet 3, there were highly significant ($p<0.001$) increases in DM, OM, EE and NFE apparent digestibility values, and inclusion of corn in the diets slightly improved the CF digestibility ($p>0.05$) (37.7 vs. 33.8%). At high and low DMI level, the CF digestibility was not much different. Slight higher ($p>0.05$) values of nutrient digestibility were on the low intake level for Diet 1, but for Diet 2 and 3, there were inconsistent differences for the nutrient components.

Energy balance

Energy balance is shown in table 5. Gross energy (kcal/day) intake was higher ($p<0.001$) on Diet 1 followed by Diet 2 and Diet 3. The energy losses through feces and urine were also higher ($p<0.001$) on Diet 1 followed by Diet 2 and 3, and both losses were higher ($p<0.001$) on high level of intake.

Methane production

Daily CH_4 emission (g/day) for goats fed on alfalfa based diets at two levels of intake are shown in table 6. Irrespective of the diets, higher ($p<0.001$) CH_4 production (g/day/goat) was on the high-intake level compared to the low intake. However, CH_4 production (g/100 g DMI) was the same (2.31) and the CH_4 (g) per 100 g digestible dry matter (DDM) intake was slightly lower for the high intake level. Methane emission per 100 g DDM intake was almost similar among intake levels and non-significantly increased in the corn-included diets (table 6). High intake level produced a higher energy loss through CH_4 but the energy losses through CH_4 per DMI among the two intake levels were same (0.305 kcal/g DMI). Diets 2 produced slightly more CH_4 than Diet 3 and Diet 1, but the energy losses through CH_4 per DMI were higher ($p<0.001$) on Diet 3 and Diet 2 than that for Diet 1. Methane conversion ratio (MCR%, energy loss as CH_4 per GE intake) for Diets 1, 2 and 3 were 5.2%, 7.1% and 8.0%, respectively. The MCR values were higher for Diet 3 than that for Diet 2 and the values for both the diets were higher ($p<0.001$) than for Diet 1.

Digestible energy was higher ($p<0.001$) on the high level of intake but for the diets there was small

Table 5. Energy balance (kcal/day) of goats fed on different diets based on corn and alfalfa at two intake levels

	Intake level	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
Gross energy intake	High	4,479.0	3,693.0	3,308.7	3,874.0[a]	154.7	189.4	267.89
	Low	2,239.3	1,858.8	1,653.0	1,917.0[b]	0.001	0.001	0.331
	Mean	3,359.1[a]	2,775.9[b]	2,362.6[c]				
Feces energy	High	1,975.0	1,192.0	765.33	1,360.4[a]	61.5	75.4	106.6
	Low	964.8	620.8	406.3	663.9[b]	0.001	0.001	0.002
	Mean	1,469.9[a]	906.4[b]	560.1[c]				
Digestible energy	High	2,504.0	2,501.0	2,543.3	2,513.6[a]	102.8	125.9	178.1
	Low	1,274.5	1,238.0	1,246.8	1,253.1[b]	0.001	0.981	0.968
	Mean	1,889.3[a]	1,869.5[a]	1,802.4[a]				
Urine energy	High	188.5	118.0	94.0	137.1[a]	6.19	7.58	10.72
	Low	99.3	79.8	71.8	83.6[b]	0.001	0.001	0.001
	Mean	143.9[a]	98.9[b]	81.3[c]				
Methane energy	High	216.3	269.8	282.0	253.6[a]	16.2	19.8	78.6
	Low	128.5	127.8	127.5	127.9[b]	0.001	0.283	0.242
	Mean	172.4	198.8	193.7				
Metabolizable energy	High	2,099.3	2,113.3	2,167.3	2,122.9[a]	85.28	104.5	147.7
	Low	1,046.8	1,030.5	1,047.5	1,041.6[b]	0.001	0.943	0.953
	Mean	1,573.0	1,571.9	1,527.4				
Heat production	High	1,648.3	1,513.5	1,550.3	1,572.6[a]	85.6	104.8	148.3
	Low	1,238.3	1,110.0	1,160.0	1,169.4[b]	0.001	0.461	0.995
	Mean	1,443.3	1,311.8	1,327.3				
Retained energy	High	450.8	600.3	617.3	550.6[a]	35.1	43.1	61.0
	Low	-191.5	-79.3	-112.5	-127.7[b]	0.001	0.014	0.630
	Mean	129.8[b]	260.1[a]	200.1[ab]				

Means with different superscripts in rows differs significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

Table 6. Methane production by goats fed on alfalfa based diets at high and low levels of intake

	Intake level	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
Methane g/day	High	16.38	20.43	21.36	19.22[a]	1.21	1.49	2.10
	Low	9.73	9.67	9.66	9.69[b]	0.001	0.286	0.242
	Mean	13.06	15.06	14.67				
Methane g/100 g DMI	High	1.66	2.50	2.92	2.31	0.135	0.165	0.134
	Low	1.96	2.36	2.60	2.31	0.994	0.001	0.182
	Mean	1.81[b]	2.43[a]	2.74[a]				
Methane g/100 g DDMI	High	2.86	3.64	3.73	3.38	0.163	0.200	0.282
	Low	3.36	3.47	3.38	3.40	0.899	0.082	0.116
	Mean	3.11	3.55	3.53				
Energy loss as methane kcal/g DMI	High	0.218	0.330	0.386	0.305	0.017	0.021	0.030
	Low	0.259	0.311	0.342	0.305	0.994	0.001	0.182
	Mean	0.239[b]	0.320[a]	0.361[a]				
Methane conversion ratio (MCR) (%GE intake)	High	4.82	7.28	8.51	6.73	0.004	0.005	0.007
	Low	5.73	6.88	7.56	6.72	0.997	0.001	0.185
	Mean	5.23[b]	7.08[a]	7.97[a]				

Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

difference which favored of Diet 1. Metabolizable energy values were higher ($p<0.001$) on the high level of intake but the diets did show small differences which favored Diet 1. Energy loss as HP was higher

Table 7. Partition of digestible energy and metabolizable energy of goats fed on different levels of alfalfa and corn based diets at two intake levels

	Intake level	Diets			Mean	SEM and significance		
		1	2	3		Intake	Diet	Intake × Diet
Digestibility (DE/GE)	High	0.559	0.676	0.772	0.660	0.009	0.012	0.017
	Low	0.568	0.666	0.735	0.663	0.793	0.001	0.553
	Mean	0.563^{c}	0.671^{b}	0.761^{a}				
Partition of digestible energy								
Urine	High	0.076	0.047	0.036	0.055^{b}	0.003	0.004	0.005
	Low	0.078	0.065	0.058	0.067^{a}	0.001	0.001	0.072
	Mean	0.077^{a}	0.056^{b}	0.049^{b}				
Methane	High	0.086	0.108	0.110	0.101	0.005	0.006	0.008
	Low	0.101	0.103	0.100	0.101	0.90	0.122	0.129
	Mean	0.094	0.104	0.105				
Metabolizable energy	High	0.838	0.845	0.853	0.845^{a}	0.006	0.007	0.011
	Low	0.821	0.832	0.842	0.831^{b}	0.049	0.078	0.909
	Mean	0.829^{b}	0.838^{ab}	0.847^{a}				
Metabolizable energy								
ME per kg DM	High	2,124.7	2,589.8	2,986.9	2,529.0	3.56	4.36	6.17
(M/D, kcal)	Low	2,112.8	2,511.2	2,872.8	2,499.8	0.436	0.001	0.539
	Mean	$2,118.7^{c}$	$2,550.1^{b}$	$2,922.8^{a}$				
ME/GE (q)	High	0.469	0.571	0.658	0.558	0.008	0.009	0.014
	Low	0.466	0.554	0.634	0.551	0.442	0.001	0.552
	Mean	0.468^{c}	0.563^{b}	0.645^{a}				
Partition of ME								
Heat	High	0.784	0.716	0.712	0.74^{b}	0.033	0.046	0.057
	Low	1.189	1.071	1.106	1.12^{a}	0.001	0.076	0.082
	Mean	0.987^{a}	0.893^{b}	0.937^{ab}				
Retained	High	0.216	0.285	0.288	0.260^{a}	0.033	0.041	0.057
	Low	-0.190	-0.070	-0.106	-0.122^{b}	0.001	0.074	0.812
	Mean	0.013^{b}	0.107^{a}	0.0628^{ab}				

Means with different superscripts in rows differs significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

($p<0.001$) at the high level of intake when compared to the low but there was little difference ($p>0.05$) among the diets. High intake level had positive RE and the low intake level had negative balance for all the diets. Irrespective of intake level, retained energy was highest ($p<0.01$) on Diet 2 followed by Diet 3 and Diet 1 (table 6).

Energy partition

Energy partition calculations are shown in table 7. Energy digestibility (DE/GE), metabolizability (ME/GE) and the concentration of ME in the DM (kcal/kg DM, M/D) increased markedly with increasing the corn inclusion ($p<0.001$) in the diets. Intake levels did not show any significant changes in energy digestibility, metabolizability and ME per kg DM. Of the DE, the proportion lost as methane was not affected by the diet and intake levels, but the proportion lost as urine was affected by the diets and intake levels. The CH_4 energy loss was about 10% of DE for low and high intake level. Diet 1 lost 9.4% of DE through CH_4, and Diets 2, 3 lost 10.4 and 10.5%, respectively. The high intake level and the diet containing high roughage (Diet 1) lost more ($p<0.001$) energy as urine; consequently, the ME/DE values were affected. The energy loss as urine was 6.7% of the total energy intake at the low-intake level, while on the high intake it was 5.5%. The loss was 7.7% of DE for Diet 1, and for Diet 2 and Diet 3 were 5.6 and 4.9%, respectively. The highest ($p<0.001$) ME/DE values were on Diet 3 (0.847) followed by Diet 2 (0.838) and Diet 1 (0.829), and the ME/DE value at high-intake level (0.845) was higher than low intake level (0.831) ($p<0.001$).

The proportion of ME lost as heat production was higher ($p<0.001$) at low intake level (1.12 vs. 0.74) while ME lost as heat showed a higher trend with the diet of high alfalfa level. Diet 1 lost 98.7% of the ME for heat production; the values for Diet 2 and 3 were 89.3 and 93.7%, respectively. Consequently, the retained energy of ME was higher ($p<0.05$) for Diet 2 (10.7%) compared to Diet 3 (6.3%) and Diet 1 (1.3%).

The diets were prepared on the basis of TDN (Itoh et al., 1978) for Japanese goats. The digestible crude protein (DCP) intake (g/kg $W^{0.75}$) was higher for Diet 1 followed by the Diet 2 and Diet 3 (table 8). The DE (kcal/kg $W^{0.75}$) intake was higher for Diet 2 with little differences ($p>0.05$) among the diets.

Nitrogen balance

Major changes occurred in N balance with the diets and intake levels (table 9). Nitrogen intakes, fecal nitrogen and urinary nitrogen output were higher ($p<0.001$) for Diet 1 and at the high intake level compared to the other diets and low intake level. The amount of N digested was higher ($p<0.001$) on Diet 1, but the retained N was lower ($p>0.05$) for Diet 1. Retained N per nitrogen intake (NI) and the retained N per nitrogen digested were higher for Diet 2 and Diet 3, compared to Diet 1.

DISCUSSION

The primary objective of this study was to examine the effects of high and low level of intake on nutrient digestibility. The results in this study showed that higher level of feed intake increased the rumen pH ($p>0.05$), (NH_3-N) ($p<0.001$), total TVA and propionic acid ($p>0.05$) and butyric acid ($p<0.001$), but decreased acetic acid ($p<0.05$) proportion. Digestibility values for nutrients high and low intake level were almost similar ($p>0.05$), although it had been presumed that the low intake level could increase the digestibility of feed. Results of this study showed that inclusion of corn with alfalfa showed differences in fermentation characteristics that affected the nutrient digestibility of the diet. High alfalfa based diets (100% alfalfa pellet) produced higher VFA than those diets of low alfalfa level. With corn included in alfalfa, the diets produced higher ($p<0.001$) NH_3-N concentrations in the rumen (table 4). The slightly higher CF digestibility values were for the Diet 2 and Diet 3, and the digestibility of CF was higher for high intake level. That was possibly due to the higher NH_3-N concentrations which might influence the fermentation activities as well as fiber degradation. This supports Perdock (1987) and Islam (1999) who reported that higher concentrate as well as higher rumen NH_3-N concentration could increase rumen fermentation and degradability of the fiber of the diets.

The GE was higher ($p<0.001$) on Diet 1 than that of other two diets. Energy loss as feces and urine was higher on Diet 1, but the energy loss as CH_4 did not differ significantly among the diets. No differences ($p>0.05$) were obtained in DE and ME among the diets, while the RE was higher on Diet 2 and Diet 3 than that of Diet 1. The higher losses as feces and urine ($p<0.001$) as well as methane ($p>0.05$) of Diet 1 resulted in lower retained energy. This showed that the dietary supplement of concentrate with fibrous energy source decreased energy loss as urine and feces and increased the retained energy. The results of significantly decreased energy losses through feces and urine on the diets of corn supplementation is in contrast to the work of Sutton et al. (1991) and Keady and Mayne (1998) with silage who found no significant effect of supplementation with concentrates on feces and urine output.

Methane emission (g/day) ($p>0.05$), methane (g/100 g DM), energy loss as CH_4 (kcal/g DMI) and MCR (% GE intake) were higher ($p<0.001$) on Diet 3 and Diet 2 compared to Diet 1. Methane per 100 g digestible dry matter intake (DDMI) and per animal were not significantly different ($p>0.05$) (table 6). This could be due to the inclusion of corn. The diets that

Table 8. Intakes of digestible crude protein (DCP), total digestible nutrient (TDN) and digestible energy (DE) of goats fed on different diets based on alfalfa and corn at two intake levels

	Intake level	Diets			Mean	SEM and significance level		
		1	2	3		Intake	Diet	Intake × Diet
DCP intake	High	9.80	7.61	5.44	7.81[a]	0.213	0.261	0.369
(g/kg$^{0.75}$)	Low	5.34	3.82	2.80	3.99[b]	0.001	0.001	0.001
	Mean	7.57[a]	5.71[b]	3.93[c]				
TDN intake	High	38.5	41.8	43.0	40.9[a]	0.522	0.639	0.904
(g/kg$^{0.75}$)	Low	20.5	21.3	22.3	21.4[b]	0.001	0.001	0.053
	Mean	29.5[b]	31.5[a]	31.2[a]				
DE intake	High	180.9	190.4	188.8	186.5[a]	2.21	2.70	3.82
(kcal/kg$^{0.75}$)	Low	96.4	96.2	98.1	96.9[b]	0.001	0.152	0.199
	Mean	138.7	143.3	136.9				

Means with different superscripts in rows differs significantly. Diet 1, 100% alfalfa pellet, Diet 2, 70% alfalfa pellet and 30% corn, Diet 3, 40% alfalfa pellet and 60% corn.

included corn were richer in readily available carbohydrates and usually increase propionic acid concentration but both diets (2 and 3) produced a lower proportion of propionic acid than the Diet 1 though higher butyric. The higher methane production supports Ørskov et al. (1991) who concluded that an increased level of propionic acid could decrease the CH_4 production. Bonhomme (1990) found that an addition of readily fermentable carbohydrates (e.g. cereal grain) to diets fed at maintenance levels causes a proliferation in the ciliate population. Ciliates are symbiotic with methanogens (Stumn and Zwart, 1986; Finlay et al., 1994) and the increase in CH_4 production when grain is fed at maintenance may be due to an increase in hydrogen transfer between these microorganisms (Krumholz et al., 1983). Some support is provided by this study in which methane production was lower from the 100% alfalfa Diet 1 than from the Diets 2 and 3 that included corn.

The values for MCR obtained in this study were almost similar to the values reported by Terada et al. (1985) for sheep, goat and cattle on a range of roughage concentrate based diets. The mean MCR value obtained from the alfalfa and corn based diets was a little higher than the values reported by Moss and Givens (1999) for heifers on lucerne (Medicago sativa) and concentrate based diets. Highest MCR values were from Diets 2 and 3 where corn was included at the rate of 30% and 60%, respectively. Similar results were reported by Terada et al. (1985) who found that the MCR value from goats fed on 100% grass hay wafer was lower than that for the 70% wafer with 30% concentrate and 30% wafer and 70% concentrate based diets. Higher methane emission and MCR for Diets 2, 3 were possibly due to the inclusion of corn, which is starch rich.

Significant differences ($p<0.001$) in digestibility (DE/GE), metabolizability and ME per kg DM (M/D) were found among the diets while values for intake levels were similar ($p>0.05$). Corn increased the metabolizability values significantly and reduced urinary energy loss.

Nitrogen intake and losses as feces and urine were highest ($p<0.001$) on Diet 1, which resulted in a lower retained N on the Diet 1 compared to the other diets. Higher ($p<0.001$) retained N per N intake (%) and retained N per N digested (%) values were obtained on Diets 2, 3. The low intake level (0.9 times of the TDN requirement for maintenance of Japanese goats) (Itoh et al., 1978) resulted in a mean DCP intake of 3.99 g/kg $W^{0.75}$ (table 8) which was higher than the requirement for maintenance of Japanese goats estimated by Itoh et al. (1978).

The N losses as feces per N intake were similar among the diets and ranged from 29.1 to 29.9% of the N intake. Consequently, the CP apparent digestibility values of the diets were also similar (table 4). The higher N loss in urine from Diet 1 than Diets 2 and 3 could represent a greater risk of environmental pollution from ammonia and nitrate in the manure (Yano and Nakajima, 1996).

The results of this experiment supported Castillo et al. (1999) who reported that a low degradable starch level using corn produced lower urine N output than the high degradable starch level when using wheat and barley.

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