Effects of Protein and Carbohydrate Supplements on Feed Digestion in Indigenous Malaysian Goats and Sheep

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ABSTRACT : Experiments were conducted to determine the effects of soybean meal (SBM) as a source of protein and sago meal (SM) as a source of carbohydrate on *in situ* and *in vivo* digestibility of dietary components in four male goats (Kambing Katjang) and four male sheep (Malin) weighing 25-35 kg. Rumen volume, as well as rumen fluid dilution rate were also determined. The animals were housed in single pens with individual feeding and drinking troughs and each animal was fitted with a rumen fistula. They were fed two diets : chopped rice straw+200 g soybean meal (SBM), and chopped rice straw+190 g soybean meal+300 g sago meal (SBM+SM). Rice straw was offered *ad libitum*. The supplements were isonitrogenous (80 g crude protein/animal/d), but the proportions of dry matter (DM), organic matter (OM), crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF) were lower in the SBM supplement (191, 165, 11, 40, 15 g/animal/d for DM, OM, CF, NDF and ADF, respectively) than in the SBM+SM supplement (445, 423, 25, 102, 38 g/animal/d for DM, OM, CF, NDF and ADF, respectively). Two animals from each species were fed either supplement in a cross-over design in two periods. Each period lasted for four weeks. *In situ* and *in vivo* digestibility studies were carried out, followed by the determination of rumen volume and rumen fluid dilution rate. The results showed that straw DM and total DM intakes of goats (average of 48.7 g/kg $W^{0.75}$, 72.7 g/kg $W^{0.75}$, respectively) were significantly ($p<0.01$) higher than sheep (average of 35.6 g/kg $W^{0.75}$, 61.6 g/kg $W^{0.75}$, respectively), but OM, N and GE intakes were not significantly different between the two animal species. When the effect of supplements was compared, animals fed SBM+SM supplement had significantly ($p<0.001$) higher DM, OM and GE intakes than animals fed SBM supplement. Potential degradabilities of rice straw DM were significantly ($p<0.01$) higher in goats (average of 48.8%) than in sheep (average of 46.1%). The supplements had no significant effect on the potential degradabilities of DM, OM and NDF, but they had a significant ($p<0.05$) effect on the degradation rates of DM and NDF. The addition of sago meal in the diet reduced the degradation rates of DM and NDF of rice straw in the rumen. Potential degradability of DM of soybean meal was not significantly different between animal species as well as between supplements. Sago meal was highly degradable. At 24 h of incubation in the rumen, 90-95% of DM loss was observed. There was a significant interaction between animal species and supplements in the *in vivo* digestibility of ADF and GE. In animals fed SBM supplement, the *in vivo* digestibility of ADF was significantly ($p<0.05$) higher in goats ($50.6\pm4.22\%$) than in sheep ($44.4\pm3.21\%$), but digestibility of GE was significantly ($p<0.05$) higher in sheep ($70.2\pm1.93\%$) than in goats ($63.0\pm3.07\%$). The digestibility values of CP and OM were significantly ($p<0.05$) higher in sheep when compared to goats. Animals fed SBM+SM supplement showed significantly ($p<0.05$) higher DM and OM digestibility values than animals fed SBM supplement, but digestibility values of CP were significantly ($p<0.05$) higher in animals fed SBM supplement. Differences in *in vivo* digestibility values of CF and NDF were not significantly different between animal species or supplements. Water intake, rumen volume (l/kg $W^{0.75}$), rumen fluid dilution rate and mean retention time were similar between the two animal species. However, rumen fluid dilution rate and mean retention time was significantly ($p<0.01$) affected by supplements. Animals fed SBM+SM had faster rumen fluid dilution rate and consequently shorter mean retention time. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 464-469*)

Key Words : Goats, Sheep, Straw, Supplements, Digestion

INTRODUCTION

The indigenous goats (*Capra hircus*) and sheep (*Ovis aries*) in Malaysia are known as Kambing Katjang and Malin, respectively, and they are usually reared on small farms where the emphasis is on intensive crop production. Fibrous residues, like rice straw and oil palm fronds and empty fruit bunches from the crops are important sources of feed materials for ruminants, including goats and sheep. The relative productivity of goat and sheep depends upon the ecotype involved. Each species exhibits many different ecotypes, but only a few have been studied for their actual and potential productivity. Sheep are grazing animals whereas goats prefer to browse (Terril and Slee, 1991; Gall, 1991). The abilities of the two species to utilise fibrous residues are important considerations for development of feeding strategies for their survival in the natural environment.

The objective of this study was to compare the digestive abilities of Malaysian indigenous goats (Kambing Katjang) and sheep (Malin) fed rice straw supplemented with soybean meal only or with soybean meal+sago meal.

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MATERIALS AND METHODS

Animals and diets

Eight animals, consisting of four male local goats (Kambing Katjang) and four male local sheep (Malin), about one-year-old were used. The weights of the animals were in the range of 25-35 kg and each animal was fitted with a rumen fistula. The animals were housed in single pens and were dewormed (Dectomax) and given multivitamins (Stress-Vitam) by injection. Before the experiments, they were transferred to individual metabolic cages to facilitate faeces and urine collection. Each metabolic cage was fitted with food and water containers.

The diets fed daily per animal per day were chopped rice straw+soybean meal (200 g fresh weight), and rice straw+soybean meal (190 g fresh weight)+sago meal (300 g fresh weight). The rice straw was used as the basal diet and fed *ad libitum*. The animals were fed once a day (0800-0900 h). Rice straw was offered at 110-120% of the previous day's intake and the amount consumed was determined by measuring the difference in the amount of fresh batch of rice straw offered and the amount refused. Table 1 shows the chemical composition of each diet. The supplements were isonitrogenous, but the amount of DM, OM, CF, NDF, ADF and GE increased with the addition of sago meal.

The experiments were divided into two periods. Each period lasted for 4 weeks. During the first period, two goats and two sheep were given soybean meal (SBM) supplement, while another two goats and two sheep were given soybean+sago meal (SBM+SM) supplement. The supplements were crossed over in the second period.

Table 1. Nutrients present in daily supplements of soybean meal (SBM) or soybean meal and sago meal (SBM+SM) provided to goats and sheep (g/animal/d, unless otherwise stated)

Composition	SBM	SBM+SM
Dry matter	191	445
Crude protein	80	80
Organic matter	165	423
Crude fibre	11	25
Ether extract	8	11
Neutral detergent fibre	40	102
Acid detergent fibre	15	38
Gross energy (MJ/animal/d)	3.5	7.4

EXPERIMENTAL PROCEDURES

In situ digestion

Degradabilities of rice straw, soybean meal and sago meal were determined by using the nylon bag technique (Ørskov and McDonald, 1979). The nylon bags used were 15 cm×9 cm with 40 μm pore size. Straw, soybean meal and sago samples were dried at 60℃ for 48 h and ground through a 2 mm screen. Three grams of each sample were put in separate nylon bags and placed in the rumen. The rice straw samples were incubated for 0, 8, 24, 32, 48, 56 and 72 h, while the soybean meal and sago meal for 0, 4, 8, 12, 24, 32 and 48 h. After incubation, the bags were rinsed with tap water and then dried at 65℃ in a forced-draught oven to constant weights. Residues from the nylon bags were analysed for dry matter (DM), organic matter (OM) and crude protein (CP) by using standard procedures (AOAC, 1984) and neutral detergent fibre (NDF) by using the method of Van Soest et al. (1991). The DM, OM, CP and NDF losses from each bag were calculated. The percentage of material degraded "p" after time "t" was described by the equation given by Ørskov and McDonald (1979). There was very little DM left in the sago meal samples after incubation in the rumen. After 24 h of incubation, 90-95% of DM loss was observed for the sago meal sample.

In vivo digestion

Subsamples of feeds offered and refused, and faecal outputs were collected daily for seven days after the adaptation period of one week. The daily faecal samples (10% aliquot) were stored at -20℃. All feed and refusal rice straw samples as well as faecal samples were pooled at the end of the experimental period for analyses. They were dried at 60℃ in a forced-air oven for 48 h, then ground through a 2 mm screen.

Dried feed and faecal samples were analysed for DM, OM, crude protein (CP), crude fibre (CF), ether extract (EE) (AOAC, 1984), NDF and acid detergent fibre (ADF) (Van Soest et al., 1991) and gross energy (GE) (Bomb Calorimeter, PAR Adiabatic Company).

Water intake and rumen volume

Water intake was measured daily by weighing the water containers after each fill. Rumen volume and dilution rate were determined after the *in vivo* digestibility study was completed. Co-EDTA was used as a marker and was prepared according to the method described by Uden et al. (1980). The rumen was dosed once with Co-EDTA (6 mg Co/kg BW). The marker was introduced into the rumen a little at a time and mixed with the rumen content manually. The rumen contents were sampled at 1, 3, 5, 7, 9, 15, 21, 27, 33 and 48 h after dose. The samples were immediately strained through 1.5 mm screen into plastic vials and stored at -20℃ until used.

Thawed rumen samples were centrifuged at 1,600 g for 45 min. The supernatant was diluted five times

Table 2. Daily intakes of DM, OM, N and GE of goats and sheep fed rice straw supplemented with soybean meal (SBM) or soybean meal and sago meal (SBM+SM)

Intake	SBM		SBM+SM		S×S'	Main effects	
	Goat (n=4)	Sheep (n=4)	Goat (n=4)	Sheep (n=4)		Species	Supplements
Straw DM (g/kg $W^{0.75}$)	49.2 (8.36)	39.4 (2.91)	48.2 (7.32)	31.9 (10.02)	NS	**	NS
Total DM (g/kg $W^{0.75}$)	63.4 (8.27)	54.6 (3.20)	81.9 (6.34)	68.5 (7.43)	NS	**	***
OM (g/kg $W^{0.75}$)	44.7 (5.78)	39.2 (2.35)	60.6 (7.89)	56.32 (4.31)	NS	NS	***
N (g/kg $W^{0.75}$)	1.4 (0.18)	1.3 (0.11)	1.3 (0.14)	1.3 (0.13)	NS	NS	NS
GE (MJ/kg $W^{0.75}$)	0.51 (0.08)	0.48 (0.04)	0.82 (0.08)	0.83 (0.11)	NS	NS	***

[1] Interaction between animal species and supplements.
NS=Not significantly different; * Significantly different at 5% level ($p<0.05$); ** Significantly different at 1% level ($p<0.01$); *** Significantly different at 0.1% level ($p<0.001$).
Values in parentheses are standard deviations.

with distilled water and analysed for Co using the Atomic Absorption Spectrophotometer (air-acetylene flame) at 240.7 nm. Plots of natural logarithms of concentration of Co (mg/l rumen fluid) versus time (in hour) from the rumen fluid of each animal after a single dose of Co-EDTA into the rumen were regressed linearly. Rumen volume in litres was calculated according to the method described by Czerkawski (1986).

Statistical analysis

Effects of animal species or types of supplement (SBM and SBM+SM) and periods on feed intake, degradation, digestibility of feeds and liquid outflow rates were analysed by two way analysis of variance using the SAS program (SAS, 1988) and treatment means compared by the least significant difference method. The effect of period was not significant for all the results obtained.

RESULTS

Feed intake

Table 2 shows the DM, OM, N and GE intakes of goats and sheep fed rice straw and supplemented with SBM or SBM+SM during the experimental periods.

There was no significant interaction between animal species and supplements on all the parameters studied. However, when the effect of species was compared, goats showed significantly ($p<0.01$) higher intakes of straw DM and total DM (average of 48.7 g/kg $W^{0.75}$, 72.7 g/kg $W^{0.75}$, respectively) than sheep (average of 35.6 g/kg $W^{0.75}$, 61.6 g/kg $W^{0.75}$, respectively), but OM, N and GE intakes were not significantly different between the two species of animals. When the effect of supplements was compared, animals fed SBM+SM supplement had significantly ($p<0.001$) higher total DM, OM and GE intakes than those fed SBM supplement, but the straw DM intakes of animals were not significantly different between the two supplements.

***In situ* digestion**

Potential degradability (a+b) and degradation rate (c) per h of DM, OM, and NDF of rice straw after 0-72 h of incubation in the rumen of goats and sheep fed SBM or SBM+SM supplements are presented in table 3. There was no significant interaction between animal species and supplements in potential degradabilities as well as degradation rates of rice straw DM, OM or NDF. However, when the effect of species was compared, goats had significantly ($p<0.01$) higher potential degradability of DM of rice straw (average of 48.8%) than sheep (average of 46.1%). The supplements had no significant effect on the potential degradabilities of DM, OM and NDF, but they had a significant ($p<0.05$) effect on the degradation rates of DM and NDF. The addition of sago in the diet reduced the degradation rates of DM and NDF of rice straw in the rumen.

Table 4 shows the potential degradability and degradation rates of DM and N of soybean meal after 0-48 h incubation in the rumen of goats and sheep fed either SBM or SBM+SM supplements. There was no significant interaction between animal species and supplements in all the parameters studied. The potential degradability as well as the degradation rate of DM were not significantly affected by animal species or supplements. The potential degradability of N was also not significantly affected by animal species or supplements, but the degradation rate was significantly ($p<0.05$) affected by animal species. It was significantly ($p<0.05$) higher in sheep than in goats.

***In vivo* digestion**

Table 5 shows the percentage digestibilities of DM, CP, OM, CF, NDF, ADF and GE *in vivo* in goats and sheep fed SBM or SBM+SM supplement. There was no significant interaction between animal species and supplements for percentage digestibilities of DM, CP, OM, CF and NDF, but there was a significant ($p<0.05$) interaction for percentage digestibilities of

Table 3. Potential degradabilities (a+b) and degradation rates (c) of DM, OM and NDF of rice straw after 0-72 h incubation in the rumen of goats and sheep fed rice straw supplemented with soybean meal (SBM) or soybean meal and sago meal (SBM+SM)

Parameter	SBM		SBM+SM		S×S[1]	Main effects	
	Goat	Sheep	Goat	Sheep		Species	Supplement
DM							
c (h^{-1})	0.033 (0.002)	0.031 (0.002)	0.027 (0.002)	0.026 (0.003)	NS	NS	*
(a+b) (%)	49.7 (1.42)	45.4 (1.90)	47.9 (2.03)	46.7 (3.08)	NS	**	NS
OM							
c (h^{-1})	0.034 (0.001)	0.032 (0.006)	0.029 (0.001)	0.032 (0.003)	NS	NS	NS
(a+b) (%)	50.4 (2.73)	45.8 (4.71)	49.8 (1.76)	50.0 (3.84)	NS	NS	NS
NDF							
c (h^{-1})	0.041 (0.001)	0.035 (0.004)	0.029 (0.003)	0.028 (0.003)	NS	NS	*
(a+b) (%)	47.1 (1.77)	43.5 (2.81)	44.9 (3.88)	44.7 (5.76)	NS	NS	NS

[1] Interaction between animal species and supplements.
NS=Not significantly different; * Significantly different at 5% level ($p<0.05$); ** Significantly different at 1% level ($p<0.01$).
Values in parentheses are standard deviations.

Table 4. Potential degradabilities (a+b) and degradation rate (c) of DM and nitrogen (N) of soybean meal after 0-48 h incubation in the rumen of goats and sheep fed rice straw supplemented with soybean meal (SBM) or soybean meal and sago meal (SBM+SM)

Parameter	SBM		SBM+SM		S×S[1]	Main effects	
	Goat	Sheep	Goat	Sheep		Species	Supplements
DM							
c (h^{-1})	0.022 (0.004)	0.023 (0.003)	0.023 (0.002)	0.024 (0.003)	NS	NS	NS
(a+b) (%)	76.8 (3.46)	82.0 (2.05)	77.2 (3.07)	76.4 (1.61)	NS	NS	NS
N							
c (h^{-1})	0.026 (0.001)	0.028 (0.002)	0.025 (0.001)	0.027 (0.001)	NS	*	NS
(a+b) (%)	68.0 (2.06)	72.4 (4.46)	67.2 (1.38)	70.0 (5.94)	NS	NS	NS

[1] Interaction between animal species and supplements.
NS=Not significantly different; * Significantly different at 5% level ($p<0.05$).
Values in parentheses are standard deviations.

Table 5. Percentage digestibility of DM, CP, OM, CF, NDF, ADF and gross energy (GE) of soybean meal (SBM) or soybean meal and sago meal (SBM+SM) supplemented rice straw diet in goats and sheep

Parameter	SBM		SBM+SM		S×S[1]	Main effects	
	Goat (n=4)	Sheep (n=4)	Goat (n=4)	Sheep (n=4)		Species	Supplements
DM	59.46 (3.71)	59.0 (1.51)	66.0 (2.51)	69.0 (2.07)	NS	NS	*
CP	71.1 (1.92)	75.5 (2.05)	66.7 (2.38)	72.3 (4.21)	NS	*	*
OM	62.3 (2.99)	65.0 (2.81)	69.1 (1.70)	73.1 (2.20)	NS	*	*
CF	61.7 (2.32)	63.7 (1.73)	60.7 (2.33)	62.5 (4.04)	NS	NS	NS
NDF	52.3 (4.21)	55.4 (3.21)	54.0 (1.88)	57.3 (2.75)	NS	NS	NS
ADF	50.6 (4.22)	44.4 (3.21)	46.5 (1.60)	46.3 (1.62)	*	*	NS
GE	63.0 (3.07)	70.2 (1.93)	77.4 (2.35)	79.1 (1.00)	*	*	*

[1] Interaction between animal species and supplements.
NS=Not significantly different; * Significantly different at 5% level ($p<0.05$).
Values in parentheses are standard deviations.

ADF and GE. In animals fed SBM supplement, percentage digestibility of ADF was significantly higher in goats (50.6±4.22%) than in sheep (44.4±3.21%), but the percentage digestibility of GE was significantly ($p<0.05$) higher in sheep (70.2±1.93%) than in goats (63.0±3.07%). When the effect of animal species was compared, the percentage digestibilities of CP and OM were significantly

($p<0.05$) higher in sheep than in goats. When the effect of supplement was compared, animals fed SBM+SM showed significantly ($p<0.05$) higher percentage digestibilities of DM and OM than those fed SBM supplement. However, digestibility of CP was significantly ($p<0.05$) higher in animals fed SBM supplement.

Rumen volume

The values for water intake, rumen volume, rumen fluid dilution rate constant and mean retention time in goats and sheep fed SBM or SBM+SM supplement are presented in table 6. The results showed that goats and sheep had similar water intake, but rumen volume was significantly ($p<0.05$) larger in goats than in sheep. However, when expressed as percent metabolic body weight, rumen volume was not significantly different between the two animal species. Mean retention time of fluid was also similar between goats and sheep. When the effect of supplement was compared, animals fed SBM+SM supplement had a higher rumen fluid dilution rate constant than those fed SBM supplement. Consequently, animals fed SBM supplement had longer mean retention time than animals fed SBM+SM supplement.

DISCUSSION

Soybean meal and sago were used as sources of protein and energy, respectively, to improve the nutritive value of rice straw. The amount of CP in the supplements of both diets was maintained at 80 g/animal/d, but the amounts of DM, OM, CF, NDF, ADF and GE were enhanced with the addition of sago meal to the diet (table 1).

The DM intake of straw in goats was significantly ($p<0.05$) higher than in sheep (table 2). Differences in DM intake of poor quality roughages between the two animals species have been reported but are rather inconsistent. Gihad (1976) and Antoniou and Hadjipanayiotou (1985) reported that goats showed higher DM intake than sheep when fed poor quality roughages, whereas Sharma and Rajora (1977) reported otherwise.

Although goats had higher DM intake than sheep, the digestibility of DM of the total feed was not significantly different between the two animal species. This is rather surprising as higher DM intake is usually associated with a reduction in digestibility (Van Soest, 1982). It is also interesting to note that the potential degradability of DM of rice straw (table 2) and the percentage digestibility of ADF (cell wall components consisting mainly cellulose and lignin) of the total feed was significantly ($p<0.05$) higher in goats than in sheep (table 5). It has been suggested that higher fibre digestibility is associated with higher concentrations of cellulolytic rumen microorganisms (Devendra, 1978). Gihad et al. (1980) have reported that goats have a larger population of cellulolytic rumen bacteria than sheep fed straw-based diet. Recently, Ho et al. (1998) also found that in straw-based diet, the population of rumen fungi (all of which are cellulolytic) was much higher in goats than in sheep. However, Doyle et al. (1984) attributed the ability of goats to digest more low quality forage than sheep to longer ruminal retention time and higher capacity to recycle and conserve N. Longer ruminal retention time may be of advantage to fibre digestion (Domingue et al., 1991).

The addition of sago meal to the diet did not improve potential degradabilities of DM, OM or NDF of rice straw, but instead reduced the degradation rate of DM and NDF. The addition of easily fermentable carbohydrate depressed the degradation of cell wall components in the rumen. Sago is a storage product of the sago palm, composed mainly of starch and is easily digestible (90-95% DM loss after 24 h incubation in the rumen). Hence, it provides a readily fermentable substrate for the rumen microbes. Higher carbohydrate in the rumen increases the lag time and decreases potential extent of fibre digestion (Mertens and Loften, 1980).

Table 6. Water intake (WI), rumen volume (RV), rumen fluid dilution rate constant (k) and mean retention time (MRT) of goats and sheep fed rice straw supplemented with soybean meal (SBM) or soybean meal and sago meal (SBM+SM)

Intake	SBM		SBM+SM		S×S'	Main effects	
	Goat (n=4)	Sheep (n=4)	Goat (n=4)	Sheep (n=4)		Species	Supplements
WI (l/d)	2.43 (0.19)	2.54 (0.36)	2.80 (0.71)	2.73 (0.77)	NS	NS	NS
RV (l)	5.40 (0.57)	4.80 (0.04)	5.55 (0.10)	4.95 (0.08)	NS	**	NS
RV (l/kg $W^{0.75}$)	0.40 (0.04)	0.41 (0.02)	0.42 (0.04)	0.403 (0.03)	NS	NS	NS
k (h^{-1})	0.045 (0.003)	0.046 (0.004)	0.055 (0.002)	0.049 (0.003)	NS	NS	**
MRT (h)	22.50 (1.38)	21.98 (1.90)	18.61 (1.31)	20.11 (1.80)	NS	NS	**

[1] Interaction between animal species and supplements.

NS=Not significantly different; ** Significantly different at 1% level ($p<0.01$).

Values in parentheses are standard deviations.

Nevertheless, the addition of sago meal may provide a better niche for microbial activity as both DM and OM digestibilities *in vivo* were enhanced by the addition of sago meal (table 5, effects of supplements). This digestion pattern was also observed by Murphy et al. (1994) who reported that an increase in concentrate diet increased DM digestibility in lambs. Digestibility of GE was also increased in animals fed SBM+SM, while that of CP decreased. Increased ruminal digestibility of energy may reduce solubility and degradability of protein source such as SBM (Loerch et al., 1983).

Although rumen volume was larger in goats than in sheep, the effect was largely due to differences in body weights. Water intake was similar between the animal species fed either supplement. This is in contrast to the results reported by Antoniou and Hadjipanayiotou (1985) who observed a lower water intake in goats than in sheep fed barley straw plus concentrate. Animals fed SBM+SM supplement showed faster dilution rate constant and consequently shorter mean retention time than animals fed SBM supplement.

In conclusion, the results of the present study showed that goats had a higher straw DM intake than sheep when fed rice straw supplemented with SBM or SBM+SM. Animals fed SBM+SM supplement had higher total DM, OM and GE intakes than animals fed SBM supplement. There was no effect of different supplements on straw DM intake of goats and sheep. Goats seemed to be able to digest DM of rice straw (*in situ*) and ADF (*in vivo*) better than sheep. *In vivo* digestibilities of both DM and OM were improved with carbohydrate supplement, but CP digestibility was higher in animals fed without carbohydrate supplement.

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