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Research Article
Effects of Total Mixed Rations Containing Treated or Untreated Soybean Meal on the Energy Utilization of Kacang Goats

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Abstract
Background and Objective: There have been many efforts to improve the low productivity of Kacang goats. Feeding a total mixed ration (TMR) containing sources of energy and protein could improve the performance of the goat. Soybean meal is one of the protein sources that are palatable but highly degradable in the rumen, therefore, it was treated with formaldehyde. The aim of this study was to evaluate the energy utilization, volatile fatty acids (VFAs) and acetate-propionate acid (A/P) ratio of Kacang goats fed TMR diets containing different treatments of soybean meal. **Methodology:** Fourteen yearling Kacang bucks, weighing 17.6±1.2 kg, were arranged in a completely randomized design consisting of 3 different treatments that included an SBM control (n = 5): Untreated SBM, SBM50 (n = 5): 50% untreated SBM+50% formaldehyde-protected SBM and SBM100 (n = 4): 100% formaldehyde-protected SBM. The TMR consisted of 30% *Pennisetum purpureum*, 30% *gliricidia* leaves, 19.2% cassava waste product, 13.8% wheat bran, 7% SBM and 1% mineral mix that were mixed and resulted in 14-15% crude protein and 56-60% TDN. The goats were weighed weekly over 70 days and the average daily gain (ADG) was calculated using linear regression. Data were analyzed by an analysis of variance using the SPSS statistics software version 19. **Results:** The energy intake and digestible energy (DE) of the SBM control group (13.0 MJ and 7.7 MJ, respectively) were higher than those of the SBM50 group (10.2 MJ and 5.8 MJ, respectively) but they were relatively similar to the SBM100 group (11.3 MJ and 6.7 MJ, respectively). The energy conversion ratio (energy intake, DE and metabolizable energy [ME]) also had the same pattern. Digestible energy (% energy intake), faecal production, urine production, methane energy loss (MJ) and ME were similar between the treatments. Intake, digested and metabolizable energy (MJ kg^{-1} $BW^{0.75}$) were also the same between the treatments. Total VFA and the A/P ratio before feeding were also similar between the treatments. In fact, the A/P ratio of the SBM control at 3 h and 6 h was higher than that of SBM50 but it was relatively similar to SBM100. **Conclusion:** Energy utilization of untreated SBM was better than that of 50% formaldehyde-protected SBM but it was similar to that of SBM100. The control group had an A/P ratio that was higher than the SBM50 group. In fact, total VFA was similar between the treatments.

Key words: Gliricidia leaf, indigenous goat, metabolizable energy, methane energy, A/P ratio

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Previous research has been conducted to improve the low productivity of Kacang goats, e.g., utilization of a feed supplement, protein sources or energy sources[1,2]. Feeding a total mixed ration (TMR) containing sources of energy and protein could improve the performance of the goat. Adiwinarti *et al.*[3] reported that soybean meal (SBM) was better than fish meal to improve the productivity of Kacang goats. Soybean meal is a protein source that is palatable but highly degradable in the rumen. Previous studies have been conducted to increase the rumen undegradable protein (RUP) in ruminants using formaldehyde, especially in cattle[4,5]. In fact, data regarding using formaldehyde to increase the rumen undegradable protein in goats are rarely reported, therefore, this study observed Kacang goats fed on SBM treated with 1% formaldehyde compared to those goats fed on untreated SBM. This study focused on the energy utilization, volatile fatty acids (VFAs) and the acetate-propionate (A/P) ratio of Kacang goats fed a TMR containing different treatments of soybean meal.

MATERIALS AND METHODS

Fourteen yearling Kacang bucks, weighing 17.6±1.2 kg, were arranged in a completely randomized design consisting of 3 different treatments that included a control: [(n = 5) untreated SBM], SBM50: [(n = 5) 50% untreated SBM+50% formaldehyde-protected SBM] and SBM100 [(n = 4): 100% formaldehyde-protected SBM]. The TMR consisted of 30% *Pennisetum purpureum*, 30% *gliricidia* leaves, 19.2% cassava waste product, 13.8% wheat bran, 7% SBM and 1% mineral mix that were mixed and resulted in 14-15% crude protein and 56-60% Total Digestible Nutrients (TDN) (Table 1). The soybean meal was protected using 1% formaldehyde that was calculated based on dry matter SBM.

The faeces and urine of each goat were collected, weighed and sampled during 14 days of the collection period. Daily faeces were sun-dried for 3 days and oven-dried at 55°C for 24 h. Urine was collected daily into flasks containing 100 mL of 20% H_2SO_4. At the end of the collection period, the collected dried faeces samples and urine were homogenized individually and then frozen until they were analyzed. The energy of the feed, faeces and urine was determined using a bomb calorimeter. Digestible energy (DE) was calculated as the dietary gross energy intake minus the faecal energy. The difference between the DE and the energy loss from urine and methane was determined as metabolizable energy (ME). Methane loss was measured using a methane analyzer for 10 min, repeated every 3 h for 2 days[6]. The conversion factor of 9.45 kcal L^{-1} was used to convert the methane gas volume to energy[7]. Volatile fatty acids (acetate, propionate and butyrate acids) were analyzed from rumen fluid at 0, 3 and 6 h after feeding were determined by gas chromatography (Shimadzu GC-8, Tokyo, Japan). The goats were weighed weekly over 70 days and the average daily gain (ADG) was calculated using linear regression. Data were analyzed by a one-way analysis of variance using the SPSS statistics software version 19[8]. The level of significance was based on $p<0.05$.

RESULTS AND DISCUSSION

Dry matter intake (DMI) of the control group (SBM control) was approximately 704.48±92.81 g/day or 70.75±9.24 g kg^{-1} $LW^{0.75}$, while that of the SBM50 group was

Table 1: Feed composition and nutrient contents

Nutrients	SBM control	SBM50	SBM100
Feed composition (%)			
Pennisetum purpureum	30.00	30.00	30.00
Gliricidia leaves	30.00	30.00	30.00
Cassava waste product	19.20	19.20	19.20
Wheat bran	13.80	13.80	13.80
Soybean meal	7.00	3.50	-
Formaldehyde-protected SBM (RUP)	-	3.50	7.00
Nutrient content (%)			
Dry matter (%)	91.50	90.90	91.40
Based on 100% dry matter content (%)			
Ash	10.10	9.60	9.30
Ether extract	2.60	2.80	2.60
Crude fibre	29.20	31.70	29.60
Crude protein	15.60	14.10	14.30
Nitrogen-free extract	42.60	41.80	44.20
Total digestible nutrients	58.00	55.80	60.10

Table 2: Energy intake, digestible energy, and metabolizable energy of Kacang goats fed a total mixed ration containing different treatments of soybean meal

	Treatments			
Parameters	SBM control	SBM50	SBM100	p-value
Energy intake (MJ/day)	13.0[a]	10.2[b]	11.3[ab]	0.013
Energy intake (MJ kg^{-1} BW$^{0.75}$)	1.3	1.1	1.1	0.094
Energy loss from				
Faecal energy (MJ/day)	5.2	4.4	4.5	0.106
Urinary energy (MJ/day)	0.4	0.4	0.3	0.880
Methane energy (MJ/day)	1.3	0.9	1.0	0.418
Digestible energy (MJ/day)	7.7[a]	5.8[b]	6.7[ab]	0.016
Digestible energy (MJ kg^{-1} BW$^{0.75}$)	0.8	0.6	0.7	0.093
Digestible energy (%)	59.2	56.3	59.8	0.300
Metabolizable energy (MJ/day)	6.1	4.6	5.4	0.087
Metabolizable energy (MJ kg^{-1} BW$^{0.75}$)	0.6	0.5	0.5	0.281
Metabolizable energy (%)	47.0	45.4	48.3	0.830

SBM control: Untreated SBM, SBM50: 50% untreated SBM+50% formaldehyde-protected SBM, SBM100: 100% formaldehyde-protected SBM, Means with different superscripts (a and b) within a row are significantly different (p<0.05)

Table 3: Energy conversion ratio

	Treatments			
Parameters	SBM control	SBM50	SBM100	p-value
GE conversion ratio (MJ g^{-1})	0.2[a]	0.4[b]	0.2[ab]	0.036
DE conversion ratio (MJ g^{-1})	0.1[a]	0.2[b]	0.1[ab]	0.035
ME conversion ratio (MJ g^{-1})	0.1[a]	0.2[b]	0.1[ab]	0.030

SBM control: Untreated SBM, SBM50: 50% untreated SBM+50% formaldehyde-protected SBM, SBM100: 100% formaldehyde-protected SBM, Means with different superscripts (a and b) within a row are significantly different (p<0.05)

541.2±48.0 g/day or 59.8±3.7 g kg^{-1} LW$^{0.75}$ and that of the SBM100 group was 606.9±65.9 g/day or 62.6 g kg^{-1} LW$^{0.75}$. Based on the body weight, the DMI of the SBM control containing untreated SBM and 58% TDN was 3.29% of the body weight, while that of SBM50 containing 55.8% TDN was 2.52% of the body weight and that of SBM100 containing 60.1% TDN was 2.67% of the body weight. These results were in accordance with the intake pattern, which is affected by the feed energy level. The dry matter intake of the low-energy diet was higher than that of the high-energy diet.

Energy intake, digestible energy and metabolizable energy: Metabolizable energy intake was affected by diet type. In this study, the ME intake of the control group was 6.1 MJ/day but it was not significantly different from the SBM50 and SBM100 groups. A study by Phengvichith and Ledin[9] reported a lower ME intake (2.6 MJ/day) observed in a diet that consisted of Gamba grass with gliricidia and of 5.9 MJ/day in a diet that consisted of Gamba grass, gliricidia, cassava and concentrate. Another factor that affected the ME intake was goat breed. Beker *et al*.[10] stated that different goat breeds could affect the ME intake, for instance, in grazing studies, the ME intake of Angora goats was 8.5 MJ/day, that of Boer goats was 11.5 MJ/day and that of Spanish goats was 9.6 MJ/day.

The energy intake and digestible energy of the control group (13.0 and 7.7 MJ, respectively) were higher (p<0.05) than those of the SBM50 group (10.2 and 5.8 MJ, respectively) but they were relatively similar (p>0.05) to the SBM100 group (11.3 and 6.7 MJ, respectively) (Table 2). The supplementation of SBM50 decreased the energy intake, although this decrease was relatively similar to that found with the SBM100 supplementation. The value of energy intake was reflected in the digestible energy as well as metabolizable energy as shown in Fig. 1. In fact, the energy intake and DE (MJ kg^{-1} BW$^{0.75}$) were not significantly different (p>0.05) between the treatments. This indicated that a high energy intake and digestible energy were caused by the differences in body weight.

The energy conversion ratio (energy intake, DE and ME) of the control group was better (p<0.05) than that of the SBM50 group but it was similar to the SBM100 group (Table 3). These results showed that goats fed untreated SBM more efficiently converted energy to body weight gain than goats fed 50% formaldehyde-protected SBM. However, digestible energy (% energy intake), ME (MJ/day), energy intake (MJ kg^{-1} BW$^{0.75}$), digestible energy (MJ kg^{-1} BW$^{0.75}$) and metabolizable energy (MJ kg^{-1} BW$^{0.75}$) were similar between the treatments. The metabolizable energy in this study

Table 4: Volatile fatty acids and A/P ratio

	Treatments			
Parameters	SBM control	SBM50	SBM100	p-value
Total VFA (mM L^{-1})				
0 h	134.0	91.4	90.2	0.075
3 h after feeding	143.1	111.1	116.3	0.512
6 h after feeding	141.4	113.4	120.7	0.383
Acetate (mM L^{-1})				
0 h	98.7	66.8	66.9	0.091
3 h after feeding	107.2	78.8	85.6	0.426
6 h after feeding	105.3	81.0	88.2	0.280
Propionate (mM L^{-1})				
0 h	23.4	16.4	15.8	0.079
3 h after feeding	25.8	22.6	22.7	0.416
6 h after feeding	26.2	22.8	23.3	0.653
Butyrate (mM L^{-1})				
0 h	11.9[a]	8.3[ab]	7.5[b]	0.021
3 h after feeding	10.0	9.7	8.1	0.528
6 h after feeding	9.8	9.6	9.2	0.948
A/P ratio				
0 h	4.2	4.1	4.2	0.940
3 h after feeding	4.2[a]	3.5[b]	3.7[ab]	0.020
6 h after feeding	4.1[a]	3.6[b]	3.8[ab]	0.048

SBM control: Untreated SBM, SBM50: 50% untreated SBM+50% formaldehyde-protected SBM, SBM100: 100% formaldehyde-protected SBM, Means with different superscripts (a and b) within a row are significantly different (p<0.05)

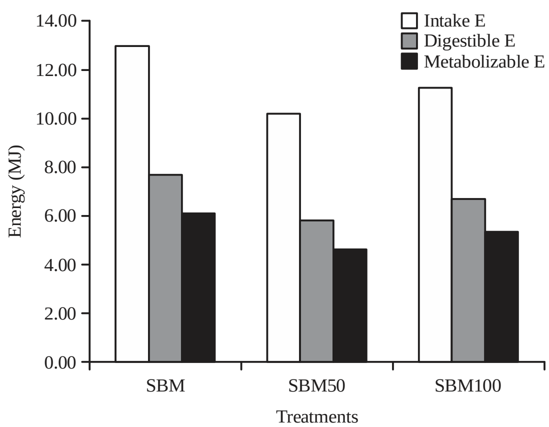

Fig. 1: Energy intake, digestible energy and metabolizable energy of control, SBM50 and SM100 goats, SBM control: Untreated SBM, SBM50: 50% untreated SBM+50% formaldehyde-protected SBM, SBM100: 100% formaldehyde-protected SBM

(4.6-6.1 MJ/day) was lower than that reported by Islam *et al.*[7] (4.4 to 8.9 MJ/day) and Wang and Xue[11] (8.3 to 8.5 MJ/day).

Volatile fatty acids and A/P ratio: The total VFAs produced was not significantly different (p>0.05) between the treatments at 0, 3 and 6 h after feeding (Table 4). The A/P ratio before feeding was also similar (p>0.05) between the treatments. However, the A/P ratio at 3 and 6 h of the control was significantly higher (p<0.05) than that of SBM50 but it was relatively similar to that of SBM100. This might be the cause for the digested dry matter of the control group (452.0 g) tending to be slightly higher (p = 0.08) than that of the SBM50 group (324.1 g). The digested crude fibre of the control group was 86.5 g and that of the SBM50 goats was 65.6 g. Jelantik *et al.*[12] reported that the total VFAs in Kacang goats fed urea-ammoniated grass hay and sun-dried fish or fish meal was 44.1-61.1 mM and that the A/P ratio was 3.65-4.28.

The protein-energy ratio did not affect acetate production. Mawati *et al.*[13] stated that sheep fed a low protein:energy (TDN) ratio of 1:6.30 had similar acetate and propionate acid production to that in a diet containing a 1:3.68 protein:energy ratio (p>0.05), however, 6 h after feeding, the acetate and propionate acid ratio tended to decrease significantly (p<0.05). Meanwhile, Karimizadeh *et al.*[14] stated that the physical form of a diet affected the acetate concentration. More specifically, a complete feed in mash form produced an acetate concentration that was similar to a complete feed in block form, however, a pellet form of complete feed produced an acetate concentration that was significantly lower. Meanwhile, the physical form of a diet did not alter the acetate-propionate ratio (p>0.05). This result showed that the feed form could modify ruminal fermentation. Abubakr *et al.*[2] reported that goats fed palm oil by-products had similar VFAs composition, such as acetate, propionate and butyrate. Abuelfatah *et al.*[15] also reported a similar accetate-propionate ratio in goats fed linseed oil.

This study showed that the energy utilization of untreated SBM was better than that of 50% formaldehyde-protected SBM but it was similar to that of 100% formaldehyde-protected SBM. The control group had an A/P ratio that was higher than the SBM50 group but similar to the SBM100 group. In fact, the total VFAs was similar between the treatments.

CONCLUSION

Total mixed rations containing untreated SBM for Kacang goats produced better energy utilization compared to those containing formaldehyde-protected SBM.

SIGNIFICANCE STATEMENT

This study discover that Kacang goats produced better energy utilization using TMR containing untreated SBM to increase the production. Thus, formaldehyde-protected SBM that should increase the production could not be applied for Kacang goats.

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