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Research Article
Improved Productivity of Kacang Goats Reared by Farmers Using Balanced Rations with Different Sources of Protein

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Abstract

Objective: The aim of this study was to improve the productivity of kacang goats raised by farmers by changing their feed. The dietary changes included using balanced ration, containing protein from animals (fish meal, FM/IR_1) and plants (agro-industrial by product; soybean meal, SBM/IR_2). Feed was provided in the form of total mixed rations (TMR). **Materials and Methods:** Twelve years-old kacang goats that weighed 17.84±1.57 kg each were divided into three groups of treatments using a completely randomized design. **Results:** The average daily gain (ADG) of the control groups (41.57 g) was lower than that of improved ration 1 (IR_1) group (72.75 kg) and improved ration 2 (IR_2) group (91.71 kg) because the DMI/$BW^{0.75}$, CP, EE and NFE intake of the control group was lower compared to the other groups. The retained N in control goats was the lowest while the retained N in IR_2 goats was highest; IR_2 was similar to IR_1 goats. The N retention (%) and retained N conversion ratios were similar. Metabolizable energy (ME) across treatments was similar but the ME conversion ratio of IR_1 (0.07±0.01 Mj g^{-1}) and IR_2 (0.07±0.01 Mj g^{-1}) was higher than that of the control (0.11±0.02 Mj g^{-1}); IR_1 was similar to IR_2. **Conclusion:** Fish meal and soybean meal supplemented in feed rations can improve the nutrient intake, digestibility, N retention and ME in kacang goats, as well as increase of their productivity (ADG).

Key words: Energy utilization, farming conditions, improved rations, nitrogen balance, kacang goats

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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

The performance of small ruminants is affected by the nutrients in their daily feed that help them meet maintenance and production requirements[1]. Protein and energy are the main determinants that alter performance in small ruminants. In Indonesia, goats are fed crop residues and generally do not meet their crude protein requirements. Supplementation of fibrous goat feed with protein has been found to be beneficial[2].

In the tropics, where protein is a limited nutrient, supplementation with nitrogenous feed has improved the performance of ruminants. Supplementation has included the use of soybean meal[3,4], leguminous forage[5-8] and agro-industrial products. Indigenous livestock in Indonesia, in this case, kacang goats, are usually reared traditionally, allowed to eat grass during the day and housed at night. However, the goats do not perform to their maximum potential.

Based on previous research, goats reared by farmers in Indonesia had lack of protein. Agro-industrial by products, including soybean meal (SBM) and fish meal (FM), are available as feed protein sources. The crude protein content of SBM is 420.3 g kg^{-1} and the crude protein content in FM is 473.7 g kg^{-1}. The aims of this study were to improve the production of kacang goats by adding two different sources of plant (SBM) and animal (FM) protein to their diet and to compare the production and nitrogen status of kacang goats fed these diets.

MATERIALS AND METHODS

Twelve years-old kacang goats with an initial body weight of 17.84±1.57 kg were used in this study and divided into groups using a completely randomized design[9]. The first group (n = 4) was the control and was fed natural grass. The second group (n = 4) was fed using a balanced ration (improved ration/IR_1) in the form of TMR. The source of protein mainly came from Fish Meal (FM). The third group was fed using balanced rations (improved ration/IR_2) in the same form as the second group but the source of protein came from soybean meal (SBM). The feed ingredients and nutrient content of the rations are shown in Table 1. The goats were fed three times a day at 8:00 AM, 12:00 PM and 4:00 PM, with a 45.0 g kg^{-1} dry matter ration of their body weight. Water was provided *ad libitum*. The goats were dewormed orally with 1.5 mL/head of valbendazol and were administered anti-parasite medications subcutaneously using 0.5 mL/head of intermectin.

The goats were penned individually and total daily feces and urine were collected every day at 7:00 AM during the 8th week of the treatment period for 14 days. The feces were weighed and sampled with approximately 100 g from each goat, sun-dried for 3 days and then oven-dried at 55-60°C. After the 14 day period, the dried feces were thoroughly mixed from the entire collection period and analyzed. Urine was collected in a container that had 100 mL of 100 mL L^{-1} sulfuric acid and sampled with approximately 100 mL daily. The urine samples from the 14 day collection period were

Table 1: Feed ingredients (%) and nutrient content in the rations (g kg^{-1} dry matter basis) of kacang goats fed natural grass as the sole ingredient (farming condition) and improved balanced rations using two different protein sources: IR_1 (fish meal) and IR_2 (soybean-meal)

		Improved rations using different protein sources	
Feed material/nutrients	Control	Fish meal, FM (IR_1)	Soybean meal, SBM (IR_2)
Feed ingredients (%)			
Natural grass	100.00	-	-
Pennisetum purpureum	-	30.00	30.00
Gliricidia leaves	-	30.00	30.00
Cassava waste product	-	20.10	19.20
Wheat bran	-	13.75	13.80
Fish meal	-	6.15	-
Soybean meal	-	-	7.00
Nutrient content in the rations (g kg^{-1})			
Dry matter	185.8	912.6	915.3
Ash	120.6	104.1	101.1
Ether extract	23.7	24.8	25.6
Crude fiber	346.2	296.8	291.8
Crude protein	109.2	152.6	155.9
Nitrogen free extract	400.4	438.0	425.6
TDN	632.3	562.1	579.5

Feed usually given by farmers = Control. IR_1: Improved rations containing fish meal (FM) as a protein source, IR_2: Improved rations containing soybean meal (SBM) as a protein source

mixed individually and frozen until analysis for the nitrogen content. The parameters measured included average daily gain (ADG) for 70 days, nutrient intake, nitrogen intake, fecal and urinary nitrogen, retained nitrogen and retained nitrogen conversion ratio. The data were analyzed using a one-way analysis of variance (ANOVA) with SPSS statistics software version 19[10].

RESULTS AND DISCUSSION

In this study, the control group was reared based on the conditions of farmers in Indonesia and the only feed given was natural grass. In the improved ration 1 (IR_1) group and the improved ration 2 (IR_2) group, goats were given balanced feed. The forage provided was in the form of *Pennisetum purpureum* and *Gliricidia sepium*. The balanced rations contained additional feed, where the source of protein used came from fish meal (FM for IR_1) or soybean meal (SBM for IR_2). Fish meal contained 473.7 g kg^{-1} crude protein (CP) and 605.7 g kg^{-1} total digestible nutrients (TDN), while soybean meal contained 420.3 g kg^{-1} CP and 801.4 g kg^{-1} TDN (Table 2).

The *Pennisetum purpureum* used in this study contained 83.0 g kg^{-1} of CP and 550.0 g kg^{-1} of TDN, while Gliricidia leaves of the leguminosae family contained 224.0 g kg^{-1} of CP and 722.0 g kg^{-1} TDN (Table 2). The *Gliricidia sepium* used in this study contained relatively high TDN content and was used because it is abundantly available, can grow on dry land and has a rather high organic material content of 860.0 g kg^{-1}. Likewise, the protein content is rather high at approximately 220.0 g kg^{-1}. Gliricidia is a forage crop that is mostly used in tropical countries as ruminant feed[11].

The dry matter intake (DMI) (g kg^{-1} b.wt.,$^{0.75}$) for IR_1 and IR_2 was higher as compared to the control ($p<0.01$) at approximately 11.31 points for IR_1 and 16.75 points for IR_2 (Table 3). There was a trend towards increased consumption in the IR_1 and IR_2 groups compared to the control group. This trend was also observed for CP intake (g), Ether extract (EE) intake (g), crude fiber (CF) intake (g), Nitrogen free extract (NFE) intake (g) and TDN intake (g) (Table 3).

In the IR_1 group, the DMI was 65.11±6.60 g kg^{-1} b.wt.,$^{0.75}$; however, in the IR_2, in which SBM was used as a protein source, the DMI was 70.75±9.24 g kg^{-1} b.wt.,$^{0.75}$ (Table 3), indicating a tendency towards a higher DMI (g kg^{-1} b.wt.,$^{0.75}$) in the IR_2 group. Similar, patterns were also found in CP intake (g/day), EE intake (g/day), CF intake (g/day), NFE intake (g/day) and TDN intake (g/day). These values were higher when SBM was used as a protein source compared with when FM was used as a source of protein, suggesting that SBM protein may be more beneficial than FM protein.

Table 2: Feed composition (g kg^{-1}) used in the ration

		DM basis (g kg^{-1})					
Items	DM (g kg^{-1})	CP	EE	CF	NFE	Ash	TDN
Natural grass	185.8	109.2	23.7	346.2	400.4	120.6	632.3
Pennisetum purpureum	884.9	83.0	24.0	335.0	417.0	141.0	550.0
Gliricidia sepium leaves	849.0	224.0	27.0	228.0	290.0	231.0	727.0
Dried cassava	897.2	18.0	-	158.9	812.1	11.0	829.6
Wheat bran	903.8	149.1	40.7	128.4	622.8	59.0	738.8
Fish meal	944.7	473.7	112.5	45.0	115.6	253.2	605.7
Soybean meal	925.8	420.3	3.1	31.0	472.5	73.1	801.4

Table 3: Nutrient intake (g/day±SD), average daily gain (g±SD) and feed conversion ratio of kacang goats fed natural grass as the sole ingredient (according to the farmers condition) and an improved balanced ration using two different sources of protein: IR_1 (fish meal) and IR_2 (soybean meal)

		Improved rations using different protein sources	
Feed material/nutrients	Control	Fish meal, FM (IR_1)	Soybean meal, SBM (IR_2)
DMI (g)	502.17±39.11^{Aa}	597.86±51.10^{a}	707.48±92.81^{Bb}
DMI (g kg^{-1} b.wt.$^{0.75}$)	53.88±3.48^{Aa}	65.11±6.60^{b}	70.75±9.24^{Cb}
DMI (g kg^{-1} b.wt.)	25.60±1.9^{a}	31.20±3.6^{ab}	32.90±4.4^{b}
CP intake (g)	52.62±7.29^{A}	94.72±7.25^{B}	115.75±23.78^{B}
EE intake (g)	11.89±0.93^{Aa}	14.82±1.27^{b}	18.09±2.37^{Cc}
CF intake (g)	173.83±13.54^{a}	177.45±15.17^{a}	206.44±27.08^{a}
NFE intake (g)	201.05±15.66^{Aa}	261.84±22.38^{b}	301.08±39.49^{Bb}
TDN intake (g)	317.78±34.74^{a}	346.46±42.53^{a}	412.35±80.07^{a}
ADG (g)	41.57±5.61^{A}	72.75±4.93^{B}	91.71±6.97^{C}
FCR	12.20±1.49^{A}	8.22±0.38^{B}	7.72±0.88^{B}

^{A,B,C}Row means with different superscripts differ significantly at $p<0.01$, while ^{a,b,c}row means with different superscripts differ significantly at $p<0.05$. Control: Natural grass, IR_1: Total mixed ration containing fish meal and IR_2: Total mixed ration containing soybean meal

Table 4: Nitrogen balance of kacang goats fed natural grass as the sole ingredient and rations using two different sources of protein: Fish meal (IR_1) and soybean meal (IR_2)

		Improved rations using different protein sources	
Parameters	Control	Fish meal, FM (IR_1)	Soybean meal, SBM (IR_2)
Nitrogen intake (g/day)	8.42±1.17^{A}	15.16±1.16^{B}	18.52±3.81^{B}
Fecal nitrogen (g/day)	2.79±0.39^{A}	5.24±0.37^{B}	5.87±0.77^{B}
Fecal N (g kg^{-1} of N intake)	332.90±45.1	347.30±37.9	320.70±30.5
Digested N (g/day)	5.63±1.00^{Aa}	9.92±1.27^{b}	12.65±3.08^{Bb}
Digested N (g kg^{-1} of N intake)	667.10±45.1	652.70±37.9	679.30±30.5
Urinary N (g/day)	3.28±0.23	4.25±3.79	2.98±0.61
Urinary N (g kg^{-1} of N intake)	393.00±41.1	270.40±217.6	169.00±57.3
Retained N (g/day)	2.35±0.86^{A}	5.66±2.76^{AB}	9.67±3.55^{B}
Retained N (g kg^{-1} of N intake)	274.10±68.8	382.30±190.6	510.40±86.3
ADG (g)	41.57±5.61^{A}	72.75±4.93^{B}	91.71±6.97^{C}
Retained N conversion ratio	0.06±0.02	0.08±0.04	0.10±0.03

^{A,B}Row means with different superscripts differ significantly at p<0.01, while ^{a,b}row means with different superscripts differ significantly at p<0.05. Control: Natural grass, IR_1: Total mixed ration containing fish meal and IR_2: Total mixed ration containing soybean meal

SBM is often used as a protein supplement for ruminants because it is palatable and has a well-balanced amino acid composition[12]. SBM protein is mostly digested inside the rumen. Sadeghi *et al.*[12] found that the value of DM SBM degradation was 955.0 g kg^{-1} in the rumen and that the value of CP degradation was 980.0 and 880.0 g kg^{-1} [13], indicating that SBM protein is easily degraded in ruminants and then fermented by microbes, such that proliferation and microbe enzymatic activity inside ruminants is more optimal with SBM protein. Fish meal protein degradation in the rumen was found to be low at 473.2 g kg^{-1} [14].

The differences in DMI between IR_1 and IR_2 and nutrient intake (e.g. CP intake, EE intake, CF intake and TDN intake) were reflected in ADG and FCR. The ADG of the control goats was 41.57±5.61 g/day. When the goats were given more feed than the control group, the ADG increased by approximately 31.18 points in the IR_1 group and 50.14 points in the IR_2 group. The goat group given IR_2 rations produced a higher ADG (91.71±6.97 g/day) compared with the goat group given IR_1 rations (ADG: 72.75±4.93 g/day) (Table 3), demonstrating that SBM protein was more readily available than FM protein. Chumpawadee *et al.*[14] found that the effective degradability of dry matter in fish meal was only 423.7 g kg^{-1}, organic matter was 462.2 g kg^{-1} and CP was 473.2 g kg^{-1}.

Nitrogen and energy utilization: The N intake of the control group was very low (8.42±1.17 g/day). Nevertheless, by providing balanced rations with different protein sources, there was an increase in the N intake (p<0.01) to 15.16±1.16 g/day in the IR_1 group and 18.52±3.81 g/day in the IR_2 group. A low N intake in the control group was supported by El-Meccawi *et al.*[15] who found that using wheat straw as a sole diet resulted in an N intake value of 5.61±11.7 g/day. The N intake was significantly higher (p<0.01) in the IR_1 and IR_2 groups compared to the control group. The goat group receiving SBM protein (IR_2) had higher N intake values compared with the goat group receiving the FM protein source (IR_1); the difference between them was approximately 3.36 points (Table 4). The same pattern was found in digested N. In the goat group that received IR_2 ration, the digested N was higher (p<0.01) compared with the goat group that was reared based on the farmer's conditions (Table 4).

The retained N in the control group had the lowest value (2.35±0.86 g/day), while those in the IR_2 group had the highest level (9.67±3.55 g/day); this difference was approximately 7.32 points higher (p<0.01) compared with the control group but it did not differ significantly compared with the IR_1 group (5.66±2.76 g/day). Thus, the higher the N intake, the more retained N was found in the goats; however, N retention (g kg^{-1}) was the same across all treatments. Thus, the retained N was also influenced by N intake. The retained N of IR_1 and IR_2 goats was higher than that of Sudan goats (2.72-3.71 g/day), as reported by Elamin *et al.*[16] and the retained N of Indian local goats (0.30-5.10 g/day) as reported by Singh and Kundu[17]; however, the retained N was lower than Ettawah goats (5.17-15.20 g/day), as reported by Akhsan *et al.*[18]. The nitrogen retention (g kg^{-1}) in this study was also higher than that reported in another study by Elamin *et al.*[16] (272.0-319.1 g kg^{-1}).

The N intake of control goats was lower than those of the IR_1 and IR_2 groups, which were 8.42±1.17, 15.16±1.16 and 18.52±3.81 g/day, respectively. In addition, the N digestion of the control group was the lowest compared to those of the IR_1 and IR_2 groups, which were 5.63±1.00, 9.92±1.27 and 12.65±3.08 g/day, respectively.

The Nitrogen fecal loss of the IR_1 and IR_2 goats was higher than the N urine loss, which is in agreement with Ajibola[19] who

Table 5: Energy utilization (Mj/day±SD) of kacang goats fed natural grass as the sole ingredient (control) and improved rations using two different sources of protein: fish meal (IR_1) and soybean meal (IR_2)

		Improved rations using different protein sources	
Feed material/nutrients	Control	Fish meal, FM (IR_1)	Soybean meal, SBM (IR_2)
Energy intake (GE) (Mj/day)	8.59±0.67^{A}	10.81±0.92^{AB}	13.08±1.71^{B}
Fecal energy (Mj/day)	2.69±0.39^{A}	4.77±2.24^{B}	5.32±0.49^{B}
Digested energy (Mj/day)	5.89±0.49^{a}	6.03±0.68^{ab}	7.76±1.26^{b}
Digestible energy (g kg^{-1})	686.50±34.4^{A}	556.50±34.9^{B}	591.30±22.3^{B}
Urinary energy (Mj/day)	0.29±0.10	0.31±0.17	0.28±0.06
Methane energy (Mj/day)	0.94±0.17	0.87±0.45	1.22±0.47
Metabolizable energy (Mj/day)	4.66±0.39	4.85±0.89	6.26±1.12
GE conversion ratio (Mj g^{-1})	0.21±0.03^{A}	0.15±0.01^{B}	0.14±0.02^{B}
DE conversion ratio (Mj g^{-1})	0.14±0.02^{A}	0.08±0.01^{B}	0.08±0.01^{B}
ME conversion ratio (Mj g^{-1})	0.11±0.02^{A}	0.07±0.01^{B}	0.07±0.01^{B}

^{A,B}Row means with different superscripts differ significantly at p<0.01, while ^{a,b}row means with different superscripts differ significantly at p<0.05. Control: Natural grass, IR_1: Total mixed ration containing fish meal and IR_2: Total mixed ration containing soybean meal

reported the percentage of fecal N loss to be higher than the percentage of urinary N loss. The fecal Nitrogen output in this study (320.7-347.3 g kg^{-1}) was lower than that found by Elamin *et al.*[16] on Sudan goats (309.7-374.1 g kg^{-1}) and Singh and Kundu's[17] study on Indian local goats (387.9-654.5 g kg^{-1}). However, in the control goats, N urine loss was higher than N fecal loss. The high N urine loss of the control goats could be a result of the low availability of fermentable energy in ruminants. The control group's rations contained lower NFE than that of the IR_1 or IR_2 group's rations. In addition, the NFE intake of the control goats was lower than that of the IR_1 and IR_2 goats (Table 3).

Tshabalala *et al.*[20] reported that high N concentrations in the urine could be a result of low availability of fermentable energy. The N concentration in the urine of the control goats (393.0 g kg^{-1}) was higher than that found by Elamin *et al.*[16] (339.9-362.5 g kg^{-1}); however, Singh and Kundu[17] reported high N concentration in the urine of Indian local goats that was approximately 291.5-418.2 g kg^{-1}. The percentage of Nitrogen loss in feces and urine was relatively the same (p>0.05) across treatments, indicating that fecal and urinary N loss was influenced by N intake, which is in line with previous studies[16,19]. The retained N conversion ratio was also similar (p>0.05) across treatments. These results indicated that, to increase a gram of ADG, the same amount of retained N was needed. High retention of N is caused by high N intake.

Energy intake in the control group was 8.59±0.67 Mj/goat/day (Table 5) and increased to 13.08±1.71 Mj/day in the IR_2 group (p<0.01), indicating that, when feed was improved with SBM (IR_2), it increased energy intake by 5.49 points (Table 5). However, the energy intake of the control group was similar (p>0.05) to that of the IR_1 group (10.81±0.92 Mj/day), with a difference of 2.22 points. The Digested Energy (DE) of the control group was 5.89±0.49 Mj/day, while the DE of the IR_1 group was 6.03±0.87 Mj/day. The DE of the IR_2 group (7.76±1.26 Mj/goat/day) was higher (p<0.05) than that of the control group but it was similar to the IR_1 group, suggesting that SBM provided the best DE (Table 5). In fact, the DE conversion ratio of the IR_1 (0.08±0.01 Mj g^{-1}) and IR_2 (0.08±0.01 Mj g^{-1}) groups was better (p<0.01) than that of the control group (0.14±0.02 Mj g^{-1}); the IR_1 group was the same (p>0.05) as the IR_2 group. Urine energy loss, methane energy loss and ME were similar across treatments (p>0.05); however, the ME conversion ratio of the IR_1 (0.07±0.01 Mj g^{-1}) and IR_2 (0.07±0.01 Mj g^{-1}) groups was better (p<0.01) than that of the control group (0.11±0.02 Mj g^{-1}); the IR_1 group was the same (p>0.05) as the IR_2 group. These results demonstrate that adding FM and SBM to rations increased ADG in kacang goats.

CONCLUSION

It is concluded that fish meal and soybean meal supplementation can improve the nutrient intake, digestibility, N retention and metabolizable energy in kacang goats and increase their productivity (ADG).

SIGNIFICANCE STATEMENT

This study showed that fish meal and soybean meal supplementation can improve nutrient intake, digestibility, N retention and metabolizable energy in kacang goats and increase their daily gain. In addition, total mixed rations were more palatable for kacang goat rather than feeding roughage and concentrate separately. Thus, improved rations can be applied to increase N retention, metabolizable energy and the daily gain of kacang goats. This study will help farmers better understand the dietary needs of kacang goat.

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