Original Research

Journal of Advanced Veterinary Research
(2026) Volume 16, Issue 1, 47-50

Effect of different processed legume proteins on the performance of dairy Goats

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ARTICLE INFO

Received: 04 November 2025

Accepted: 25 November 2025

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Keywords:

Crotalaria sp, Digestibility, Feed intake, Milk, Dairy goat.

ABSTRACT

The study aimed to examine the performance of Etawah crossbred dairy goats fed with *Crotalaria* as a substitute for protein source in concentrate. The study was carried out in 2 stages: 1) in vitro study to evaluate the digestibility of dry matter and organic matter from seven types of concentrates; 2) In vivo study using the best 3 types of concentrates from the results of in vitro study. The best concentrates in the first study were R1, R2 and R4. This implementation used 16 lactating Etawah crossbred dairy goats divided into 4 goats for each treatment, with a lactation period of 1 - 3 months and a goat body weight of + 39.3 kg. The data was processed by analysis of variance followed by Duncan's double test. The results showed that the treatment using *C. juncea* and *C. usaramoensi* as a source of protein concentrate influenced increasing the quantity and quality of milk. Total milk production with concentrate treatment R.2 (3.87 liters/week); R.3 (3.40 liters/week); R.1 (2.87 liters/week) and R.4 (1.58 liters/week). The quality of milk fat and solids nonfat with almost the same order as the amount of production, namely R.3 (5.21% and 9.26), R.2 (5.07% and 9.30%), R.1 (3.4% and 9.36%), R.4 (3.92 and 8.85%). The conclusion of this study was that the substitution of *Crotalaria* sp. (*C. juncea* and *C. usaramoensi*) as a source of protein concentrate gave a better production performance of dairy goats than the control concentrate.

Introduction

The livestock sector continues to grow, and efficient and sustainable production methods are becoming increasingly important. Dairy goats are a type of animal that is increasingly popular because of their superior milk production in a variety of environmental conditions. The dietary needs of dairy goats must be carefully considered to remain optimal. Protein intake is essential for growth, reproduction and milk production (Boshoff *et al*., 2024). However, protein-source feedstuff such as soybean and palm kernel meals has quite prices and compete with other industrial sectors (Pexas *et al*., 2023). In response to this condition, alternative protein sources were needed at low cost and were easily available. One of the alternative protein source feed ingredients that can be given to goats is legumes. Achmadi *et al*. (2023) reported that legumes such as moringa oleifera could replace soybean meal as a source of protein for goats.

Legumes have been recognized as an important source of protein for animal feed in recent years, especially in tropical countries. In addition to being rich in essential amino acids, legumes can also improve soil fertility by fixing nitrogen, which will help sustainable farming methods (Ravari *et al*., 2022). *Crotalaria* sp. were legumes that have the potential as a source of protein in feed and have different nutritional profiles and advantages (Araujo *et al*., 2023). Although legumes have the advantage of high protein content and are beneficial for soil fertility, legumes can have a negative impact on livestock. Legumes have a high risk of bloating in livestock (Phelan *et al*., 2014). One effort to reduce the negative impact of legumes was to process them before giving them to livestock. One of them to process them is by physically drying and reducing the size of the legumes and mixing them with concentrate.

Based on that explanation, therefore this study aimed to investigate the performance of dairy goats when fed different types of legumes i.e. *Crotalaria juncea*, *Crotalaria usaramoensi* and *Tephrosia vogelii*. By examining various performance metrics such as nutrients digestibility, feed intake, milk yield, and milk composition, this research seeks to identify the most effective legume for enhancing dairy goat productivity. Furthermore, understanding the impact of different legumes on dairy goat performance can provide valuable insights for farmers and feed manufacturers, promoting the adoption of more sustainable and efficient feeding strategies in the dairy goat industry

Materials and methods

This study was carried out with two stages of study. The first stage was in vitro study, and the second stage was in vivo study. The in vitro study was carried out at the feed and nutrition laboratory Universitas Diponegoro, and the in vivo study was carried out at Regional Technical Implementation Unit (RTIU) for Superior Animal Breeding, Semarang Regency, Central Java, Indonesia.

The first stage of study

The in vitro study aimed to determine the digestibility of dry matter and organic matter in concentrates containing *Crotalaria juncea*, *Crotalaria usaramoensi* and *Tephrosia vogelii*. The nutrient contents of the legumes are shown in Table 1. The in vitro digestibility test method refers to Tilley and Terry according to the Harris and Karmas (1986) guidelines. The composition of the feed ingredients and the nutrient content of the

Table 1. Nutrient content of leguminosae (%)

Leguminosae	DM	CP	CF	EE	Ash	NFE	TDN*)	NDF	NFC
Crotalaria usaramoensi	20.2	27.2	15.4	3.3	6.9	47.2	73.5	22.1	40.5
Crotalaria juncea	19.8	25.3	22.7	0.9	4.3	46.6	68.6	25.2	34.1
Tephrosia vogelii	23.3	13.5	26.6	6.8	10.1	42.8	62.9	39	30.4

*Calculated using the formula Sutardi (1983). DM = Dry Matter, CP= Crude Protein, CF=Crude Fiber, EE=Ether Extract, NFE = Nitrogen-Free Extract, TDN = Total Digestible Nutrient, NDF= Neutral Detergent Fiber, NFC= Non Fiber Carbohydrate concentrate are shown in Table 2. The three best concentrates compositions based on the digestibility of dry matter and organic matter in the first stage of the study were used for the second stage of the study. The legume was dried using oven at 60 degree celcius temperature, and after that the legumes were grounded using disk meal machine until become in the form of flour.

The second stage study

Dairy goat production performance was measured by the in vivo research. Treatment was done by using 3 types of concentrates made from the best legume protein from the results of in vitro testing in the first stage of research and one control. The best concentrates in the second stage of research were R1(*C. usaramoensi*), R2 (*C. juncea*) and R3 (*C. vogelii*).This implementation used 16 lactating Etawah crossbred dairy goats divided into 4 goats for each treatment, with 1 - 3 months of lactation in the first period of lactation and a goat body weight of 39.3 + 2,35 kg. The ration treatments were as follows:

R1= 50% elephant grass + 50% concentrate containing *C. usaramoensi*.
R2= 50% elephant grass + 50% concentrate containing *C. juncea*.
R3= 50% elephant grass + 50% concentrate containing *C. vogelii*.
Control= 50% elephant grass + 50% concentrate control.

The forage given in the four treatments were the same, namely elephant grass (Pennisetum purpureum). The variables observed in the third stage of the study included the level of dry matter consumption and the amount of milk production and milk quality which included total solids, fat content and solid nonfat (SNF). The study was conducted at the Regional Technical Implementation Unit (RTIU) for Superior Animal Breeding, Semarang Regency, Central Java, Indonesia. The nutrient content of feed is presented in Table 3.

The data was processed by analysis of variance followed by Duncan's Multiple Range Test (DMRT). The adaptation phase was carried out for

Table 2. The feed and nutrient composition (%).

Feed ingredient	R1	R2	R3	R4	R5	R6	R7
Coconut meal	5	5	5	5	5	5	5
Palm oil meal	5	5	5	5	5	5	5
Pollard	15	15	15	15	15	15	15
Rice bran	52	52	52	52	52	52	52
Cassava meal	7	7	7	7	7	7	7
Molasses	5	5	5	5	5	5	5
Soybean meal	5	5	5	5	5	5	5
C. usaramoensi	6	0	0	3	3	0	2
C. juncea	0	6	0	3	0	3	2
T. vogelii	0	0	6	0	3	3	2
Total	100	100	100	100	100	100	100
Nutrients content	R1	R2	R3	R4	R5	R6	R7
Dry matter	88.83	88.59	88.8	88.72	88.77	88.75	88.75
Ash	1.1	1.65	1.4	1.43	1.3	1.53	1.42
Crude protein	12.3	12.62	12.13	12.89	12.54	12.48	12.64
Ether extract	3.69	3.52	4.02	3.73	3.91	3.85	3.83
Crude fiber	24.39	24.17	24.66	24.21	24.33	24.55	24.36
Nitrogen free extract	58.52	58.03	57.78	57.73	57.92	57.6	57.75
TDN	65.26	65.08	65.26	65.51	65.58	65.19	65.42

TDN = Total Digestible Nutrient
R1 = 50% elephant grass + 50% concentrate R1 (*C. usaramoensi*)
R2 = 50% elephant grass + 50% concentrate R2 (*C. juncea*)
R3 = 50% elephant grass + 50% concentrate R3 (*T. vogelii*)
R4 = 50% elephant grass + 50% concentrate R4 (*C. usaramoensi* and *C. juncea*)
R5 = 50% elephant grass + 50% concentrate R5 (*C. usaramoensi* and *T. vogelii*)
R6 = 50% elephant grass + 50% concentrate R6 (*C. juncea* and *T. vogelii*)
R7 = 50% elephant grass + 50% concentrate R7 (*C. usaramoensi* and *C. juncea* and *T. vogelii*)

Table 3. Nutrient content of feeding treatment (%).

Nutrient contents	R1	R2	R3	Control
Dry matter	91.27	91.15	91.21	91.25
Ash	5.34	5.62	5.51	5.49
Crude protein	11.99	12.15	12.28	11.9
Ether extract	3.33	3.24	3.35	3.49
Crude fiber	28.74	28.63	28.65	28.87
NFE	50.6	50.36	50.21	50.25
TDN*)	60.51	60.42	60.63	60.51

*Calculated using the formula Sutardi (1983), NFE = Nitrogen-Free Extract, TDN = Total Digestible Nutrient
R1 = 50% elephant grass + 50% concentrate R1 (*C. usaramoensi*)
R2 = 50% elephant grass + 50% concentrate R2 (*C. juncea*)
R3 = 50% elephant grass + 50% concentrate R3 (*T. vogelii*)
Control = 50% elephant grass + 50% concentrate concentrate control

10 days by adapting the dairy goats to the given treatment feed, until the feed ratio was obtained according to the specified treatment. The data collection stage was carried out by recording the amount of feed given and the remaining feed and collecting the remaining feed as feed consumption data. Feed consumption was calculated using the formula:
Dry matter (DM) consumption= [given (g)×% DM given]–[remaining(g)×% DM remaining]
Organic matter (OM) consumption= [DM consumption (g)] × [% OM]
Ether extract (EE) consumption= [DM consumption (g)] × [% EE]

Milk production was measured every day for 3 months by collecting the milk produced, while milk quality was measured every day using lactoscan.

Results

Biological evaluation in the first stage of the study on the digestibility of dry matter and organic matter in seven concentrate feeds containing the three types of legume greens is presented in Table 4. The results of the analysis of variance showed differences ($p < 0.05$) in digestibility between the seven concentrates containing legumes. The digestibility of dry matter in concentrates R1 with R2 and R4 did not show any differences, while the digestibility of dry matter between R1 and R2 with R3, R5, R6 and R7 showed differences ($p < 0.05$), as well as between R3 (*C. vogelii*), R4 (*C. usaramoensi* and *C. juncea*), R6 (*C. vogelii* and *C. juncea*) and R7 (*C. vogelii*, *C. juncea* and *C. usaramoensi*) with R5 (3% of *C. vogelii* and 3% of *C. usaramoensi*). The highest to lowest dry matter digestibility of the seven concentrate feed formulas was R1 (77.71%), R2 (77.58%), R4 (74.19%), R3 (71.73%), R6 (70.97%), R7 (67.48%) and R5 (62.67%). The digestibility of organic matter in concentrate feed R1 (79.05%) and R2 (79.19%) was not significantly different from R4 (74.19%) but was significantly different ($p < 0.05$) from R3, R5, R6 and R7. The digestibility of organic matter between R4 and R3 and R6 was not different, while between R4 and R5 and R7 it was significantly different ($p < 0.05$%), as well as between R5 and R7.

Feed intake, milk yield and quality of dairy goats are presented in Table 5. The amount of feed given to the goats was the same, consisting of elephant grass and treatments R1, R2 and R3, as well as the concentrate R4.

Discussion

The seven rations contained relatively the same crude protein and TDN, 12 and 65% respectively, and were composed of the same feed ingredients, but the amount/proportion of the composition of each feed ingredient was different. Concentrate feed R1, with *C. usaramoensi* as a protein source provided the highest digestibility but was not different from R2 containing *C. juncea* green protein, while the digestibility of feed containing *T. vogelii* (R3) was the lowest among the three legume sources. Among the three legume combinations, the combination in the R4 treatment (50% *C. usaramoensi* + 50% *C. juncea*) had the highest digestibility, even higher than R3 although statistically not significantly different. Feed digestibility is influenced by several factors, including the fiber content of a feed ingredient and the content of non-structural carbohydrates (Castro-Montoya and Dickhoefer , 2018), as well as the type and concentration of rumen microbes (Achmadi *et al*., 2023).

Fiber is a nutrient fraction that is slowly digested by rumen microbes, while non-structural carbohydrates are nutrient fractions that are easily digested by rumen microbes. Different sources of fiber from the feed ingredients that make up the concentrate in the seven concentrate feeds appear to affect the overall digestibility of the concentrate feed. The ruminal effective degradation of NDF fiber in the agricultural by-product feed ingredients used in this study was different, varying between 12 and 47%. Thus, different feed ingredient compositions and different ruminal degradation rates of concentrates in feed affect total digestibility. In addition to being influenced by feed fiber, digestibility is also influenced by the degradability of non-structural carbohydrates and proteins. Non-structural carbohydrates are a nutrient fraction (carbohydrates) that are easily digested (Boshoff *et al*., 2024). The metabolic products of non-structural carbohydrate degradation by rumen microbes are energy (ATP) and volatile fatty acids consisting of acetate, propionate and butyrate which are then broken down into alpha keto acids. Protein by rumen microbes will also be partially degraded to produce ATP and volatile fatty acids, in addition to producing acetate, propionate and butyrate, some of which have branched chains, namely isobutyrate and isovalerate, especially from proteins containing branched chain amino acids.

The availability of these metabolic products will then be utilized by

Table 4. Dry matter (DM) and organic matter (OM) digestibility.

Digestibility	R1	R2	R3	R4	R5	R6	R7
DM, %	77.71±3.12^{a}	77.58±2.44^{a}	71.73±4.75^{bc}	74.19±1.44^{ab}	62.67±2.50^{d}	70.97±4.12^{bc}	67.48±1.83^{c}
OM %	79.05±2.11^{a}	79.19±3.36^{a}	75.07±3.95^{bc}	77.11±5.55^{ab}	67.48±1.79^{d}	74.73±3.78^{bc}	71.33±1.90^{c}

Different superscripts in same line are significantly different ($p<0.05$)
R1 = 50% elephant grass + 50% concentrate R1 (*C. usaramoensi*)
R2 = 50% elephant grass + 50% concentrate R2 (*C. juncea*)
R3 = 50% elephant grass + 50% concentrate R3 (*T. vogelii*)
R4 = 50% elephant grass + 50% concentrate R4 (*C. usaramoensi* and *C. juncea*)
R5 = 50% elephant grass + 50% concentrate R5 (*C. usaramoensi* and *T. vogelii*)
R6 = 50% elephant grass + 50% concentrate R6 (*C. juncea* and *T. vogelii*)
R7 = 50% elephant grass + 50% concentrate R7 (*C. usaramoensi* and *C. juncea* and *T. vogelii*)

Table 5. Feed intake and milk yield and quality.

Parameter	R1	R2	R3	Control
Feed intake (g/d)	1.525±155.43^{a}	1.545±111.46^{a}	1.587±46.01^{a}	1.430±33.16^{a}
Milk yield (l/week)	2.875±583,63^{a}	3.575±814.19^{a}	3.400±289.39^{a}	1.575±811.10^{b}
Fat (%)	3.40±1.08^{b}	5.07±2.04^{a}	5.21±1.38^{a}	3.92±0.49^{b}
Solid non fat (%)	9.36±0.15^{a}	9.30±0.39^{a}	9.26±0.07^{a}	8.85±0.21^{b}
Total solid (%)	13.16±0.42^{b}	14.37±0.37^{a}	14.46±0.59^{a}	12.77±0.28^{b}
Protein (%)	3.20±0.05^{a}	3.17±0.14^{a}	3.16±0.02^{a}	3.01±0.08^{a}

Different superscripts in same line was significantly different ($p<0.05$)
R1 = 50% elephant grass + 50% concentrate R1 (*C. usaramoensi*)
R2 = 50% elephant grass + 50% concentrate R2 (*C. juncea*)
R3 = 50% elephant grass + 50% concentrate R3 (*T. vogelii*)
Control = 50% elephant grass + 50% concentrate concentrate control

rumen microbes to proliferate, thereby increasing the concentration/number of rumen microbes (Harahap *et al*., 2019). The impact of increasing the rumen microbial population is increased feed digestibility. Concentrate feed R1 and R2 seem to follow the above phenomenon. This can be seen from the composition of the feed ingredients, especially the green protein source.

As shown in Table 5, the highest milk production was achieved in dairy goats that received concentrate R2 (concentrate containing *C. juncea*), followed by R3 (concentrate containing 50% *C. juncea* and 50% *C. usaramoensi*), R1 (concentrate containing *C. usaramoensi*) and control ration. Milk production was the result of nutrient intake and uptake of metabolite products in the mammary glands. Concentrate feed R1 to R3 was sufficient to support milk production for PE goats compared to concentrate in feed control. The availability of energy and protein are macronutrient factors that affect milk production (Boshoff *et al*., 2024). The adequate energy (TDN) and protein content in concentrates R1, R2 and R3 were better than concentrate in feed control, so its effect on goats performance, which was reflected in milk yield.

Concentrate feed R1 (containing *C. usaramoensi*), R2 (containing *C. juncea*) and R3 (concentrate containing *T. vogelii*) have the same in vitro digestibility, so that the milk production of the three rations is relatively the same, however, it is different from concentrate feed control, so that it has a significant effect on milk production. This is due to the content of protein, crude fiber and TDN in R1, R2 and R3 which are relatively the same, so that they do not affect nutrient utilization to be better than control. The protein content in the ration is very important during the lactation phase to support milk production, because the availability of protein in the ration will provide the availability of amino acids needed to synthesize milk protein (Meng *et al*., 2016). In addition, sufficient energy levels are very important to maintain high milk production. Energy is an important component of the ration, which has a direct impact on milk production. Energy is needed for lactose synthesis, which determines the volume of milk produced. Adequate energy levels ensure that goats have the energy needed to maintain high milk production levels. The right balance between protein and energy is essential as both nutrients must be in the right proportions to optimize milk production. This study was similar with the study reported by Vouraki *et al*. (2023) who reported that the ewes receiving the diet with grain legumes were able to utilize energy and protein supply towards meeting the demands for maintenance and milk production in an equally efficient way with those receiving soybean increase milk yield compare than only receive from soybean meal.

Based on Table 3, the research rations were prepared based on livestock needs during lactation and formulated with relatively the same protein and energy content, with relatively the same level of dry matter consumption. Relatively the same dry matter consumption with relatively the same level of dry matter digestibility in R1, R2 and R3 resulted in the nutrients utilized for production also being the same, so that it did not have a significant effect on milk production (Supriyati *et al*., 2016). In contrast to control which had significantly lower digestibility ($P < 0.05$) compared to R1, R2 and R3, so that nutrient utilization for milk production was also lower which resulted in low milk production in control.

Metabolite products from the digestibility of R1, R2 and R3 concentrate feed are thought to be more optimally utilized by the mammary glands so that their effect on milk production appears higher. The sufficient amount of metabolite products and their optimal utilization can also be reflected in the quality of dairy goat milk in the study. These results can be seen from the fat content and total solids of goat milk. Goats that received additional R3 concentrate had higher fat content (5.21%) and total solids (14.96%) compared to goats that received additional R1, R2 or control concentrates. The solid non-fat content between treatments R1, R2 and R3 was relatively no different and higher than goats that received control concentrate. The utilization of legumes in R1, R2 and R3 significantly ($P < 0.05$) can increase the production and quality of goat milk in the study. The provision of legumes such as alfalfa (*Medicago sativa*) in dairy cow rations can increase the availability of high-quality protein and can improve the nutritional balance of dairy cows, thereby increasing the availability of energy, protein, and minerals needed for better milk production. (Mertens, 2009; Boshoff *et al*., 2024).

The use of legumes in rations R1, R2 and R3 did not have a significant effect on the quality of milk protein. It is suspected that the level of protein degradation in the ration is not balanced with the availability of energy, so that microbial protein synthesis is not optimal and the intake of amino acids for milk protein synthesis is reduced. Johansen *et al*. (2018) stated that if the energy in the feed is insufficient, protein from legumes can be used as an energy source and reduce its availability for milk protein synthesis. This is in line with Edson *et al*. (2018), who reported that feed supplementation with legume leaf flour did not significantly affect milk protein levels.

Conclusion

Legumes *C. juncea* and *C. usaramoensi* have the potential as a source of ruminant feed. The concentrate containing legumes *C. juncea* and *C. usaramoensi* in goat rations can increase the production and quality of PE goat milk.

Acknowledgements

This work is supported by the Faculty of Animal and Agricultural Sciences, Universitas Diponegoro Research Program No. 41/UN7.5.5.2/HK/2022.

Conflict of interest

The authors have no conflict of interest to declare.

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