Research Article

High-Quality Forage and Palm Concentrate Concerning Milk Production in Etawa Crossbreed Goats

Arief[1]*, Roni Pazla[2]

[1]Department of Animal Production Technology, Faculty of Animal Husbandry, Andalas University. Jl. Raya Limau Manis Campus, Padang, West Sumatra, Indonesia; [2]Departemen of Nutrition and Feed Technology, Faculty of Animal Husbandry, Andalas University. Jl. Raya Limau Manis Campus, Padang, West Sumatra, Indonesia.

Abstract | The value of goat's milk is influenced by its content. Forage is the main element that forms milk fat. We aimed to enhance the production of FCM (Fat-Corrected Milk) in Etawa crossbreed goats through the use of a mixture of high-quality forages such as *Mirasolia diversifolia* (*Md*), *Indigofera zoolingeriana* (*Iz*), and *Gliricidia sepium* (*Gs*) with palm concentrate (PC). We used a completely randomized design, implementing four treatments with four replicates as follows: Treatment T1: Control; 60% Company Ration + 40% Company Concentrate, T2: 60% (*Md*+*Gs*) + 15% CC +25% PC, T3: 60% (*Iz*+*Gs*) + 15% CC + 25% PC, T4: 60% (*Md*+*Iz*) + 15% CC +25% PC. The findings indicated that there were no significant differences in FCM production among the treatments, except for T3, which demonstrated higher production. Milk fat and lactose levels also did not exhibit significant differences. However, there were significant variations ($P < 0.05$) in the consumption and digestibility of crude fiber, crude fat, and nitrogen-free extract. A mixture of forages, including *Mirasolia diversifolia, Indigofera zoolingeriana,* and *Gliricidia sepium*, combined with palm concentrate, can balance the company's ration FCM milk production.

Keywords | *Gliricidia sepium*, Goat, *Indigofera zoolingeriana,* Milk, *Mirasolia diversifolia,* Palm concentrate

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***Correspondence** | Arief, Department of Animal Production Technology, Faculty of Animal Husbandry, Andalas University. Jl. Raya Limau Manis Campus, Padang, 25163, Indonesia; **Email:** aarief@ansci.unand.ac.id
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INTRODUCTION

Forages and concentrates are essential components for optimal milk production and quality in dairy goats. However, in Indonesia, there are challenges concerning the provision of forages and concentrates within the community. The community only knows natural grass as a source of forage, while its availability is limited due to the limited growing areas as a result of housing construction, road development, highways, and other infrastructure development. The concentrate is a strengthening feed whose price is quite high on the market, so farmers cannot afford to buy it in large quantities.

Mirasolia diversifolia (*Md*), *Indigofera zoolingeriana* (*Iz*), and *Gliricidia sepium* (*Gs*) are high-quality forages that have not been widely utilized and cultivated by dairy goat farmers. The crude protein content of these forages is 21.75 (Pazla et al., 2023a), 27.01 (Badarina et al., 2023), and 19.11% (Adrizal et al., 2021), respectively. When compared with field grass, which contains only 7-11% crude protein (Elihasridas et al., 2023a), *Md, Iz*, and *Gs* possess the capacity to enhance dairy goats performance. This potential is attributed to their high crude protein content. Crude protein is degraded by rumen microbes into ammonia (NH_3) (Antonius et al., 2023; Pazla et al., 2023b; Zain et al., 2023). NH_3 is essential for rumen microbes to synthesize their body proteins (Synthesis of proteins by microorganisms) (Pazla et al., 2018a; Putri et al., 2019, 2021). Microbial protein plays a crucial role as a nutrient that enhances both milk production and quality (Rosmalia et al., 2022; Sari et al., 2022).

Palm concentrate (PC) is an alternative to commercial concentrates with high prices. It is derived from palm kernel cake, a by-product of the palm oil processing industry. The use of PC as a substitute for the company's concentrate has the potential to sustain both the production and quality of milk in Etawa crossbreed goats (Arief et al., 2018a, b, 2020, 2023a; Arief and Pazla, 2023). The mixture *Md* with napier grass in etawa crossbreed goat ration can optimize digestibility and milk production (Pazla et al., 2022). Arief and Pazla (2023) reported milk quality of etawa crossbreed goat can optimize with the mixture *Gs* and palm concentrate in the ration. The use of a mixture of *Md, Iz,* and *Gs* with PC for the Etawa crossbreed goat has not been previously studied. We aimed to evaluate the effectiveness of combining high-quality forages such as *Md*, *Iz,* and *Gs* with PC in the Etawa crossbreed goat ration.

MATERIALS AND METHODS

Research site

Ration trials on Etawa crossbreed goats were performed at Toni Farm livestock company in Payakumbuh City, West Sumatra. The feed ingredients, feces, fat, and milk lactose content analysis was performed at the Payakumbuh Polytechnic Laboratory, West Sumatra.

Research materials

We employed 16 Etawa crossbreed goats with an average weight of 60±1.31 kg. These dairy goats are in their second lactation. The goats were placed in individual pens equipped with feeding and drinking facilities.

The research ration consisted of forage and concentrate. The forage used includes company forage, *Md*, *Iz,* and *Gs*, while the concentrate consists of both company concentrate (CC) and palm oil concentrate (PC). The ratio of forage and concentrate is 60:40. Forage and concentrate were given separately. The concentrate was administered twice daily, in the morning and the afternoon. On the other hand, forage was provided three times a day: In the morning, during the afternoon, and in the evening. PC is produced from a blend of palm kernel meal, bran, corn, and minerals. The chemical structure of the feed components comprising the ration is presented in Table 1. The structure and chemical analysis of the ration are presented in Table 2.

Experimental design

We employed an experimental approach utilizing a fully randomized design, which consisted of four dietary treatments and four repetitions as follows: T1 (Control): 60% company ration + 40% company concentrate, T2: 60% (*Md*+*Gs*) + 15% CC +25% PC, T3: 60% (*Iz*+*Gs*) + 15% CC +25% PC, and T4: 60% (*Md*+*Iz*) + 15% CC +25% PC.

Table 1: Chemical composition of feed ingredients.

Chemical Composition (%)	Feedstuff					
	CF	Md	Iz	Gs	PC	CC
Dry Matter	26.03	23.13	21.24	21.42	93.06	30.67
Organic Matter	87.93	84.65	92.41	94.85	94.07	94.33
Crude Protein	25.43	25.07	25.29	19.11	12.53	08.32
Crude Fiber	28.02	22.62	12.87	19.75	19.05	20.37
Crude fat	2.73	1.62	3.64	2.98	3.50	5.82
TDN	56.46	56.72	61.42	66.07	77.54	78.26
NFE	31.75	35.34	40.51	53.01	58.99	59.82
Ash	12.07	15.35	07.59	05.15	5.93	5.67

Total digestible nutrient (TDN), Nitrogen free extract (NFE), *Mirasolia diversifolia* (Md). *Indigofera zoolingeriana* (Iz), *Gliricidia sepium* (Gs), Palm concentrate (PC), Company forages (CF), Company concentrates (CC)

Table 2: Ratio composition and chemical composition of treatment rations.

Feedstuff	Treatments (% DM)			
	T1	T2	T3	T4
Company Forages	60	0	0	0
Ms	-	40	-	30
Gs	-	20	15	-
Iz	-	-	45	30
Pc	-	25	25	25
CC	40	15	15	15
Total	100	100	100	100
Chemical Composition				
Dry Matter	27.89	31.40	30.64	31.18
Organic Matter	90.49	90.50	93.48	90.79
Crude Protein	18.59	18.23	18.63	19.49
Crude Fiber	24.96	20.82	16.57	18.47
Crude Fat	3.97	2.99	3.83	3.33
TDN	65.18	67.03	68.67	66.57
NFE	42.98	48.46	49.90	46.48
Ash	9.51	9.50	6.52	9.22

Dry matter (DM), *Mirasolia diversifolia* (Md), *Indigofera zoolingeriana* (Iz), *Gliricidia sepium* (Gs), Palm concentrate (PC), Company forages (CF), Company concentrates (CC).

Statistical analysis

The data underwent analysis of variance, and IBM SPSS version 21 software was employed for this purpose. Treatment distinctions were evaluated through the application of the Duncan Test at a significance level of 5% (Steel and Torrie, 2002).

The measured parameters included ration consumption (crude fat, crude fiber, and NFE), the digestive efficiency of food substances (crude fat, crude fiber, and NFE), dairy production, milk fat, and lactose content. The food substances were assessed through the AOAC method (AOAC, 2016). Milk fat and lactose content were determined using Lactoscan Pro 201. Milk production (FCM) was calculated based on the method described by Mavrogenis and Papachristoforou (1988).

$$FCM = M\ (0.411 + 0.147f)$$

Where; FCM = fat-corrected milk production (at 4% fat); M= the weight of milk in Kg; f = the amount of fat present in milk.

Research period

This research comprises three phases: A 14-day adaptation phase, a 14-day initial phase, and a 5-day data collection phase. The adaptation phase aims to get the goats used to eating the new ration. The initial phase aimed to eradicate the influence of the previous ration, while the collection phase was used to determine milk production, ration consumption, feces collection, and the digestibility of nutrients and milk quality. Ration consumption was calculated by weighing the difference between the quantity of food provided to the livestock with the residual amount. Fecal samples, comprising 10% of the total feces, were then sun and oven-dried at 60°C/48 h. Subsequently, the stool samples were analyzed for their chemical composition based on AOAC (2016).

Table 3: Feed Intake of The Treatment Ration.

Parameters (kg/day)	Treatment			
	T1	T2	T3	T4
Crude Fat Intake	0.072	0.059	0.067	0.076
Crude Fiber Intake	0.371	0.409	0.328	0.454
Nitrogen-Free Extract Intake	0.782	0.953	0.934	0.989

RESULTS AND DISCUSSION

Consume crude fats, crude fibers, and nitrogen-free extract (NFE)

The consumption of crude fiber, crude fat, and NFE in the diet of lactating Etawa crossbreed goats is presented in Table 3. The treatments showed no significant effects on the consumption of crude fiber, crude fat, and NFE. The mixture of *Md, Iz,* and *Gs* forages with PC can match the consumption of forages and company concentrates.

Digestibility of crude fiber, crude fat, and nitrogen free extract (NFE)

The digestibility of crude fiber, crude fat, and NFE is presented in Figures 1, 2, and 3. The treatments showed significant (P<0.05) differences in the digestive ability of crude fat, crude fiber, and NFE. The highest digestive ability of crude fiber and crude fat was found in T3.

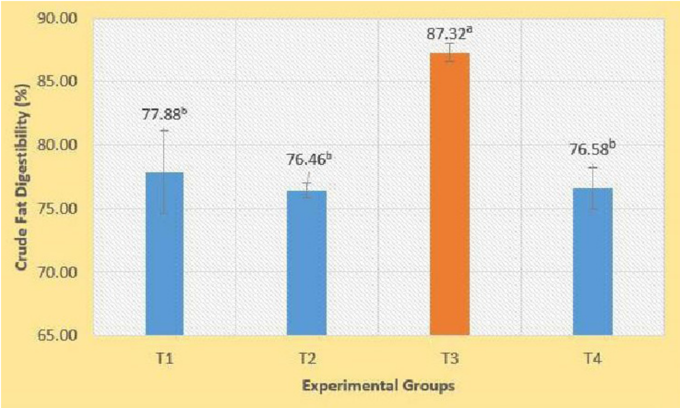

Figure 1: Crude fat digestibility of treatment ration (%).

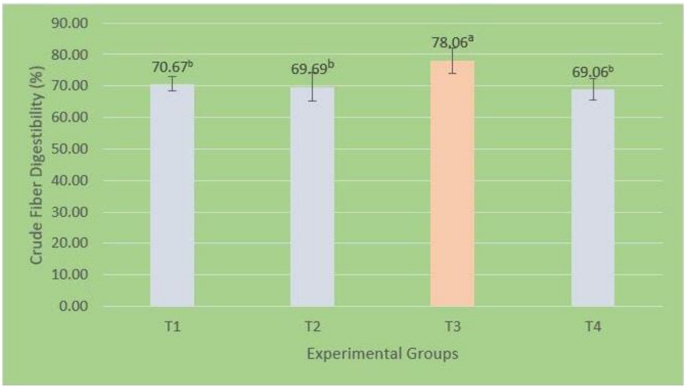

Figure 2: Crude fiber digestibilty of treatment ration (%).

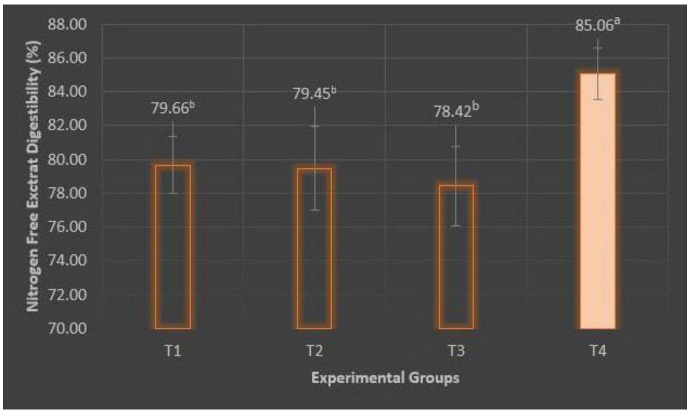

Figure 3: Nitrogen free extract digestibility of treatment ration (%).

The digestibility of crude fat and crude fiber among treatments T1, T2, and T4 showed no significant differences. The T4 exhibited the highest NFE digestibility, whereas treatments T1, T2, and T3 demonstrated no significant differences.

Milk production

Milk production (FCM) for each treatment is presented in Figure 4. The treatments showed insignificant (P<0.05) differences in milk production. The replacement of company rations with a combination of forages and PC successfully maintained milk production. Although there was no statistical significance, T3 yielded the highest milk production, whereas T4 had the lowest milk production.

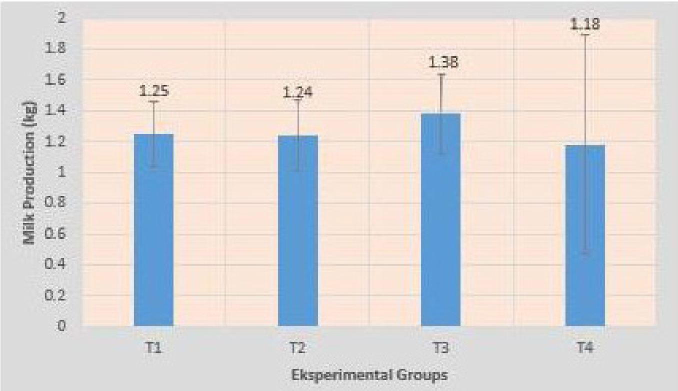

Figure 4: Milk production of treatment ration (kg).

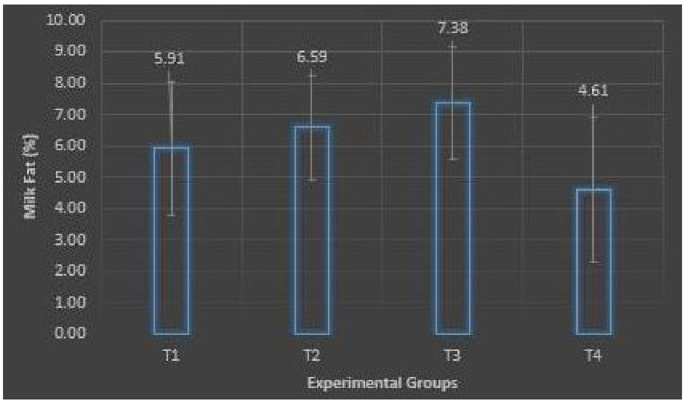

Figure 5: Milk fat of treatment ration (%).

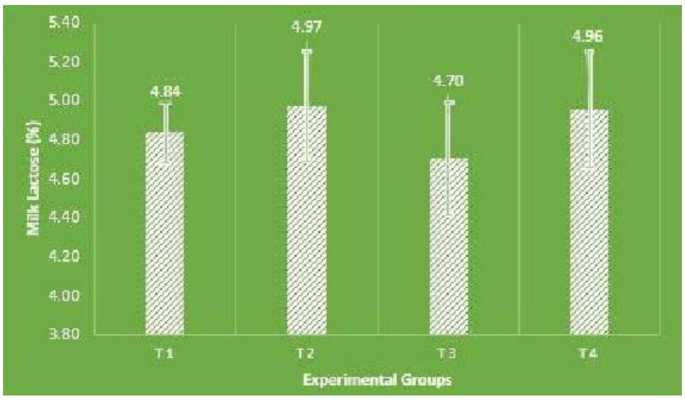

Figure 6: Milk lactose of treatment ration (%).

Milk fat and lactose content

The milk fat and lactose content of the treated milk are presented in Figures 5 and 6. The treatments showed insignificant differences in the fat and lactose content of the milk. Replacing company rations with a combination of forages and PC maintained milk fat and lactose levels. Although not statistically significant, T3 produced the highest milk fat content and the lowest lactose.

Consumption of crude fats, crude fiber, and NFE

The nonsignificant differences between the ration treatments were attributed to the level of palatability and livestock preferences for the given rations being consistent. Pazla et al. (2018b) and Jamarun et al. (2023), have stated that feed ingredients' palatability directly influences attractiveness and can stimulate livestock appetite. Aroma, texture, and odor significantly impact the taste. Considering our results, it is evident that the provided ration possesses an aroma, texture, and odor that enhances livestock appetite. Arief and Rizqan (2023b) discovered that the consumption of crude fat, crude fiber, and NFE did not differ in the Etawa cross-breed goat ration containing field grass, *Md*, cassava, and PC, with consumption values of 0.07 kg/d, 0.51 Kg/d, and 1.11Kg/d, respectively. The forage-to-concentrate ratio of 60:40 in the feed also leads to consistent livestock consumption. Disparities in the forage and concentrate ratio within the ration will result in differences in the amount of ration consumed by livestock (Pazla et al., 2023c). In addition, the four treatments were prepared with nearly identical protein and energy balances, ensuring nearly identical nutritional quality. Febrina et al. (2017) and Marquest et al. (2022) have affirmed that ration consumption is influenced by feed quality and digestibility level.

Digestibility of crude fats, crude fiber, and nitrogen free extract

Significant differences in the digestive ability of crude fiber, crude fat, and NFE were attributed to the influence of the nutrient composition of the feeds, specifically the crude fiber and NFE content, and the capacity of rumen microbes to break down feed. The highest digestive ability of crude fat and crude fiber was found in the T3, which included rations containing *IZ* and *Gs* forage along with PC. The T3 contained a lower crude fiber value than the other treatments. Crude fiber acts as a limiting factor for rumen microbes in the degradation of feed and its conversion into an energy source (Jamarun et al., 2017a, b, c; Pazla et al., 2020; Elihasridas et al., 2023b). The highest NFE content in T3, at 49.90%, also greatly facilitates the development of rumen microbes. NFE is a carbohydrate fraction easily metabolized by rumen microbes (Pazla et al, 2023d). The higher the NFE value, the more significant its contribution to energy production and milk quality. The fat content across treatments remained within the tolerance limits for rumen microbes. Rumen microbes are disturbed in digesting crude fat when the fat content exceeds 5% (Makmur et al., 2019; Jamarun et al., 2020). The high digestibility of ration fat in T3 was due to an increase in the rumen microbial population, a result of the low crude fiber content and high NFE content in T3. While the digestibility of NFE in T4 is indeed higher than that in T3, the levels of NFE in T4 are lower than in T3, resulting in nearly equal total NFE digestion between T4 and T3. In the T4 treatment, rumen microbes are believed to degrade more of the NFE content in the ration, leading to optimal digestibility.

Milk production

Milk production, which showed no significant variation among treatments, can be attributed to nearly identical feed quality factors. The rations were prepared with proteins that showed minimal variation between treatments. The energy content (TDN) also exhibited minor differences. This study found almost identical availability of protein and energy, resulting in no discernible differences in milk production. However, Figure 4 reveals that the T3, comprising a ration containing *Iz, Gs* forage, and PC, achieved the highest FCM milk production. The quantity of digested food substances, such as crude fat and crude fiber, was also highest in the T3, leading to optimal milk production in this treatment.

The consumption of the same ration was the primary reason for the absence of differences in milk production between treatments. Larson (1979) states that milk production relies heavily on blood nutrients associated with the efficiency of the consumed food. The milk production (FCM) produced in this study closely resembled that reported by Arief et al. (2023b), ranging from 1.22 to 1.41 Kg with rations comprising field grass, *Md*, and PC. However, it was lower than that documented by Pazla et al. (2022), which ranged from 0.51 to 0.54 kg with a ration consisting of palm fronds, *Md*, and elephant grass. This variation can be attributed to the differences in the type of ration provided.

Milk fat and lactose content

The fat and lactose content of the milk, which did not differ between the ration treatments, was a result of the nearly identical quality of the rations provided. Feed consumption was nearly identical in each treatment, ensuring that the nutritional intake for milk fat and lactose formation remained consistent. However, the T3 exhibited a higher fat value than the other treatments. This condition occurred due to the high digestibility of crude fiber and crude fat at T3. The digestibility of crude fiber and crude fat closely correlates with milk fat value. Arief et al. (2023b) identified a correlation between milk fat content and the digestive ability of crude fiber and crude fat. Crude fiber, when fermented by rumen microbes, produces acetic acid, a fundamental component in milk fat formation (Despal et al., 2021a, b). Optimal degradation of crude fiber in the rumen results in elevated acetate levels, consequently increasing milk fat content (Florendo et al., 2018; Fatmawati et al., 2022). The consistent milk fat content across the treatments resulted from the equal ratio of forage and concentrate in the rations. The ratio of concentrate in the ration greatly affects the fat content of milk. Milk fat content will decrease if the ratio of concentrate in the ration is raised (Schmidely and Sauvant, 2001).

The lowest milk lactose value was found in T3. This is very natural because milk fat is the opposite of milk lactose. Milk lactose binds with water. When the milk has a high lactose level, it will have a higher water content, whereas if the milk has a low lactose level, it will contain less water but a higher fat content. Milk lactose is synthesized from the NFE substance, which is transformed into propionic acid in the rumen. Propionic acid is taken up from the rumen wall and transformed into glucose in the liver. Glucose enters the mammary gland cells and is converted into lactose (Sondakh et al., 2017). The quality of milk is determined by the fat content contained in the milk. The quality of the milk improves as its fat content increases. In this study, the milk's fat and lactose content meet the criteria for premium milk quality as defined by the Thai Agricultural Standard (2008).

CONCLUSIONS AND RECOMMENDATIONS

Providing a mixture of *Md, Iz,* and *Gs* forage with PC to Etawa crossbreed goats balanced the FCM milk production of the company. The three ration formulations can serve as a foundation for dairy goat farmers in providing nutrition to their livestock.

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NOVELTY STATEMENT

This study introduces a new ration formulation for Etawa-breed dairy goats, incorporating high-quality forages and palm oil concentrates. This combination optimizes the milk production of Etawa crossbreed goat milk.

AUTHOR'S CONTRIBUTION

ARIEF designed the research concept and provided field supervision, while Roni Pazla conducted *in-vivo* research, performed laboratory analysis, analyzed the data, and drafted the document.

Ethical statement

This study has obtained ethical approval from the Faculty of Medicine at Andalas University regarding the use of animals in research experiments with number: 115/ UN.16.2/KEP-FK/2023.

Conflict of interest

The author affirms that there are no conflicts of interest regarding the research or publication of this manuscript.

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