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Optimizing Goat Milk Production and Quality: Evaluation of Local Feed Sources for Sustainable Nutrition in the Tropics

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ABSTRACT

The primary objective of this study was to evaluate the effects of replacing forage and conventional concentrate with alternative local feed ingredients such as cassava leaves (*Manihot esculenta*), Gamal leaves (*Gliricidia sepium*), and palm kernel meal-based concentrate on ration consumption, fiber digestibility, milk production, milk fat content, and the fatty acid composition of milk produced by *Peranakan etawa* (PE) goats. Four dietary treatments were applied: ration A (50% forage and 50% conventional concentrate), ration B (15% cassava leaves, 35% Gamal leaves, 15% palm kernel meal-based concentrate and 35% conventional concentrate), ration C (15% cassava leaves, 35% Gamal leaves, 25% palm kernel meal-based concentrate, and 25% conventional concentrate), and ration D (15% cassava leaves, 35% Gamal leaves, 35% palm kernel meal-based concentrate, and 15% conventional concentrate). The results indicated that forage substitution had no significant effect ($P>0.05$) on neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter consumption, hemicellulose, cellulose, and fiber digestibility. Milk yield ranged from 1.30 to 1.41kg/day, with ration C yielding the highest milk fat content (5.89%). Regarding the fatty acid profile, ration B delivered the highest concentration of monounsaturated fatty acid (MUFA, 41.69%), while ration C produced the lowest proportion of saturated fatty acid (SFA, 56.98%). Overall, the stability of consumption and fiber digestibility, combined with the advantageous milk fatty acid composition observed in ration B, suggests that this formulation is a promising strategy for producing high-quality milk in tropical livestock systems under sustainable and economically feasible conditions. The outcomes of this study suggest that future research should explore the long-term effects of substituting local feed on animal health and reproductive performance, as well as its economic feasibility for smallholder farmers in tropical regions.

Keywords: Goat milk production, Local feed sources, Cassava leaves, Palm kernel meal, Sustainable livestock nutrition.

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INTRODUCTION

The livestock sector in the tropics faces significant challenges in maintaining sustainable production due to its dependence on conventional forages and concentrates. Limitations in quality consistency and high feed costs demand innovation in utilizing abundant local ingredients. Cassava leaves (*Manihot esculenta*) and Gamal leaves (*Gliricidia sepium*) are examples of local feed ingredients with high nutrient content, making them potential sources of animal feed that can reduce feed costs (Adrizal et al., 2021; Arief et al., 2024a). Palm kernel meal, a by-product of the palm oil industry, is a valuable feed ingredient due to its relatively high energy and protein content, making it suitable as a concentrate source in ruminant diets (Arief & Pazla, 2023a).

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The nutritional analysis of cassava leaves reveals crude protein (CP) levels of 13-24%, crude fiber (CF) levels of 16-54%, and total digestible nutrients (TDN) between 60-71%. (Oni et al., 2011; Rochana et al., 2018; Utomo et al., 2019). Gamal leaves contain a high percentage of CP, ranging from 18-25%, moderate CF levels of 15-36% and a relatively good TDN value of 65-70% (Da Silva Brito et al., 2020). In comparison, a concentrate mixture of palm kernel meal, corn, bran, and minerals contains 12.53% CP, 19.05% CF, and 77.54% TDN (Arief et al., 2024b). This information suggests that these raw materials can be combined to provide sufficient nutrients required by livestock to support performance.

Most experiments on feed ingredients have focused primarily on their effects on livestock growth performance. Few studies have examined the combination of cassava leaves, Gamal leaves and palm kernel meal concentrate in *Peranakan etawa* (PE) goat milk production, milk fat and fatty acid composition, fiber intake, and digestibility (Arief et al., 2023). Furthermore, the digestibility of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, cellulose, and other indices commonly used to assess feed quality has rarely been comprehensively evaluated. This study seeks to address this gap by evaluating the substitution of forage and conventional concentrates with a combination of cassava leaves, Gamal leaves, and palm kernel meal-based concentrates.

MATERIALS & METHODS

Study Location and Duration

The experimental procedures were conducted at Toni Farm in Payakumbuh, West Sumatra, Indonesia, 516 meters above sea level. The study lasted 45days, consisting of a 25-day acclimation phase, a 15-day feeding trial, and 5days for data collection. Ambient temperatures during the study ranged from 22 to 35°C.

Experimental Animal

Sixteen lactating Etawa crossbreed goats were utilized, averaging 60±2.31kg in body weight. Each animal was in its second lactation and a completely randomized design was employed to assign the goats to four dietary treatments, each with four replicates.

Dietary Treatments

The goats were fed one of the following four experimental rations:

Control (A): 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC).

Treatment B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC).

Treatment C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC.

Treatment D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC.

The forage-to-concentrate ratio across all treatments was maintained at 50:50. The conventional concentrate was composed of tofu pulp, jackfruit skin, and starch-rich cassava flour. The nutrient composition of the diets, including dry matter (DM), crude protein (CP), fiber fractions and total digestible nutrients (TDN), was determined through laboratory analysis. The chemical content of feed ingredients is provided in Table 1, while the ration composition and chemical content of treatment rations are shown in Table 2.

Table 1: Chemical content of feed ingredients

Chemical Content (%)	Feedstuff				
	CF	CL	Gs	PKCC	CC
Dry Matter	26.03	31.10	21.42	93.06	30.67
Organic Matter	87.93	89.85	94.85	94.07	94.33
Crude Protein	25.43	27.15	19.11	12.53	08.32
Crude Fiber	23.02	19.12	19.75	19.05	20.37
Crude fat	2.73	3.52	2.98	3.50	5.82
TDN	61.46	70.21	66.07	77.54	78.26
NFE	31.75	39.26	53.01	58.99	59.82
Ash	12.07	10.15	05.15	5.93	5.67
NDF	48.27	56.13	37.87	62.84	61.54
ADF	36.45	33.69	8.92	36.02	48.55
Cellulose	24.4	28.48	14.07	16.97	24.46
Hemicellulose	11.82	22.44	28.46	26.82	12.99
Lignin	11.72	6.87	6.49	3.92	4.54

TDN: total digestible nutrient; NFE: nitrogen-free extract, Gs: *Gliricidia sepium*; PKCC: palm kernel cake concentrate; CF: conventional forages; CL: cassava leaves; CC: conventional concentrates

Table 2: Ration composition and chemical content of treatment rations

Feedstuff	Treatment			
	A	B	C	D
Conventional Forages	50	0	0	0
Casava leaves	-	15	15	15
Gliricidia sepium	-	35	35	35
Palm kernel cake concentrate	-	15	25	35
Conventional Concentrate	50	35	25	15
Total	100	100	100	100
Chemical Composition				
Dry Matter	28.35	36.86	43.09	49.33
Organic Matter	91.13	93.80	93.75	93.75
Crude Protein	16.87	15.55	15.97	16.40
Crude Fiber	21.69	19.77	19.64	19.50
Crude Fat	4.28	4.32	4.08	3.85
TDN	69.86	72.68	72.61	72.53
NFE	45.79	54.23	54.06	54.06
Ash	8.87	6.20	6.23	6.25
NDF	54.90	52.64	52.77	52.90
ADF	42.50	30.57	29.31	28.06
Cellulose	24.43	20.30	19.55	18.80
Hemicellulose	12.40	21.90	23.28	24.66
Lignin	8.13	5.48	5.42	5.36

Data Collection and Parameters

1. Feed Intake

Dry Matter Intake (DMI) was calculated as the product of daily feed consumption and dry matter content of the feed. Furthermore, the intake of fiber components such as NDF, ADF, cellulose, and hemicellulose was determined by multiplying the DMI by the respective nutrient concentrations in the ration.

2. Fibre Digestibility

The digestibility of NDF, ADF, cellulose, and hemicellulose was measured using daily fecal weight recorded during the 5-day data collection period. Fecal samples were dried and ground before being analyzed, following standard procedures.

3. Milk Quality

Milk Fat Content was determined by analyzing milk samples collected twice daily using an automatic milk testing analyzer. The Fatty Acid Profile of the milk, including saturated fatty acids (SFA), monounsaturated fatty acids

(MUFA), and polyunsaturated fatty acids (PUFA), was analyzed using gas chromatography.

Chemical Analysis

Feed ingredients were chemically analyzed for their composition (CP, DM, ether extract, crude fiber, ash and NFE) according to AOAC (2016) methods. Fiber fractions (ADF, NDF, cellulose, and hemicellulose) were analyzed using Van Soest's detergent system (Van Soest et al., 1991).

Statistical Analysis

Feed intake, fiber digestibility, and milk fat content were analyzed using ANOVA to evaluate the effects of dietary treatments. Duncan's multiple range test was applied for post-hoc comparisons at a significance level of $P<0.05$.

The fatty acid profile of the milk was not subjected to statistical analysis. However, results were presented and interpreted descriptively, focusing on trends and possible implications of the dietary treatments with respect to polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), and saturated fatty acids (SFA) levels.

RESULTS

Ration Consumption

Ration consumption, including acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter (DM), cellulose, and hemicellulose, is a crucial parameter for evaluating the acceptance and utilization of feed by livestock. In this study, substituting conventional forages and concentrates with a combination of cassava leaves, Gamal leaves and palm kernel meal-based concentrates did result in significant changes ($P>0.05$) in DM intake or other fiber components. Average DM consumption ranged from 1.81-1.98kg/day, while NDF, ADF, cellulose and hemicellulose consumption ranged from 0.96-1.09 kg/day, 0.51-0.84kg/day, 0.34-0.48kg/day, and 0.25-0.45kg/day, respectively (Table 3).

Table 3: Consumption of dry matter, NDF, ADF, Cellulose and Hemicellulose

Parameters (Kg)	Treatment			
	A	B	C	D
Dry matter	1.98±0.01	1.93±0.05	1.89±0.06	1.81±0.04
NDF	1.09±0.02	1.02±0.05	1.00±0.03	0.96±0.04
ADF	0.84±0.03	0.59±0.02	0.55±0.08	0.51±0.02
Cellulose	0.48±1.02	0.39±1.01	0.37±1.08	0.34±1.05
Hemicellulose	0.25±1.06	0.42±1.06	0.44±1.05	0.45±1.04

A: 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC); B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC); C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC; D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC. There was non-significant difference among treatments ($P>0.05$)

Fiber Digestibility

Fiber digestibility, including acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose and hemicellulose, is a key parameter for evaluating ration quality and utilization efficiency in livestock. In this study, replacing forage and concentrate with a combination of cassava leaves, Gamal leaves, and palm kernel meal-based concentrate resulted in no significant differences ($P>0.05$) between treatments. Average NDF digestibility ranged from 64.39 to 66.43%, ADF from 61.98 to 64.89%, cellulose from 67.01 to 69.66%, and hemicellulose from 77.01 to 79.66% (Table 4).

Table 4: Digestibility of NDF, ADF, Cellulose and Hemicellulose

Parameters (%)	Treatment			
	A	B	C	D
NDF	64.39±1.07	65.55±1.07	64.61±1.06	66.43±1.04
ADF	61.98±1.06	63.68±1.06	62.97±1.03	64.89±1.03
Cellulose	67.01±1.02	68.32±1.01	67.33±1.08	69.66±1.05
Hemicellulose	77.01±1.06	78.32±1.06	77.33±1.05	79.66±1.04

A: 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC); B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC); C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC; D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC. There was non-significant difference among treatments ($P>0.05$)

Milk Production

Milk production is a key parameter for evaluating ration efficiency in dairy goats. In the trial, substituting conventional forage and concentrate with a combination of cassava leaves (*Manihot esculenta*), Gamal leaves (*Gliricidia sepium*), and palm kernel meal-based concentrate did not result in significant variation in milk production among treatments ($P>0.05$). On average, daily milk production ranged from 1.30 to 1.41kg/day, with treatment A (control) having the highest value (1.41kg/day) and treatment C the lowest (1.30kg/day) (Fig. 1).

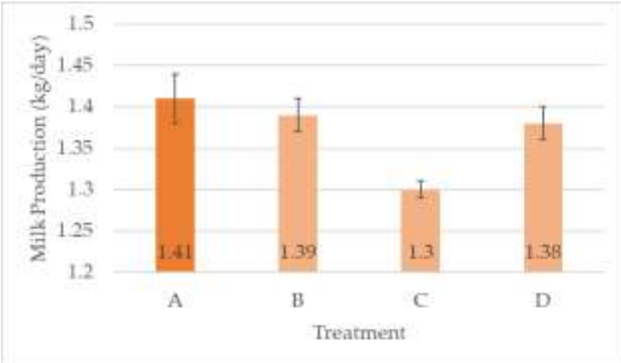


Fig. 1: Milk Production A: 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC); B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC); C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC; D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC.

Milk Fat

Milk fat is an important parameter for evaluating milk quality and reflects the efficiency of lipid metabolism in livestock. This study found no significant differences ($P>0.05$) in milk fat content among treatments when conventional forage and concentrate were substituted with cassava leaves (*Manihot esculenta*), Gamal leaves (*Gliricidia sepium*), and palm kernel meal-based concentrates. The average milk fat across treatments ranged from 3.50 to 5.89%, with treatment C showing the highest value (5.89%) and treatment D the lowest (3.50%) (Fig. 2).

Milk Fatty Acid

Milk fatty acid content is strongly influenced by ration composition, particularly the type of fat consumed and the extent of fiber fermentation in the rumen. In this study, the highest SFA content was observed in treatment D (Table 5 and Fig. 6), most likely due to the higher proportion of palm kernel meal-based concentrate (35%), which is known for its saturated fat content. The fatty acid profile of milk from treatments A, B, and C is shown in Fig. 3, Fig. 4, and Fig. 5.

Table 5: Milk Fatty Acid of the treatment rations

Parameters (% Area)	Treatment			
	A	B	C	D
MUFA	1.50±0.67	41.69±0.32	33.30±0.91	32.94±0.57
PUFA	0.78±0.54	0	0	0
SFA	59.04±0.62	57.68±0.43	56.98±0.29	67.58±0.78

A: 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC); B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC); C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC; D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC

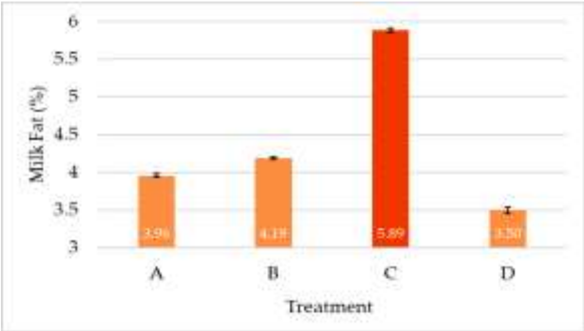


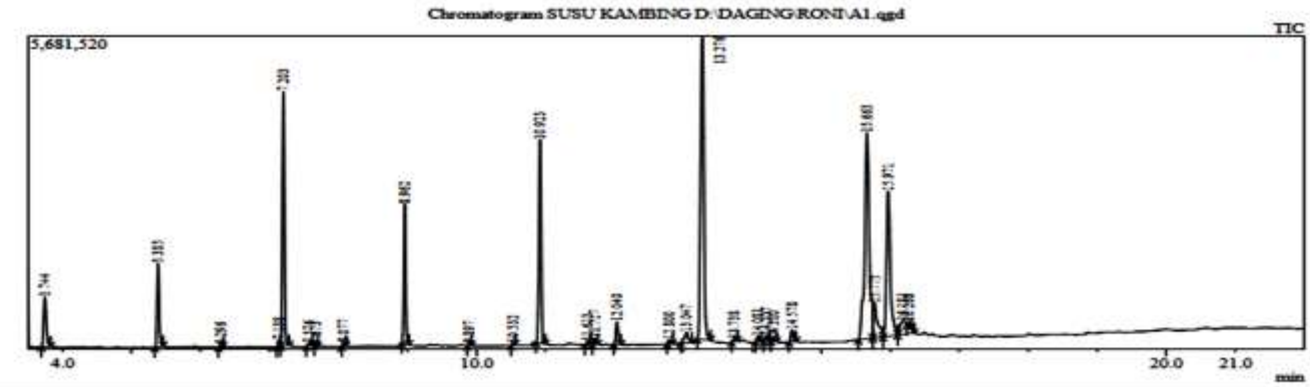
Fig. 2: Milk Fat A: 50% native grasses and shrubs (conventional forage) and 50% conventional concentrate (CC); B: 50% cassava leaves and *Gliricidia sepium*, 35% CC, and 15% palm kernel cake concentrate (PKCC); C: 50% cassava leaves and *Gliricidia sepium*, 25% CC, and 25% PKCC; D: 50% cassava leaves and *Gliricidia sepium*, 15% CC, and 35% PKCC.

DISCUSSION

Such results indeed confirm previous reports by Ardani et al. (2024), who demonstrated the ability of tropical goats to sustain consumption of diets with high crude fiber contents with little indication of reduced intake.

DM consumption in this study was also observed to be 1.83 to 2.07kg per day for goats offered local forage-based diets, reflecting the quality of feed ingredients and the degree of livestock adaptation to the given ration. The consumption rate in this present study also correlates well with those documented by Fattah et al. (2018). This could result from minimal alteration in total dry matter consumption when using local feed ingredients, such as *Gliricidia sepium*.

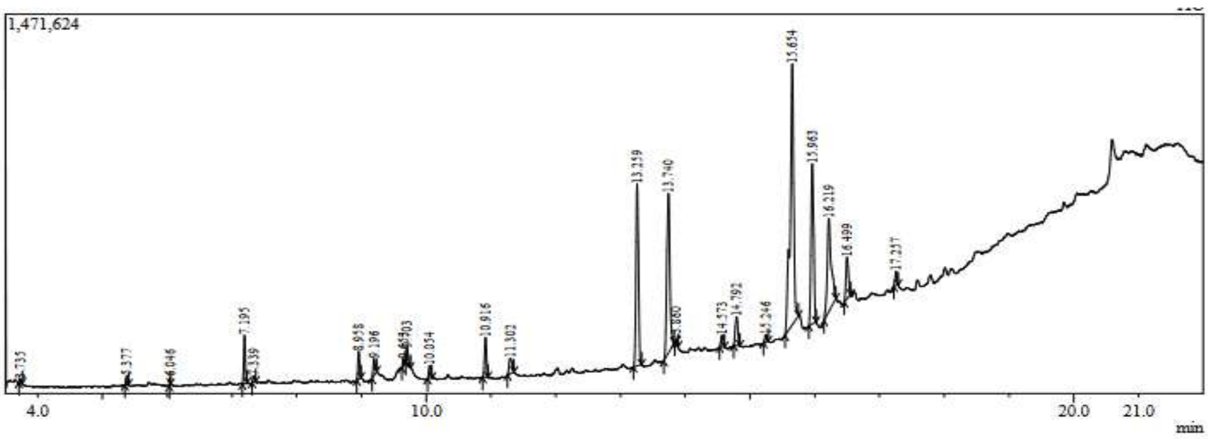
Other research conducted by Mojisola (2010), Oni et al. (2010), and Costa (2017) showed that the substitution of conventional forage with cassava leaves resulted in DM consumption in dairy goats ranging from 1.8-2.1kg/day, with NDF consumption of 1-1.2kg/day. This value is comparable to the outcomes of this study, which indicate that Gamal leaves and cassava leaves are acceptable substitutes for conventional forage. However, the findings here are lower than those reported by Rahman et al. (2013), Santos et al. (2016), and Rodrigues et al. (2021), who used an extruded oil palm meal-based concentrate to achieve energy intake levels exceeding NDF consumptions of 1.2 to 1.3kg/day. The difference could be due to variations in concentrate formulation and differences in energy and protein content levels.



Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	3.744	3.690	3.830	2563891	2.98	913101	3.26	2.81		METHYL 3-(3-(1,5-DIMETHYLF
2	5.385	5.335	5.460	3452706	4.01	1519529	5.43	2.27		OCTANOIC ACID METHYL EST
3	6.296	6.260	6.325	80279	0.09	43258	0.15	1.86	MI	Nonanoic acid, methyl ester
4	7.138	7.105	7.160	231555	0.27	122250	0.44	1.89		methyl Z-4-decenoate
5	7.203	7.160	7.285	10301768	11.97	4622697	16.53	2.23	V	DECANOIC ACID, METHYL ES'
6	7.576	7.535	7.620	142974	0.17	51656	0.18	2.77	MI	Decanoic acid
7	7.673	7.650	7.700	54510	0.06	33898	0.12	1.61	MI	Tridecanoic acid, 4,8,12-trimethyl-,
8	8.077	8.045	8.110	123903	0.14	68883	0.25	1.80	MI	Undecanoic acid, methyl ester
9	8.962	8.915	9.025	5328635	6.19	2537419	9.07	2.10		DODECANOIC ACID, METHYL
10	9.897	9.865	9.930	77467	0.09	39403	0.14	1.97	MI	Tridecanoic acid, methyl ester
11	10.532	10.500	10.560	84309	0.10	42079	0.15	2.00	MI	Tetradecanoic acid, 12-methyl-, me
12	10.923	10.865	11.000	9072826	10.54	3693139	13.21	2.46		Myristic acid, methyl ester
13	11.613	11.575	11.650	131872	0.15	62340	0.22	2.12	MI	Pentadecanoic acid, methyl ester
14	11.717	11.680	11.760	273464	0.32	119749	0.43	2.28		Tetradecanoic acid, 12-methyl-, me
15	12.040	11.990	12.095	997458	1.16	413405	1.48	2.41		Pentadecanoic acid, methyl ester
16	12.800	12.765	12.845	188995	0.22	79673	0.28	2.37	MI	Hexadecanoic acid, methyl ester
17	13.047	12.965	13.125	768064	0.89	190362	0.68	4.03	MI	9-Hexadecenoic acid, methyl ester,
18	13.276	13.200	13.400	18142164	21.08	5507628	19.69	3.29		Hexadecanoic acid, methyl ester
19	13.738	13.700	13.780	135431	0.16	50322	0.18	2.69	MI	Heptadecanoic acid
20	14.081	14.040	14.135	284568	0.33	109837	0.39	2.59	MI	Hexadecanoic acid, 14-methyl-, me
21	14.207	14.165	14.250	305044	0.35	120724	0.43	2.53	MI	Hexadecanoic acid, 14-methyl-, me
22	14.310	14.270	14.350	146507	0.17	59710	0.21	2.45	MI	CIS-10-HEPTADECENOIC ACID
23	14.578	14.530	14.635	596534	0.69	217059	0.78	2.75		Hexadecanoic acid, 15-methyl-, me
24	15.663	15.535	15.745	16880726	19.61	3745292	13.39	4.51		9-Octadecenoic acid, methyl ester
25	15.775	15.745	15.895	2929566	3.40	636274	2.28	4.60	V	14-Octadecenoic acid, methyl ester
26	15.971	15.895	16.110	10314108	11.98	2632440	9.41	3.92	V	Heptadecanoic acid, 16-methyl-, m
27	16.181	16.110	16.350	2275533	2.64	248687	0.89	9.15	V	9,12-Octadecadienoic acid (Z,Z)-
28	16.268	16.240	16.305	191838	0.22	86170	0.31	2.23	MI	9,12-Octadecadienoic acid (Z,Z)-,
				86076695	100.00	27966984	100.00			

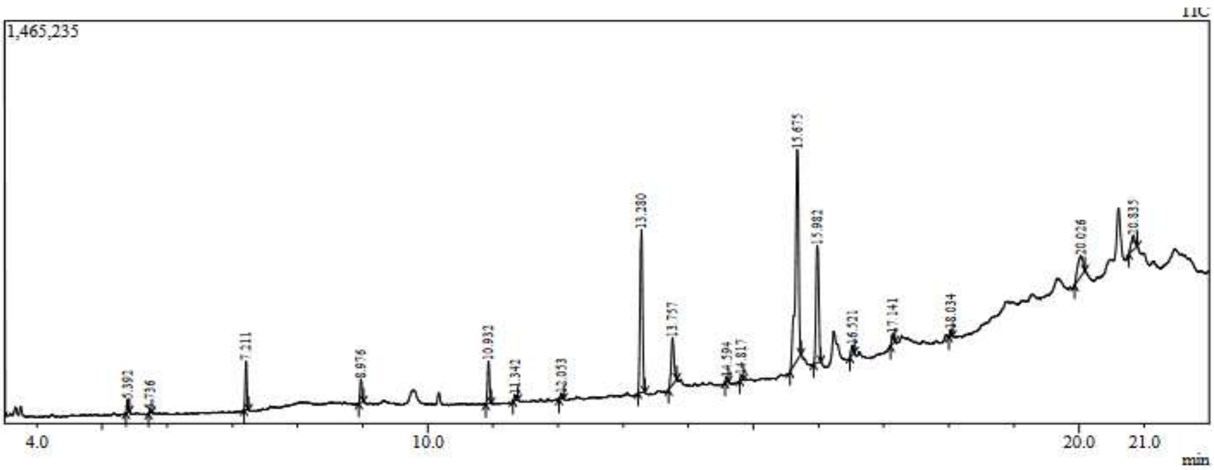
Fig. 3: Profile Milk Fatty Acid of the A treatment rations.



Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	3.735	3.710	3.765	23828	0.18	14661	0.32	1.63	MI	METHYL 3-[3-(1,5-DIMETHYLH
2	5.377	5.345	5.405	64484	0.48	35150	0.77	1.83	MI	OCTANOIC ACID METHYL EST
3	6.046	6.035	6.055	20645	0.15	32127	0.71	0.64	MI	9,10 DIDEUTERO OCTADECAN
4	7.195	7.160	7.235	331400	2.45	188564	4.15	1.76	MI	Decanoic acid, methyl ester
5	7.339	7.310	7.370	46876	0.35	24027	0.53	1.95	MI	2,6-Octadien-1-ol, 3,7-dimethyl-, p
6	8.958	8.925	8.995	209235	1.54	106670	2.34	1.96	MI	Dodecanoic acid, methyl ester
7	9.196	9.165	9.235	135320	1.00	64467	1.42	2.10	MI	Dodecanoic acid
8	9.653	9.625	9.675	41280	0.30	22906	0.50	1.80	MI	1,2-Benzenedicarboxylic acid, dietl
9	9.703	9.680	9.760	130054	0.96	61265	1.35	2.12	MI	1,2-Benzenedicarboxylic acid, dietl
10	10.054	10.020	10.090	98012	0.72	49575	1.09	1.98	MI	Dodecanoic acid, trimethylsilyl este
11	10.916	10.870	10.955	333237	2.46	153960	3.38	2.16	MI	Pentadecanoic acid, methyl ester
12	11.302	11.255	11.355	186277	1.37	58981	1.30	3.16	MI	Myristic acid
13	13.259	13.200	13.325	1769227	13.06	705487	15.51	2.51	MI	Hexadecanoic acid, methyl ester
14	13.740	13.670	13.830	1985628	14.65	620132	13.63	3.20	MI	Pentadecanoic acid
15	13.860	13.840	13.890	22973	0.17	15851	0.35	1.45	MI	Dodecane, 1,1-dimethoxy-
16	14.573	14.530	14.610	115145	0.85	45377	1.00	2.54	MI	16-Methyl-heptadecanecarboxylic a
17	14.792	14.750	14.845	292461	2.16	112033	2.46	2.61	MI	Hexadecanoic acid, trimethylsilyl e
18	15.246	15.210	15.280	64967	0.48	27270	0.60	2.38	MI	Octadecanoic acid, 2-propenyl este
19	15.654	15.540	15.750	3823693	28.22	1012445	22.26	3.78	MI	9-Octadecenoic acid, methyl ester
20	15.963	15.910	16.020	1721932	12.71	621663	13.67	2.77	MI	Heptadecanoic acid, 16-methyl-, m
21	16.219	16.140	16.325	1546435	11.41	360061	7.92	4.29	MI	2-HYDROXYCYCLOPENTADEC
22	16.499	16.455	16.555	465376	3.43	161345	3.55	2.88	MI	Eicosanoic acid
23	17.257	17.220	17.290	120839	0.89	54959	1.21	2.20	MI	Oleic acid, trimethylsilyl ester
				13549324	100.00	4548976	100.00			

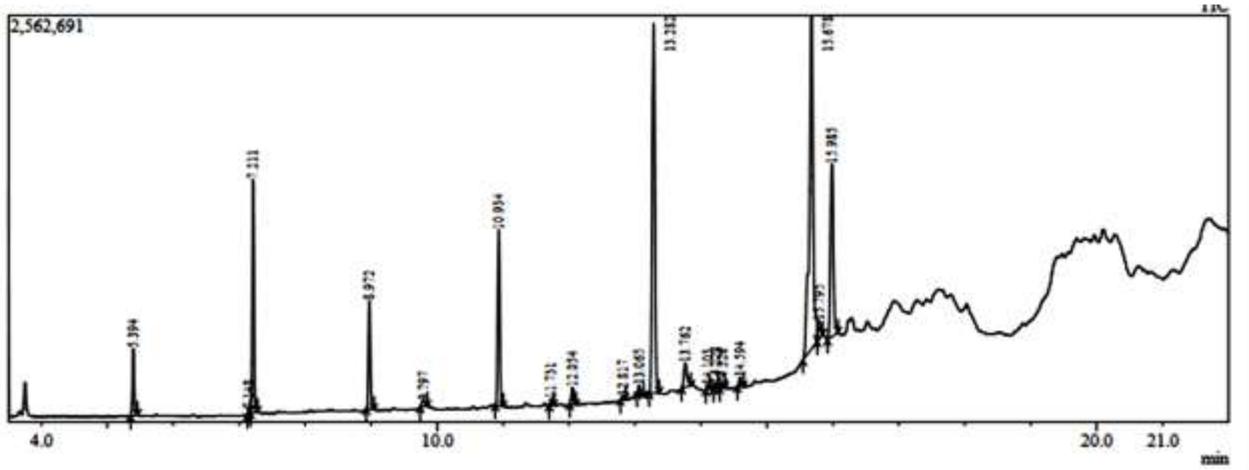
Fig. 4: Profile Milk Fatty Acid of the B treatment rations.



Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	5.392	5.365	5.420	80924	1.05	45875	1.69	1.76	MI	OCTANOIC ACID METHYL EST
2	5.736	5.715	5.760	17708	0.23	11618	0.43	1.52	MI	Heptane, 1,1-dimethoxy-
3	7.211	7.180	7.250	318942	4.12	176253	6.48	1.81	MI	Decanoic acid, methyl ester
4	8.976	8.940	9.015	181599	2.35	85378	3.14	2.13	MI	Dodecanoic acid, methyl ester
5	10.932	10.890	10.975	341946	4.42	153701	5.65	2.22	MI	12-methyl-tridecanoic acid methyl
6	11.342	11.310	11.380	45754	0.59	19055	0.70	2.40	MI	Myristic acid
7	12.053	12.015	12.085	40834	0.53	18836	0.69	2.17	MI	Pentadecanoic acid, methyl ester
8	13.280	13.230	13.335	1476866	19.08	592481	21.78	2.49	MI	Hexadecanoic acid, methyl ester
9	13.757	13.700	13.825	534425	6.90	170715	6.28	3.13	MI	Pentadecanoic acid
10	14.594	14.565	14.620	33377	0.43	17276	0.64	1.93	MI	Heptadecanoic acid, methyl ester
11	14.817	14.790	14.850	34049	0.44	16807	0.62	2.03	MI	Hexadecanoic acid, trimethylsilyl e
12	15.675	15.560	15.730	2577434	33.30	764783	28.12	3.37	MI	9-Octadecenoic acid, methyl ester
13	15.982	15.925	16.035	1183859	15.29	426235	15.67	2.78	MI	Heptadecanoic acid, 16-methyl-, m
14	16.521	16.480	16.555	87491	1.13	33946	1.25	2.58	MI	Eicosanoic acid
15	17.141	17.105	17.175	86009	1.11	36863	1.36	2.33	MI	Octadecyl acetate
16	18.034	18.000	18.060	48926	0.63	24017	0.88	2.04	MI	5,8,11,14-Eicosatetraenoic acid, etl
17	20.026	19.930	20.090	433647	5.60	74998	2.76	5.78	MI	Dodecanoic acid, 1,2,3-propanetriy
18	20.835	20.765	20.895	216967	2.80	51296	1.89	4.23	MI	Dodecanoic acid, 1,2,3-propanetriy
				7740757	100.00	2720133	100.00			

Fig. 5: Profile Milk Fatty Acid of the C treatment rations.



Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	5.394	5.350	5.455	858884	3.15	420740	4.24	2.04		OCTANOIC ACID METHYL EST
2	7.148	7.120	7.165	39423	0.14	25270	0.25	1.56	MI	4-Decenoic acid, methyl ester
3	7.211	7.170	7.275	2796498	10.26	1470417	14.83	1.90		Decanoic acid, methyl ester
4	8.972	8.925	9.045	1413238	5.18	686301	6.92	2.06		Dodecanoic acid, methyl ester
5	9.797	9.745	9.850	130496	0.48	35568	0.36	3.67	MI	1,2-Benzenedicarboxylic acid, dietl
6	10.934	10.880	11.005	2494056	9.15	1108219	11.18	2.25		12-methyl-tridecanoic acid methyl
7	11.731	11.700	11.770	84709	0.31	42965	0.43	1.97	MI	Tetradecanoic acid, 12-methyl-, me
8	12.054	12.010	12.105	259862	0.95	107557	1.09	2.42		Pentadecanoic acid, methyl ester
9	12.817	12.780	12.850	51686	0.19	23359	0.24	2.21	MI	Pentadecanoic acid, 14-methyl-, me
10	13.065	13.030	13.130	135908	0.50	59102	0.60	2.30		9-Hexadecenoic acid, methyl ester,
11	13.282	13.215	13.370	6199984	22.74	2329508	23.50	2.66		Hexadecanoic acid, methyl ester
12	13.762	13.710	13.850	540690	1.98	154000	1.55	3.51		Pentadecanoic acid
13	14.103	14.070	14.135	59991	0.22	27889	0.28	2.15	MI	Hexadecanoic acid, 14-methyl-, me
14	14.228	14.190	14.260	76818	0.28	32901	0.33	2.33	MI	16-Methyl-heptadecanecarboxylic :
15	14.326	14.285	14.360	51407	0.19	22651	0.23	2.27	MI	CIS-10-HEPTADECENOIC ACID
16	14.594	14.555	14.645	149573	0.55	60106	0.61	2.49		Hexadecanoic acid, 14-methyl-, me
17	15.678	15.545	15.765	8410194	30.85	2100549	21.19	4.00		9-Octadecenoic acid, methyl ester
18	15.795	15.765	15.845	343938	1.26	115909	1.17	2.97	V	9-Octadecenoic acid (Z)-, methyl e
19	15.985	15.920	16.080	3168413	11.62	1089783	10.99	2.91		Heptadecanoic acid, 16-methyl-, m
				27265768	100.00	9912794	100.00			

Fig. 6: Profile of Milk Fatty Acid of the D treatment rations.

While no notable variations were detected between the treatments in this study, the stability of consumption indicates that local feed ingredients such as cassava leaves, Gamal leaves, and palm kernel meal-based concentrates can replace conventional feed ingredients without reducing consumption efficiency. The similarity with the results of previous studies strengthens the validity of these findings. The combination of local feed ingredients can be a sustainable solution to support the production of small ruminants such as dairy goats.

These results are consistent with Phengvichith and Ledin (2007), Oluwadamilare and Olowofeso (2010), and Nurkhasanah et al. (2020), who reported that dairy goats in the tropics can digest crude fiber efficiently when fed cassava leaf-based diets. In their study, NDF digestibility in dairy goats reached 65%, with hemicellulose digestibility exceeding 75%. This indicates that the outcomes of their research align with the present study's findings. The ability of *Peranakan etawa* (PE) goats to utilize fiber is supported by efficient rumen microbial activity, as also reported by Ismartoyo et al. (2002) and Avornyo et al. (2020).

Supporting this, the study by Pazla et al. (2022) investigated the potential of a palm kernel meal-based concentrate to increase fiber digestibility by up to 67% in *Peranakan etawa* dairy goats, despite the relatively high crude fiber levels of such feedstuff. Palm kernel meal contains fat and protein levels that can promote lactobacilli activity in the rumen and enhance cellulose and hemicellulose degradation through microbial activity. In the present study, although no significant improvement was observed in overall fiber digestion, hemicellulose digestibility still increased, reaching 79.66%, indicating that hemicellulose was more digestible than NDF and ADF.

Broderick et al. (2008), Weiss et al. (2009), Lee et al. (2011), Räisänen et al. (2022), and Yang et al. (2022) observed that as CP content of the diet decreases, OM digestibility also decreases, which is attributed to reduced NDF digestibility. The stable ADF digestibility observed in this study, ranging from 61.98% to 64.89%, corroborates the findings of Molina-Botero et al. (2019) and Zain et al. (2020), which demonstrated that Gamal leaves could be used as protein-rich feed ingredients to improve fiber fermentation in the rumen. The nitrogen provided by the protein in Gamal leaves is sufficient to meet the nitrogen requirements of rumen microbes, thereby enhancing fermentation of fiber components, particularly NDF.

These results indicate that substituting conventional forages and concentrates with local feed ingredients does not reduce fiber digestion efficiency in PE goats. The stability of fiber digestibility across all treatments suggests that combining local feed ingredients such as cassava leaves, Gamal leaves, and palm kernel meal-based concentrate can optimally support rumen performance.

The findings of this study are consistent with those of Nascimento et al. (2021) and Beraedo (2022), who reported that dairy goats fed cassava leaf-based diets produced between 1.3 and 1.5kg of milk per day. The stability of milk production observed here indicates that the use of local feed ingredients does not compromise the capacity of *Peranakan etawa* (PE) goats to produce milk, provided that essential nutritional requirements such as protein, energy, and fiber are met. The crude protein content of the ration, ranging from 15.55 to 16.87%, was sufficient to support milk synthesis, in line with NRC (2007) recommendations for dairy goats in the tropics.

Research by Arief and Pazla (2023b) also reported similar outcomes, showing that the inclusion of *Gliricidia* in the ration did not reduce milk production due to its high protein content in *Gliricidia* (27.15%), which helps maintain metabolic efficiency. In this study, Gamal leaves likely contributed positively to the stability of milk production because of their protein content, consistent with the findings from previous studies.

Although this study yielded statistically insignificant results, the stable trend in milk production indicates that *Peranakan etawa* goats can utilize a combination of local feed ingredients without loss of production capacity. This is supported by adequate ration digestibility, including NDF (64.39–66.43%) and hemicellulose (77.01–79.66%), which provide energy through fiber fermentation in the rumen. According to Andreazzi et al. (2018) and Razzaghi et al. (2022), efficient fiber fermentation in the rumen facilitates lactose synthesis and directly influences milk volume.

The energy content of palm kernel meal-based concentrates is lower than that of concentrates formulated with high-starch ingredients such as cassava. This likely affected the net energy available for milk production and synthesis, particularly in treatments with higher levels of concentrate substitution (C and D). Nonetheless, the use of local feed resources such as cassava leaves, Gamal leaves, and palm kernel meal-based concentrates maintained milk production in PE goats without impairing animal productivity.

These findings align with those of Ukanwoko and Ibeawuchi (2014), who reported that using cassava leaves as forage does not significantly affect milk fat content, as the protein and energy levels of the ration remain sufficient to support fat metabolism. The higher milk fat levels observed in treatment C can be attributed to the higher proportion (25%) of palm kernel meal-based concentrate, which provides additional energy for milk fat synthesis via volatile fatty acids (VFA) metabolism in the rumen, particularly through acetic acid.

Ferreira et al. (2022) indicated that palm kernel meal serves as an excellent feed ingredient mainly because its high fiber and fat concentrations increase the acetic acid level in the rumen, which is the most important precursor in milk fat synthesis. Although the specific values of milk fat were not significantly different in this research, treatment C demonstrated that even local feed ingredients can suffice for fat synthesis without the addition of external ingredients such as vegetable oil or bypass fat.

These results have supported the work of Gaspe et al. (2023), who also maintained that *Gliricidia* enhances rumen metabolism by supporting microbial processes responsible for forming volatile fatty acids (VFA), especially butyric and acetic acids. Considering that *Gliricidia* was reported to have a protein content as high as 27.15%, it is likely that this influenced fiber fermentation, which in turn greatly affected lactation fat content.

However, the low milk production observed with treatment D, which used palm kernel meal concentrate at 35%, resulted in a total milk fat content of 3.50%. This suggests that the palm kernel meal concentrate did not provide sufficient net energy for lipid synthesis to replace the conventional concentrate. This could be due to the lower net energy content of palm kernel meal compared with conventional concentrates containing starch-rich ingredients such as cassava. The process of milk fat synthesis in the mammary gland may be affected by this decrease in energy.

Overall, this study demonstrated that a combination of local feed ingredients, such as cassava leaves, Gamal leaves, and palm kernel meal-based concentrate, could support the milk fat content of PE goats, comparable to that of conventional feed ingredients. Increasing milk fat content in treatment C with a moderate proportion of concentrate provides an opportunity to optimize the formulation of rations based on local ingredients to improve milk quality, especially in milk fat content.

Palm kernel meal also tends to increase the proportion of saturated fatty acids because it produces volatile fatty acids such as acetic acid during rumen fermentation, which is the primary precursor of SFA (Saeed et al., 2021). In contrast, the highest MUFA content in treatment B (41.69%) indicates that a higher proportion of forage (50% combination of cassava leaves and Gamal leaves) can increase MUFA synthesis. This may occur due to the high protein content in Gamal leaves (27.15%), which supports rumen microbial activity to reduce the biohydrogenation of unsaturated fats in the rumen, allowing more MUFA to be absorbed and metabolized (Table 5). These results align with the findings of Beyero et al. (2015), who demonstrated that increasing the inclusion of high-quality forage can enhance MUFA content in milk.

The quantification, or lack thereof, of PUFA in treatments B, C, and D indicated the efficiency with which the rumen's biohydrogenation processes convert PUFA into either SFA or MUFA. Treatment A (0.78%), which used a conventional ration of forage and company concentrates, was the only one to show PUFA. This indicates that local feed sources such as cassava and Gamal leaves do not specifically increase PUFA in milk but tend instead to increase MUFA or SFA because of their high fiber content.

It was observed that combining cassava leaves, Gamal leaves, and palm kernel meal-based concentrate alters fatty acid composition in milk. Treatment B resulted in a favorable balance between MUFA (41.69%) and SFA (57.68%). High MUFA content in this treatment highlights the potential of local feed to improve milk quality through healthier unsaturated fatty acids.

Conclusion

The replacement of forages and concentrates with a local mix of feeds, including cassava leaves (*Manihot esculenta*), Gamal leaves (*Gliricidia sepium*), and palm kernel meal-based concentrates, did not result in significant changes in ration consumption, fiber digestibility, milk yield, or milk fat content in etawa (PE) breed goats (P>0.05). However, treatment C showed the highest milk fat content (5.89%), while treatment B gave the highest MUFA content (41.69%) and was found optimal for hemicellulose digestibility (78.32%). Therefore, treatment B is considered the best formulation due to its appropriate balance of consumption, digestibility, milk production, and the fatty acid quality in milk. Thus, it may support a more economical and sustainable goat farming system in the tropics.

DECLARATIONS

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Conflict of Interest: The authors have declared no conflict of interest.

Data Availability: Data will be made available on request.

Ethics Statement: The present research conforms to the animal ethical standards and was approved by the Ethics Committee of Universitas Andalas, Faculty of Medicine (Approval No. 33/UN.16.2/KEP-FK/2023).

Author's Contribution: AA: Conception and design of the study, acquisition of data, drafting of the manuscript, and collaboration in interpreting the results. RP: Conception and design of the study, drafting of the manuscript, critical review/revision, and finalization of the manuscript. RR: Conception and design of the study, conducted lab analyses and interpretation of data, collaborated in interpreting the results. GY: Conception and design of the study, interpretation of data, conducted lab analyses, critical review/revision, and finalized the manuscript. All the authors have read and approved the finalized manuscript, statistical analyses of experimental data

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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