EFFECTS OF PALM KERNEL CAKE SUPPLEMENT ON FATTY ACID PROFILE AND MILK COMPOSITION OF LACTATING WAD GOATS FED GRASS SILAGE

Samuel Olawoye1* , Funmilayo Okeniyi 1 , Razaq Animashahun1 , Abiodun Joseph2, Timothy Adekanye3, Moji Adeniran1, Deborah Folowosele1, Omebere Okonta4, Emmanuel Adeleye1

[1]College of Agriculture, Department of Animal Science, Landmark University, Omu Aran, Nigeria

[1]College of Agriculture, Department of Animal Science, Landmark University, Omu Aran, Nigeria

[3]College of Engineering, Department of Agricultural and Biosystem, Landmark University, Omu Aran, Nigeria

[4]College of Engineering, Department of Agricultural economics and extension, Landmark University, Omu Aran, Nigeria

*Corresponding Author: Samuel Olawoye

Abstract

The scarcity of quality feed and cost-effective supplements necessitates verifiable concentrate as a supplement for goat milk production. Palm Kernel Cake (PKC), an oil palm by-product rich in protein and energy, gradually replaced Prepared Concentrate (PC) in this study. This replacement's impact on milk composition and fatty acid profile in lactating WAD goats fed grass silage basal diet was assessed. Five supplement concentrates with varying PC: PKC ratios (100:0, 75:25, 50:50, 25:75, 0:100) were fed to 25 lactating WAD goats in a randomized setting of 5 animals per group. The replacement significantly affected ($p<0.05$) milk fat, protein, specific gravity, ash, and fat-corrected milk. The highest milk fat (2.17%) came from 100%PKC supplementation, while the lowest (0.77%) came from 25% PKC. Total solid fat values were not significantly affected. Fat Corrected Milk results mirrored the milk fat trend. The 100%PKC group had the highest crude protein (8.22%), while 25% and 75%PKC were not different ($p<0.05$). Fatty acid profile, expressed as total Fatty Acid Methyl Esters (FAMEs) g/kg, showed increased medium and long-chain fatty acids as PC was replaced. In conclusion, 100% PKC supplementation enhanced milk fat, while 50% PC replacement increased long-chain polyunsaturated fatty acids in goat milk

Keywords: Prepared concentrate; Palm Kernel Cake; Supplement; Milk composition; Fatty acid profile; Lactating WAD goat.

1 INTRODUCTION

Goats, early domesticated livestock (Utaaker, 2021), are now recognized globally, especially in tropical areas, as valuable resources for those with limited means (Devendra, 2005). Local farmers find goats economically and subsistence valuable. Although goat milk is rarely consumed due to cultural beliefs

(Icoutchika, et al., 2022), it offers valuable nutrients and health benefits (Silanikove, et al., 2010; Lima, et. al., 2018), with lower allergy risk than other milks (Kapadiya, et, al. 2016; Paszczyk, et al., 2019).

Goat milk, similar in nutrient composition to cow's milk but with distinct characteristics (Singh et al., 2021), is recognized in conferences as a global source of vital nutrients (Verruck et al., 2018). Goat milk production fluctuates annually due to reproductive cycles, feed quality, and seasonal availability of agro by-products (Maroteau et al., 2014; Sandrucci et al., 2019).

Fatty acid composition in ruminant products, manipulable through diet, shows goats' resistance to milk fat depression compared to cows (Gulzar Ahmad Nayik et al., 2021). Goat milk's digestibility and nutritional content, including protein, fatty acids, and minerals, classify it as a crucial functional food (Ranadheera et al., 2019). While ruminant milk fat has high saturated fatty acids (SAFAs) associated with cardiovascular risk (Kris-Etherton, et al., 2018), goat milk's lower polyunsaturated fatty acids (PUFAs) can be enhanced for greater nutritional value (Siniarski and Gajos 2021).

The West African dwarf goat is indigenous to the tropics, known for adaptability, produces relatively high milk yield compared to cows. Palm kernel cake (PKC), an oil palm by-product with moderate crude protein (14-18%), is explored in this study for its impact on the fatty acid profile of lactating WAD goats fed with grass silage basal ration.

Materials and methods

Experimental site

This study was carried out at Landmark University, Omu-Aran situated in the derived savanah belt of Nigeria. It is located between latitude 8^0 20'N and longitude 4^0 35'E and has an approximate altitude of $3^0$6 above sea level. The rainy season begins at about the end of March and lasts until early September, while the dry season begins in early October and ends in early March. Temperature is uniformly high and ranges between 25^0 C to 30^0 C in the wet season while in the dry season, it ranges between 33^0 to 34^0 C. Relative humidity at Omu-Aran in the wet season is between 75 to 80% and about 65% in the dry season.

Experimental diet

The experimental diets are Pennisetum purpureum silage and supplementary concentrate respectively

Experimental supplementary concentrates

Prepared concentrate (PC) was made by mixing maize (33%), soybean (15%), wheat offal (50%), bone meal (1 %), salt (0.5%), and vitamin premix (0.5%) together. The proportion of the PC was replaced with palm kernel cake at 0, 25, 50, 75, and 100% levels to obtain five treatment concentrate supplements used in this study. The composition of the concentrate supplement and calculated nutrient composition are shown in Tables 1a and 1b.

Table 1a: Composition of the Concentrate Supplements

	Concentrate Supplement				
	T_1	T_2	T_3	T_4	T_5
Prepared Concentrate (%)	100	75	50	25	0
Palm Kernel Cake (%)	0	25	50	75	100
Total	100	100	100	100	100

Table 1b: Calculated Chemical Composition and Energy content of the Supplementary Concentrates

Prepared Concentrate/ Palm kernel cake	T1(100/0)	T2(75/25)	T3(50/50)	T4(25/75)	T5(0/100)
Crude protein (%)	18.1	18.08	18.05	18.03	18.00
Ether extract (%)	3.60	4.20	4.80	5.40	6.00
Crude fibre (%)	5.89	7.42	8.95	10.47	12
Metabolizable energy (Kcal/Kg)	2473.22	2398.67	2324.11	2249.56	2175.0

EXPERIMENTAL ANIMALS AND MILKING PROCEDURE

Milk samples were obtained from 25 lactating WAD goats, distributed across five groups with five replicates per diet treatment, for assessing composition and fatty acid profiles. Each lactating goat was randomly assigned to one of five experimental diets (silage and concentrate supplement). Silage, provided at 10% above the expected daily intake, was accompanied by a 400-gram concentrate supplement in a single daily ration at 8:00 hour. Fresh water and mineral salt lick were freely available in individual pens (3 x 1.5m).

Post-kidding, kids suckled for three days before milking and evaluation began. To maximize milk yield, kids were separated from does overnight (18 hours and 10 hours of the next day) before milk collection, which occurred once daily between 7 and 10 hours. Before each collection, milk parlors, utensils, and measuring cylinders were cleaned and sterilized. Does' udders were cleaned with warm water, ensuring high hygiene levels. Daily milk samples for each goat doe in each week of the twelve-week lactation study were pooled. A 50ml portion from each doe's stored (-40C) milk, randomly selected one week after collection, was used to assess milk composition and fatty acid profiles.

DATA COLLECTION

Values for total fat, crude protein, specific gravity, total solid, total acidity, ash, fat corrected milk, and solid-not-fat of milk were obtained through analytical methods of AOAC (1990).

Fatty acid profile

Analytical methods of fatty acid profile.

After melting and homogenization (vortexing for 30s) of milk samples, total fat content was determined using the Folch et al. (1975) method. The lipid phase was extracted with a 2.1 mixture of chloroform-methanol, and the filtrate was separated from the non-lipid structure by washing with saline water. For milk protein analysis, nitrogen content was measured using the Kjeldahl method (AOAC, 2000), and milk crude protein was estimated as N (%) x 6.38. Fatty acid compositions were determined in extracted milk. Following lipid extraction, hydrolysis of fats was performed in a screw-cap test tube, with 1mg of nonadecanoic acid (C19:0) added as an internal standard. Methylation of the samples was done using tetramethylguanidine (TMG) and methanol according to Philipp et al. (2007). Fatty acid methyl esters (FAMEs) were analyzed using a TRACE: type gas chromatograph (Model 2000; Thermo Finnigan Italia S.P.A., 2009 Rodano, Milan, Italy) equipped with an SSL injector and flame ionization detector.

For the separation of FAMEs, a capillary column (100m x 0.25 ID) coated with AP 2560 (Supelco Inc., Bellefonte, PA, USA) was employed. Helium served as the carrier gas at a constant pressure of 200KPa. The capillary tube's temperature ranged from 150 to 2150C during chromatography, with a total analysis time of 75 minutes. Peaks were identified based on retention times determined using a standard mixture of fatty acids with known composition (Matreya, Inc., Pine Hall Drive, State College, PA, USA; Catalogue No. 1254-7).

STATISTICAL ANALYSIS

Data obtained from milk composition and fatty acid profile were subjected to analysis of variance and means were tested (Duncan, 1955).

RESULTS

The milk composition summary for goat does fed grass-silage supplemented with prepared concentrate and PKC is presented in Table 2. The highest fat content (2.18%) was observed in the group fed 0% PC / 100% PKC, significantly surpassing other treatment groups, with the 50/50 group following closely. The lowest fat content (0.78%) was recorded in the group fed 25/75 supplementary diet to silage. The protein content was highest (8.28%) in the 0/100 group, significantly surpassing the 75/25 group (6.51%). Specific gravity was highest (1.08g/ml) in the 25/75 group, followed by the 100/0 and 50/50 groups. The lowest specific gravity (1.05g/ml) was observed in the 75/25 group. Total solid values were significantly higher in the 50/50 group (9.19%) and the 25/75 group (8.28%) compared to other groups. The 0% PKC supplementation resulted in the lowest total solid value. Total acidity was similar across all treatment groups, and ash values were comparable for 100/0, 75/25, and 25/75 groups. However, the 0/100 group had the highest ash value, followed by the 50/50 group. Fat-corrected milk values followed the same trend as milk fat content. The solid-not-fat component was highest in the 50/50 group, with other treatment groups showing comparable values.

Table 2: Milk composition of lactating WAD goat-fed *Pennisetum purpureum* silage supplemented with Palm kernel cake as replacer of Prepared concentrate

Prepared concentrate - PKC ratio (PC/PKC)

Parameters	100/0	75/25	50/50	25/75	0/100	SEM±
Protein%	4.50^{c}	6.51^{b}	5.32^{bc}	6.07^{b}	8.28^{a}	0.114
Fat %	1.13^{c}	1.07^{c}	1.66^{b}	0.78^{c}	2.18^{a}	0.040
SG g/ml	1.07^{ab}	1.05^{b}	1.06^{ab}	1.08^{a}	1.06^{ab}	0.003
T. S %	7.07^{b}	8.28^{ab}	9.19^{a}	7.91^{ab}	7.57^{ab}	0.144
T. A %	0.38^{a}	0.38^{a}	0.30^{a}	0.30^{a}	0.23^{a}	0.016
Ash%	1.09^{c}	1.06^{c}	1.36^{b}	0.92^{c}	1.62^{a}	0.021
FCM (3.5%)	22.51^{c}	21.51^{c}	32.41^{b}	16.02^{c}	42.02^{a}	0.723
SNF %	5.86^{ab}	7.13^{ab}	7.43^{a}	7.05^{ab}	5.31^{b}	0.151

*Means on the same row with different superscripts are significantly different ($p<0.05$)
SG- Specific gravity; T.S- Total solid; T.A- Total acidity; FCM- Fat corrected milk; SNF- Solid not fat.

Table 3 presents the fatty acid profile of goat milk from Does fed prepared concentrate replaced by PKC as a supplement to grass-silage.

The results revealed significant differences ($p<0.05$) in short-, medium-, and long-chain fatty acids expressed as g/kg total Fatty Acid Methyl Esters (FAMEs). The fatty acid profile varied with PKC replacement, with noticeable changes in short-, medium-, and long-chain fatty acids.

Short-chain Fatty Acids:

Short-chain fatty acids generally decreased as PKC replaced PC. C4 values decreased ($p<0.05$) as PKC replaced PC across treatment groups. C6 value (3.5130) from the 100% PKC group was the highest, similar ($p>0.05$) to 75/25 and 50/50, with similarity ($p>0.05$) between 25/75 and 0/100. For C8, the highest value ($p<0.05$) of 3.8640g/kg was from 100/0, followed by 75/25 and 0/100, while 50/50 and 25/75 were comparable ($p>0.05$).

Medium-chain Fatty Acids:

C10 values decreased ($p<0.05$) as PKC replaced PC across groups from 100/0 to 50/50 and increased significantly ($p<0.05$) from 25/75 to 0/100, with the lowest ($p<0.05$) value of 4.1700 in the 50/50 group. For C16:0, the highest value ($p<0.05$) of 25.5200 was from 25/75, followed by 75/25, with the lowest ($p<0.05$) of 23.3080 from 100/0. C16:1 (cis-19) increased ($p<0.05$) as PKC replaced PC in the supplement, indicating more medium-chain fatty acids with increased PKC.

Long-chain Fatty Acids:

The highest ($p<0.05$) values, especially C18, were from the group fed 50% PKC, except for C18:2 (trans 9,12), which had a higher ($p<0.05$) value from the 0% PKC group. Most values from PC - PKC supplement showed higher ($p<0.05$) values than 0% PKC supplement. C20 values increased ($p<0.05$) as PKC replaced

PC, while C22 values decreased ($p<0.05$) as PKC replaced PC, and C24 showed zero (0) value beyond 25% PKC replacement, indicating no replacement effect on C24.

Table 4: Fatty acid profile of the milk of the WAD goat doe fed *Pennisetum purpureum* silage supplemented with PKC as a replacer of Prepared concentrate

Fatty Acid	100/0	75/25	50/50	25/75	0/100	SEM±
C4:0	3.8830^{a}	3.7410^{b}	3.2710^{c}	2.42400^{e}	3.2310^{d}	0.001
C6:0	3.5130^{a}	3.4720^{a}	3.4740^{a}	2.2720^{b}	2.1800^{b}	0.001
C8:0	3.8640^{a}	3·8120^{b}	3.3183^{d}	3.1740^{d}	3.5480^{c}	0.001
C10:0	13.2380^{a}	12.6490^{b}	10.2483^{e}	11.2340^{d}	11.3740^{c}	0.015
C12:0	4.1700^{d}	4.7500^{c}	4.1981^{d}	5.7813^{b}	6.5850^{a}	0.002
C14:0	10.1130^{c}	10.2480^{b}	11.2160^{a}	9.9480^{d}	8.9450^{e}	0.001
C14:1 (cis-9)	0.3940^{d}	0.5280^{b}	0.4910^{c}	0.3740^{e}	0.5370^{a}	0.032
C16:0	23.3080^{d}	24.8130^{b}	23.8327^{c}	25.5200^{a}	25.3410^{a}	0.001
C16:1 (cis-9)	1.3140^{e}	1.8170^{d}	1.8413^{c}	2.2870^{b}	2.7490^{a}	0.001
C18:0	9.6753^{b}	8.9770^{e}	10.0137^{a}	9.3460^{c}	8.9960^{d}	0.001
C18:1 (trans-9)	0.0040^{a}	0.0010^{bc}	0.0000^{c}	0.0020^{b}	0.0000^{c}	0.001
C18:1 (cis-6)	2.9220^{c}	2.8290^{d}	3.2610^{b}	3.4150^{a}	2.950^{e}	0.001
C18:1 (trans-9)	1.2330^{e}	1.4000^{d}	1.7020^{b}	1.4360^{c}	1.9710^{a}	0.001
C18:1 (cis-9)	16.2647^{b}	15.6407^{d}	16.9330^{a}	15.9373^{c}	15.5930^{e}	0.001
C18:1 (trans-11)	0.0080^{a}	0.0030^{c}	0.0010^{d}	0.0050^{b}	0.0010^{d}	0.001
C18:2 (cis-9,13)	3.3650^{e}	3.7290^{b}	3.7660^{a}	3.4580^{c}	3.4260^{d}	0.001
C18:2 (trans-9,12)	0.0053^{a}	0.0020^{b}	0.0000^{c}	0.0030^{b}	0.0000^{c}	0.001
C20:0	0.2393^{e}	0.3600^{d}	0.5200^{c}	0.8620^{a}	0.8270^{b}	0.002
C18:3 (cis-6,9,12)	0.0660^{c}	0.1030^{b}	0.1500^{a}	0.0700^{c}	0.0800^{bc}	0.003
C20:1 (cis-11)	0.3322^{a}	0.4120^{a}	0.5100^{a}	0.4370^{a}	0.4350^{a}	0.023
C18:3 (cis-9,12,15)	0.7290^{a}	0.5040^{d}	0.2470^{e}	0.6330^{b}	0.5540^{c}	0.003
C20:2 (cis-11,14)	0.0010^{a}	0.0010^{a}	0.0000^{b}	0.0010^{a}	0.0000^{b}	0.000
C22:0	0.4060^{a}	0.0520^{e}	0.2877^{d}	0.3760^{c}	0.3860^{b}	0.001

C20:3 (cis-8,11,14)	0.3610^{b}	0.0177^{d}	0.1350^{c}	0.4130^{a}	0.4130^{a}	0.002
C22:1 (cis-13)	0.0090^{a}	0.0030^{bc}	0.0010^{c}	0.0050^{b}	0.0010^{c}	0.001
C20: (cis-11,14,17)	0.0060^{a}	0.0030^{b}	0.0010^{c}	0.0040^{b}	0.0060^{a}	0.001
C20:4 (cis-5,8.11,14)	0.4300^{d}	0.1170^{e}	0.5730^{a}	0.4750^{c}	0.5300^{b}	0.002
C22:2 (cis-13,16)	0.0060^{a}	0.0030^{b}	0.0010^{c}	0.0040^{b}	0.0010^{c}	0.001
C24:0	0.0010^{a}	0.0000^{b}	0.0000^{b}	0.0000^{b}	0.0000^{b}	0.000
C20:5 (cis-5,8,11,14,17)	0.0010^{a}	0.0010^{a}	0.0000^{b}	0.0010^{a}	0.0000^{b}	0.000
C24:1 (cis-15)	0.0010^{a}	0.0010^{a}	0.0000^{b}	0.0010^{a}	0.0000^{b}	0.000
C22:6 (cis-4,7,10,13,16,19)	0.0030^{a}	0.0010^{bc}	0.0030^{a}	0.0020^{ab}	0.0000^{c}	0.001

Means in the same row with the same superscripts are not different significantly ($p>0.05$).
FAs- Fatty acids; SEM- standard error of means.

DISCUSSION

The differences in the milk gross composition among goats fed supplements with varying proportions of PKC in the PC-PKC mixture supplement can be largely attributed to the replacement effect of PC by PKC, considering that all does had free access to grass-silage. The observed milk fat content across the treatments was lower compared to previous studies reporting: 3.8% (Kapadiya et al., 2016) 3.7% (Arora et. al., 2013); 3.97% (Mohmood and Usman, 2010) and a range of 3.20-5.50% (Belewu, 2001). However, the protein content in all treatments with varying PKC replacement levels for PC was higher than values reported in other studies, such as 3.42% by Kapadiya, et al. 2016, 2016, and 3.02% by Arora et. al., 2013.

The range of total solid (T.S) values (7.07-9.19%) in this study was lower than reported values for different goat breeds by Shettar (2013), Soliman (2005), and Mahmood and Usman (2010). The solid-not-fat (5.86-7.43%) value range was also lower than reported for the Jakhran goat by Shettar (2013). The ash content range (0.92 – 1.62%) was higher than reported values for Barbari and Jamnapari goat milk by Sachdeva et al., 1974. Acidity values fell between 0.05 and 0.5%, as reported by Troy and Sharp, (1934) and Sharp and McInerney (1927). The reduction in total acidity value as PKC replaced PC across the treatment groups may indicate the efficacy of PKC in improving milk quality.

The high milk fat content observed in goats receiving sole PKC (0/100) compared to other groups may be due to the energy balance of the concentrate supplement and mobilization of body fat for milk fat synthesis (Chilliard et al,. 2003). This aligns with reports stating that milk fat concentration is responsive to diet modifications (Morsy et al., 2015). The differences in milk composition compared to exotic goat milk may be attributed to breed effects, as different breeds exhibit diverse genetic characteristics (Maroteau et al., 2014; Sandrucci et al., 2019).

The high values of milk fat content and fat-corrected milk could be further linked to increased fiber and diet particle length, resulting in longer mastication time, increased salivation and influencing the acetate

production, a precursor of milk fat. The high milk protein content from animals fed combinations of PC and PKC compared to the 0% PKC group may be due to optimal utilization of concentrate combinations for protein synthesis.

The fatty acid (FA) composition in milk, influenced by forage type, showed changes in short-, medium-, and long-chain FAs. The increased values of medium and long-chain FAs observed may be attributed to the higher silage intake in groups where PKC replaced prepared concentrate, as reported by previous studies (Chilliard and Ferlay, 2004; Chilliard et al., 2007; Sanz Sampelayo et al., 2007; Renna et al. (2012a & 2012b) and Di-Trana et al. 2005)**.** The decreased short FAs values may be linked to changes in the rumen microbial flora as opined by Chilliard and Ferlay (2004).

In summary, the observed variations in milk composition and fatty acid profile across PKC replacement levels in the goat diet highlight the potential impact of dietary modifications on milk quality and fatty acid composition, with breed-specific effects and implications for nutritional value.

CONCLUSION

This study verifies the suitability of PKC as an efficacious replacer of prepared concentrate in dietary supplementation of grass-silage for lactating WAD goats. The goat doe groups that were fed 100% PKC concentrate supplements alongside the grass-silage responded to the replacement of prepared concentrate by PKC and showed improvement in the milk fat, protein, fat corrected milk, without any observable problem. At 50% replacement of prepared concentrate by PKC, the milk displayed increased unsaturated fatty acids (medium and long chain) output which indicated that most of these fatty acids are formed by replacement of prepared concentrate with PKC. It could be concluded that the replacement is beneficial to the economical production of quality goat milk.

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