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Research Article

Nutritional and Digestibility Profile of Palm Kernel Cake (*Elaeis guineensis*) Produced in Different Regions of Tanzania

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Abstract

The feed depleted livestock industry gears to exploring non-conventional animal feeds. Among them is Palm kernel cake (PKC) for its potential use as animal feed hence the need for the study. PKC samples from Kigoma, Mbeya and Morogoro were collected for analysis of its nutritional composition, Van Soest fibre analysis and digestibility (invitro and in Sacco) which were done at the Tanzania veterinary Laboratory Agency (TVLA-Dar es salaam) and department of Animal, Aquaculture and Range Sciences (DAARS)- Sokoine University of Agriculture. The study found out that PKC samples from Kigoma and Mbeya had high Crude Protein and Ash (CP 19.2% and 18.1% CP) and (7.6 and 7.3% ash) but less energy (9.6 and 9.4 MJME/kgDM) and ether extract (EE 11.1% and 11.2%EE), respectively compared with those of Morogoro (12.7%CP, 5.6% Ash, 19.8% EE and 14.4 MJME/kgDM) though they had comparable Crude Fibre (CF) value (19.1-22.1). The contents of Neutral Detergent Fibre (NDF, 68.3 and 64.4%), Acid Detergent Fibre (ADF, 34.2% and 31%) for samples of Kigoma and Mbeya, were higher than those of Morogoro (48.8% NDF and 21.4% ADF) with almost similar Acid Detergent Lignin (ADL) results (6.9, 4.7 and 5.4%, respectively). Both Invitro and In Sacco digestibility were higher for samples from Mbeya (51.2 and 53.5%) respectively in comparison to samples from Kigoma (36.8 and 38.9%) and Morogoro (34.6 and 35.8%). In conclusion the study revealed a varying nutritional composition and digestibility of PKC samples collected from different regions of Tanzania which were however within the NRC recommended level hence being suitable for ruminant feeding.

Keywords

Palm Kernel Cake, Nutritional Composition, Digestibility

1. Introduction

The rising global demand for animal-sourced protein continues to intensify due to rapid population growth in both developed and developing countries [1]. As societies strive to meet the growing nutritional needs, there is increased pressure on the livestock sector to enhance productivity. However, the major constraint towards increased productivity in the live-

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stock industry is the scarcity of animal feeds [2]. The scarcity of animal feeds both in quantity and quality in many countries including Tanzania is partly attributable to the shrinkage of grazing areas and climatic changes [3, 4] and the increasing competition for grains between man and monogastric animals [5]. Exploration of feed residues from the crop processing industries or farm by-products could probably help to fill the gap of food shortage if they are well processed, formulated and fed to the animals [6, 7].

Tanzania is one of the African countries known to be involved in palm production. The regions embarked in Palm production include Kigoma, Mbeya and Coast among others with records of production being 61.4%, 35.7% and 0.9, for Kigoma, Mbeya and Coast respectively [8]. With the production of palm (*Elaeis guineensis)* being expected to expand by introducing improved seeds from Asian countries with better low temperature properties [9, 10] so will be the increase of crop residues from the palm processing plants after oil extraction. With the scarcity of feeds facing the grazing animals like goats, sheep and cattle in the country, the crop residues from the palm processing plants could probably help to fill the gap of feed shortages.

Residues from palm have been shown elsewhere to enhance the productivity of milk and meat when fed to goats, cattle or sheep [11]. For instance, the use of palm kernel cake as animal feed has been reported in Malaysia, where it was used as a main ingredient in feedlot resulting to an excellent live weight gain of 0.6-0.8 and 1-1.2 kg of local and crossbred cattle respectively. Also, inclusion of PKC at a level of up to 50% or 80% in the feed aimed for goats and 30 % for sheep improved the weight gain and milk yield of the respective animals [11]. Literature has shown that the analysis of nutritional composition of the PKC as was done elsewhere was shown to contains16.43-18.02 %CP, 34.44-32.69%CF, 3.28-3.6%EE, 5.66 and 5.69%Ash at 20 and 30% inclusion level of PKC. The high content of nutrients observed in the plant residues could probably have accounted for the improvement of weight gain and milk yield in the studied animals [12, 7].

Various factors account for the variation in nutritional composition of PKC such as extraction method, source of sample (soil and climate), variety of the seeds and storage condition [13]. Soil properties can affect the quality of feedstuffs harvested from respective soils. Among the properties is soil organic matter which greatly affect plant yield and quality of harvested materials. Organic matter is often considered an indicator of soil fertility [14] such that except on fertilizer application, changes in soil properties are mostly affected by organic matter [15].

Despite the growing palm oil industry in Tanzania and the potential of PKC as a valuable feed supplement, limited research has been conducted to evaluate the nutritional quality and digestibility of PKC produced in different regions of the country. Given the variability in soil composition, climate, processing techniques, and storage practices, there is a likelihood of significant differences in the nutritional composition of PKC across different localities. Such differences may directly affect its feed value and suitability for use in ruminant diets. To address this knowledge gap, the present study was designed to evaluate the nutritional composition and digestibility characteristics of PKC samples collected from three major palm-producing regions in Tanzania: Kigoma, Mbeya, and Morogoro. The aim is to determine the suitability of these residues as feed supplements for ruminants and to identify potential regional differences that could inform feed formulation and processing practices. By doing so, the study contributes to the broader efforts of improving feed resource utilization, promoting sustainable livestock production, and reducing waste in agro-industrial chains.

2. Methodology

2.1. Study Area

The study was conducted at the Department of Animal, Aquaculture and Range Sciences (DAARS) laboratory and at Magadu Model Training Farm (MTF)-Sokoine university of Agriculture Morogoro and at Tanzania Veterinary laboratory Agency (TVLA)-Dar es salaam. Morogoro is located about 195 kilometres to the west of Dar es salaam and is situated on the lower slopes of the Uluguru Mountains whose peak is about 1,600 feet above sea level. Morogoro lies at the crossings of longitudes 37.0 East of the Greenwich Meridian and latitude 4.49 South of the Equator with temperature range between 17-30°C and average annual rainfall around 740 mm.

2.2. Study Animals

This study involved the use of fistulated animal located at Magadu Model Training Farm (MTF) for In Sacco digestibility. The animal was given both roughage and concentrate prior to the start of the experiment. This is to ensure conducive rumen environment for reliable results. 2 g samples of PKC are weighed and placed in the nylon bags and then they were placed in the fistulated animal to assess digestibility at different time intervals of 0, 6, 12, 24, 48, 72 and 96 hours and follow up was done which involved removing the bags at respective time interval that is the bags were collected at respective time, washed and thereafter the samples were placed in a muffle furnace to determine ash content.

2.3. Sample Collection and Preparation

Samples of PKC were collected from three different regions of Kigoma, Mbeya and Morogoro. Kigoma region is located in the west of Tanzania, Mbeya is found in the southern highland and Morogoro's location is in the central zone of Tanzania. Mechanical extraction is the commonly used method in oil extraction. Samples were collected from identified extraction plants available whereby sixteen (16) samples were collected from Kigoma, eleven (11) samples from Kyela Mbeya and

seven (7) samples collected from Ifakara Morogoro. The collected samples were then dried, ground using a grinding machine to 1 mm particle size and stored in airtight containers ready for laboratory analysis of its nutritional composition and digestibility. Soil and climatic characteristics are as shown in table 1 below;

Table 1. *Soil and Climatic characteristics of Kigoma, Mbeya and Morogoro.*

Characteristic	Kigoma	Mbeya	Morogoro
Soil pH	Slightly acidic	Slightly acidic	Acidic
Soil texture	Clay	Sand-clay	Sand-clay
CEC	Suitable	Low & suitable	Low
Macronutrient	Moderate	Moderate	Low
Micronutrient	Moderate	Moderate	High
Total Nitrogen	Low	Low	Very low
Organic matter	Medium	Medium	Moderately low
Temperature (°C)	21.5	17.6	23.5
Rainfall (mm)	861.06	944	740

*Data for temperature and rainfall from [16] and data for soil properties were obtained from the department of soil and geological science Sokoine University of Agriculture.

2.4. Analysis of Nutritional Value of PKC

Portions of the samples of about ¼ kg were taken to TVLA for proximate analysis according to [17] where the following parameters of dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash and energy were analysed using near infrared refracto-photometer (NIRS).

Another 2 g of the three samples were weighed and taken for Van Soest fibre analysis. This was also conducted at DAARS laboratory whereby Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) for the samples were obtained. This was done by subjecting the samples into different chemicals which are neutral detergent solution for NDF determination, 1 N Sulphuric acid (H_2SO_4) and Acetyl trimethylammonium bromide for ADF determination and 72% Sulphuric acid (H_2SO_4) for ADL determination [18] using Ankom fibre analyser and beakers.

Also, 2 g of each sample were weighed and placed into filter bags for In vitro dry matter and organic matter digestibility using two-stage technique of [19]. Preliminary stages involved collection of rumen liquor from fistulated bull at Magadu Model Training farm, filtered to remove traces of other feedstuffs other than the experimental diet and kept into a thermos flask so as to maintain the rumen temperature. Also, artificial saliva was prepared in the laboratory using various chemicals which were NaHCO, $Na_2HPO.7H_2O$, KCl, NaCl, $MgSO_4.7H_2O$ and $CaCl_2$. Thereafter, the in vitro dry matter and organic matter digestibility were estimated by following procedure by Tilley and Terry.

Another 2 g of each sample was weighed and placed in nylon bags for In Sacco digestibility. This was conducted at Magadu Model Training Farm (MTF) using fistulated animal. The samples of PKC were weighed and placed in nylon bags and arranged in the Teflon tube. They were then placed in the fistulated bull and set at different time intervals after which they were collected, cleaned, dried, weighed and the residues in crucibles were placed in muffle furnace (at 525-550°C for three hours) to ash so as to determine organic matter digestibility. Other bags were collected after 48 hrs then washed, dried and were taken for proximate analysis at TVLA-Dar es salaam to estimate DM, CP, CF, EE, Energy, and Ash and the obtained results were used to obtain individual component digestibility (digestibility coefficient).

2.5. Data Analysis

Data were collected and stored in excel and then they were analysed in SPSS version 26. The Kruskal-Wallis non-parametric model was employed to assess significant differences of nutritive value of PKC across locations. Tukey's Honest Significant Difference (HSD) test was employed to compare means of nutritive value among locations. Results were presented as means ± SEM, with statistical significance set at $P < 0.05$.

3. Results

The nutritional composition of PKC obtained from proximate analysis from the three regions are as shown in table 2.

The result shows that the dry matter (DM) of the samples from the three regions didn't have significant difference. Crude fibre (CF) content of samples from Mbeya were significantly higher than those from Kigoma and Morogoro which did not differ significantly (>0.05). CP and ash content of samples from Morogoro were significantly lower compared to samples from Kigoma and Mbeya which had comparable results. Also, samples from Morogoro had significantly higher EE and energy content in comparison to those from Kigoma and Mbeya which were lower and similar (>0.05).

Table 2. *Proximate analysis results of PKC from different regions of Tanzania.*

Parameter	Kigoma	Moro	Mbeya	SEM	P-Value
No. of samples	16	7	11		
DM	90.77	89.88	89.83	0.213	0.0793
CF	19.128^{b}	19.583^{b}	22.082^{a}	0.08	0.007
CP	19.145^{a}	12.565^{b}	18.068^{a}	0.185	0.0001
EE	11.063^{b}	16.8^{a}	11.113^{b}	0.102	0.0001
Ash	7.56^{a}	5.308^{b}	7.32^{a}	0.129	0.018
Energy	9.549^{b}	14.358^{a}	9.642^{b}	0.149	0.0001

From this study, it was also observed that NDF and ADF were significantly higher for samples from Kigoma and Mbeya as compared to samples from Morogoro. Additionally, ADL was significantly higher for samples collected from Kigoma, followed by Morogoro and least for samples collected from Mbeya as presented in Table 3.

The results for In vitro digestibility are presented in Table 3. It was seen that both In Vitro dry matter and organic matter digestibility of PKC samples from Mbeya were significantly higher followed by samples from Kigoma and least digestibility was observed for samples collected from Morogoro.

In Sacco digestibility results for dry matter are reported in Table 3. It was observed that both dry matter and organic matter digestibility of samples collected from Mbeya were significantly higher when compared to those from Kigoma which were also higher than those from Morogoro. Also, the observed trend of degradability was slightly higher for samples from Mbeya which had a sharp rise from between six (6) and twenty-four (24) hours followed by a slow and almost a constant rate after forty-eight (48) hours for all samples as was evidence from repeated measures analysis.

Table 3. *Results for Van Soest fibre analysis, in Vitro and In Sacco digestibility of PKC.*

Parameter	Kigoma	Moro	Mbeya	SEM	P-Value
No of samples	16	7	11		
NDF	67.886^{a}	48.44^{c}	64.219^{b}	0.114	0.007
ADF	34.166^{a}	21.4^{c}	30.941^{b}	0.180	0.007
ADL	6.804^{a}	5.431^{b}	4.747^{c}	0.094	0.007
INVIT DM	36.666^{b}	34.557^{c}	51.129^{a}	0.4	0.007
INVIT OM	32.896^{b}	24.332^{c}	47.847^{a}	0.572	0.007
INSAC DM	39.085^{b}	37.891^{c}	53.153^{a}	0.696	0.007
INSAC OM	38.347^{b}	37.024^{c}	51.841^{a}	0.227	0.007

Table 4. shows results of digestibility coefficient following In Sacco assessment of PKC samples. The study found out

that while digestibility coefficient samples (CF) for samples from Kigoma and Morogoro didn't vary significantly, they were significantly lower compared with those from Mbeya. Also, the digestibility coefficient of CP, EE, Ash and energy were significantly different for all collected samples with higher records reported for samples from Mbeya followed by those from Kigoma and least for Morogoro.

Table 4. Digestibility coefficient results for analysed samples of PKC.

Parameter	Kigoma	Moro	Mbeya	SEM	P-Value
No of samples	16	7	11		
CP	48.951[b]	39.415[c]	56.808[a]	0.188	0.007
CF	41.536[b]	41.133[b]	42.978[a]	0.314	0.006
EE	56.118[b]	49.192[c]	69.356[a]	0.128	0.007
Ash	54.378[b]	40.471[c]	72.334[a]	0.158	0.007
Energy	61.43[b]	52.322[c]	74.866[a]	0.154	0.007

4. Discussion

This study revealed varying nutritional value of PKC collected from different regions of Tanzania. For instance, nutritional values related to CP and Ash were relatively high in Kigoma and Mbeya than Morogoro while EE and energy were comparatively high in Morogoro in comparison to Kigoma and Mbeya. Also, NDF, ADF and ADL were comparatively higher for samples from Kigoma compared to those from Mbeya and Morogoro. Digestibility trials which include In vitro and In Sacco were the analysed parameters and they indicated to vary between samples of PKC collected from different regions. For instance, both in vitro and In Sacco digestibility results indicated higher scores for samples from Mbeya than those from the other regions. This is the first study to compare the nutritional values of PKC produced from different regions of Tanzania.

Despite the differing nutritional composition and digestibility of PKC observed from different regions their nutritional values were within the NRC recommendation for ruminants including goats [20]. However, based on results of this study, materials from Kigoma are proposed to be more suitable due to higher content of the analysed parameters which include CP, EE, Ash, Energy, NDF, ADF and low ADL and the fact that they readily available in bulk amounts as was observed in this study.

Results from this study are related to studies reported elsewhere. For instance, [21, 22] reported CP and CF results for samples collected from Port Harcout in the Niger Delta-Nigeria and Quevedo in the coastal plains of Nigeria respectively to be comparable to those of Kigoma and Mbeya. Also, results reported by [23] for samples from Cross River state and Akwa Ibon state in Niger, [21] for samples from Benin and Niger Delta and [22] for collected samples from Quevedo in the Coastal plains and Santa Domingo in Nigeria reported CP result from Akamkpa, Nifor, Benin and Santa Domingo indicating CP values from those regions to be lower than those of Kigoma and Mbeya but higher than samples from Morogoro. The variation observed in the CP content from this study could have been due to difference in processing method [24]. Also, according to [21, 25] PKC with high EE had low CP content compared to those with low EE.

The observed ash content from the study was within the range of ash results reported by [26] but high compared to the results reported by [21, 22]. Ash is a critical component in quantifying mineral composition of feeds for bone development, enzyme function and overall metabolism. Furthermore, EE results from this study were similar with those reported by [13]. In contrast, [21, 22] reported lower values compared to the study results. However, [27] reported high EE results. Additionally, the energy results reported from this study were comparable to the results reported by [21, 27] but they were lower compared to those of [23] in Akamkpa region in Cross River State in Nigeria but higher for those samples collected from Nifor in Akwa Ibon State in Nigeria. The variation observed in the level of EE and energy could have been due to difference in the method used in oil extraction and efficiency of machines used to extract oil as it was also shown by [21].

NDF results for samples from Kigoma are comparable with the results reported by [24] but they were found to be higher than those of [13]. However, comparing with the results reported by [22], the study results were found to be lower.

Moreover, [13] reported higher ADF result than the results from this study. However, the ADL results observed from this study was found to be lower compared to results which were reported by [13] and those reported by [22]. The studied PKC samples from this study implied less content of lignin and this implies that there will be little detrimental effect on NDF and

starch digestibility by animals and also little negative effect on energy utilization of feeds as was reported by [28] who concluded that high lignin content (>13) has negative effect on NDF and starch digestibility and energy use which in turn affect animal production. NDF, ADF and ADL are essential to support rumen function, digestibility and overall animal health as was reported by [20].

The In Sacco digestibility results from this study were lower compared with those of [29] who reported PKC degradability of 57.16%.

Comparing to the [30] study, the results obtained from this study revealed higher In vitro digestibility for all the samples. Determination of digestibility of feeds is vital as it act as a measure of a food's quality because it directly determines the proportion of nutrients in the food that are available for absorption into the body of an animal [31].

Compared to results by [26], the reported digestibility coefficient from the study was seen to be lower for CP, CF, EE and energy except ash which had high digestibility coefficient for all analysed samples.

The study suggest that the differing nutritional values of PKC collected from different regions could have been due to differing soil properties, climate, topography of the regions holding the plants in addition to different extraction methods used and storage condition.

5. Conclusion

In conclusion the study revealed a varying nutrition composition (CP, CF, EE, Energy and Ash) and digestibility of PKC samples collected from different regions of Tanzania. This could be attributable to differing soil properties, climate, topography of the regions holding the plants in addition to different extraction methods and storage condition. Kigoma and Mbeya samples showed higher crude protein and ash levels, while Morogoro samples excelled in ether extract and energy content. Digestibility trials indicated superior performance of Mbeya samples in both In Vitro and In Sacco analyses. Despite these variations, all PKC samples met NRC recommendations, confirming their suitability for ruminant feeding. Kigoma's PKC residues is particularly recommended due to its balanced composition with little variations and availability in bulk. These findings highlight the potentiality of PKC as a sustainable feed resource in Tanzania.

Abbreviations

PKC	Palm Kernel Cake
TVLA	Tanzania Veterinary Laboratory Agency
DAAR	Department of Animal, Aquaculture and Range Science
CP	Crude Protein
MJME	Megajoules Metabolizable Energy
DM	Dry Matter
KG	Kilogram
CF	Crude Fibre
EE	Ether Extract
NDF	Neutral Detergent Fibre
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
NIRS	Near Infrared Refracto-photometer
MTF	Model Training Farm
CEC	Cation Exchange Capacity

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Author Contributions

Esta Daudi Mollel: Conceptualization, Writing – original draft

Charles Moses Lyimo: Data curation, Methodology, Supervision, Writing – review & editing

Lusekelo Mwangengwa: Data curation, Methodology, Supervision, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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