Supplementation of Palm Kernel Cake (PKC) on Crossbred Growing Goats: Effects on Carcass, Meat Quality and Hematological Parameters.

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SUMMARY

The increasing demand for animal protein necessitates adequate feed supply to support higher production per animal. This study evaluated the effects of palm kernel cake (PKC) supplementation on carcass characteristics, meat quality, and hematological parameters in goats. Eighteen (18) crossbred (Saanen × Local) growing goats (5 months old, 12±2 kg) were assigned to three dietary treatments in a completely randomized design, receiving 0%, 30%, or 50% PKC for 8 weeks. Feed was provided at 3% of body weight daily. Daily feed intake and body weight were recorded, and carcass and meat quality traits were assessed after slaughtering four goats per treatment group. Blood samples for hematological analysis were taken every two weeks. Goats receiving 30% PKC exhibited significantly higher feed intake and weight gain. No significant improvements were noted at the 50% level. The T2 group (30% PKC) recorded the most efficient feed conversion ratio (0.149), followed by T3 (0.192) and T1 (0.380). Carcass weight, meat tenderness, and pH did not differ significantly among groups. Meat color parameters in the semitendinosus muscle showed no significant differences; however, in the biceps femoris, the L* score was significantly higher in T3. Hematological and biochemical indices remained within normal physiological ranges, indicating no adverse effects.

Keywords: Palm Kernel Cake (PKC), Goat, Feed Intake, Carcass Characteristics, Meat Scores, Hematological Parameters

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INTRODUCTION

The growing demand for animal sourced protein to meet the demand for growing population both in developed and developing countries (Ibrahim, 2011, Estes, 2012) is the driving force towards the need for increased animal production. However, the major constraint in the livestock industry is the scarcity of animal feeds both in quantity and quality in many countries including Tanzania and is partly attributable to the shrinkage of grazing areas and climatic changes (Thornton, 2010, Ngunga *et al*., 2016, Maleko *et al*.,2018). Feed cost makes up to 50–70% of the total expenditures in livestock production. However, relying on forages alone does not always provide adequate nutrition for fast growing animals hence, additional protein and energy (hay or concentrate) are offered to maintain acceptable goat performance (Wilkinson and Stark, 1987).

Exploration of feed residues from the crop processing industries or farm by-products could probably help to fill the gap of food shortage if well processed, formulated and fed to the animals (Swidiq *et al*., 2012, Akram *et al.,* 2019). Studies done elsewhere have indicated clearly the nutritional benefits of the industrial crop remnants to boost up production of meat and milk when supplemented as animal feeds (Tona *et al*., 2015). Furthermore, the use of agro-industrial by-products such as palm kernel cake has gained attention due to their availability, affordability, and variable nutritional quality across production regions (Mollel et al., 2025).

Residues from palm (*Elaeis guineensis)* have been shown elsewhere to enhance productivity of milk and meat when fed to goats, cattle or sheep (Zahari *et al.*, 2005). For instance, the use of palm kernel cake (PKC) 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. Inclusion of palm kernel cake at a level of up to 50% or 80% in feeds aimed for goats and 30 % for sheep improved the weight gain and milk yield of the respective animals (Zahari *et al*., 2005). The analysis of nutritional composition of the PKC done elsewhere was shown to contains 16.43-18.02 % CP, 34.44-32.69% CF, 3.28-3.6% EE, 5.66 and 5.69% ASH. The high content of nutrients in the plant residues could probably have accounted for the improvement of weight gain and milk yield in the studied animals (Tona *et al.,* 2015).

Goats are among the most commonly domesticated animals, valued for their production of meat and milk. They also contribute to household income, thereby improving farmers' livelihoods by offsetting daily consumption expenses (Gebeyehu *et al.,* 2013). As intermediate feeders, goats possess the ability to secrete proline-rich proteins that help mitigate the effects of anti-nutritional factors. They are also well adapted to survive extended periods of water scarcity (Mazhangara *et al.,* 2019). Due to their small body size, goats require minimal space and are easy to manage, making them particularly suitable for handling by women and children (Anaeto *et al.,* 2010; Neupane *et al.,* 2018).

Moreover, goats produce high quality meat and milk. Milk has therapeutic attributes due to presence of caproic, caprylic and capric vitamins which have medicinal values for various ailments and are easily digestible since they are short chain (Yadav *et al*., 2016; Iommelli *et al*., 2022). It contains large amount of taurine, conjugated fatty acids, Ca, Mg and P than cow milk (Yadav *et al*., 2016; Iommelli *et al*., 2022) hence its recommended for infant, old and convalescent.

Comparing with cow milk, goat milk contains 47 % more of vitamin A, 25% more of vitamin B6 and 13% more of Ca, has high buffering capacity thus highly useful for treatment of gastric ulcers, therefore a good substitute to patients allergic to cow milk (Getaneh *et al.,* 2016). Also, the milk is rich in the medium chain fatty acids which help in mal-absorption syndromes, chyluria, steatorrhea, hyperlipoproteinemia and in cases of intestinal resection, coronary bypass, premature infant feeding, childhood epilepsy and gallstones (Getaneh *et al.,* 2016). Medium chain fatty acids also inhibit cholesterol deposition, dissolve cholesterol gallstones and contributes to normal growth of infants (Getaneh *et al.,* 2016), has small fat globules (2 micrometers compared to 11.5-15 micrometers of cows) hence ease digestion and therefore, goat milk is sometimes called complete food (Getaneh *et al.,* 2016).

Goat meat is a major source of dietary protein, fat, vitamins and minerals for the human beings, it has lower total fat and cholesterol content, a good source of desirable fatty acid due to the fact that it deposits higher amounts of polyunsaturated fatty acid than other ruminants and thus more attractive to health-conscious consumers (Banskalieva *et al.,* 2000; Mahgoub *et al*.,2002). It is lean, have sensory and visual appealing, has low calorie, low fat and low cholesterol product when compared to chicken, pork, beef and lamb meat (McMillin and Brock 2005, Webb *et al.,* 2005, Mazhangara *et al*., 2019). Additionally, it has greater unsaturated to saturated fatty acid ratio, and can improve the health of human populations vulnerable to malnutrition, reduce risk of obesity and its associated metabolic diseases such as insulin resistance, type II diabetes mellitus, cardiovascular diseases and metabolic syndrome (Shija *et al*., 2013; Malekian *et al*., 2014). It is an excellent source of vitamin B12, potassium and iron hence avoid cases of Anemia especially to women in the child bearing age (Darnton-Hill *et al*., 2015). Its tenderness is lower than lamb and beef (Smith *et al.,* 1974). The study was therefore conducted to see the effect of PKC on health and production performance of growing goats.

METHODOLOGY

Study area

The study was conducted at Sokoine University of Agriculture at Magadu Model training farm (MTF) and at the department of Animal, Aquaculture and Range Sciences (DAARS)- Morogoro which lies at 37.00° E longitude and 4.49° S latitude, with temperature range between 17-30 ^{0}C and average annual rainfall around 740mm.

Housing preparation and animal management

A slated floor system was adopted where each goat was confined in its own cage to ease data collection. Feeders were prepared such that residue collection was made more effective. Water trough ensured adlib clean water throughout the study period. Proper hygienic condition was achieved by waste removal in the cages daily. A total of 18 crossbred (Saanen*local) growing goats of age (5months) and weight (12±2) were used following study by Dahlan *et al* (2000) with some modification. The goats were bought at Kidago farm located at Mikese-Morogoro Rural. Prior to experimentation, handling of animals and all experimental protocols were carried out according to the guidelines of the Animal Ethics, established by the Sokoine University of Agriculture Research and Ethical Committee. After collection, the animals were subjected to two weeks period to adopt to a new environment during which parasite control (both endo and ectoparasite) was done by giving them ivermectin. Vaccination against contagious caprine pleuropneumonia (CCPP) was done and housed in individual suspended stalls.

Feed Preparation

Hay was prepared using *Brachiaria brizantha* (cultivar), which was harvested, then partially sun-and air-dried, followed by chopping to reduce particle size and increase surface area for efficient mixing during Total Mixed Ration (TMR) preparation and feeding. All feed ingredients were analyzed for their nutritional composition before compounding the TMR according to AOAC (1990) as shown in Table 1. Additional feed ingredients, including maize meal, maize bran, soybean meal, palm kernel cake (PKC), mineral premix, and salt, were then incorporated. A vertical mixing machine was used to ensure homogenous blending and produce a consistent TMR. Three dietary treatments were formulated: Treatment 1 (T1 – 0% PKC), Treatment 2 (T2 – 30% PKC), and Treatment 3 (T3 – 50% PKC) as seen in table 2. Feed was provided at 3% of the animals' body weight per day, with 75% given in the morning (8:00 am) and 25% in the evening (4:00 pm). Residual feed was collected each morning before the next feeding to determine the animals' daily feed intake.

Table 1: Nutrient composition of feed ingredients used in feed formulation to be fed to experimental animals.

Analysed parameter	Feed ingredient				
	PKC	**B B**	**MM**	**MB**	**SBM**
DM (%)	90.77	87.2	89.2	92.6	91.6
CF (%)	19.128	36.8	1.4	8.8	8
CP (%)	19.145	4.3	12.9	8.7	48.9
EE (%)	11.063	4.1	3.6	9.3	20.3
Ash (%)	7.56	4.1	5.4	5.6	5
Energy (MJME/kg)	9.549	5.3	12.4	13.6	13.4

*PKC-Palm kernel cake, BB-*Brachiaria brizantha*, MM-Maize meal, MB- Maize bran, SBM- Soya bean meal.

Table 2: Feed formulation showing % PKC inclusion in a study assessing the effect of PKC on intake, weight gain, carcass quality and quantity and hematological parameters

Ingredients composition (g/kg)	T1	T2	T3
Brachiaria brizantha	50	47	46
Palm kernel cake (PKC)	0	6.9	11.5
Maize meal	20	25	28
Maize bran	23	16.1	11.5
Soya bean meal	5	3	1
Mineral premix	1.5	1.5	1.5
Salt	0.5	0.5	0.5

Experimental Setup

The animals were randomly placed in their cages and the diets were allocated randomly 6 animals per treatment then after first feeding those which received control (T1), diet2 (T2) and diet3 (T3) were continuously fed the respective diet for 56 days (8 weeks) by adopting a study by Dahlan *et al.* (2000) with some modifications. Feed was provided twice everyday i.e. early morning (8 am) and in the evening (4 pm), daily intake data were recorded daily by taking the difference between what was fed and refusals, body weight were obtained fortnightly while carcass and meat quality parameters were analysed after the feeding period was over. Blood collection was done through jugular vein for hematology and biochemsitry analysis. Clean water was provided adlib every morning and changed whenever it was found dirty.

Data Collection

Daily intake and body weight

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Data on daily intake were taken daily by subtracting the difference between what was fed and refusals, changes in body weight were taken once every week using digital weighing scale to measure the effect of the diets offered on weight gain. FCR was calculated using the formular below;

FCR=Amount of feed taken/ weight gained

Carcass, non-carcass and meat quality parameters

At the end of the feeding trial, four (4) goats from each treatment group were randomly selected and humanly slaughtered after 18 hours of fasting prior to which final body weight was recorded. Carcass weight, weight of empty GIT, heart, liver and lung weight were recorded. Samples of the hind limb were then taken to the laboratory for meat quality traits measurement including meat colour, pH, temperature and meat tenderness. A spear-end digital portable pH meter was used to measure pH of the meat of semitendinosus and biceps femoris muscles of the hind limb of the cut pieces for all selected and slaughtered goats.

Colour of the meat internal surface was graded using a portable colorimeter (Konica Minolta) for relative lightness (L*), redness (a*) and yellowness(b*) whereby L* values range from 0 to100 (black-white) while a* and b* range from -120 to 120 where a* range from green if negative (-) to red when positive (+) whereas b* range from blue if negative (-) to yellow if the observed meat colour is positive (+).

Meat temperature of the hind limb was measured using a thermometer for all the slaughtered experimental goats and average data was subjected to statistical analysis. Shear force for meat samples from the hind limb were measured using shear force machine (Zwick/Roell) and measurements were recorded in Newton's (N). The meat pieces were packed in polythene bags, cooked at 70-80^{0}C, cooled in running water for 1 hour, dried using a cloth to remove traces of surface moisture, and then the pieces were measured to obtain shear-force value and results were subjected to statistical analysis.

Blood and hematological parameters

Through jugular vein blood samples were collected before the start of the experiment and after every two weeks and they were taken to the laboratory for analysis at the Department of Physiology, Biochemistry and Pharmacology at the college of Veterinary Medicine and Biomedical Sciences Sokoine University of Agriculture. Vacutainer tubes with EDTA were used for blood sample collection used for blood cell analysis while vacutainer tubes with NaFl were used for collection of blood samples for biochemical parameters (triglyceride, cholesterol, protein and glucose). Erba kit protocol was used.

Data Analysis

The effect of PKC inclusion on feed intake, body weight, carcass and non-carcass components, blood metabolites, and hematological parameters was analyzed using Analysis of Variance (ANOVA) under the General Linear Model (GLM) procedure implemented in SPSS statistical software version 26. Where significant differences were detected, means were separated using Tukey's Honest Significant Difference (HSD) test at a 5% level of significance.

RESULTS

Daily feed intake, body weight gain and feed conversion ratio

Observed daily feed intake was significantly high for T2 diet (373.87), while T1 (373.87) and T3 (346.965) had comparable intake levels. Similarly, weight gain was significantly greater in the T1 group (2507.971), followed by T2 (1805.003), with the lowest gain observed in T1 (905.850). Moreover, T2 group recorded the best FCR followed by T3 and least observation was on T1 (0.14907, 0.19224 and 0.37978 respectively).

Carcass and non-carcass parameters

Carcass weight varied significantly among treatments, with T1 goats recording the highest average weight (11.378 kg), whereas T2 (9.228 kg) and T0 (8.643 kg) remained statistically similar. Furthermore, goats in the T1 group exhibited significantly higher empty gastrointestinal tract (3.68 kg) and heart weights (0.102 kg) compared to T0 and T2. However, liver and lung weights did not show significant differences across the three dietary treatments, as indicated in Table 3.

Table 3: Feed intake, weight gain and carcass and non-carcass components

Parameter	T1	T2	T3	SEM	P-Value
No. of samples	6	6	6		
Intake(g)	343.998^{b}	373.871^{a}	346.965^{b}	2.79	0.01
Body wgt(g)	905.850^{c}	2507.971^{a}	1805.003^{b}	115.067	0.007
FCR	0.37978^{a}	0.14907^{c}	0.19224^{b}	0.002	0.001
Carcaswgt(kg)	8.643^{b}	11.378^{a}	9.228^{ab}	0.637	0.034
EmptyGIT(kg)	3.244^{b}	3.681^{a}	3.204^{b}	0.164	0.415
Heart wgt (kg)	0.0688^{b}	0.102^{a}	0.0773^{b}	0.129	0.018
Liver wgt(kg)	0.189	0.21	0.188	0.086	0.083
Lung wgt(kg)	0.148	0.144	0.134	0.0153	0.665

Meat quality

Meat tenderness (34.627–36.238 N) and pH (5.65–5.75) values did not differ significantly among the three dietary treatments. Similarly, color scores for the semitendinosus muscle indicated no significant differences across treatments for lightness (L = 41.9–48.41), redness (a = 7.15–8.73), or yellowness (b = 3.59–5.14). In the biceps femoris muscle, redness and yellowness scores were also statistically similar. However, lightness (L*) was significantly higher in T2 (49.95) compared to T0 (42.44) and T1 (41.2), as shown in Table 4.

Table 4: Meat quality parameters

Parameters	Treatments				
Tenderness(N)	T1 (0%)	T2 (30%)	T3 (50%)	SEM	p- value
Semitendinosus	34.698	36.242	34.627	±0.056	0.786
Biceps femoris	35.563	36.238	34.365	±0.056	0.052
pH	5.75	5.65	5.65	0.15	0.7221
colour					
Semitendinosus					
Lightness (L)	45.44	41.9	48.41	±0.49	0.06584
Redness (a)	8.24	8.73	7.15	±0.657	0.5844
Yellowness (b)	4.91	5.14	3.59	±0.423	0.7101
Biceps femoris					
Lightness (L)	42.44^{b}	41.2^{b}	49.95^{a}	±0.913	0.03453
Redness (a)	5.2^{a}	5.19^{a}	7.16^{b}	±0.72	0.03453
Yellowness (b)	8.66^{a}	9.53^{a}	8.20^{a}	±1.76	0.9151

Blood and hematological parameters presented in Table 5. All recorded parameters were within the normal physiological range for healthy goats across all treatment diets. Triglyceride levels ranged from 50.199 to 59.618 ±13.84 mg/dL, cholesterol from 63.307 to 68.507 ±5.662 mg/dL, and glucose from 46.622 to 49.498 ±5.6 mg/dL. Total protein levels ranged between 7.25 and 7.704 ±0.475 g/dL, white blood cells from 11.806 to 13.288 m/mm³, and red blood cells from 11.092 to 12.869 M/mm³.

Table 5: Blood and Hematological parameters

Parameter	T1	T2	T3	SEM	P-Value
No. of samples	6	6	6		
Triglyceride(mg/dl)	59.618	50.199	56.895	13.84	0.78
Cholesterol (mg/dl)	64.772	68.507	63.307	5.662	0.643
Glucose (mg/dl)	49.498	46.622	47.355	5.6	0.867
Total protein (g/dl	7.704	7.25	7.37	0.475	0.623
WBC (m/mm^3)	13.288	11.806	12.722	1.146	0.434
RBC (M/mm^3)	11.869	12.092	12.069	2.072	0.41

DISCUSSION

Goat meat is regarded as lean red meat with desired nutritional characteristics, somewhat dark, more coarse and less juicy than lamb meat. The leanness makes it mostly preferred by health-conscious meat consumers as it is associated with less cardiac problems (Casey *et al.,* 2003; Webb *et al.,* 2005). This study was done to see the response on health and production performance of growing goats fed palm kernel cake (PKC). It was found out that PKC can stand a place expensive and competitive of concentrates which are used between man and livestock. This is because of its good nutritional attributes as it was reported by Mollel et al 2025 whose report indicated that PKC have considerably high CP and energy to meat most ruminant's nutrient requirement especially goats (NRC 2007). Generally, goats performed well after feeding them a diet with 30% PKC inclusion in terms of intake, changes in body weight, carcass and meat quality traits and blood parameters.

It was observed in this study that goat's intake and body weight gain revealed a quadratic effect with the inclusion of PKC in the diet fed to the animals. This study results relate to study done by da Silva *et al.* (2020); Rodrigues *et al.* (2021); Ferreira *et al.* (2022) which also revealed a quadratic effect on daily feed intake and weight gain. However, the other studies observed quadratic effect at lower inclusion levels unlike this study results which had maximum gain at 30% inclusion. The study implied an increase in weight gain of goats with supplementation of 30% PKC as was also seen on cows fed traditional ration supplemented with PKC (Olawoye *et al*., 2020). Furthermore, Olawoye *et al*., 2020 reported higher values of feed conversion ratio compared to study results, this suggests the reason for the reported increase in body weight of goats in the current study with supplementation of PKC.

Carcass weight, weight of empty GIT and heart weight were significantly higher for goats receiving T1 diet compared to T0 and T2. This effect of increased weight could have been attributed by the results on nutritional composition of PKC as was reported by Tona *et al.* (2015) and Mollel *et al.* (2025). The quadratic effect revealed in this study could have been caused by the high level of crude fibre (CF) content of PKC causing physical fill reducing intake hence less weight gain. Variability in nutrient composition and digestibility of locally sourced feed ingredients has been reported to influencing animal performance outcomes (Mollel *et al.,* 2025). However, fibre content is important as it contributes to lean meat (Lu *et al*.,2005) which is preferred by health-conscious consumers since it is associated with low cardiovascular problems (Webb *et al*., 2005).

pH of goat meat usually ranges between 5.8-6.2 as was reported by Kannan *et al.* (2014); Simela *et al.* (2004). However, pH reported in this study did not differ significantly for all the three treatment diets although it was slightly higher than the recommended value for desirable eating quality for red meat reported by Tarrant & Sherington (1980) to be 5.5. This may have been contributed by the fact that chevon has low glycolytic potential yielding meat with high pH. This calls for the need for minimizing antemortem stress as was also reported by Pophiwa *et al.* (2020) because goats especially male (which were used in this study) are more prone to stress (Mota-Rojas *et al*., 2006; Sako and Sedumedi, 2022). Low meat pH is associated with tender and bright red meat (Simela *et al.,* 2004).

Meat tenderness is one among the most important factors affecting satisfaction of consumers. The reported shear-force from this study did not differ significantly for all treatment diets contrary to results reported by Rodrigues *et al.* (2021)

whereby shear-force was seen to increase at higher levels of PKC inclusion in the diet. Moreover, comparing this study results with those reported by Perry *et al.* (2001) and Hopkins *et al.* (2006) who reported that goat meat of shear force value below 40 is tender, then the reported results of this study implies that PKC inclusion in goats diet is associated with tender meat.

Carpenter et al. (2001) reported that meat colour normally determines consumers perception on the quality of meat and this ultimately influence the decision to purchase. Meat colour is a function of a muscle's pigment content and light scattering properties. pH above 6 is associated with dark meat since myofibres hold a lot of water preventing light penetration hence dark meat and vice versa and this could be the reason for the high L* score reported in this study (Sako *et al.,* 2022). Low meat pH is associated with tender and bright red meat (Simela *et al.,* 2004a). This could be the reason for the low a* score reported in this study. Except for L* score of biceps which differed significantly, the rest of the scores were comparable and hence compares well with previous studies done by Pophiwa *et al*. (2017).

These parameters are important in the assessment of the health status of animals. For example, red blood cells help in air circulation therefore if a certain feed is associated with decreasing its level it will reduce blood circulation. White blood cells levels in the blood tells if an animal is infected. Cholesterol is associated with cardiac problems since high levels causes clogging of arteries (Sidik *et al.,* 2019), thus it is important to see if feeds have effects on such levels in the blood of animals. Such parameters can be affected by among others nutrition, breed, age, sex, management and health (Sidik *et al.* 2019). The reported cholesterol level of goat blood serum in this study didn't differ significantly for all diets and fell within normal range (63.307-68.507mg/dl) for healthy goats. This is similar to results by Daramola *et al*. (2005); Mohammed *et al*.(2016); Sidik *et al.* (2019). Additionally, the reported level of triglyceride was within the normal range (0-200mg/dl but higher than those of Sidik *et al*. (2019). Findings of blood glucose from this study indicated comparable results for all diets and fell within normal range for healthy goats as was reported by Mohammed *et al*.(2016); Khan *et al.,* 2020. Moreover, the reported blood total protein results in this study falls between required range and did not differ significantly among all treatment diets. These results are comparable with those reported by Mohammed *et al.* (2016). This implies that PKC has less detrimental effect on health of goats.

White blood cells reported in this study didn't significantly differ for all diets. Additionally, they were within the normal range. These results are similar with those reported by Al-Bulushi *et al*., 2017 but higher in comparison with those of Mazzuca Pizetti *et al* (2021). Red blood cells findings from this study didn't significantly differ for all diets. Additionally, it was within recommended level for healthy animals (Mohammed *et al.,*2016), However, they were slightly higher than those of Mohammed et al (2016), Al-Bulushi *et al*.,2017, Mazzuca Pizetti *et al.*, 2021.

CONCLUSION

The study demonstrated that supplementing goat diets with 30% palm kernel cake (PKC) significantly improved daily feed intake, weight gain, and carcass weight without adversely affecting meat quality or blood parameters. Meat tenderness, pH, and most color attributes remained within acceptable ranges, with minimal variation across treatments. Hematological and biochemical indices also stayed within normal physiological limits, indicating no negative health effects. These findings suggest that PKC can serve as a cost-effective alternative protein source in goat feeding strategies, particularly in regions where conventional feed ingredients are scarce or expensive, promoting sustainable livestock production. Incorporating locally available industrial by-products with known nutritional and digestibility profiles can enhance feed efficiency and reduce production costs.

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Authors have declared no conflicting interest.

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