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Research Article

Effects of Coconut Oil Inclusion and Fiber Adjustment in Total Mixed Rations on the Nutrients Composition of Diets for Dairy Cows Compared to Forage-based Diet

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Abstract

The objective of this study was to formulate total mixed ration (TMR) for lactating dairy cows that include coconut oil (CO) and adjusted neutral detergent fibre (NDF) to ensure that every bite consumed by the animal is nutritionally balanced with potential of greenhouse gases mitigation. Therefore, it was hypothesized that inclusion of CO up to 6% in TMR, with proportional reduction in NDF, would reduce greenhouse gases without adversely affecting the nutritive composition of the diets. Forage-based diet was used as a control (T1) compared to TMR that incorporated coconut oil at 0, 2, 4 and 6% with adjusted NDF at 47.66%, 41.64%, 34.67% and 29.01% levels as T2, T3, T4 and T5 respectively. Rhodes grass (*Chloris gayana*) hay, wheat bran, maize germ, sunflower meal, canola meal, and a mineral premix were ingredients used and analyzed using Proxime and Van Soest procedures for chemical composition of the diets. Parameters analyzed: dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), calculated non-fibre carbohydrates (NFC), gross energy (GE), and mineral content. Statistical analysis was done using SAS, 9.4 (2002) considering Complete Randomized Design (CRD) with Tukey at 5% significance. Results demonstrated that all nutritive parameters were higher in the TMR diets than in the forage-based diet, while meeting the nutrient requirements of lactating dairy cows. Within the TMR diets, DM, 45.6-46.1%; CP, 17.9-19.3%; and GE, 17.9-18.7 MJ kg^{-1}) did not differ significantly ($P > 0.05$). However, NFC was significantly higher in T4, 22.9% and T5, 23.4% than in T2, 13.5% and T3,12.9% ($P < 0.05$). Ether extract and NDF differed significantly ($P < 0.05$) among all diets, reflecting the intended increase in CO inclusion and proportional reduction in NDF. Concentrations of calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), and chlorine (Cl) were significantly lower ($P < 0.05$) in the TMR diets than in the forage-based diet. The findings demonstrate that TMRs supplemented with up to 6% coconut oil and proportionally adjusted NDF can satisfy the recommended nutrient requirements of lactating dairy cows despite their relatively lower mineral concentrations. Therefore, supplemental mineral blocks are recommended during feeding to ensure adequate mineral intake without compromising rumen function, milk production, or animal health.

Keywords

Coconut Oil Inclusion, Total Mixed Ration, Nutritive Value

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1. Introduction

Ruminant production in developing Countries depend largely on natural forage resources, whose availability fluctuates seasonally throughout the year [1]. However, the nutritional requirements of livestock are often not met because seasonal forage shortages, poor forage quality, and reduced digestibility, exacerbated by climate change, limit nutrient supply. Consequently, alternative feed resources are required to overcome these constraints, satisfy animal nutrient requirements, sustain productivity, and contribute to food security in response to increasing global population growth.

Meeting the nutrient requirements of dairy cows is essential for improving productivity, maintaining animal health, and enhancing the sustainability of dairy production systems. Feed ingredients of both plant and animal origin vary considerably in their nutritive value depending on factors such as species, stage of maturity, season, and soil fertility. This variability must be accurately accounted for during feed formulation to ensure that diets provide adequate nutrients to meet the physiological requirements of dairy cows. Nutritional factors such as fibre content, nutrient density, digestibility, and anti-nutritional compounds directly influence feed intake, nutrient utilization, and animal performance. Appropriate nutrient supply is closely associated with growth, health, milk production, and overall feeding efficiency [2]. Conversely, inadequate nutrient provision compromises productivity and increases the susceptibility of animals to disease.

The dairy industry requires precise nutritional management to optimize animal performance while minimizing environmental impacts. Among the major dietary components, fibre and crude protein have a direct influence on feed intake, rumen microbial activity, nutrient utilization, and ultimately milk production. Structural carbohydrates, particularly neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL), are important indicators of fibre quality and digestibility and can guide decisions regarding feed processing or pretreatment when necessary. Considering the variability in feed ingredients and the changing nutrient requirements of dairy cows, chemical analysis of feedstuffs and formulated diets is essential for accurate ration formulation. Proximate analysis provides a reliable method for determining nutrient composition and ensuring that diets meet nutritional requirements while minimizing nutrient losses to the environment.

Proximate analysis provides quantitative information on the chemical composition and nutrient density of feed ingredients, thereby supporting accurate ration formulation to meet the high metabolic demands of lactating dairy cows. In this study, feed ingredients including coconut oil, Boma Rhodes (*Chloris gayana*) hay, maize silage, maize bran, maize germ, soybean cake, and canola meal were analysed because of their diverse nutritional characteristics. The nutrient composition of these ingredients and the formulated total mixed rations (TMR) was determined using proximate analysis to quantify dry matter (DM), crude protein (CP), ether extract (EE), ash, and calculated non-fibre carbohydrates (NFC). Structural carbohydrate fractions, including neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL), were determined using the method of Van Soest [3].

Coconut oil was included as a dietary supplement because of its potential to increase dietary energy density. It is a rich source of medium-chain saturated fatty acids that can improve nutrient digestibility and reduce enteric methane emissions through anti-methanogenic mechanisms [4, 5]. However, the effects of coconut oil on animal performance depend on factors such as dietary fibre concentration, diet composition, and inclusion level. Therefore, analysing the chemical composition of coconut oil alongside the other dietary ingredients is essential for predicting its effects on animal performance and productivity [6].

The aim of this study was to determine the effects of coconut oil supplementation and adjusted dietary fibre levels on the nutritional composition of total mixed rations for lactating dairy cows, with particular emphasis on ether extract (EE) and neutral detergent fibre (NDF) as the primary response variables. It was hypothesized that the inclusion of coconut oil combined with reduced dietary fibre would increase the energy density of the diets while decreasing NDF concentration without compromising the nutrient requirements of lactating dairy cows.

2. Materials and Methods

2.1. Experimental Site

Analysis was carried out at Laboratory of the Department of Animal Sciences, Egerton University Njoro Main Campus, Kenya. The main campus is situated at an approximate longitude of 35 °35' East and latitude of 0 °23' South, situated at an altitude of about 2,238 meters above sea level. Egerton University is located approximately 25 km southwest of town of Nakuru and 182 Km to Nairobi, the capital city in Kenya [7].

2.2. Feed Preparation and Sampling

Coconut oil as the main ingredient for research was purchased from a traditional processor in Mombasa County. Hay used was of Boma Rhodes (*Chloris gayana*) and maize silage were produced at the Beef Research Institute in KALRO-Lanet for feeding research animals.

Other feed ingredients such as maize bran, maize germ, soybean meal, canola meal and minerals and vitamins premix were acquired from the local feed manufacturer in Nakuru County and kept in the store for total mixed ration formulation.

Total mixed ration diets were composed of Boma rhodes

(*Chloris gayana*) hay, maize bran, maize germ, soybean cake, canola meal, and used as the primary experimental feeds, supplemented with coconut oil (CO) at inclusion levels of up to 6% as follows: T1-forage diet, T2- TMR+0% of CO, T3- TMR+2% of CO; T4-TMR+4% of CO and T5-TMR+6% of CO with dietary fibre (NDF) in each treatment of TMR respectively 47.66%, 41.64%, 34.61% and 29.013%. Proximate analysis was performed in the following parameters: Dry matter (DM), crude protein (CP), ether extract (EE), gross energy (GE), Ash, and Van Soest [3] method for neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL). All diets were formulated to meet lactating cow's nutrient requirement at mid-lactation [8].

2.3. Analytical Procedures

The samples were weighed, oven-dried at 60°C for 24 hours and ground using a Wiley mill through a 1 mm sieve. Samples were analysed for nutrient composition following the procedure recommended [9]. Dry matter (DM) was determined using the AOAC international method 930.15. Ankom 200 fibre Analyzer was used to determine fibre content following Van Soest procedure on neutral detergent fibre (NDF) content by adding heat-resistant α-amylase and sodium sulphite, after which determination of acid detergent fibre (ADF) was determined using, and Acid detergent lignin (ADL) after igniting the sample at 500°C during 4 hours [3].

Gross energy was determined using a bomb calorimeter. Ether Extract (EE, method 920.39) was determined using Soxhlet apparatus and extractor (FOSS, Hoganas, Sweden), and ash was measured by incinerating at 550°C for 4 hours using a muffle furnace (method 942.05). Crude protein content was analyzed using the Kjeldahl digestion unit (method 990.03), and the total nitrogen multiplied by a conversion factor 6.25x N content. Non-fibrous carbohydrates (NFC) were calculated using the formula number 1 as suggested by Weiss & Tebbe [10].

$$NFC=100- (NDF+ CP+ EE+ Ash)$$

2.4. Statistical Analysis

All parameters were subjected to analysis variance (ANOVA). General Linear Model procedure was used in the SAS 9.4 (Statistical Analytical System, Institute Inc., Cary, NC, (2020) following Randomized Complete Design (CRD). The statistical model was specified as

$$Yij = \mu + ti + eij$$

where Yij = effect of the diet (nutrient output)
μ = overall mean effect
ti = true effect of the (Ti) diet
eij = error term of the (Yj)

The means results (variable response) were obtained using LSMeans syntax and separated adopting significant effect at 5% using Tukey's test.

3. Results

The chemical composition of the feed ingredients used in the formulation of the experimental diets is presented in Table 1. Rhodes grass hay exhibited the highest neutral detergent fibre (NDF) concentration (65.54%), followed by wheat bran (52.94%) and sunflower cake (45.97%), whereas canola cake had the lowest NDF content (32.49%). Sunflower cake contained the highest CP (33.39%) among the protein supplements, followed by canola cake, 29.69%. Coconut oil consisted almost entirely of ether extract, 99.0%.

Table 1. *Nutritive value of the ingredients.*

Ingredients	Nutrients							
	DM (%)	GE (MJ/kg)	CP (%)	NDF (%)	ADF (%)	ADL (%)	EE (%)	Ash (%)
Wheat Bran	94.856	16.211	14.448	52.935	16.134	3.184	3.942	4.739
Canola cake	94.684	17.704	29.687	32.486	19.503	5.566	4.946	4.619
Sunflower Cake	94.984	18.335	33.39	45.97	23.405	4.765	9.334	5.07
Maize Germ	94.007	20.908	15.641	33.699	15.239	1.892	3.397	3.121
Rhodes grass ha	97.305	16.901	8.862	65.539	42.744	4.677	1.849	7.46
Coconut oil							99.00	
Silage	33.05	17.900	7.420	43.550	25.201	3.103	2.722	4.191

DM=Dry Matter; GE=Gross energy; CP=Crude Protein; NDF= Neutral Detergent Fibre; ADF=Acid Detergent Acid; ADL=Acid Detergent Lignin; EE=Ether Extract

The composition of the experimental diets is shown in Table 2. Four total mixed rations (TMR) were formulated with graded levels of coconut oil, 0, 2, 4 and 6% of dietary dry matter, while the control treatment consisted of the conventional forage-based diet under ranching condition. Coconut oil was included as the experimental factor, and all TMR diets were formulated to be comparable in crude protein and energy supply while varying primarily in dietary fat concentration and fibre content.

Table 2. *Experimental diet composition.*

Ingredients	Treatments				
	T1-Control	T2-TMR+0CO	T3-TMR+2CO	T4-TMR+4CO	T5-TMR+6CO
Chloris gayana (hay)		31.21	30.30	23.00	13.50
Wheat bran		12.61	12.10	14.70	16.00
Maize germ		21.97	20.60	25.20	31.38
Canola meal	forage	12.79	13.00	14.80	14.20
Sunflower meal		20.41	21.00	17.30	17.92
Coconut oil		0	2	4	6
Premix (Min +vitam)[1]		1	1	1,00	1
Total (% TMR+CO)		100	100	100	100
Maize Silage 33.05% as fed	(33.05%) 5.33	(33.05%) 5.33	(33.05%) 5.73	(33.05%) 5.46	(33.05%) 5.31
Total (% DM)	28.65	45.44	46.07	45.57	45.195

1-mineral blocks (sodium chloride, calcium, phosphorus, magnesium, copper, manganese, zinc, cobalt, iodine, selenium, molybdenum); vitamin A, D_3, and E. TMR- Total Mixed Ration; CO-coconut oil, 2,4 and 6 percent of coconut oil inclusion in diets. Control* = forage from grazing animal composed by grass with some legumes

The nutrient composition of the experimental diets is presented in Table 3. Dry matter (DM) content was significantly lower ($P < 0.05$) in the control forage diet, 28.65% than in the TMR diets, which ranged from 45.20 to 46.07% DM and did not differ significantly from one another ($P > 0.05$).

Table 3. *Nutritive composition of the experimental diets.*

Nutrient	Treatments					SEM	P -Value
	T1-Control	T2-TMR +0CO	T3-TMR +2CO	T4-TMR +4CO	T5-TMR +6CO		
DM (%)	28.653^{b}	45.440^{a}	46.070^{a}	45.570^{a}	45.195^{a}	±0.545	0.0001
CP (%)	15.138^{b}	17.940^{a}	18.750^{a}	18.800^{a}	19.300^{a}	±0.147	0.0001
GE ($MJkg^{-1}$)	11.536^{b}	17.890^{a}	17.591^{a}	18.208^{a}	18.667^{a}	0.727	0.0014
NFC[1](%)	14.353^{b}	13.538^{b}	12.8701^{b}	22.857^{a}	23.359^{a}	±0.563	0.0001
EE (%)	1.934^{d}	1.900^{d}	3.950^{c}	5.300^{b}	7.500^{a}	±0.043	0.0001
Ash (%)	8.386^{b}	5.900^{d}	5.495^{d}	7.337^{c}	10.642^{a}	±0.058	0.0001
NDF (%)	50.775^{a}	47.656^{b}	41.635^{c}	34.600^{d}	29.013^{e}	±0.420	0.0001
ADF (%)	38.147^{a}	34.735^{a}	35.998^{a}	27.834^{c}	23.703^{c}	±0.352	0.0001

Nutrient	Treatments					SEM	P -Value
	T1-Control	T2-TMR +0CO	T3-TMR +2CO	T4-TMR +4CO	T5-TMR +6CO		
Ca (%)	3.733[a]	0.125[b]	0.122[b]	0.376[b]	0.123[b]	±0.136	0.0001
P (%)	2.817[a]	0.342[b]	0.334[b]	0.338[b]	0.354[b]	±0.038	0.0001
Mg (%)	1.890[a]	0.162[b]	0.175[b]	0.160[b]	0.178[b]	±0.009	0.0001
Na (%)	3.067[a]	0.015[b]	0.014[b]	0.019[b]	0.051[b]	±0.054	0.0001
Cl (%)	-	0.075[a]	0.073[a]	0.074[a]	0.078[a]	±0.003	0.6839

1-calculated from other analysed nutrients; NFC- Non-fibre carbohydrates; DM-Dry matter; CP-Crude protein; GE-Gross energy; EE- Ether extract; NDF-Neutral detergent fibre; ADF-Acid detergent fibre; Ca- Calcium; P-Phosphorus; Mg- Magnesium; Na-Sodium, Cl-Chloride; TMR - Total mixed ration; CO- coconut oil, SEM-Standard error mean· DM-Dry matter; CP-Crude protein; GE-Gross energy; EE- Ether extract; NDF-Neutral detergent fibre; ADF-Acid detergent fibre. Different letters in the same row denote different treatment means ($p<0.05$).

Crude protein concentration increased from 15.1% in the control diet to between 17.9 and 19.3% in the TMR diets ($P < 0.05$). Similarly, gross energy (GE) was significantly higher in the TMR diets (17.59-18.7 MJ kg^{-1} DM) than in the control diet (11.53 MJ kg^{-1} DM; $P < 0.05$). However, no significant differences in CP or GE were observed among the TMR diets ($P > 0.05$), indicating that the diets were successfully formulated to be approximately iso-nitrogenous and iso-energetic despite increasing levels of coconut oil.

Non-fibre carbohydrates (NFC), calculated as 100 − (NDF + CP + EE + ash), differed significantly among treatments ($P < 0.05$). Diets containing 4 and 6% coconut oil, T4 and T5 had the highest NFC concentrations, 22.86 and 23.36%, respectively, whereas the control and the lower-fat TMR diets contained between 12.87 and 14.35%.

As intended during diet formulation, NDF concentration decreased progressively with increasing coconut oil inclusion, from 47.66% in the 0% coconut oil TMR to 29.01% in the 6% coconut oil TMR ($P < 0.05$). The control diet contained the highest NDF concentration,50.78%. Acid detergent fibre (ADF) also declined with increasing coconut oil inclusion, decreasing from 34.74-36.00% in the lower-fat TMR diets to 23.70% in the 6% coconut oil diet ($P < 0.05$).

Ether extract (EE) increased linearly with increment of coconut oil supplementation ($P < 0.05$), rising from 1.90% in the control and 0% coconut oil TMR to 3.95, 5.30 and 7.50% in the 2, 4 and 6% coconut oil diets, respectively. This confirms that the dietary fat concentration increased as intended with coconut oil supplementation.

Ash content also differed among treatments ($P < 0.05$), with the highest value observed in the 6% coconut oil diet (10.64%) and the lowest values in the 0 and 2% coconut oil diets (5.90 and 5.50%, respectively). Concentrations of calcium, phosphorus, magnesium and sodium were markedly higher in the control forage diet.

4. Discussion

The dry matter (DM) concentration of total mixed rations (TMR) is an important determinant of feed intake, nutrient intake and ration uniformity. Variations in the moisture content of individual feed ingredients, particularly silages, can alter the overall DM concentration of the diet and consequently influence dry matter intake (DMI). In the present study, the DM concentration of the formulated TMR diets ranged from 45.2 to 46.1%, which falls within the range of 41-68% reported for TMR containing maize silage [11, 12]. In contrast, the forage-based control diet contained only 28.65% DM because fresh forage had a high moisture content. Maize silage contained approximately 67% moisture, which substantially reduced the DM concentration of the mixed ration. Previous studies have shown that fluctuations in dietary moisture can affect feed palatability, nutrient distribution within the TMR, sorting behavior and nutrient intake [13, 14]. To minimize these effects, nutrient analyses in the present study were performed on a dry matter basis, allowing diets to be formulated consistently despite differences in ingredient moisture content.

As expected, increasing coconut oil inclusion progressively increased dietary ether extract (EE) concentration from 1.9% in the control and the TMR without coconut oil to 3.95, 5.30 and 7.50% in the diets containing 2, 4 and 6% coconut oil, respectively. The small amount of EE in the TMR without coconut oil originated from oil-containing feed ingredients such as canola cake and sunflower cake. Although the forage-based control diet contained a similar EE concentration to the TMR without coconut oil, its fat was derived primarily from natural forage lipids. These findings agree with Hollmamn [15], who reported that coconut oil supplementation increased the total fat concentration of dairy cow diets. Similarly, Lovatti [16] observed increased dietary fat content and improved animal performance following supplementation with coconut oil and palm fat. Studies by Vogel et al [17-19] likewise demonstrated

that increasing dietary lipid supply through fat supplementation increased dietary energy density and modified milk fat composition. Collectively, these studies suggest that moderate inclusion of supplemental fat can enhance dietary energy concentration, although the long-term effects depend on the amount and source of fat as well as interactions with dietary fibre.

Neutral detergent fibre (NDF) concentration decreased progressively as coconut oil inclusion increased because higher-fat diets required lower proportions of fibrous ingredients, particularly, roughage (e.g Rhodes grass hay in this study). Consequently, the control diet had the highest NDF concentration (50.78%), followed by the TMR without coconut oil (47.66%), whereas diets containing 2, 4 and 6% coconut oil contained 41.64, 34.60 and 29.01% NDF, respectively.

Fibre is essential for maintaining rumen function because it stimulates chewing activity, saliva secretion and rumen buffering, thereby helping to maintain ruminal pH and reducing the risk of digestive disorders [20, 21]. Similarly, Kronqvist [22], reported that increasing forage inclusion in TMR increased dietary NDF concentration. Although reducing dietary fibre increases energy density, excessive reductions may compromise rumen health if physically effective fibre becomes limiting. Therefore, balancing dietary fibre and supplemental fat is essential for maintaining rumen function while improving dietary energy supply. Previous recommendations suggest that dietary fat concentrations above approximately 3% can be used successfully when adequate effective fibre is maintained in the ration [23, 24].

Non-fibre carbohydrates (NFC) were highest in the diets containing 4 and 6% coconut oil because these diets contained greater proportions of maize germ and lower fibre concentrations. Increasing energy concentrate ingredients generally increases NFC concentration and dietary energy density. However, excessive rapidly fermentable carbohydrates may increase the risk of ruminal acidosis, reduced rumen motility, laminitis and liver abscesses [25]. In the present study, adequate inclusion of Rhodes grass hay and wheat bran maintained relatively high dietary fibre concentrations, which may help reduce these risks despite the higher NFC content of the diets. Schingoethe [26] similarly recommended incorporating high-fibre ingredients into high-concentrate rations to maintain rumen health and optimize nutrient utilization.

The TMR diets contained approximately 18-19% of CP, whereas the forage-based control diet contained 15.14% CP. These values are consistent with recommendations for lactating dairy cows, where dietary CP requirements generally range from 12 to 18% depending on milk yield and stage of lactation [27]. For cows producing moderate milk yields (approximately 11-13 kg day^{-1}), CP concentrations around 14% may be adequate [28], whereas higher-producing cows generally require diets containing 16-18% CP. Zhao [29] reported that increasing dietary CP can improve milk production, although excessive protein supplementation may increase nitrogen excretion without further production benefits. The inclusion of high-quality protein ingredients, such as canola cake and sunflower cake in the present study, was intended to supply adequate rumen-degradable and undegradable protein to support microbial protein synthesis and milk production. Efficient synchronization of dietary protein with fermentable carbohydrates remains important for improving nitrogen utilization and reducing nitrogen losses.

The mineral composition of the forage-based control diet was generally higher than that of the formulated TMR diets. Calcium and phosphorus are essential for skeletal development, muscle function, enzyme activity and milk synthesis, with recommended dietary concentrations of approximately 0.6-1.0% calcium and 0.35-0.45% phosphorus for lactating dairy cows, depending on production level [30]. The analyzed calcium and phosphorus concentrations in the TMR diets were below these recommendations, indicating that mineral supplementation through commercial mineral premixes or mineral blocks would be necessary to satisfy the nutritional requirements of lactating cows when feeding these rations.

Overall, the formulated TMR diets successfully achieved the intended increases in dietary fat while maintaining comparable crude protein and energy concentrations. The gradual reduction in fibre concentration and corresponding increase in ether extract and non-fibre carbohydrates demonstrate that coconut oil can be incorporated into dairy cow diets to increase dietary energy density. However, maintaining adequate effective fibre and appropriate mineral supplementation remains essential to preserve rumen health and meet the nutritional requirements of lactating dairy cows.

5. Conclusion

The formulated total mixed rations containing graded levels of coconut oil were successfully developed to provide diets with increased energy density while maintaining comparable crude protein concentrations. Increasing coconut oil inclusion progressively increased dietary ether extract and reduced neutral detergent fibre, demonstrating that dietary fat concentration can be manipulated through ration formulation without compromising the overall nutritional balance of the diets. The proximate and Van Soest analyses confirmed that the formulated rations met the intended nutrient specifications and provided a useful basis for evaluating their nutritional quality and potential feeding value for lactating dairy cows.

Although the formulated total mixed rations were designed to satisfy the major nutrient requirements of lactating dairy cows, the analyzed calcium and phosphorus concentrations indicate that additional mineral supplementation would be required during feeding to ensure adequate mineral nutrition. Further in vivo studies are recommended to evaluate the effects of these coconut oil-based total mixed rations on feed intake, nutrient digestibility, rumen fermentation, milk yield, milk composition and animal health under practical production conditions.

6. Recommendation

Based on the findings of this study, it is recommended that the formulated total mixed rations containing graded levels of coconut oil be evaluated under in vivo feeding conditions using lactating dairy cows. Mineral supplementation, such as mineral blocks or commercial mineral premixes, should be provided to meet calcium, phosphorus and other mineral requirements. Future studies should assess the effects of these diets on dry matter intake, nutrient digestibility, rumen fermentation characteristics, milk yield, milk composition, feed efficiency, animal health and economic viability under practical dairy production systems.

Abbreviations

TMR	Total Mixed Ration
CO	Coconut Oil
NDF	Neutral Detergent Fibre
ADF	Acid Detergent Fibre
ADF	Acid Detergent Lignin
NFC	Non-fibre Carbohydrate (Starch and Sugars)

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Author Contributions

Antonio Jaime Manhique: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – review & editing, Writing–original draft

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Anthony Kingo'ri: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing

Isako Tura: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing

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Data Availability Statement

The data is available from the corresponding author upon reasonable request and part of it is reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interests.

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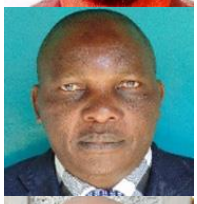
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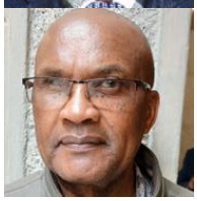
Biography



Antonio Jaime Manhique is a PhD student at Department of Animal Science, Egerton University, Kenya. He is also an assistant lecture at Instituto Superior Politécnico de Gaza, Mozambique since 2011. Graduated Masters in Animal Nutrition from Egerton University in 2017. He contributed to alternative feed ingredients for animal nutrition from which he published some manuscript. He worked in partnership with NGO such as Save the Children to support Mozambican communities developing sustainable feed alternatives in dry season for both monogastric and ruminants.



James Ondiek is a Professor at Department of Animal Science, Egerton University, Kenya. He completed his PhD in 2012 at Egerton University- Kenya with research topic on "Evaluation of tree and shrub forages as feed supplements to livestock in Kenya" His Masters in Animal Science was completed in 1998 at Makerere University. He has 95 Peer reviewed publications in refereed journals and presented 76 papers in scientific conference proceedings. He wrote extension materials including one (1) book, 9 booklets and 3 pamphlets. He has over 30 years of University teaching.



Anthony Kingo'ri is a professor in the Department of Animal Science, Egerton University, Kenya and the immediate former chairman of the department. He completed his PhD in Animal Nutrition in 2004. He has researched on locally available non-conventional feed resources as alternatives of imported ingredients like soya bean and fishmeal in livestock diets in Kenya. He is the programme academic leader of the MSc and PhD animal nutrition programmes in the department of animal science. He has supervised 6 PhD students and 10 MSc students to completion. He has also published several articles in peer-reviewed journals.



Isako Tura, senior Research Scientist in animal production at the Beef Research Institute, Kenya Agricultural and Livestock Research Organization (KALRO). He completed his PhD in Animal Nutrition in 2023 at Egerton University, Kenya focusing on Climate-resilient livestock systems. He has published over 20 papers in peer-review journals with other several as both author and co-author, under review for publications. He was awarded a distinction in 2023 for his work on feeding camel calves with a locally available plant-based milk replacer for enhanced performance in Kenya. As a senior scientist, he has led different research projects with successful results for increasing of livestock productivity in Kenya

Research Field

Antonio Jaime Manhique: Animal Nutrition, Greenhouse gases mitigation from livestock, Livestock Management Practices

James Ondiek: research in ruminant animal nutrition utilizing locally available feed resources, effects of climate change on livestock production

Anthony Kingo'ri: nutrient requirements of indigenous chicken, Prosopis pods as feed ingredient for chicken and rabbits, Grasshopper as a protein for chicken, Probiotics as mitigation against anti-nutritive factors in feedstuffs research

Isako Tura: Climate-resilient livestock systems, Animal nutrition, 3- Animal Genetic improvement