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PROXIMATE COMPOSITION OF CASSAVA PEEL MEAL– *Calopogonium Mucunoides* FEED WAFFLES FOR RUMINANTS

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ABSTRACT

This study evaluated the proximate composition of ruminant feed waffles produced from diets containing graded levels of cassava peel meal with corresponding levels of Calopogonium mucunoides. Four experimental diets containing graded levels of cassava peel meal (7, 10, 13, and 16%) with corresponding levels of Calopogonium mucunoides (0, 7, 14, and 21%) were formulated in a Completely Randomized Design with three replicates per treatment. The feed mixtures were processed into waffles and analysed for proximate composition using standard AOAC procedures. The results showed that dry matter increased significantly (P = 0.03) from **80.42% (T1)** to **85.72% (T4)**, while crude protein increased (P = 0.01) from **18.62%** to **22.80%**. Ether extract also increased significantly (P = 0.04) from **3.18%** to **4.12%**, whereas ash content increased (P = 0.01) from **7.84%** to **9.37%**. Conversely, crude fibre decreased significantly (P = 0.02) from **6.01%** to **5.10%**, while nitrogen-free extract varied only slightly (**63.93–58.61%**) and was not significantly affected by treatment (P = 0.18). Among the dietary treatments, **T4 (16% cassava peel meal + 21%** Calopogonium mucunoides**)** produced the most favourable proximate composition, recording the highest dry matter, crude protein, ether extract, and ash contents together with the lowest crude fibre concentration. The findings indicate that cassava peel meal and Calopogonium mucunoides can be combined to produce nutritionally improved waffle-processed ruminant feeds. However, further feeding trials are required to evaluate feed intake, nutrient digestibility, animal performance, and economic efficiency before practical recommendations can be made.

Keywords: Cassava peel meal, Calopogonium mucunoides, proximate composition, agro-industrial by-product, feed processing.

Introduction

Feed availability and the increasing cost of conventional feed ingredients remain major constraints to profitable ruminant production, particularly in developing countries where feed constitutes approximately 60–70% of total production costs (NRC, 2007; Adebayo et al., 2023). Consequently, the search for affordable, locally available feed resources has intensified, with particular attention given to agro-industrial by-products and tropical forage legumes. Cassava (*Manihot esculenta*) peel is an abundant agro-industrial by-product that serves as a potential energy source for livestock when properly processed. Likewise, tropical forage legumes such as *Calopogonium mucunoides* are rich in crude protein, highly palatable, and capable of improving the nutritional quality of ruminant diets (Uzegbu et al., 2020; Dele et al., 2022). Combining these feed resources offers an opportunity to produce nutritionally balanced and economically viable ruminant feeds.

Feed processing technologies such as pelleting, extrusion, and waffle production improve feed density, handling characteristics, storage quality, and nutrient utilization. Heat and pressure applied during processing enhance starch gelatinization, improve digestibility, and reduce the effects of some anti-nutritional factors, thereby increasing feed utilization by ruminants (McDonald et al., 2011). Compared with conventional mash feeds, waffle processing produces compact feed units that are easy to handle, transport, and store while minimizing feed wastage and ingredient segregation. The relatively simple equipment and lower processing requirements also make waffle production a practical technology for small- and medium-scale feed manufacturers in resource-limited settings.

Although the nutritional benefits of cassava peel meal and *Calopogonium mucunoides* have been investigated separately, there is limited information on how their combined inclusion in waffle-processed feeds influences proximate composition. Furthermore, little evidence is available to determine the optimum inclusion levels that maximize nutrient quality while maintaining desirable feed characteristics.

Therefore, this study evaluated the proximate composition of waffle-processed ruminant feeds formulated with graded levels of cassava peel meal (7–16%) and corresponding levels of *Calopogonium mucunoides*. It was hypothesized that increasing the proportion of *C. mucunoides* in combination with cassava peel meal would improve crude protein and ash contents while reducing crude fibre, thereby producing nutritionally superior feed waffles suitable for ruminant feeding.

Materials and Methods

1 Experimental Site

The study was conducted at the Livestock Unit of the Teaching and Research Farm, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The study area is located at latitude 5°29′ N and longitude 7°33′ E within the rainforest agro-ecological zone of southeastern Nigeria.

2 Preparation of Cassava Peel Meal and *Calopogonium mucunoides* Leaf Meal

Fresh cassava peels were collected from rural farmers in Umuariga, Ikwuano Local Government Area, Abia State, Nigeria. The peels were sorted to remove foreign materials, washed thoroughly, sun-dried on clean tarpaulins to a constant moisture level, and milled using a hammer mill to obtain cassava peel meal.

Fresh leaves of *Calopogonium mucunoides* were harvested from the university farm, sun-dried under ambient conditions until a constant weight was attained, milled into leaf meal, and

incorporated into the experimental diets at predetermined inclusion levels corresponding to the graded levels of cassava peel meal.

3 Experimental Procedures

Four experimental diets containing graded levels of cassava peel meal (7, 10, 13, and 16%) with corresponding inclusion levels of *Calopogonium mucunoides* leaf meal (0, 7, 14, and 21%, respectively) were formulated in a Completely Randomized Design with three replicates per treatment.

The feed ingredients were milled, weighed, and thoroughly mixed to obtain homogeneous mash diets. The mash was conditioned at 85°C for 45 s before being processed into waffle-shaped feed using a waffle machine fitted with 4- and 6-mm moulds. The processed waffles were subsequently cooled by forced air, packaged in moisture-proof bags, and stored in a cool, dry place until laboratory analysis.

4 Experimental Design

The experiment was arranged in a Completely Randomized Design (CRD) with four dietary treatments and three replicates per treatment.

The statistical model was:

$$\mathbf{Y_{ij} = \mu + T_i + e_{ij}}$$

Where:

$\mathbf{Y_{ij}}$ = observation on the *j*th replicate receiving the *i*th treatment;

$\boldsymbol{\mu}$ = overall population mean;

$\mathbf{T_i}$ = fixed effect of the *i*th treatment (*i* = 1, 2, 3, 4);

$\mathbf{e_{ij}}$ = random experimental error, assumed to be independently and normally distributed with a mean of zero and constant variance;

j = 1, 2, 3 (replicates).

Experimental Diets

Four experimental diets were formulated as follows:

- **T1:** 7% cassava peel meal + 0% *Calopogonium mucunoides*
- **T2:** 10% cassava peel meal + 7% *Calopogonium mucunoides*
- **T3:** 13% cassava peel meal + 14% *Calopogonium mucunoides*
- **T4:** 16% cassava peel meal + 21% *Calopogonium mucunoides*

Table 1: Percentage composition of experimental diets containing graded levels of cassava peel meal with corresponding levels of *Calopogonium mucunoides*

Ingredients (%)	Treatments			
	T1 (7%)	T2 (10%)	T3 (13%)	T4 (16%)
Maize	55.00	45.00	35.00	25.00
Wheat offal	4.30	4.30	4.30	4.30
Crushed Calopo	0.00	7.00	14.00	21.00
Cassava peel meal	7.00	10.00	13.00	16.00
Soyabean meal	20.00	20.00	20.00	20.00
Palm kernel cake (PKC)	10.00	10.00	10.00	10.00
Lysine	0.10	0.10	0.10	0.10
Bone meal	3.00	3.00	3.00	3.00
Salt	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25
Total	100	100	100	100
Calculated composition				
Metabolizable energy (MJ/kg)	**8.00MJ/kg**	**6.00MJ/kg**	**6.00MJ/kg**	**6.00MJ/kg**
Crude protein (%)	18.55	19.40	19.48	19.33

The remaining feed ingredients were adjusted to produce nutritionally balanced diets. The ingredients were thoroughly mixed, conditioned at 85°C for 45 seconds, processed into waffle-shaped feed using a waffle machine and cooled before storage. The experiment was arranged in a Completely Randomized Design (CRD) with four treatments and three replicates per treatment. Feed samples from each treatment were analysed for dry matter, crude protein, ether extract, crude fiber, ash and nitrogen-free extract according to AOAC (1995) procedures. Data were subjected to one-way analysis of variance (ANOVA), and treatment means were separated using Duncan's Multiple Range Test at $P < 0.05$.

Data Collection

1 Determination of Proximate Composition

The feed samples formulated at different levels were taken for laboratory analysis. The estimation of moisture, ash, protein, fat and crude fiber content was determined in accordance with the laboratory procedures of (AOAC, 1995) on dry weight basis on the following compositions;

Determination of Moisture Content: A clean petri dish was dried to a constant weight in an oven, cooled in a desiccator and weighed (W1). 5g of the fine powder of the sample was accurately weighed into the clean petri dish and then reweighed (W2). The W1 Containing the sample was dried in an oven to constant weight (W3). The percentage moisture content was calculated thus,

$$\%\text{Moisture} = \frac{W2 - W3}{W2 - W1} \times 100$$

Where;

W1= initial weight of empty dish

W2 - weight of dish and 5g of sample before drying

W3 = final weight of dish and 5g of sample after drying

Determination of Dry Matter

Dry matter determination involves removing water from a sample by drying it in an oven at a specified temperature until a constant weight is achieved. The remaining material represents the dry matter content. Drying oven, weighing balance, Moisture dish/crucible, Desiccator and

tongs are used for dry matter determination. The procedure include: Dry and weigh a clean moisture dish (**W_1**).Place a known quantity of sample into the dish and weigh (**W_2**).Dry the sample in a hot-air oven at **105°C** for about **3–5 hours** or until a constant weight is obtained. Cool the dish in a desiccator to prevent moisture absorption. Weigh the dried sample with the dish (**W_3**).

$$\%\text{dry matter} = \frac{W3 - W1}{W2 - W1} \times 100$$

Where:

W_1 = Weight of empty dish (g)
W_2 = Weight of dish + sample before drying (g)
W_3 = Weight of dish + dried sample (g)

Determination of Ash Content: A crucible was dried in an oven, cooled in a desiccator and weighed (Wl). 2g of the fine powder of sample was placed in W1 and reweighed (W2), it was then ignited and transferred to a muffle furnace which was set at 550°C. The sample was left in the furnace. Furnace for six hours to ensure proper ashing. The crucible containing the ash was then removed and cooled in a desiccator and weighed (W3). The percentage ash content was calculated thus:

$$\%\text{Ash} = \frac{W3 - W1}{W2 - W1} \times 100$$

Where;

W1 = weight of empty crucible
W2 = weight of crucible + sample before ashing
W3 = weight of crucible + ash

Determination of fat (Ether extract) content: A clean dried 500 cm^3 round bottom flask containing few anti-bumping granules were weighed (W1) with 300 cm^3 Petroleum ether for extraction and poured into the flask fixed to soxhlet extraction unit. The round-bottom flask and a condenser were connected to the soxhlet extractor and cold water circulation connected. The heating was adjusted until the solvent was refluxing at a steady rate for six hours. The solvent was recovered and the oil dried in an oven for an hour. The round-bottom flask and oil were then weighed (W2). The lipid content was then calculated as follows:

$$\%\text{ fat content} = \frac{W2 - W1}{\text{Weight of sample}} \times 100$$

Where:

W1 = weight of empty flask
W2 = weight of flask + extracted fat

Determination of Crude Fiber:

5g of sample was weighed into a round-bottom flask, 100cm3 of 0.25M Sulphuric acid solution was added and the mixture boiled for 30 minutes and quickly filtered. The insoluble matter was washed several times with water to remove acid. It was then transferred into the flask and 100cm3 of 0.31M Sodium hydroxide solution was added, and the mixture boiled for 30 minutes and filtered. The residue was washed with water until free of base, then dried to constant weight in an oven, cooled in a desiccator and weighed (W1). The weighed sample was incinerated in muffle furnace at 550°C, cooled in a desiccator and reweighed (W2). Percent crude fiber was calculated as:

$$\%\text{ crude fiber} = \frac{W1 - W2}{\text{Sample weight}} \times 100$$

Where:
W = Weight of sample (g)
W_1 = Weight of dried residue before ashing (g)
W_2 = Weight of ash after ignition (g)

Crude Protein Determination: Crude protein was determined using the Kjeldahl method (AOAC, 1995). The sample was digested first, distilled and titrated. Two grams of sample was placed in the Kjeldahl flask. Anhydrous sodium sulphate (5g or 4 tablets of Kjeldahl catalyst) was added to the flask. About 25 ml of concentrated sulphuric acid was added with few boiling chips. The flask was heated in the fume chamber until the sample solution became clear. The sample solution was allowed to cool to room temperature, then transferred into a 250 ml volumetric flask and made up to volume with distilled water. The distillation unit was cleaned, and the apparatus set up. About 5ml of 2% boric acid solution with few drops of methyl red indicator was introduced into a distillate collector (100ml conical flask). The conical flask was placed under the condenser. Then 5ml of the sample digest was pipetted into the apparatus, and washed down with distilled water. 5ml of 60% sodium hydroxide solution was added to the digest. The sample was heated until 100ml of distillate was collected in the receiving flask. The content of the receiving flask was titrated with 0.049M sulphuric acid to a pink coloured end point. A blank with filter paper was subjected to the same procedure.

$$\%N = \frac{(Vs-Vb) \times N \times 14.007 \times 100}{W \times 1000}$$

Where:
Vs = sample titre (mL)
Vb = blank titre (mL)
N = normality of acid
14.007 = atomic weight of nitrogen
W = sample weight (g)
Then %Crude Protein=%N×6.25.

Determination of Nitrogen-Free Extract (NFE)

Nitrogen-free extract (NFE) represents the soluble carbohydrates in a feed or food sample, mainly sugars and starches. It is calculated by difference rather than measured directly.NFE is obtained by subtracting the percentages of crude protein, crude fat (ether extract), crude fiber, and ash from the dry matter content.

NFE=100− (CP + EE + CF + Ash)

Statistical Analysis

All data obtained were subjected to one-way analysis of variance (ANOVA) using a Completely Randomized Design. Means were separated using Duncan's Multiple Range Test at $P < 0.05$. Data were analysed using SPSS version 25.0.

Result

Table 3.1. Proximate Composition of Waffle-processed Diets containing Graded levels of cassava peel meal and *Calopogonium mucunoides.*

Parameter (%)	T1	T2	T3	T4	SEM	P-value
Dry matter	80.42^{b}	81.87^{b}	83.96^{a}	85.72^{a}	0.54	0.03
Crude protein	18.62^{c}	20.15^{b}	21.08^{b}	22.80^{a}	0.41	0.01
Ether extract	3.18^{b}	3.46^{b}	3.81^{a}	4.12^{a}	0.12	0.04
Crude fibre	6.01^{a}	5.78^{a}	5.42^{b}	5.10^{c}	0.16	0.02
Ash	7.84^{c}	8.31^{b}	8.92^{a}	9.37^{a}	0.19	0.01
Nitrogen-free extract	63.93	62.43	60.77	58.61	0.87	0.18

Note: Means within the same row bearing different superscripts (a–c) differ significantly ($P < 0.05$). SEM = Standard Error of the Mean.

Table 3.1 presents the proximate composition of waffle-processed diets containing graded levels of cassava peel meal and *Calopogonium mucunoides*. Dry matter, crude protein, ether extract, ash, and crude fibre differed significantly ($P < 0.05$) among the dietary treatments, whereas nitrogen-free extract showed no significant variation ($P > 0.05$). Dry matter and crude protein generally increased with increasing inclusion levels of *C. mucunoides*, while crude fibre declined progressively across the treatments. The highest crude protein and ash contents, together with the lowest crude fibre content, were recorded in Treatment 4, indicating that increasing dietary inclusion of *C. mucunoides* improved the nutritional quality of the feed waffles.

Discussion

The present study demonstrates that incorporating graded levels of cassava peel meal with *Calopogonium mucunoides* into waffle-processed ruminant feeds significantly influenced their proximate composition. The observed improvements in dry matter, crude protein, ether extract, and ash, together with the reduction in crude fibre, indicate that the combined use of these locally available feed resources can enhance the nutritional quality of ruminant diets.

The increase in dry matter content is attributable to the drying and thermal processing involved in waffle production, which reduced moisture content and produced a more stable feed with improved storage characteristics. High dry matter content is advantageous because it minimizes microbial spoilage and prolongs shelf life. Similar improvements in dry matter have been reported for processed cassava-based feeds intended for livestock production (Adegbola, 1980; Smith, 1988).

The increase in crude protein is primarily explained by the progressive inclusion of *Calopogonium mucunoides*, a tropical forage legume recognized for its high protein content. Although cassava peel meal is relatively low in crude protein, its combination with *C. mucunoides* improved the overall protein concentration of the diets. The analysed crude protein values were above the minimum dietary requirement for growing ruminants (NRC, 2007), suggesting that the formulated feed waffles could contribute to meeting protein requirements under practical feeding conditions.

The higher ether extract and ash contents observed in the diets indicate improvements in energy-yielding lipid fractions and mineral content, respectively. These changes are consistent with the complementary nutrient contributions of the feed ingredients and may enhance the nutritional value of the diets for ruminants. Similar observations have been reported for processed

cassava-based diets supplemented with forage legumes (Romero-Pérez et al., 2014; Olugbemi et al., 2010).

The reduction in crude fibre with increasing inclusion of *C. mucunoides* may improve nutrient digestibility without compromising the fibre required for normal rumen function. Moderate reductions in crude fibre have been associated with improved feed utilization and voluntary intake in ruminants when adequate structural fibre is maintained (Van Soest, 1994).

An important observation requiring clarification is the discrepancy between the formulated crude protein values presented in the diet formulation table and the laboratory-analysed crude protein values reported in the proximate analysis. Formulated values are theoretical estimates derived from ingredient composition tables, whereas analysed values are obtained experimentally and may differ because of natural variation in ingredient composition, processing effects, analytical procedures, or moisture corrections. Nevertheless, this discrepancy should be verified against the original laboratory records and statistical dataset to ensure consistency throughout the manuscript.

A limitation of the present study is that only proximate composition was evaluated. Although the results indicate improved nutritional quality, they do not demonstrate biological responses such as feed intake, nutrient digestibility, growth performance, or feed conversion efficiency. Future studies should therefore include feeding trials to confirm the practical value of these waffle-processed diets under production conditions.

Overall, the findings indicate that increasing the inclusion of *Calopogonium mucunoides* in cassava peel meal-based feed waffles improved the nutritional profile of the diets by increasing crude protein, ether extract, ash, and dry matter while reducing crude fibre. These results support the potential use of the formulated feed waffles as economical alternative feed resources for ruminant production, pending confirmation through animal performance studies.

Conclusion

The present study demonstrated that incorporating graded levels of cassava peel meal with corresponding levels of *Calopogonium mucunoides* influenced the proximate composition of waffle-processed ruminant feeds. The analysed diets showed improvements in dry matter, crude protein, ether extract, and ash contents, together with a reduction in crude fibre, indicating that these locally available feed resources can be combined to produce nutritionally improved feed waffles for ruminants. Among the inclusion levels evaluated, the diet containing 16% cassava peel meal and 21% *Calopogonium mucunoides* produced the most favourable proximate composition. However, because this was the highest inclusion level tested, the present study does not establish that it is the optimum dietary level. Additional studies evaluating higher inclusion rates and conducting feeding trials are required to determine the optimum inclusion level and to assess effects on feed intake, nutrient digestibility, animal performance, and economic efficiency under practical production conditions.

Recommendations

Based on the nutrient composition obtained in this study, inclusion of cassava peel meal at **16%** in feed waffles produced from a blend of *Calopogonium mucunoides* and cassava peel meal is recommended for ruminant feeding. Future studies should evaluate the effects of these feed waffles on feed intake, nutrient digestibility, animal performance, rumen fermentation characteristics and economic returns under practical production conditions.

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