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Phytochemical and Mineral Composition of Raw Cocoyam (*Xanthosoma Mafafa*) Tuber Meal

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Abstract

This study evaluated the phytochemical and mineral composition of raw cocoyam (*Xanthosoma mafafa)* tuber meal, a potential alternative feed source for livestock. Tubers of the *X. mafafa* variety of cocoyam were harvested from Owerri, Imo State. The tubers were cleaned, washed, and left to dry in the shade, then weighed. After that, they were peeled, cut into smaller sizes, and ground into pulp using a locally fabricated grinder. The wet pulp was collected and blanched within three hours. The cocoyam tuber meal was dried under shade for seven days to retain its quality, stored in a plastic bag, labeled, and later taken to the laboratory for analysis. Anti-nutritional factors, including tannins (1771.80 ± 87.85mg/kg), oxalates (374.25 ± 170.66 mg/kg), phenols (726.43 ± 390.10 mg/kg), phytates (44.73 ± 0.60 mg/kg), and trypsin inhibitors (992.78 ±22.58 mg/kg). Mineral analysis demonstrated significant levels of potassium (19966.22 ± 99.40 mg/kg), sodium (4293.55 ± 13.10 mg/kg), magnesium (1638.43 ± 15.20 mg/kg), and calcium (522.60 ± 10.98 mg/kg). Microminerals such as iron (96.40 ± 1.98 mg/kg), zinc (64.31 ± 1.80 mg/kg), manganese (17.97 ± 0.71 mg/kg), and copper (.20 ± 0.20 mg/kg) were also present. The Ca and Na ratios were determined as 0.76 and 0.216, respectively. Raw *X. mafafa* tuber meal has high levels of tannins, oxalates, phenols, phytates, and trypsin inhibitors, posing challenges that can be mitigated with processing. Its mineral content suggests low and mild supplementation for poultry diets. Further research on processing methods is needed for optimal livestock use.

Keywords: *X. mafafa*, cocoyam, phytochemical, mineral, tuber meal

Introduction

The challenge of providing sufficient, high-quality food, particularly through animal agriculture, for the growing global population is compounded by diminishing natural resources. The FAO [1] projected that by 2050, the global population will surpass 9.2 billion, with food demand rising by 35-56% [2]. For Nigeria with a population of 213.4 million and a 3.1% annual growth rate [3], enhancing food production is essential for food security. However, the high cost of conventional feed materials, such as maize, a staple crop and the primary energy source for poultry feed (50-60%), is in high demand, creating competition between human and animal consumption. This has prompted research into alternative feed sources. Alternative grains like sorghum and millet which can replace maize in animal feeds remain expensive due to their use in human food and industry. Root crops such as cassava and cocoyam have been researched for poultry diets [5]. Nigeria, a leading cassava and cocoyam producer, faces rising cassava prices due to industrial use [6]. Cassava, a staple crop in Nigeria, has been used as a maize substitute in poultry diets, reducing costs [7]. However, increased industrial use of cassava, particularly in bakery and alcohol production, has made it less affordable for livestock feed in recent times [8].

In contrast, cocoyam, another root crop, is underutilized despite Nigeria being a leading global producer [9]. Cocoyam has superior nutritional value compared to other roots and tubers, though lower than maize [10]. Cocoyam (*Xanthosoma spp*), rich in carbohydrates and protein, shows promise, but its anti-nutrients require processing and additives like betaine hydrochloride for effective use [11]. One species of cocoyam, *Xanthosoma mafafa*, offers potential as animal feed but contains anti-nutrients like oxalates and tannins, which limit its use. These anti-nutrients contribute to the acrid nature of the tuber, causing irritations in the mouth, throat, and skin, and have been reported to cause inflammation of tissues, especially when subjected to limited processing [11-13]. The variability in the concentrations of certain phytochemicals such as phenol and oxalate further complicate the reliable use of this tuber meal as a consistent feed ingredient.

Despite the presence of high levels of anti-nutrients, *X. mafafa* tuber meal is a potentially valuable feedstuff due to its richness in macro and micro minerals [14]. The levels of these minerals suggest that, with appropriate processing to reduce anti-nutrient levels, *X. mafafa* tuber meal could be a cost-effective and nutritionally beneficial alternative to traditional feed ingredients like maize [15,16]. This study explores the feasibility of utilizing *X. mafafa* tuber meal in livestock and poultry diets, thereby providing a potentially sustainable and locally available feed resource. This study aimed to evaluate the phytochemical and mineral compositions of *X. mafafa* tuber meal.

Materials and Methods

Study Area

The study was carried out at the Teaching and Research Farm of the School of Agriculture and Agricultural Technology (SAAT), Federal University of Technology (FUTO) in Imo state, southeastern Nigeria which lies between latitude 5^o 4^1, and 6^o 3^1 N and longitude 6^o 15^1 and 7^o 34^1 E, at an altitude of about 90m above sea level, except for elevations of about 200 m at the Okigwe highlands [17]. The mean annual rainfall is usually 2500 mm, while the mean daily temperature ranges from 26.5 - 27.5^0 C and humidity from 70 - 80% (18).

Production of cocoyam tuber meal (CTM)

Tubers of *X. mafafa* variety of cocoyam was harvested from waste dump sites at Owerri, Imo State, where they grow luxuriantly [19]. The tubers were cleaned, and washed with potable water to remove remaining sands, and impurities, and left in a shade to dry after which they were weighed with a weighing scale, and their weights recorded. Thereafter, the cocoyam was peeled and cut into smaller sizes, before grinding them into pulp using a locally fabricated grinder to produce the wet cocoyam tuber meal. The pulp of the cocoyam tuber meal (CTM) was collected with a plastic bucket and used for the blanching experiment within three hours of its production [11]. The CTM was dried in a plastic sheet under shade for 7 days and subsequently stored on a plastic bag until needed for laboratory analysis.

Determination of phytochemical concentrations of the CTM

This was carried out according to the methods described by AOAC [20] to determine the oxalate, phenol, tannin, phytate and trypsin inhibitor concentration in the CTM.

***A. Determination of oxalate concentration of CTM*:** This was carried out according to the method described by Karamad *et al*. [21]. One gram of the CTM sample was weighed into a 250 ml conical flask and 75 ml of $3H_2SO_4$ was added. Thereafter, it was filtered using Whatman No 1 filter paper and 25 ml of the filtrate was pipetted into a flask and heated to near boiling and was titrated while hot against 0.05M $KMnO_4$ solution until a faint pink colour persists for at least 30 seconds using methyl red as indicator. The oxalate content was calculated by taking 1 ml of 0.05M $KMnO_4$ as equivalent to 2.2 mg of oxalate.

***B. Determination of total phenol concentration*:** About 100 mg (0.1 g) of the CTM was weighed into a conical flask and 100 ml of distilled water added to dissolve the sample. 1 ml of the solution was then pipetted into a test tube and 0.5 ml 2N Folin-Ciocalteu reagent and 1.5 ml 20% $NaCO_3$ solution added. Up to 10 ml of the solution was made with distilled water and shaken vigorously and allowed to stand for 2 hours, and absorbance read at 765 nm. The following concentrations of garlic acid standard, 0.5, 1, 2, 4, 6, 8 and 10 mg was prepared and the absorbance's of the garlic acid concentrations read off. A calibration curve for the garlic acid standard was drawn, i.e., absorbance against concentration and by tracing the absorbance of the CTM sample down the concentration axis the concentration of the sample it was extrapolated.

$$\text{Calculation: Phenol content mg/kg} = \frac{\text{Conc. obtained in mg/l} \times \text{volume of sample}}{\text{Sample weight} \times 1000} \quad (1)$$

C. Determination of tannin 2 (Preferable method): The tannin concentration in the CTM sample was determined as follows; 1g of dry well blended sample was weighed into a flask and 25 ml of solvent mixture (80:20 that was Acetone:10% glacial acetic acid) agitated and added and left to stand for 30 min at room temperature for proper extraction. The mixture was filtered or transferred into a centrifuge tube, and centrifuge at 2500 rpm for 15 min., and the supernatant decanted thereafter into a graduated measuring cylinder, and volume recorded. The absorbance of the supernatant was then read.

Standard tannic acid: Tannic acid standards 0.5, 1, 2, 4, 6, 8 and 10 mg was prepared, and the absorbencies of the tannic acid concentrations read off at a wavelength of 500 nm. A calibration curve for the tannic acid standards was drawn (that is absorbance against concentration), and the absorbance of the sample extrapolated by tracing down the concentration axis to obtain the tannic acid concentration of the sample.

Calculation

$$\text{Tannic Acid content mg/kg} = \frac{\text{Conc. obtained in mg/l x volume of sample}}{\text{Sample weight}} \quad (2)$$

D. Determination of phytate (phytic acid) concentration: 2 g of the CTM was weighed into a 250 ml conical flask and 100 ml of 2% concentrated HCl added and allowed to soak for 3 hours and then filtered. To this, 50 ml of the filtrate was pipetted into a 250 ml beaker and 107 ml of distilled water added to improve acidity. Then, 10 ml of 0.3% ammonium thiocyanate solution was added as indicator, and titration was done with standard iron III chloride ($FeCl_3$) solution which contains 0.00195 g iron/ml until a brownish yellow color appeared and persist for 5 min. The phytic acid content was calculated as shown below

Calculation:

$$\text{Phytic acid mg/kg} = \frac{0.00195 \text{ x volume of titrant } (FeCl_3) \text{ x vol. of sample}}{\text{Sample weight}} \quad (3)$$

E. Determination of trypsin inhibitor concentration: The trypsin inhibitor in the CTM samples was determined using the following procedure: 1 g of dry well blended CTM sample was weighed into a flask, and 50 ml of 0.5M NaCl added, then the mixture was stirred for 30 min and thereafter centrifuged at 1500 rpm for 5 minutes. The filtrate was kept, and 10 ml pipetted into another flask and 2 ml of standard trypsin solution of known concentration (say 2 mg/l) added. The absorbance at 410 nm was measured using 10 ml of same substrate (the sample filtrate) as blank. Also, 1, 2, 4, 6, 8, and 10 mg/l standard trypsin inhibitor were prepared, and their absorbencies measured at 410 nm. A standard graph of absorbance against concentration was plotted, and the absorbances of the sample extrapolated by tracing down the concentration axis to obtain the trypsin inhibitor concentration of the samples.

Calculation

$$\text{Trypsin inhibitor content mg/kg} = \frac{\text{Conc. obtained in mg/l x volume of sample}}{\text{Sample weight}} \quad (4)$$

Data Analysis

The data generated from the study were entered into the data sheet of the Statistical Packages for Social Sciences [2], data sheet, where means, range, standard deviation, and coefficient of variation were estimated for each parameter.

Results and Discussion

Phytochemical analysis of raw X. maffafa tuber meal

The result of the phytochemical analysis of raw *X. maffafa* tuber meal is shown on Table 1. The table shows that the mean values of tannin, oxalate, phenol, phytate and trypsin inhibitors in the *X. maffafa* tuber meal were 1771.80 ± 87.85, 726.43 ± 390.10, 374.25 ± 170.66, 44.73 ± 0.60, 992.78 ±22.58 mg/kg respectively which indicates high values of these phytochemicals in the tuber meal. The CV values of the tannin, phytate and trypsin inhibitor were narrow (1.33 – 4.95) while those of phenol and oxalate were very wide (53.70 and 45.60 respectively), indicating that the later means should not serve as reference values for the parameters in the study area.

Generally, the major drawback to the use of cocoyam tuber as feedstuff is their high contents of anti-nutrients, which lowers their palatability because of the acrid nature of the tuber that causes irritations in the mouth, throat, and skin. The raw tuber has also been reported to cause inflammation of tissues, especially when they are subjected to limited processing before use [14]. The common anti-nutrients found in cocoyam include phytates, oxalates, tannins, saponins, hydrogen cyanide, trypsin, and alpha amylase inhibitors (Abdurashid and Agwunobi, 2012; McEwan *et al.* [23].

Ukwu [1] reported lower 1066.19, 270.49, 24.67 and 633.01 mg/kg concentrations of tannin, phenol, phytate and trypsin inhibitors respectively in raw *X. maffafa* tuber meal from Imo State. Abdulrashid and Agwunobi, [22] also reported much lower tannin (152.02 mg/kg) and phytate (129.10 mg/kg) in sundried raw *X. sagittifolium tuber* meal. Igbua *et al.* [24], also recorded a lower oxalate value of 232 mg/kg in maize compared to the mean oxalate value of 374.25 Mg/Kg obtained in *X. maffafa* in the present study. The trypsin inhibitor value obtained in *X. maffafa* tuber meal is within the range of 500 – 1000 mg/kg reported by Igbua *et al.* [25] for maize. The similar trypsin inhibitor values in *X. maffafa* compared to maize indicate that *X maffafa* could suitably replace maize in diets of poultry with little or no trypsin inhibitory effect. These results however indicate the need for adequate processing in order to reduce the concentration of oxalate and other antinutrients inherent in the raw *X. maffafa* tuber meal.

Table 1: Phytochemical values of raw *X. maffafa* tuber meal

Parameters	CT 1	CT 2	CT 3	Range	Mean ± SD	% CV
Tannin (mg/kg)	1859.55	1651.74	1804.10	1651.74 -1859.55	1771.80 ± 87.85	4.95
Phenol (mg/kg)	1026.65	817.91	996.84	817.91 - 1026.65	726.43 ± 390.10	53.70
Oxalate (mg/kg)	451.70	497.30	468.80	451.70 - 497.30	374.25 ± 170.66	45.60
Phytate (mg/kg)	43.89	45.22	45.09	43.89 – 45.22	44.73 ± 0.60	1.33
T. inhibitor (mg/kg)	1021.91	966.86	989.57	966.86 - 1021.91	992.78 ±22.58	2.27

CT 1,2,3, (Cocoyam Tuber Replicate 1,2,3,); SD (Standard Deviation), CV (Coefficient of Variation), T. inhibitor (Trypsin inhibitor).

Mineral analysis of X. maffafa tuber meal

The mean macro mineral concentrations in the raw *X. maffafa* tuber meals are shown in Table 2. From the result potassium recorded the highest mean value followed by sodium and magnesium, while calcium recorded the lowest. The CV values were generally narrow and ranged from 0.30 – 2.10, indicating that the mean values could serve as reference for the industry. Amadi and others, [26] reported higher calcium (2345.00 mg/kg), Mg (2361.33 mg/kg) and phosphorus (785.50 mg/kg) but lower K (11815.00 mg/kg) and sodium (1246.00 mg/kg) contents in *X. maffafa* tuber meal from Imo State. Azene and Molla [27] also reported 60.83, 37.61, 710.00 and 186.74 mg/100g phosphorus, Na, K and Ca respectively in *C. esculenta* tuber meals from Ethiopia. This study indicating that *C. esculenta* has probably higher Ca and lower K than *X. maffafa*. Similarly, table 2 showed that the raw *X. maffafa* tuber meal contained higher iron (96.40 mg/kg and Zn (64.31 mg/kg) than manganese (19.97 mg/kg) and Cu (9.20 mg/kg). The CV across mean values were again narrow (2.10 – 3. 97), indicating that the mean value could serve as reference at the study area. Ukwu [11] reported much higher iron, copper and zinc values (732.50, 45.06, and 216.98 mg/kg) respectively in *X. maffafa* tuber meals from same study area. Wada *et al. (*27) however reported similar mineral values in *X. sagittifolium* from Ethiopia with the values ranging from 24.80 – 37.40, 82.00 – 98.80, 10.40 – 11.40 and 30.07 -31.20 mg/kg for Mn, Fe, Cu and Zn respectively. Then Zinc content is practically lower in the *X. sagittifolium* while the Mn content is higher. These results indicates that the *X. maffafa* tuber meal is rich in both macro and micro minerals, with the order of mineral concentrations being K > Na > Mg > Ca > Fe > Zn > Mn > Cu.

Table 2: Mineral concentrations (mg/kg) in *X. maffafa* tuber meal

Parameters	CT1	CT2	CT3	Mean ± SD	Range	% CV
(a)Macro minerals						
Calcium	524.4	534.96	508.26	522.60 ± 10.98	508.26 - 534.98	2.1
Magnesium	1617.82	1643.68	1653.79	1638.43 ± 15.20	1617.82 - 1653.79	0.92
Potassium	19881.06	20075.43	19942.17	19966.22 ± 99.40	19881.06 - 20075.43	0.41
Sodium	4275.6	4306.39	4268.67	4293.55 ± 13.10	4275.60 - 4306.39	0.3
Phosphorus	697.135	694.64	662.97	678.91 ± 12.93	662.97 - 694.64	1.9
(b)Micro minerals						
Manganese	18.69	16.99	18.22	17.97 ± 0.71	16.99 - 18.69	3.97
Iron	96.94	93.75	98.52	96.40 ± 1.98	93.75 -98.52	2.1
Copper	9.42	8.95	9.21	9.20 ± 0.20	8.95 - 9.42	2.1
Zinc	62.4	66.64	63.89	64.31 ± 1.80	62.40 - 66.65	2.73

CT 1,2,3, (Cocoyam Tuber Replicate 1,2,3,); SD (Standard Deviation), CV (Coefficient of Variation)

Table 3 shows mineral ratios in the *X. maffafa* tuber meal. The result shows that the mean Ca:P and Na K ratios in the tuber meal were 0.76 and 0.216 respectively with the CV values being narrow (1.24 – 2.18 respectively). Ukwu [11] reported a much higher 2.99 and lower 0.11 Ca:P and Na:K ratios respectively in *X. maffafa* from the same study area. Azene and Molla [28] also reported similar higher 3.07 Ca:P and lower 0.05 Na:K ratios in *C. esculenta* tuber meals from Ethiopia. The Ca:P ratio of 2:1 and Na:K ratio of 1 – 1.5 have been reported as optimal for broilers and other forms of poultry [29], indicating that *X. maffafa* tuber meals-based diets will require appropriate mineral supplementation.

Table 3: Mineral ratios in the raw *X. maffafa* tuber meal

	CT1	CT2	CT3	Mean	Range	CV
Ca/P	0.75	0.77	0.77	0.76 ± 0.01	0.75 – 0.77	1.24
Na/K	0.22	0.22	0.21	0.216 ± 0.004	0.21 - 0.22	2.18

CT 1,2,3, (Cocoyam Tuber Replicate 1,2,3,); CV (Coefficient of Variation)

Conclusion

The phytochemical analysis of raw X. maffafa tuber meal revealed high concentrations of tannins, oxalates, phenols, phytates, and trypsin inhibitors, with mean values of 1771.80 mg/kg, 374.25 mg/kg, 726.43 mg/kg, 44.73 mg/kg, and 992.78 mg/kg respectively. The narrow coefficient of variation (CV) for tannin, phytate, and trypsin inhibitors suggests that these values are consistent and can be used as reference points. However, the wide CV for phenol and oxalate indicates variability, suggesting that these values may not be reliable references. The high levels of anti-nutrients present pose a challenge for using X. maffafa tuber meal as feed due to its potential to cause irritation and inflammation. However, adequate processing can mitigate these effects, making it a viable alternative to traditional feed ingredients like maize. The mineral analysis indicated that *X. mafafa* tuber meal is rich in both macro and micro minerals, with potassium having the highest concentration, followed by sodium, magnesium, and calcium. The micro mineral content also showed significant levels of iron and zinc. The mineral ratios, particularly Ca:P and Na:K, highlight the necessity for appropriate mineral supplementation when using *X. mafafa* tuber meals in poultry diets to meet optimal nutritional requirements.

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