

Functional Properties, Proximate Composition of Water Yam–Cocoyam Composite Flour and Sensory Qualities of *Ekpang nkukwo* Made from the Flour Blends

Ekanem, M. C.^{1,2}; Inyang U. E.²; and Elijah, A. I.²

¹Department of Food Technology, Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene, Nigeria.

²Department of Food Science and Technology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

Corresponding author: fonyekanem@gmail.com

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Abstract

This study evaluated the functional properties, proximate composition and energy value of water yam-cocoyam composite flour and sensory properties of *Ekpang nkukwo* made from the flour blends. The blending ratios used were 100:00, 90:10, 80:20, 70:30, 60:40 and 50:50 (water yam: cocoyam flour). The 100% water yam flour served as control sample. Result showed that bulk density, foam capacity and wettability increased from 0.70-0.88 g/ml, 9.06 – 20.46% and 15.03-17.50 s. respectively while swelling capacity, water absorption and oil absorption capacities as well as gelation temperature decreased from 78.57- 46.66 ml/g, 2.07-1.76 mL/g 1.22-0.73 mL/g and 81.00 - 75.66 °C respectively with increase in cocoyam flour supplementation. Protein, fat, ash and fibre increased significantly ($p<0.05$) from 1.33-2.27%, 0.89-1.04%, 1.76 -2.17% and 1.53-2.69% respectively while carbohydrate and energy value decreased significantly ($p<0.05$) from 94.49 - 91.83% and 391.29 - 385.76 kcal/100 g respectively with increase in cocoyam flour supplementation. Sensory evaluation of *Ekpang nkukwo* revealed that 70:30 had a significantly ($p<0.05$) higher score for all the sensory attributes evaluated. The findings showed that supplementation of water yam with cocoyam flour enhanced the nutritional quality of water yam-cocoyam composite flour. Based on the sensory attributes, 70% water yam flour+30% cocoyam composite flour has been recommended for preparation of *Ekpang nkukwo*.

Keywords: Water Yam, Cocoyam, Composite Flour, Functional Properties, *Ekpang nkukwo*.

Introduction

Ekpang nkukwo is a traditional delicacy native to the Efik and Ibibio ethnic groups of Southern Nigeria, typically prepared from grated water yam tubers and cocoyam corms into paste, wrapped in cocoyam leaves and cooked with palm oil, periwinkle, fish, and other condiments (Udensi *et al.*, 2011). The health benefits of *Ekpang nkukwo* are based on the major ingredients, which are water yam, cocoyam and leafy greens.

Cocoyam is valued for its digestible starch derived from taro corm ranging from 1 – 5 μm particle size which is significantly smaller than that of corn and wheat (James *et al.*, 2020). It is highly medicinal for diabetic patients because it has low starch content, easily digestible and contains protein more than the other root tubers (Oloye *et al.*, 2020). Cocoyam also contains vitamin (thiamine, riboflavin, and niacin) and minerals (phosphorus, zinc,

magnesium, copper, iron, and calcium) in reasonable amount (James *et al.*, 2019). Water yam (*Dioscorea alata*, L.), the most widely grown among the family of *Dioscorea* spp., is a valuable source of carbohydrate to supply human needs of energy and nutrients, especially in arid regions. Its high water content gives rise to its name 'water yam. According to Wireko-Manu *et al.* (2013), water yam contains high level of total dietary fibre (TDF) which makes it suitable for management of pile, constipation and diabetes. It is also rich in vitamin C, beta carotene, vitamin E, calcium, potassium, magnesium, copper and antioxidants.

Preparation of *Ekpang nkukwo* usually involves grating of peeled water yam and cocoyam into a smooth paste using a locally made manual grater called *Okwok*. The preparation process is very tedious, time-consuming and often times causes injury during grating of the water and cocoyam due to the sharp edges of the grater and remain home based or artisanal because it is being carried out on small batches with rudimentary equipment. The grating technique is characterized by inconsistent product quality due to the slippery nature of the yam, when a blender or a greater is used and most times, it is accompanied with poor hygiene and unacceptable standard (Filli *et al.*, 2011). Thus, many people who cherish the dish are discouraged from preparing and eating it at home due to the stress involved which also contribute to the high cost of *Ekpang nkukwo* in commercial outlets.

It is believed that *Ekpang nkukwo* could be prepared from water yam-cocoyam composite flour instead of the traditional paste obtained from grated water yam and cocoyam mixture. Composite flour is an innovative flour that has attracted much attention in research as well as food product development (Hasmadi *et al.*, 2014; Emmanuel *et al.*, 2019). It is defined as a mixture of flours obtained from tubers which are rich in starch such as cassava, yam, potato, and protein-rich flour and cereals, with or without wheat flour that is created to satisfy specific functional characteristics and nutrient composition (Noorfarahzilah *et al.*, 2014). Composite flour has better nutritional value such as minerals, vitamins, fibres and proteins than flour milled from any specific cereal alone. Shanti *et al.* (2005) reported that composite flour mixture could provide a balanced nutrient and functionality. Functional properties such as water absorption, oil absorption, swelling capacity, and foaming ability directly affect processing, cooking performance and product acceptability (Chandra and Samsher, 2013). Given the increasing interest in optimizing indigenous foods for improved functionality and consumer preference, composite flours technology, involving the blending of different flours, enhances the functional and nutritional properties of food products (Adebowale *et al.*, 2009).

Preparation of *Ekpang nkukwo* using water yam-cocoyam composite flour could address the challenges associated with the grating process. However, the sensory properties of *Ekpang nkukwo* made from water yam-cocoyam composite flour have not been investigated. Also, the optimal ratio of water yam flour: cocoyam flour for preparation of an acceptable quality of *Ekpang nkukwo* is not known. Therefore, this study was carried out to determine the functional properties, proximate composition and energy value of water yam-cocoyam composite flour and sensory properties of *Ekpang nkukwo* made from the blends.

Materials and Methods

Samples Collection and Preparation

Freshly harvested water yam (*Dioscorea alata*) and cocoyam (*Colocasia esculenta*) tubers and corm were purchased from Akpan Andem market, Uyo, Akwa Ibom State, Nigeria. Identification and authentication was done by Dr. Johnny Imoh, a Botanist at the Pharmacy Herbarium, University of Uyo, Uyo. The tubers were peeled, washed, sliced, oven-dried at 65 °C, and milled into fine flour using attrition hammer mill. The flours were sieved (250 µm) and stored in airtight containers prior to analysis. Water yam flour and cocoyam flour were processed following the method of Udo *et al.* (2022) as presented in figure 1.

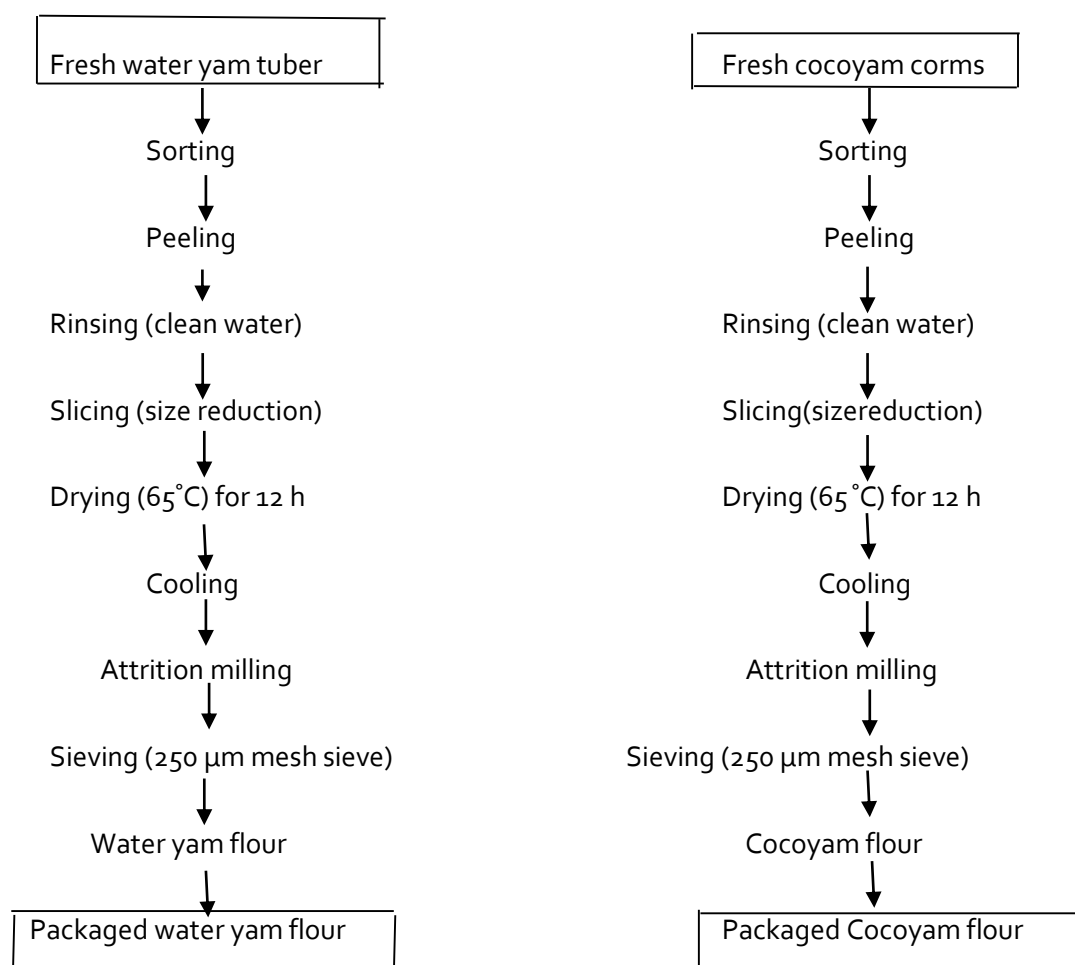


Figure 1: A flow diagram for the processing of water yam and cocoyam flour

Source: Udo *et al.* (2022)

Formulation of Water Yam and Cocoyam Flour Blends

Water yam flour was supplemented with cocoyam flour using the following ratios: 100:00, 90:10, 80:20, 70:30, 60:40 and 50:50 (water yam flour: cocoyam flour) as shown in Table 1. A 100 % water yam flour served as the control sample.

Table:1. Formulation of water Yam-Cocoyam flour blends

Samples	Water yam (g)	Cocoyam (g)
WC ₁	100	0
WC ₂	90	10
WC ₃	80	20
WC ₄	70	30
WC ₅	60	40
WC ₆	50	50

WC: Water yam-cocoyam composite flour

Methods of Analysis

Functional Properties Analysis

Functional properties of the flour determined included bulk density, swelling capacity, water absorption capacity, oil absorption capacity, foaming capacity, gelatinization temperature and wettability.

Determination of Bulk Density

This was determined using the method described by Onwuka (2005). Two grammes (2 g) of sample was filled in a 10 ml graduate cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample.

The volume was recorded.

$$\text{Bulk density} = \frac{\text{Weight of Sample (g)}}{\text{Volume of Sample (cm}^3\text{)}}$$

Determination of Swelling Capacity

Swelling capacity was determined according to the method given by Robertson *et al.* (2000). Two grammes (2 g) of flour sample was mixed with 10 ml of distilled water in a calibrated cylinder at room temperature ($30 \pm 2^\circ\text{C}$). After equilibration for 18 h, the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gramme of original sample dry weight.

$$\text{Swelling capacity \%} = \frac{\text{Change in volume of sample}}{\text{Original weight of samples}}$$

Determination of Water Absorption Capacity

The method described by Onwuka (2005) was used. Two grammes (2 g) of the flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 ml of water. It was shaken on a plate form tube rocker for 1 min at room temperature ($30 \pm 2^\circ\text{C}$). The sample was

allowed to stand for 30 min and centrifuged at 120 °C for 30 min. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC (\%)} = \frac{\text{Amount of water added} - \text{Free water}}{\text{Weight of Sample}} \times \text{Density of water} \times 100$$

Determination of Oil Absorption Capacity

The method by Onwuka (2005) was used. Two grammes (2 g) of the flour was mixed with 10 ml refined corn oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2 °C) for 1 h. It was centrifuged at 160 °C for 20 min. The volume of the free oil was recorded and decanted. Fat absorption capacity was expressed as mL of oil bound by 100 g dried flour.

$$\text{OAC (\%)} = \frac{\text{Amount of Oil added} - \text{Free Oil}}{\text{Weight of Sample}} \times \text{Density of Corn oil} \times 100$$

Determination of Foaming Capacity

Foaming capacity (FC) was determined according to the method described by Onwuka (2005). Two grammes (2 g) of flour sample was weighed and added to 50 ml distilled water in a 100 ml measuring cylinder. The suspension was mixed and properly shaken to foam and the total volume after 30 s was recorded. The percentage increase in volume after 30 s was expressed as foaming capacity.

$$\text{Foaming capacity (\%)} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

Determination of Gelatinization Temperature

Gelatinization temperature was determined following the method of Shinde (2001). Two grammes (2 g) of flour sample was weighed accurately in triplicate and transferred to 20 ml screw capped tubes. Ten (10) ml of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature.

Determination of Wettability

One grammes (1 g) of sample was added into a 25 mL graduated cylinder. It was inverted and clamped at a height of 10 cm from the surface of a 600 mL beaker containing 500 mL of distilled water. The finger was removed to allow the test material to be dumped. The wettability is the time required for the sample to become completely wet.

Proximate Composition Determination

The AOAC (2005) method was used to determine proximate composition while total energy was estimated using Atwater conversion factors (4 kcal/g for protein, 9 kcal/g for fat, and 4 kcal/g for carbohydrate).

Determination of Crude Protein

Digestion: Two grammes (2 g) each of the flour sample was weighed into a 100 mL Kjeldahl flask. Exactly 2.5 g of anhydrous Na_2SO_4 , 0.5 g of CuSO_4 and 5 mL of concentrated H_2SO_4 was added into the flask and allowed to stand for 2-3 h. The flask was heated in a fume chamber, gently boiling initially for fumes to appear and later heated more intensely until the solution was clear. After cooling, the content was transferred into a 100 mL volumetric flask and made up to the mark with repeated washing using distilled water.

Distillation: A 5 mL volume of each sample digest was mixed with 5 mL of boric acid indicator and 3 drops of methyl red in a 100 mL conical flask and then steam distilled into conical flask using 100 mL of 60 % NaOH. Distillation was done for 5 min until colour change from purple to green. Exactly 5 ml distillate was collected and titrated against 0.01 N HCl to a purple colour end point. The percentage protein was calculated as follows:

$$\% \text{ Nitrogen} = \frac{T \times 14.01 \times 0.01}{2.0 \times 100} \times 20 \times 100$$

where:

T = Titre value

2.0g = Weight of the sample

20 = Dilution factor

0.01 = Normality of HCL

14.01 = Atomic mass of nitrogen

% Protein = % Nitrogen x 6.25 (where 6.25 = conversion factor of protein)

Determination of Crude Fat Content

Two grammes (2 g) of the sample were weighed into a weighed thimble of the apparatus. Petroleum ether (300 mL) was filled into the round bottom flask and the extractor thimble was sealed with cotton wool. The soxhlet apparatus was allowed to reflux for about 6 h after which the thimble was removed. Petroleum ether was collected from the flask after which it was dried at 105 °C for 1 h in a hot air oven, cooled in a dessicator and weighed. This procedure was carried out for all the samples.

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100$$

Determination of Crude Fibre

Exactly 2 g of the sample was weighed and mixed with 200 ml of H_2SO_4 (1.25 % solution) and allow to boil for 30 min. The solution was filtered through Muslin cloth fixed to a funnel. This was washed with boiling water until completely free from acid. The residue was return into 200 ml boiling NaOH and allows to boiled for 30 min. The mixture was allowed to cool and filtered through filter paper (Whatman No. 1) and the residue obtained was then cooled in a desiccator and weighed. The weighed sample residue was ashed in a

muffle furnace at 550 °C for 30 min. The sample was removed from the furnace when its temperature is 200 °C. It was cooled in a dessicator and weighed. The loss in weight of the incinerated residue before and after incineration was taken as the crude fibre content, percentage crude fibre was calculated using the expression:

$$\% \text{ crude fibre} = \frac{\text{Loss in Weight on ignition}}{\text{Weight of food sample}} \times 100$$

Determination of Total Ash

Two grammes (2g) of well blended sample was weighed into a shallow ashing dish (a crucible) that was ignited, cooled in dessicator and weighed soon after reaching room temperature. Both the crucible and their content was transferred into a muffle furnace ignited at 550 °C. Ashing was done for 8 h, crucible and the ashed sample was removed from the muffle furnace, moistened with a few drops of water to expose the un-ashed carbon, dried in the oven at 100 °C for 4 h and re-ashed at 550 °C for another hour. This was removed from muffle furnace, cooled in a dessicator and weighed soon after reaching room temperature. Percentage ash was calculated using this expression:

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample used}} \times 100$$

Determination of Carbohydrate Content (by difference)

The total carbohydrate content was estimated as the difference between 100 and the total sum of moisture, protein, fat, crude fibre and ash as described by AOAC (2005).

% carbohydrate = 100 – (% moisture + % ash + % protein + % fat + % crude fibre).

Determination of Moisture Content

Cleaned crucibles were dried in hot air oven at 100 °C for 1hour to obtain a constant weight and then cooled in a desiccator. Two grammes (2 g) of each of the samples was weighed into the different crucibles and dried at 100 °C until a constant weight was obtained.

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where, W₁ = Initial weight of the empty crucible

W₂ = Weight of dish + sample before drying

W₃ = weight of dish + sample after drying

Preparation of *Ekpang nkukwo*

The composite flour samples were reconstituted into paste, wrapped in cocoyam leaves and prepared according to the method described by Udobong *et al.* (2024) with slight modification. The method of Udevi (2019) was adopted, with slight modification, for ingredients formulation as presented in Table 2 while the flow chart for the preparation of *Ekpang nkukwo* is presented in figure 2.

Table 2: Ingredients Formulation for Preparation *Ekpang nkukwo*

Ingredient	WC1	WC2	WC3	WC4	WC5	WC6
Water yam(g/100 g)	100	90	80	70	60	50
Cocoyam (g/100 g)	0	10	20	30	40	50
Salt(g)	1	1	1	1	1	1
Seasoning cube(maggi)(g)	4	4	4	4	4	4
Dry fish(g)	10	10	10	10	10	10
Pepper(g)	5	5	5	5	5	5
Cray fish (g)	10	10	10	10	10	10
Water (ml)	200	200	200	200	200	200
Palm oil (ml)	15	15	15	15	15	15
Periwinkle (g)	15	15	15	15	15	15
Meat(g)	2	2	2	2	2	2
Onions(g)	5	5	5	5	5	5
Scent leave (g)	2	2	2	2	2	2

Source: Udevi. (2019) with slight modification

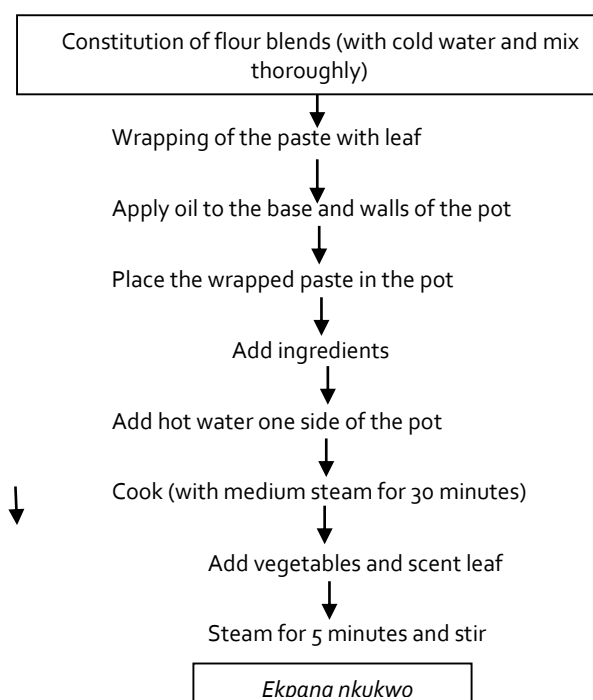


Fig. 2: Flow Diagram for the Preparation of *Ekpang nkukwo*

SOURCE: Udobong *et al.* (2024) with slight modification

Sensory Evaluation

A 30-member semi-trained panel drawn from the staff and students of Akwa Ibom State Polytechnic, Ikot Osurua, Akwa Ibom State was used for sensory assessment of the samples. Stone and Sidel (2012) recommended 20-50 members for a semi-trained panel. A 9-point hedonic scale ranging from like extremely (9) to dislike extremely (1) as described

by Iwe (2014) was used for the evaluation. Each of the samples was rated for taste, aroma, appearance, mouthfeel, consistency and general acceptability. The samples were coded with three-digit random numbers and presented in identical plates. Water was provided for the panelists to rinse their mouth in between tasting of the samples.

Statistical Analysis

Data obtained were subjected to a one-way Analysis of Variance (ANOVA) using statistical package for Social Science (SPSS). Means were separated using Duncan Multiple Range Test (DMRT) at $P < 0.05$.

Results and Discussion

Functional Properties of Water Yam-Cocoyam Composite Flour

Table 3 presents the functional properties of water yam–cocoyam composite flours. Bulk density increased significantly ($p < 0.05$) with increasing cocoyam supplementation, from 0.70 g/ml for the 100% water yam flour to 0.88 g/ml for the blend containing 50% water yam flour and 50% cocoyam flour, suggesting that cocoyam has a denser particle structure due to smaller granules size, higher starch compactness and lower porosity (Adebowale *et al.*, 2005; Amandikwa, 2012). Bulk density is a measure of heaviness of solid samples, which is important for determining packaging requirements, material handling and application in the food industry (Falade and Okafor, 2015). According to Akubor and Badifu (2004), flours with high bulk densities (> 0.7 g/ml) can be used as thickeners in food products,

The swelling capacity, water absorption and oil absorption capacities decreased from 78.57 mL/g, 2.07 mL/g and 1.22 mL/g respectively, in the control sample (100% water yam flour) to 46.66 mL/g, 1.76 mL/g and 0.73 mL/g in the blend supplemented with 50% cocoyam flour. Water yam (*Dioscorea alata*) is known to have higher swelling power in comparison to other species of yam (Baah *et al.*, 2006, Walter *et al.*, 2000) as observed in this study but cocoyam starch granules contain higher amylase and more crystalline region which restrict water penetration and limit swelling capacity and solubility (Sefa-Dedeh and Agyir, 2004). Swelling capacity is the measure of the starch ability to absorb water and swell, and also reflects the extent of associative forces in the starch granules (Awuchi *et al.*, 2019), which is largely controlled by the strength and character of the micellar network within starch granules. The low swelling capacity obtained in this study is attributed to the highly ordered internal arrangement in their starch granules (Nwafor, 2020). Flours with high swelling powers are suitable for making dough with high elasticity (Baah and Ellis, 2005).

The decrease in water absorption capacity (WAC) of the flour blend with increase in the proportion of cocoyam flour may be connected to the proportion of amylose and amylopectin in the starch granules and the difference in the physical structure of the starch granules in water yam (Hauwa *et al.*, 2016). Water absorption capacity is the amount of water (moisture) taken up by food/flour to achieve the desirable consistency and create quality food product (Awuchi *et al.*, 2019).

It was also observed that oil absorption capacity significantly declined from 1.22 mL/g in the control sample (100% water yam) to 0.73 mL/g in the blend containing 50% water yam and

50% cocoyam. Cocoyam flour has lower lipid-binding proteins, hence decreasing oil absorption capacity as supplementation increased. Oil absorption capacity is an essential functional property that contributes to enhancing mouth feel while retaining the food products' flavor (Iwe *et al.*, 2016).

There was no significant ($p > 0.05$) difference in gelation temperature among the control sample, sample supplemented with 10% and sample supplemented with 20% cocoyam flour, beyond which it decreased significantly ($p < 0.05$). However, gelation temperature of sample supplemented with 40% cocoyam flour was not significantly ($p > 0.05$) different from the one supplemented with 50% cocoyam flour. Cocoyam starch typically has lower gelatinisation temperature due to weaker intermolecular forces within granules (Moorthy, 2002). Water yam starch has a more ordered structure, requiring more heat to disrupt the crystalline structure, this lowers gelation temperature and could improve energy efficiency in food processing. This is the temperature at which gelatinization of starch take place (Chandra and Samsher, 2013). Gelation characteristic is an important functional property of food components such as starch, protein, etc. as food additive or material, and is directly related to its texture and its viscoelasticity (Awuchi *et al.*, 2019).

Conversely, the foaming capacity and wettability increased from 9.06% and 15.03 s. for the 100% water yam flour to 20.46 % and 17.50 s. for the blend supplemented with 50% cocoyam flour. Cocoyam flour contains proteins with better surface-active properties, enhancing foam formation and higher amylose in cocoyam may also increase viscosity of the continuous phase, stabilising foam (Sefa-Dedeh and Agyir-Sackey, 2004). Foaming capacity measures the amount of interfacial area created by protein during foaming (Zhu *et al.*, 2017). Flours can produce foams due to surface-active proteins (Adebowale and Lawal, 2003). Protein is mainly responsible for foaming. Foaming capacity and stability generally depend on the interfacial film formed by the proteins, which maintains the suspension of air bubbles and slows down the coalescence rate (Awuchi *et al.*, 2019).

The increase in wettability of the flour blend as the proportion of cocoyam flour increased in the blend may due to that fact that Cocoyam (*Colocasia esculenta*) flour exhibits higher starch crystalline, fibre content and reduced porosity which slows water penetration (Amandikwa, 2012). The result revealed that the 100% water yam flour wetted faster than other flour blends. However, the higher wettability values recorded for the flour blends indicated that the blends could be used for improving the texture of dough meal and certain dishes, than the control flour. Wettability in food formulations could be affected by some factors such as surface polarity or contact surface, polarity of the molecules, porosity, size and heterogeneity of the flour (Anon *et al.*, 2021). According to Iwe *et al.* (2017), wettability is a function of dispersing flour samples in water and the sample with the lowest wettability dissolves fastest in water. Wettability is said to be the time (seconds) required to wet all the particles of a solid material (flour) (Okafor *et al.*, 2015).

Table 3: Functional Properties of Water Yam-Cocoyam Composite Flour

Parameters	Blending ratios (water yam flour: cocoyam flour)					
	100:00	90:10	80:20	70:30	60:40	50:50
Bulk density (g/ml)	0.70 ^f ±0.05	0.74 ^e ±0.01	0.77 ^d ±0.01	0.81 ^c ±0.01	0.85 ^b ±0.01	0.88 ^a ±0.05
Swelling capacity (ml/g)	78.57 ^a ±2.77	77.95 ^a ±2.00	77.33 ^a ±2.51	62.22 ^b ±3.84	59.61 ^b ±1.08	46.66 ^c ±1.01
Water absorption (mL/g)	2.07 ^a ± 0.11	2.05 ^a ±0.00	2.06 ^a ±0.11	1.96 ^b ± 0.05	1.83 ^b ±0.05	1.76 ^c ±0.05
Oil absorption capacity (mL/g)	1.22 ^a ±0.17	1.20 ^a ± 0.00	1.00 ^b ± 0.00	0.93 ^b ± 0.11	0.80 ^c ±0.11	0.73 ^c ±0.11
Foam capacity (%)	9.06 ^c ±1.52	10.58 ^c ±0.90	12.09 ^b ±0.86	13.92 ^b ±1.25	17.71 ^a ±1.10	20.46 ^a ±2.46
Gelation temp. (°C)	81.00 ^a ±1.73	81.21 ^a ±1.00	81.33 ^a ± 1.15	79.00 ^b ±1.00	76.00 ^c ±0.00	75.66 ^c ±0.57
Wettability (sec)	15.03 ^c ±7.23	15.89 ^c ±6.00	16.00 ^c ±5.13	16.76 ^b ±4.04	17.00 ^a ±1.35	17.50 ^a ±4.00

Values are means± SD of triplicate determinations. Means with different superscripts within the same row are significantly p<0.05) different.

Proximate Composition and Energy Value of Water Yam-Cocoyam Composite Flour (in dry matter basis)

Table 4 shows the proximate composition and energy values of water yam-cocoyam composite flour (on dry matter basis). Moisture, protein, fat, ash and fibre content significantly (p<0.05) increased with increase cocoyam flour supplementation in the blends ranging from 3.16%, 1.33% 0.89%,1.76% and 1.53% respectively for the control sample to 3.38%, 2.27%, 1.04%, 2.17% and 2.69% respectively for the blend supplemented with 50% cocoyam flour. The significant increase in the protein content (3.16 to 3.38%) of the flour samples with increase in the proportion of cocoyam could be attributed to the level of protein content in cocoyam flour than water yam flour (Adeyanju *et al.*, 2019). Protein content of cocoyam is higher (1.12% for taro and 1.55% for tannia) when compared to water yam and other tropical root crops (Owusu-Darko, 2014). Protein regulates metabolic processes in the form of enzymes, hormones and acts as body defense mechanism to fight foreign infections as well as maintain cells and body tissues (Winarno, 2008). According to Kumar *et al.* (2017), proteins present in foods are required for body building and repair. Proteins are needed for the maintenance of body tissues. They also play a vital role in the synthesis of plasma proteins, hemoglobin, hormones, enzymes, coagulation factors and antibodies.

The fat content in the samples were observed to increase as the proportion of cocoyam flour increased in the blend (Udo *et al.* (2022). High-fat diets considerably increase the amount of energy required by body (Aiyesanmi and Oguntokun, 1996: Udo *et al.*, 2022). High fat flours can also be used as flavor enhancers and to improve the palatability of dishes in which they are used. This suggests that this product would be high-energy foods suitable for athletes, military personnel, and others who require a lot of energy to function.

Ash content of the water yam-cocoyam flour (1.76 – 2.17%) increased as the proportion of cocoyam flour increased in the composite flour. The ash content of the water yam-cocoyam flour reported in the present study was found to be within the ash content of water yam-cocoyam flour reported by Udo *et al.* (2022). Ash content is known to reveal the composition of total inorganic minerals in foods. This could be attributed to the rich mineral content of the incorporated cocoyam flour which is also reported by Udo *et al.* (2022). The

mineral content of the flour is linked to the ash content, which is mainly influenced by two factors: flour types and the milling process. It was reported by Bodor *et al.* (2024), Aiyesanmi and Oguntokun (1996) and Udo *et al.* (2022) that flours with low ash content can be used for all purposes and flours with higher ash content are suitable for the production of diet products.

Also, fibre content in the composite flour used in this study increased as the proportion of cocoyam flour increased in the samples which was also reported by Udo *et al.* (2022). Fibre content was noticeably high in the sample containing 40% cocoyam flour. The high crude fibre content of cocoyam than water yam flour could be due to the dried radicles' remnants (Abebe *et al.*, 2018). Similar values were reported by Egounlety (2002). Fibre is needed to assist in digestion, keep the gastrointestinal tract healthy and blood sugar stable. It also helps in slows down the release of glucose during digestion, so cells require less insulin to absorb that glucose.

Conversely, the carbohydrate content of the flour blend decreased as the proportion of cocoyam flour increased as reported by Udo *et al.* (2022). The decrease could be attributed to the low carbohydrate content by cocoyam (*Colocasia esculenta*) than water yam as well as their processing method.

The energy values obtained for the formulated samples were found to be within the range of 385.76 to 391.29 kcal/100 g. These values represent the amount of energy in food that can be supplied to the body for maintenance of basic body function such as breathing, circulation of blood, physical activities and thermic effect of food (Nwafor and Kanu, 2020). Although protein is listed among the four principal classes of energy yielding macronutrients, it is not considered as a key supplier of dietary energy (Prentice, 2005).

Table 4: Proximate Composition and Energy Value of Water Yam-Cocoyam Composite Flour (Dry Matter Basis)

Parameters	Blending ratios (water yam flour: cocoyam flour)					
	100:00	90:10	80:20	70:30	60:40	50:50
Moisture (%)	3.16 ^f ± 0.06	3.20 ^e ± 0.05	3.25 ^d ± 0.06	3.29 ^c ± 0.06	3.34 ^b ± 0.06	3.38 ^a ± 0.06
Protein (%)	1.33 ^f ± 0.03	1.52 ^e ± 0.02	1.70 ^d ± 0.05	1.89 ^c ± 0.07	2.08 ^b ± 0.04	2.27 ^a ± 0.03
Fat (%)	0.89 ^f ± 0.06	0.92 ^e ± 0.07	0.95 ^d ± 0.03	0.98 ^c ± 0.06	1.01 ^b ± 0.03	1.04 ^a ± 0.03
Ash (%)	1.76 ^f ± 0.07	1.84 ^e ± 0.03	1.92 ^d ± 0.07	2.00 ^c ± 0.08	2.08 ^b ± 0.08	2.17 ^a ± 0.06
Fibre (%)	1.53 ^f ± 0.06	1.76 ^e ± 0.03	2.00 ^d ± 0.05	2.23 ^c ± 0.08	2.46 ^b ± 0.03	2.69 ^a ± 0.06
Carbohydrate (%)	94.49 ^a ± 0.05	93.96 ^b ± 0.02	93.43 ^c ± 0.09	92.90 ^d ± 0.07	92.37 ^e ± 0.06	91.83 ^f ± 0.06
Energy Value kcal/100g	391.29 ^a ± 0.02	390.93 ^b ± 0.02	389.07 ^c ± 0.02	387.98 ^d ± 0.03	386.89 ^e ± 0.02	385.76 ^f ± 0.05

Values are means ± SD of triplicate determinations. Means with different superscripts within the same row are significantly ($p < 0.05$) different.

Sensory Properties of *Ekpang nkukwo* Prepared from Water Yam-Cocoyam Composite Flour

Table 5 presents results of sensory attributes while figure 3 is a pictorial presentation of *Ekpang nkukwo* prepared from water yam-cocoyam composite flour. The sensory attributes of *Ekpang nkukwo* were significantly ($p < 0.05$) affected by blending ratio of cocoyam and water yam flour in the composite blend.

The score ranged from 7.00 to 8.50 for taste, 6.95 to 7.10 for aroma, 7.15 to 7.82 for appearance, 5.30 to 8.70 for mouthfeel, 5.80 to 8.10 for consistency and 5.35 to 8.00 for general acceptability. *Ekpang nkukwo* prepared from 70% water yam and 30% cocoyam was rated significantly ($p < 0.05$) higher in sensory attributes (taste, aroma, appearance, texture, mouthfeel, consistency and general acceptability) than other samples. The 100% water yam sample was less acceptable due to its softer texture and lower cohesiveness, while higher cocoyam proportions ($\geq 40\%$) resulted in firmer texture and slightly reduced palatability.



Fig. 3. *Ekpang nkukwo* prepared from the Water Yam and Cocoyam Composite Flour
W = water yam, C = cocoyam

Table 5. Sensory mean scores of *Ekpang nkukwo* made from water yam cocoyam flour blends

Parameters	Blending ratios (water yam flour: cocoyam flour)					
	100:00	90 :10	80:20	70 :30	60:40	50:50
Taste	7.00 ^d ±0.10	7.50 ^c ±0.09	7.95 ^b ±0.12	8.50 ^a ±0.03	7.90 ^b ±0.15	7.55 ^c ±0.05
Aroma	7.00 ^a ±0.05	7.10 ^a ±0.12	6.95 ^a ±0.06	7.05 ^a ±0.10	7.04 ^a ±0.09	7.01 ^a ±0.05
Appearance	7.15 ^b ±0.07	7.20 ^b ±0.06	7.35 ^b ±0.10	7.62 ^a ±0.05	7.70 ^a ±0.03	7.82 ^a ±0.60
Mouthfeel	5.30 ^d ±0.10	6.60 ^c ±0.02	7.90 ^b ±0.08	8.70 ^a ±0.05	7.80 ^b ±0.03	7.75 ^b ±0.04
Consistency	5.80 ^d ±0.03	6.00 ^c ±0.10	6.82 ^b ±0.07	7.95 ^a ±0.10	8.05 ^a ±1.05	8.10 ^a ±0.07
General Acceptability	5.35 ^f ±0.15	5.65 ^e ±0.03	6.30 ^d ±0.04	8.00 ^a ±0.13	7.50 ^b ±0.05	7.10 ^c ±0.06

Means with different superscripts at the row differ significantly at $p < 0.05$

Conclusion

The study demonstrated that incorporating cocoyam into water yam flour significantly improved bulk density, foam capacity, protein, fibre, and ash contents of the composite flour while reducing swelling capacity, water absorption, carbohydrate, and energy values. *Ekpang nkukwo* prepared from 70:30 water yam–cocoyam flour blends was most acceptable to consumers. Thus, supplementation of water yam flour with 30% cocoyam flour is recommended for enhanced nutritional and sensory quality of *Ekpang nkukwo*. Studies on storage stability of the composite flour should be carried out to ascertain the shelf life of the flour.

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