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CHEMICAL COMPOSITION OF WATER YAM (*DIOSCOREA ALATA*)–COCOYAM (*COLOCASIA ESCULENTA*) COMPOSITE FLOUR SUPPLEMENTED WITH COWPEA (*VIGNA UNGUICULATA*) FLOUR AND CONSUMER ACCEPTABILITY OF *EKPANG NKUKWO* MADE FROM THE FLOUR BLENDS

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ABSTRACT: *This study evaluated the chemical composition of water yam-cocoyam composite flour (70: 30) supplemented with cowpea flour and sensory characteristics of Ekpang nkukwo prepared from the flour blends. Water yam-cocoyam composite flour was supplemented with cowpea flour as follows: 100:00, 90:10, 80:20, 70:30 and 60:40. A 70:30 water yam flour: cocoyam flour served as the control. Proximate, mineral and vitamin composition were evaluated to assess the nutritional quality of the flour blends while sensory evaluation was carried out on Ekpang nkukwo prepared from the flour blends. Result showed that protein, fat, ash and fibre increased significantly ($p<0.05$) from 1.89-20.54%,0.98-1.28%, 2.00-6.17%, 2.23-3.65% respectively while carbohydrate and energy decreased significantly ($p<0.05$) from 92.90-68.38%, 387.98-367.12 kcal/100 g respectively with increase in cowpea flour supplementation. Similarly, mineral (potassium, calcium, zinc, iron) and vitamin (beta carotene, vitamin B_1, B_2, B_3, B_9 and C) contents increased significantly ($p<0.05$) with increase in cowpea flour supplementation. However, sodium content of the flour blend decreased significantly ($p<0.05$) with increase in cowpea flour supplementation. Sensory attributes of Ekpang nkukwo prepared from the flour blends revealed no significant ($p>0.05$) difference in appearance, taste, aroma, mouthfeel, consistency and general acceptability scores between Ekpang nkukwo prepared from the control sample (water yam-cocoyam composite flour without cowpea supplementation) and that of 10% cowpea supplemented flour blend. However, beyond the 10% cowpea flour supplementation, sensory scores decreased significantly ($p<0.05$) with increase in cowpea flour supplementation. This study recommends the use of 10% cowpea flour supplemented yam–cocoyam composite flour for preparing nutritionally enhanced Ekpang nkukwo without compromising consumer acceptability of the product.*

KEYWORDS: Water yam flour, Cocoyam flour, Cowpea flour, Composite flour, proximate composition, *Ekpang nkukwo*, Consumer acceptability.

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INTRODUCTION

Ekpang nkukwo (water yam-cocoyam pottage) is a traditional delicacy native to southeastern Nigeria, particularly among the Efik and Ibibio ethnic groups of Akwa Ibom and Cross River States respectively. It is also popular in Cameroon among the Bantu tribe, Bakweri (Eze, 2022). It is typically made from grated water yam and cocoyam wrapped in tender cocoyam leaves known as *nkukwo* and cooked with various types of fresh or smokes meat, dry fish, crayfish, periwinkle and other spices with palm oil rubbed inside the base of the pot. However, since the original cocoyam leaves used for the delicacy is not readily available, other vegetables like pumpkin leaf, scent leaf, lettuce and spinach can be used as substitute (Udevi, 2019; Piate *et al*., 2023).Despite its cultural significance and appealing taste, *Ekpang nkukwo* may not fully meet contemporary dietary requirements in terms of nutritional adequacy. Its nutritional value is largely dependent on the tuber and corm composition, which is generally high in carbohydrates but low in protein and some micronutrients (Udensi *et al*., 2012).To address this concern, there is potential for supplementation by incorporating locally available ingredients such as cowpea, thereby enhancing their nutritional profile and relevance to modern dietary needs.

The incorporation of legumes such as cowpea (*Vigna unguiculata* L. Walp) flour into root and tuber-based foods has been recognized as an effective approach to enhance their protein and micronutrient content (Adeleke and Odedeji, 2010; Olaoye *et al*., 2020). This legume is readily available, inexpensive and a popular part of traditional food system. Cowpea along with other legumes are recognized as important sources of protein (Agazounon *and* Houndekon, 2004; Affrifah *et al*., 2021). Cowpea is a nutritious food source rich in protein (24%), dietary fibre (11%), and potassium (1112 mg/100 g) but low in lipids (<2%) and sodium (16 mg/100 g) Department of Agriculture (USDA, 2021). Cowpea protein has appreciable amounts of essential amino acids except cysteine and methionine (Affrifah *et al*., 2021). The high protein content represents a major advantage in the use of cowpea in nutritional products for infant and children's food and to compensate for the large proportion of carbohydrates often ingested in African diets (Oyeyinka *et al*., 2013).Cowpea is rich in lysine, dietary fibre and essential minerals (Boye *et al*., 2010). Therefore, formulating composite flour from water yam, cocoyam and cowpea can improve both the nutritional and sensory attributes of *Ekpang nkukwo* and similar indigenous dishes. This research aimed at evaluating the chemical composition and sensory characteristics of *Ekpang nkukwo* made from varying blends of water yam–cocoyam flour supplemented with cowpea flour.

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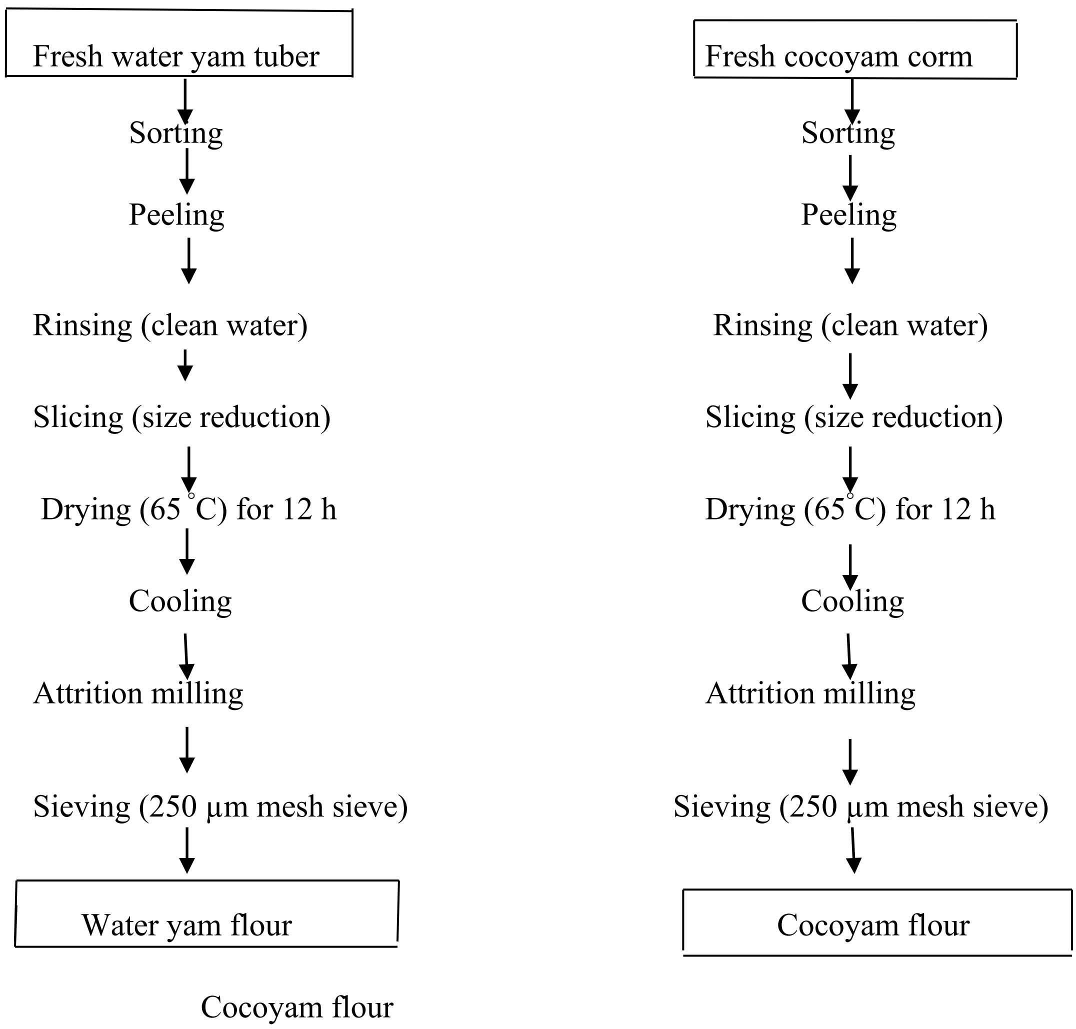
MATERIALS AND METHODS

Samples Collection and Preparation

Freshly harvested water yam (*Dioscorea alata*) tubers and cocoyam (*Colocasia esculenta*) 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 for 12 h, 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)*

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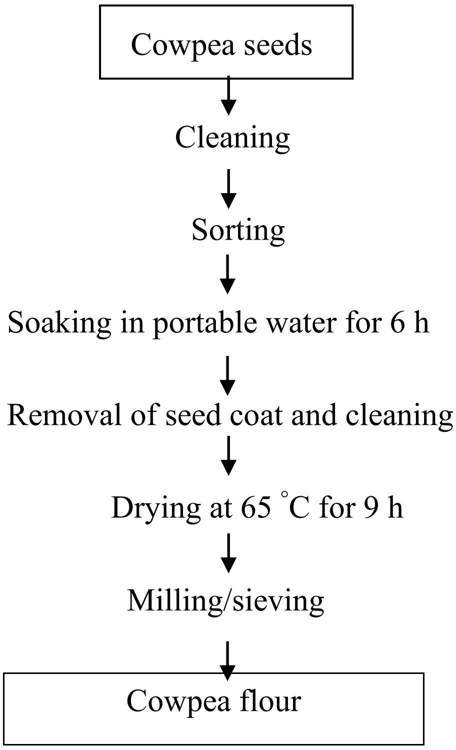
PROCESSING OF COWPEA FLOUR

The method of Osunbitan *et al.* (2015) was used for the processing of cowpea flour. Five kilogrames (5 kg) of cowpea seeds was weighed and sorted. The sorted were seeds soaked in portable water for 6 h and then the seed coats removed manually. The seeds were further rinse in water until they were clean and free of impurities. Thereafter, they were dried in an air oven (NAAFSCO BS, OVH – 102, China) at 65 °C for 9 h and milled using a hammer mill (Cu – 600 Glufex medicals and scientific, UK). They flour were sieved (250 µm) and kept in a dry, air tight container and stored at ambient temperature (27±2 °C) for further use. Cowpea flour was processed following the method of Osunbitan *et al.* 2015) modified as presented in figure 2.

Processing of Cowpea Flour

Fig. 2. A flow diagram for the processing of cowpea flour



Source: *Osunbitan et al. (2015) slight with modification.*

Formulation of Water Yam-Cocoyam Flour Blend Supplemented With Cowpea Flour

Water yam/ cocoyam flour was supplemented with Cowpea flour using the following ratios: 100:00, 90:10 80:20, 70:30, 60:40(water yam-cocoyam flour: cowpea flour) as shown in table 1.A 100% water yam-cocoyam serves as the control sample.

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Table 1.Formulation of water-cocoyam flour blends supplemented with cowpea flour

Sample	Water yam-cocoyam flour(g)	Cowpea flour (g)
WC/C1	100	0
WC/C2	90	10
WC/C3	80	20
WC/C4	70	30
WC/C5	60	40

WC: Water yam-cocoyam composite flour
C: Cowpea flour

Methods of Analysis

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 samples were 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 coloured 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)

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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.

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

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 (2 g) 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).

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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.

% 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

Determination of Total Energy

The total energy was determined by the method describe by Kanu *et al.* (2009). The total energy or the caloric value was estimated by calculation using the water quantification factors of 4, 9 and 4 Kcal/100 g respectively for protein, fat and carbohydrate as expressed below.

Caloric value (Kcal/100 g) = P x 4 + F x 9 + C x 4.

Where P = Protein content (%),
F = Fat content (%)
C = Carbohydrate content (%).

Determination of Mineral Content of Water Yam and Cocoyam Composite flour Supplemented with Cowpea Flour

Determination of Mineral Composition

The mineral content of the of Water Yam and Cocoyam Composite flour supplemented with Cowpea flour was determined using the Atomic Absorption Spectrophotometer (Buck Scientific Atomic Absorption Emission Spectrophotometer model 205, manufactured by Nowalk, Connecticut, USA) using standard wavelengths as described by Adedeye and Adewoke (1992). Two grammes of the sample was ashed following standard AOAC (2010) methods. The ashed sample was digested with 2.5 mL of 0.03 N (HCl). The digest was boiled for 5 minutes, allowed to cool to room temperature and transferred to 50 mL volumetric flask and made up to the mark with distilled water. The resulting digest was filtered with ashless Whatman (No. 42) filter paper. The filtrate from each sample was analyzed for mineral content (Potassium, Zinc, Iron, Calcium and Sodium) contents using an Atomic Absorption Spectrophotometer, Model 205, manufactured by Nowalk, Connecticut, USA). The real values were extrapolated from the respective standard curves. Values obtained were adjusted for HCl-extractability for the respective ions. All determinations were performed in triplicates.

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Determination of Vitamin Content of the Water Yam-Cocoyam composite flour Supplemented with Cowpea Flour

Beta carotene, Thiamine (B_1), riboflavin (B_2), niacin (B_3), folic acid (B_4), Pyridoxine (B_6), Folic (B_9) and Ascorbic acid (C) content were determined according to the method described by the AOAC (2010).

Determination of Beta carotene content

The AOAC (2010) calorimetric method was used. This measures the unstable colour at the absorbance of 620 nm that results from the reaction between Vitamin A and Antimony (III) chloride ($SbCl_3$). Pyrogallol (antioxidant) was added to 1 g sample prior to saponification with 100 ml alcoholic KOH. The saponification took place in a water bath for 30 minutes. The solution was transferred to a separating funnel where water was added. The solution was extracted with 1 ml of hexane. The extract was washed with equal volume of water and filtered through a filter paper containing 5 g of anhydrous Na_2SO_4 into a volumetric flask. The filtrate was rinsed with hexane and made up to the volume. The hexane was evaporated from the solution and the blank. One (1) ml chloroform and SbL3 was added to the extract and blank. The reading of the solution and the blank were taken from calorimeter adjusted from zero absorbance or 100%. Pro-Vitamin A content was calculated using equation (1).

B-carotene (μg) = $A620nm \times SL \times (VWt)$ ………………………………………………(1)

Where,

A_{260} nm = absorbance at 620 nm

SL = slope of standard curve (Vit A conc.) + A620 reading

V = final volume in calorimeter tube

Wt = weight of sample

Determination of Thiamine (Vitamin B_1) Content

The AOAC (2010) scalar analyzer method was used to determine the thiamine content of sample. One gramme (1 g) of each of the samples was homogenized in 1 N ethanoic sodium hydroxide solution. The homogenate was filtered and made to 20 ml with extract solution. Two millilitres (2 ml) aliquot was dispensed into a flask and 2 ml of potassium dichromate solution added. The resultant solution was incubated for 15 minutes at room temperature (28 ± 2 °C). The absorbance was read from a spectrophotometer (Spectrum lab 22 pc model) at 360 nm using the reagent blank to standardize the instrument at zero. Thiamine content was calculated using Equation (2)

$Thaimine\ mg\ per\ 100g = 100W \times auas \times c \times d$ ………………………………….(2)

Where,

W= weight of the sample analysed

au = absorbance of the sample solution

as = conc. of standard solution

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c = conc. of standard solution

d = dilution factor

Determination of Riboflavin (Vitamin B_2) Content

Riboflavin was determined using the AOAC (2010) method. Two grammes (2 g) of each of the samples was put in a conical flask and 50 ml of 0.2 N HCl added to lower the pH to 4.5. The solution was filtered into 100 ml volumetric flask and made up to the mark with distilled water. In order to remove interference, two tubes were taken and labelled 1 and 2. One (1) mL of glacial acetic acid was added to each of the test tubes, mixed and 0.5 ml 3% $KMnO_2$ was added and well mixed again. The flourimeter was adjusted to excitation wavelength of 470 nm and emission wavelength of 525 nm. The flourimeter was adjusted to zero deflection against using the blank (test tube 2). The fluorescence of tube 1 was read. Two (2) ml of hydrogen sulphate was added to both tubes, and the fluorescence measured within 10 seconds. This was recorded as blank reading and riboflavin content was calculated using Equation 3 as follows;

$Riboflavin\ mg\ per$ 100 g = $XY{-}X{\times}XW$ ……………………………… (3)

Where,

W=weight of sample

X= reading of sample – blank reading

Y= reading of sample + standard tube – reading of sample + standard blank

Determination of Niacin (Vitamin B_3) content

A measured weight (5 g) of each sample was treated with 50 mL of 1 N sulphuric acid (H_2SO_4) and shaken for 30 min. The mixture was treated further with 3 drops of aqueous ammonia and filtered. The filtrate (extract) was used for the analysis. Standard niacin (nicotinic acid) solution was prepared and diluted as desired. Ten (10) mL portion of the standard solution, sample extract and 10 mL of the acid solution (treated with a drop of ammonia) was dispensed into separate flasks to serve as standard, the sample and reagent blank respectively. Each of them was treated with 5 mL of normal potassium cyanide solution and acidified with 5 mL of 0.02 N H_2SO_4 solution; its absorbance was read in a spectrophotometer at a wavelength of 470 nm. The reagent blank was used to calibrate the instrument at zero. Niacin content was calculated using the formula:………………. Equation (4)

Niacin (mg/100 g) = 100/w x Au/As x c/1 x vf /va x D …………………………(4)

Where W = Weight of sample analysed

Au = Absorbance of sample

As = Absorbance of standard solution

C = Concentration (mg/mL) of standard solution

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Vf = Total volume of filtrate

Va = Volume of filtrate analysed

D = Dilution factor where applicable

Determination of Pyridoxine (B_6) Content

Exactly 5 g of each sample was dispensed in 100 mL of 5% ethanol solution in distilled water. The mixture was shaken for an hour mechanically and filtered. An aliquot (10 mL) of the filtrate was mixed with an equal volume (10 mL) of 5% potassium permanganate ($KMnO_4$) solution and 19 mL of 30% hydrogen peroxide solution (H_2O_2). The above treatment was also given to a 10 mL portion of standard riboflavin solution and the reagent blank. All the flask; standard blank and sample was allowed to stand over a water bath for half an hour and 2 mL of 40% Na_2SO_4 solution was added to each of them. This was made up to 50 mL in a volumetric flask. Their respective absorbance (sample and standard) were measured in a spectrophotometer at 510 nm wavelength content and riboflavin content calculated as follows:-

Riboflavin (mg/100 g) =100/w xAu/As x c x vf/va x D …………….. (5)

Where W = Weight of sample analysed
Au = Absorbance of sample
As = Absorbance of standard solution
C = Concentration of standard solution
Vf = Total volume of filtrate
Va = Volume of filtrate analysed
D = Dilution factor where applicable

Determination of Folate (Vitamin B9) Content

The Chromatographic method described by Zheng *et al*. (2022) was employed in the determination of folate content of the samples. Chromatographic analyses were performed on an Agilent 1260 HPLC system (Palo Alto, CA, USA) using an Akzo Nobel analytical column (Kromasi l100-5 C18, 2.1 mm × 50 mm) and a Kromasil SB-C18 pre-column (2.1 mm × 5 mm, 2.7 μM particle size) (CA, USA) at a flow rate of 0.30 mL per min. The injected sample was 20.0 μL. The temperature of the injector and column oven was separately maintained at 4 and 25 °C respectively. The detection was carried out using a UV detector set at 280 nm. The mobile phases were 0.1% (v/v) formic acid in water (phase A) and 0.1% (v/v) formic acid in acetonitrile (phase B). The gradient programe was run for a total of 8 min and 12 sec. The proportion of mobile phase B increased linearly from 5 to 9% over 2 min. In the following 6 min, the proportion of phase B increased to 9.6% and then decreased to 5% in 12 sec, followed by a subsequent equilibration. Lin 6308 was used as a control of standardization and was repeated once with every 20 samples. The process was stopped, and a check was made to determine whether the difference in folate content between the two repeats of Lin 6308 exceeded 5%. The four folate derivative standards were serially diluted and used to set the analysis conditions and determine the retention time. Derivatives were identified by retention time and quantified using a six-point calibration curve regression line generated with the external standards, and LOD and LOQ were defined as the lowest analyte concentration yielding a signal-to-noise (S/N) ratio of >3 and of >10, respectively. The linearity of the

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calibration lines was given. Accuracy was evaluated by the spiking standard with approximately two-fold concentrations of the samples and then, the recovery percentage of the added concentrations of the folate was evaluated.

Determination of Ascorbic Acid (vitamin C) Content

Ascorbic was be determined according to the 2, 6–dichlorophenol titrimetric method of AOAC (2010). One (1) g of the sample was homogenized with acetic acid solution and extracted. Vitamin C standard solution was prepared by dissolving 50 mg standard ascorbic acid tablet in 100 mL volumetric flask with distilled water. The solution was filtered out and 10 ml of the clear filtrate added into a conical flask with 2.5 mL acetone. The solution was titrated with indophenols dye solution (2, 6-dichlorophenol indophenol) for 15 seconds. The blank solution was prepared using this same method but with absence of the sample in it. Ascorbic acid was calculated as thus:

$Ascorbic\ (mg)100\ gsample{=}C{\times}V{\times}(DFWT)$

Equation Where, C = mg ascorbic acid/ml dye,

V = volume of dye used for titration of diluted sample,

DF = Dilution factor,

WT = weight of sample (g)

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.* (2022) with slight modification. The method of Udevi (2019) was adopted, with slight modification, for ingredients formulation as presented in Table 2. The flow chart for the preparation of *Ekpang nkukwo* is presented in figure 2.

Table 2. Ingredients Formulation For Preparation *Ekpang Nkukwo*

Ingredient	WC/C1	WC/C2	WC/C3	WC/C4	WC/C5
Wateryam-cocoyam (g/100 g)	100	90	80	70	60
Cowpea (g/100 g)	0	10	20	40	50
Salt (g)	1	1	1	1	1
Seasoning cube (maggi) (g)	4	4	4	4	4
Dry fish (g)	10	10	10	10	10
Pepper (g)	5	5	5	5	5
Cray fish (g)	10	10	10	10	10
Water (ml)	200	200	200	200	200
Palm oil (ml)	15	15	15	15	15
Periwinkle (g)	15	15	15	15	15
Meat (g)	2	2	2	2	2
Onions (g)	5	5	5	5	5
Scent leave (g)	2	2	2	2	2

Sources: *Udevi. (2019) with slight Modification*

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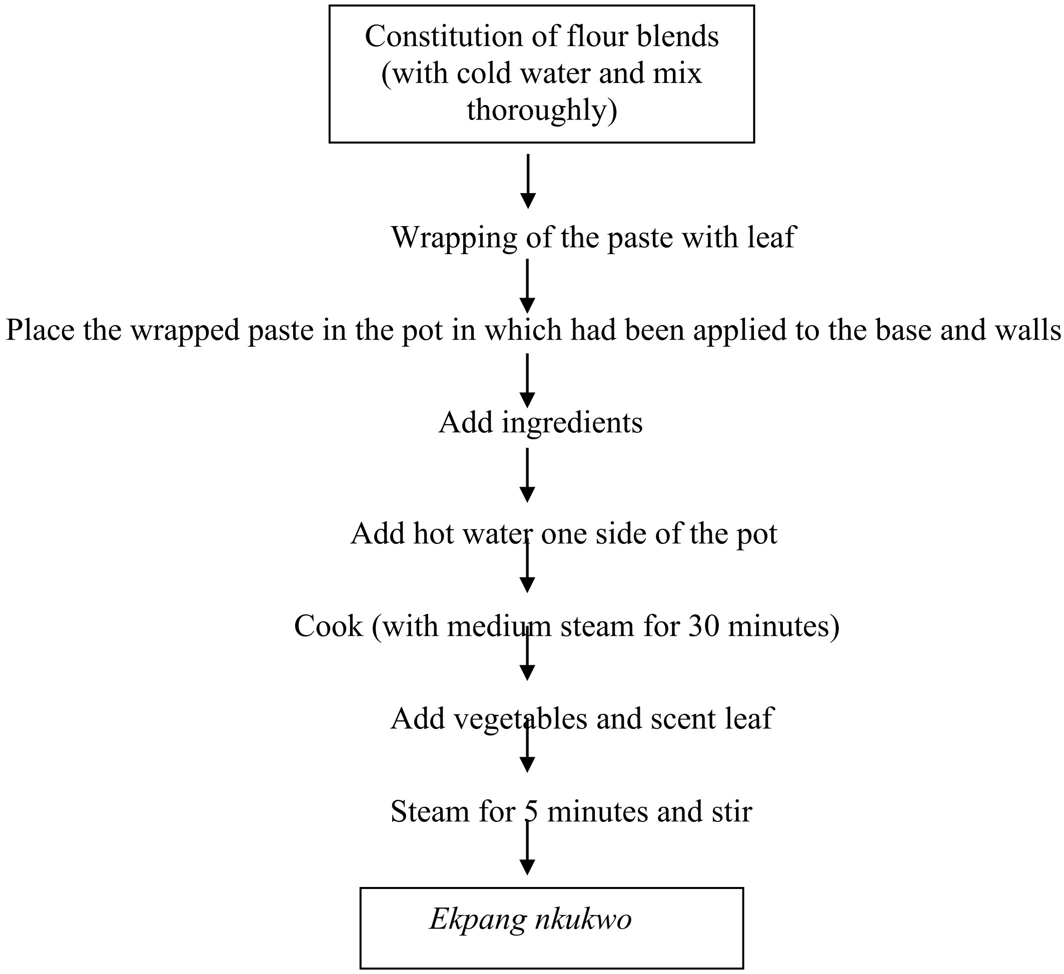
Fig .2: Flow Diagram For The Preparation Of "*Ekpang nkukwo*"



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

Sensory Evaluation

A 30-member panel of semi-trained judges drawn from the staff and students of Akwa Ibom State Polytechnic, Ikot Osurua, Akwa Ibom State was used for sensory assessment of the samples. 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, consisitency 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.

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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

Proximate Composition and Energy Value of Water yam Cocoyam Composite flour Supplemented with Cowpea flour

Table 3 shows the proximate composition and energy values of water yam-cocoyam composite flour supplemented with cowpea flour. The result showed that supplementation with cowpea flour had significant (p<0.05) effect on the proximate composition and energy value of water yam-cocoyam composite flour.

Increase in the proportion of cowpea flour in the blend resulted in significant (p<0.05) increase in moisture, protein, fat, ash and fibre content ranged from 3.29-4.24%, 1.89-20.54%, 0.98-1.28%, 2.00-6.17% and 2.23-3.65% respectively.

Generally, the moisture contents of the cowpea supplemented flour were low, suggesting good stability. The moisture content of any food is an indicator of its storage stability, susceptibility to microbial contamination and shelf life (Uyoh *et al*., 2013). Cowpea flour has more hydrophilic composition because of high proteins and fibre content (Mwangwela, 2006; Sarma *et al*., 2024). As the proportion of cowpea increased in the blend, the overall capacity of the flour blend to hold moisture increased. This behavior has been attributed to the higher water-binding capacity of legume proteins and fibre fractions compared with starchy roots/tubers.

The increase in protein content of the samples with increased cowpea flour supplementation could be attributed to the high protein content of the cowpea flour. Cowpea has been reported to contain about 19-21% protein (Ferreira *et al*., 2015). According to Otunola and Afolayan (2018), the addition of even a small amount of cowpea to cereals, roots and tubers could enhance the nutritional balance of the diet and protein quality. Consumption of products made from the formulated flour blends could be used to curb the issue of malnutrition exacerbated by the widespread consumption of monotonous diets where meals are mostly of cereals or roots which are devoid of protein (Nwafor *et al*., 2020) and also alleviate the problems of protein-energy malnutrition that is prevalence in most community in Nigeria due to limited access to nutrient-rich foods particularly impacting vulnerable groups such as children and expectant mothers (Akanbiemu, 2014; Adeyonu, 2022). Similar increase in protein content has been reported in snacks produced from water yam and cowpea flour blends (Ferreira *et al*., 2015), cassava flour supplemented with soy flour (Olatidoye and Sobowale, 2011) and plantain flour fortified with soy flour (Abioye *et al*., 2011).

Although there was increase in fat content of the flour with increase in cowpea flour supplementation, the fat contents of the cowpea supplemented flours were generally moderate. Tsegay *et al*. (2024) reported a fat content of ~2.25% for cowpea flour. The low fat content of the cowpea supplemented flour would reduce the rate at which rancidity sets in

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and subsequently increasing the shelf life of flour. This also makes the products suitable for weight management (Otunola and Afolayan, 2018).

Increase in ash content of cowpea supplemented water yam-cocoyam flour blend suggests that cowpea flour is rich in mineral elements. Akinyele *et al*. (2017); Otunola and Afolayan (2018) reported that cowpea flour has an ash content of 3–5%. This aligns with food formulation strategies where legumes are incorporated into starchy staples to improve mineral density and overall nutritional balance (Fellows, 2017).

The increase in fibre content with increase in cowpea flour supplementation of the water yam –cocoyam composite flour could be attributed to the fact that cowpea flour is rich in dietary fibre containing approximately 5–10% dietary fibre (Affrifah *et al*., 2021)**.** Fibre is nutritionally beneficial and aligns with public health recommendations encouraging increased intake of fibre-rich plant foods for improves intestinal motility and gut health, slows starch digestion and glucose release, lowering glycaemic response and Enhances satiety, which supports weight management (WHO/FAO, 2003).

On the other hand, carbohydrate and energy contents of water yam–cocoyam composite flour supplemented with cowpea flour decreased significantly ($p<0.05$) with increase in cowpea flour supplementation. Nwafor *et al*. (2019) and Tsegay *et al*. (2024) also reported decrease in carbohydrate content of water yam flour supplemented with cowpea flour and wheat-yam composite flour supplemented with cowpea flour respectively, as the proportion of cowpea flour increased in the blend. This decrease is attributable to the intrinsic compositional differences between starchy tubers and legumes**.** Water yam (*Dioscorea alata*) and cocoyam (*Colocasia esculenta*) are carbohydrate-dense roots**,** with starch as their major constituent, often accounting for over 70–80% of dry matter. Consequently, flours derived from these tubers exhibit high carbohydrate levels and energy values, since carbohydrates contribute 4 kcal/g to total metabolizable energy (FAO, 2003; Oke and Workneh, 2013).

In contrast, cowpea (*Vigna unguiculata*) flour contains lower starch content but higher proportions of protein, dietary fiber, and ash. Typical cowpea flour contains approximately 20–25% protein and 5–10% dietary fiber**,** which proportionally displace digestible carbohydrates when blended with tuber flours (Phillips *et al*., 2003; Udensi and Okoronkwo, 2006). Therefore, increasing cowpea substitution results in a dilution effect, whereby carbohydrate-rich components are replaced with protein- and fiber-rich fractions, leading to a statistically significant reduction in total carbohydrate content.

Since energy value is calculated as the sum of energy contributions from macronutrients (carbohydrate, protein, and fat), the observed reduction in carbohydrate—combined with the relatively low fat content of cowpea—explains the concomitant decrease in caloric value of the composite flour. Similar reductions in carbohydrate and energy values with increasing legume substitution have been reported in water yam–cowpea snack products (Nwafor *et al*., 2019) and other tuber–legume composite flours (Adebayo-Oyetoro *et al*., 2012). Implication of the reduction in carbohydrate and energy values of the flour resulted in improved nutritional balance by improving the protein-energy ratio of the flour. This is beneficial in addressing protein-energy malnutrition, especially in developing countries (FAO, 2013), lower glycaemic potentuial of product making cowpea-supplemented flours potentially more suitable for individuals with diabetes or those requiring controlled energy intake (Trinidad *et*

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al., 2010) and suitable for weight and lifestyle management reducing the risk of excessive energy intake while still providing essential nutrients such as protein and minerals.

Table 3: Proximate Composition and Energy Value of Water Yam-Cocoyam Composite Flour Supplemented with Cowpea Flour (Dry Matter Basis)

Parameters	Blending ratios (water yam-cocoyam flour: cowpea flour)				
	100:00	90 :10	80:20	70 :30	60:40
Moisture (%)	3.29 ^{e}±0.06	3.54 ^{d}±0.02	3.94 ^{c}±0.72	4.04 ^{b}±0.04	4.24 ^{a}±0.01
Protein (%)	1.89^{e}±0.07	6.37 ^{d}±0.02	12.09^{c}±0.02	15.23^{b}±0.02	20.54^{a}±0.03
Fat (%)	0.98^{e}±0.06	1.08 ^{d}±0.02	1.18^{c}±0.02	1.24^{b}±0.02	1.28 ^{a}±0.02
Ash (%)	2.00 ^{e}±0.08	4.07 ^{d}±0.02	4.59 ^{c}±0.02	5.85 ^{b}±0.26	6.17^{a}±0.02
Fibre (%)	2.23 ^{e}±0.08	2.80^{d}±0.02	3.15^{c}±0.02	3.32^{b}±0.02	3.65^{a}±0.02
Carbohydrate (%)	92.90^{a}±0.11	85.68^{b}±1.29	78.99^{c}±0.11	74.36^{d}±0.10	68.36^{e}±0.11
Energy Value kcal/100g	387.98^{a}±0.03	377.92^{b}±0.10	374.94^{c}±0.11	369.52^{d}±0.10	367.12^{e}±0.10

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

Mineral Composition of Water yam-Cocoyam Composite Flour supplemented with Cowpea Flour

Table 4 shows the mineral content of water yam-cocoyam composite flour supplemented with cowpea flour. Potassium content ranged from 489.23 to 928.67 mg/100g, zinc content ranged from 0.83 to 5.35 mg/100 g, iron content ranged from 2.21 to 16.85 mg/100 g while calcium content ranged from 167.14 to 357.67 mg/100 g. The result showed that the proportion of cowpea flour significantly ($p<0.05$) affected the mineral content of cowpea supplemented water yam-cocoyam composite flour. The control sample (100 % water yam-cocoyam composite flour) had significantly ($p<0.05$) lower potassium, zinc, iron and calcium contents which increased significantly ($p<0.05$) as the proportion of cowpea flour increased in the blend. This observation agrees with reports by Uduak (2018)**,** Alayande *et al*. (2012) and Famata *et al.* (2013) all of whom identified cowpea as a particularly rich source of potassium. Naiker *et al*. (2019) reported potassium levels ranging from approximately 580 to 900 mg/100 g in cowpea flour, depending on variety and processing method. The relatively high potassium concentration in cowpea is linked to its physiological role in plants, where potassium is actively accumulated for osmotic regulation, enzyme activation, and protein synthesis**,** resulting in substantial retention in the edible seed fraction (Hasanuzzaman *et al*., 2018).

Similarly, the increases in iron, zinc, and calcium reflect the higher concentrations of these minerals in cowpea seeds compared with tubers. Legumes are recognized as important plant-based sources of bioessential trace elements, particularly iron and zinc, which are often limiting in tuber- and cereal-based diets (Gibson *et al*., 2010). The significant increase in calcium content of cowpea supplemented water yam-cocoyam composite flour may also be associated with the higher ash content of cowpea flour, as calcium is a major contributor to total ash in legumes (Famata *et al*., 2013). High potassium levels (~580–900 mg/100 g**)** of cowpea flour have been reported (Naiker *et al*., 2019).

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Sodium content ranged from 44.73 mg/100 g in the control sample to 22.24 mg/100 g in the cowpea-supplemented samples. The control sample (100% water yam–cocoyam composite flour) had a significantly higher ($p < 0.05$) sodium content, which decreased significantly ($p < 0.05$) as the proportion of cowpea flour increased in the composite flour blends. The observed decrease in sodium content with increasing cowpea flour inclusion may be primarily attributable to the naturally low sodium concentration of cowpea seeds relative to root and tuber crops. Although water yam (*Dioscorea alata*) and cocoyam (*Colocasia esculenta*) are not inherently high-sodium foods, tuber flours may retain relatively higher sodium levels due to soil mineral composition, water used during processing, and intrinsic ionic balance in storage tissues (FAO, 2016; Oke and Workneh, 2013).

Cowpea (*Vigna unguiculata*), on the other hand, is consistently reported as a low-sodium legume**,** with sodium contents typically below 10–30 mg/100 g in raw or processed flour forms (Phillips *et al.*, 2003; Naiker *et al.*, 2019). Legumes generally accumulate potassium preferentially over sodium as part of their physiological mechanisms for osmotic regulation and enzyme activity**,** resulting in a high potassium-to-sodium (K:Na) ratio in the edible seeds (Welch and Graham, 2004). Similar decreasing sodium trends with increasing legume supplementation have been reported in tuber–legume and cereal–legume composite flours (Alayande *et al.*, 2012; Famata *et al.*, 2013).

Table 4. Minerals Content Of Water Yam-Cocoyam Composite `Flour Supplemented With Cowpea Flour

Parameters(mg/100 g)	Blending ratios (water yam-cocoyam flour: cowpea flour)				
	100:00	90 :10	80:20	70 :30	60:40
Potassium	$489.23^{e}\pm0.02$	$576.50^{d}\pm0.03$	$748.40^{c}\pm0.03$	$772.04^{b}\pm0.02$	$928.67^{a}\pm0.02$
Zinc	$0.83^{e}\pm0.02$	$2.65^{d}\pm0.01$	$3.34^{c}\pm0.02$	$3.85^{b}\pm0.00$	$5.35^{a}\pm0.14$
Iron	$2.21^{e}\pm0.02$	$5.34^{d}\pm0.02$	$6.35^{c}\pm0.02$	$12.14^{b}\pm0.03$	$16.85^{a}\pm0.02$
Calcium	$167.14^{e}\pm0.03$	$263.26^{d}\pm0.02$	$275.86^{c}\pm0.00$	$285.27^{b}\pm0.03$	$357.67^{a}\pm0.02$
Sodium	$44.73^{a}\pm0.02$	$34.59^{b}\pm0.03$	$34.31^{c}\pm0.02$	$24.02^{d}\pm0.02$	$22.24^{e}\pm0.02$

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

Vitamin content of Water yam-Cocoyam Composite Flour supplemented with Cowpea Flour

Table 5 presents the vitamin content of water yam-cocoyam composite flour supplemented with cowpea flour. The result shows that supplementation of water yam–cocoyam composite flour with cowpea flour significantly ($p < 0.05$) influenced the vitamin composition of the blends. The control sample (100% water yam–cocoyam composite flour) had significantly ($p < 0.05$) lower contents of β-carotene, vitamins B_1, B_2, B_3, B_9, and vitamin C, all of which increased significantly ($p < 0.05$) with increasing levels of cowpea flour supplementation. Specifically, β-carotene content ranged from 0.36 to 2.17 mg/100 g, vitamin B_2 ranged from 0.24 to 1.98 mg/100 g, vitamin B_3 ranged from 0.61 to 2.20 mg/100 g**,** vitamin B_9 ranged from 0.24 to 0.82 mg/100 g**,** and vitamin C ranged from 4.24 to 12.66 mg/100 g**.** However, vitamin B_6 content was not significantly ($p > 0.05$) affected by cowpea supplementation.

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The observed increase in vitamin contents could be explained by the comparative vitamin density of cowpea seeds relative to root and tuber crops**.** Water yam (*Dioscorea alata*) and cocoyam (*Colocasia esculenta*) are primarily sources of carbohydrates and contribute modest amounts of vitamins, particularly water-soluble vitamins, which are often reduced during peeling, slicing, drying, and milling operations (Oke and Workneh, 2013; FAO, 2003).

On the other hand, Cowpea (*Vigna unguiculata*) is recognized as a nutrient-dense legume rich in B-complex vitamins, provitamin A carotenoids, and vitamin C, depending on variety and processing method (Phillips *et al.,* 2003; Gerrano *et al*., 2019). Legumes synthesize and store B-vitamins in the seed embryo and cotyledons to support metabolic activity during germination, which explains their relatively higher concentrations in cowpea flour. As cowpea flour increasingly replaced portions of the water yam–cocoyam composite flour, the vitamin-poor tuber fraction was progressively substituted with a vitamin-rich ingredient, resulting in the significant increase observed.

The rise in β-carotene content with cowpea supplementation is consistent with reports that cowpea seeds contain measurable levels of carotenoids, which serve as precursors of vitamin A and play protective roles against oxidative stress in plants (Gerrano *et al*., 2019). Similarly, the increase in vitamins B_1, B_2, B_3, and B_9 reflects the established role of legumes as important dietary sources of B-complex vitamins involved in carbohydrate metabolism, red blood cell formation, and nucleic acid synthesis (FAO/WHO, 2004).

The increase in vitamin C content in the cowpea supplemented flour, although modest compared to fresh fruits, may be attributed to cowpea's higher ascorbic acid content relative to tubers, as well as its partial protection from oxidative losses during drying due to interactions with other antioxidants present in legumes (Phillips *et al*., 2003).

In contrast, the lack of significant ($p > 0.05$) change in vitamin B6 content suggests that both the tuber-based composite flour and cowpea flour contain comparable levels of pyridoxine, or that vitamin B_6 is relatively stable and less influenced by ingredient supplementation at the levels studied. Previous studies have reported minimal variation in vitamin B_6 content across cereal–legume and tuber–legume composite flours, supporting this observation (Adebayo-Oyetoro *et al*., 2012).

Table 5. Vitamins Composition of Samples Water Yam-Cocoyam Composite Flour Supplemented with Cowpea Flour

Parameters(mg/100 g)	Blending ratios (water yam:cocoyam flour- cowpea flour)				
	100:00	90 :10	80:20	70 :30	60:40
Beta-carotene(mg/100g)	$0.36^{e}\pm0.04$	$0.76^{d}\pm0.00$	$1.57^{c}\pm0.01$	$1.70^{b}\pm0.02$	$2.17^{a}\pm0.02$
B_1(mg/100g	$0.02^{e}\pm0.00$	$0.40^{d}\pm0.02$	$0.53^{c}\pm0.02$	$0.66^{b}\pm0.02$	$0.82^{a}\pm0.01$
B_2(mg/100g	$0.24^{e}\pm0.1$	$1.19^{d}\pm0.02$	$1.37^{c}\pm0.02$	$1.57^{b}\pm0.02$	$1.98^{a}\pm0.00$
B_3(mg/100g	$0.61^{e}\pm0.00$	$1.31^{d}\pm0.02$	$1.66^{c}\pm0.00$	$1.76^{b}\pm0.02$	$2.20^{a}\pm0.02$
B_6(mg/100g	$0.52^{a}\pm0.41$	$0.31^{a}\pm0.02$	$0.42^{a}\pm0.02$	$0.52^{a}\pm0.01$	$0.64^{a}\pm0.03$
B_9(µg/100 g	$0.24^{e}\pm0.02$	$0.43^{d}\pm0.01$	$0.65^{c}\pm0.02$	$0.73^{b}\pm0.02$	$0.82^{a}\pm0.02$
C(mg/100g	$4.24^{e}\pm0.02$	$7.23^{d}\pm0.00$	$7.54^{c}\pm0.00$	$8.38^{b}\pm0.00$	$12.66^{a}\pm0.00$

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

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Sensory Evaluation of *Ekpang nkukwo* Prepared from Water yam-Cocoyam Composite Flour supplemented with Cowpea flour

Table 5 presents the sensory attributes while figure 3 is a pictorial presenation of *Ekpang nkukwo* prepared from water yam–cocoyam composite flour supplemented with cowpea flour. The results indicate that proportion of cowpea flour significantly ($p < 0.05$) affected the sensory attributes of the product.

There were no significant ($p>0.05$) difference in appearance, taste, aroma, mouthfeel, consistency and general acceptability scores between *Ekpang nkukwo* prepared from the control sample (water yam-cocoyam composite flour without cowpea supplementation) and that of 10% cowpea supplemented flour blend. However, beyond the 10% cowpea flour supplementation, sensory scores decreased significantly ($p<0.05$) with increase in cowpea flour supplementation.

The significant effect could be explained by the compositional and functional differences between water yam–cocoyam composite flour and cowpea flour**,** which directly influence sensory perception. Water yam and cocoyam flours are rich in starch, which contributes to the characteristic softness, smooth texture, cohesiveness, and bland taste traditionally associated with *Ekpang nkukwo*. Starch gelatinization during cooking plays a critical role in forming the desirable mouthfeel and structural integrity of the product (Otegbayo *et al*., 2014).

In contrast, cowpea flour introduces higher protein, dietary fiber, and lipid contents**,** which modify the physicochemical properties of the dough and cooked product. Increased protein content enhances water absorption and protein–starch interactions, leading to changes in texture such as increased firmness or reduced elasticity at higher substitution levels (Adebowale *et al*., 2012). Dietary fiber from cowpea may also interfere with starch gelatinization, resulting in a coarser mouthfeel or altered cohesiveness, which panelists can perceive during sensory evaluation.

Cowpea supplementation further influences flavour due to the presence of characteristic legume-derived volatile compounds formed during cooking, including aldehydes and alcohols associated with beany notes. At moderate substitution levels, these flavours may enhance product complexity and acceptability, while excessive inclusion may produce overpowering legume flavours that deviate from the traditional sensory profile of *Ekpang nkukwo* (Phillips *et al*., 2003; McWatters *et al*., 2003).

Overall, the differences observed across sensory attributes reflect the combined effects of compositional changes, starch–protein interactions, fibre content, and flavour development resulting from increasing cowpea flour supplementation. Similar sensory trends have been reported in tuber–legume and cereal–legume composite products, where acceptability depends on achieving an optimal balance between nutritional enhancement and sensory quality (Adebayo-Oyetoro *et al*., 2012; Nwafor *et al.,* 2019).

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Figure 3: *Ekpang nkukwo* prepared from the Water yam- Cocoyam Composite Flour W = water yam-cocoyam, C = cowpea flour

Table 6. Sensory Evaluation mean score value for *Ekpang nkukwo* prepared from Water Yam-Cocoyam Composite Flour Blends Supplemented with Cowpea Flour

Parameters(mg/100 g)	Blending ratios (water yam-cocoyam flour: cowpea flour)				
	100:00	90 :10	80:20	70 :30	60:40
Appearance	8.25^{a}±1.48	8.25^{a}±1.48	4.35^{b}±0.48	4.00^{b} ±0.00	4.00^{b} ±0.00
Taste	8.70^{a}±0.30	8.90^{a}±0.73	6.95^{b}±0.60	6.30^{c}±0.47	5.70^{d}±0.47
Aroma	9.00^{a}±0.00	8.65^{ab}±0.48	6.15^{bc}±0.74	6.05^{bc}±8.93	4.00^{c}±0.00
Mouthfeel	9.00^{a}±0.00	9.00^{a}±0.00	7.60^{b}±0.50	6.15^{c}±0.36	6.00^{c}±0.00
Consistency	8.87^{a}±0.78	8.75^{a}±0.78	7.05^{b}±0.60	6.00^{c}±0.00	6.00^{c}±0.00
General Acceptability	8.50^{a}±1.10	8.50^{a}±1.10	7.20^{b}±0.41	6.15^{c}±0.36	6.00^{c}±0.00

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

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CONCLUSION

This study demonstrates that supplementation of water yam–cocoyam composite flour with cowpea flour significantly ($p< 0.05$) improved the protein, fat, ash and fibre contents; mineral (potassium, calcium, zinc, iron) content as well as vitamin (beta carotene, vitamin B_1, B_2, B_3, B_9, C) contents but resulted in a significant decrease in sodium content of the flour blends. Based on the result of this study, use of 10% cowpea flour supplemented yam–cocoyam composite flour with has been recommended for preparing *Ekpang nkukwo* with balanced between nutritional enhancement and consumer acceptability.

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