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Research Article

Evaluation of Yam - Cow Pea Flour Fortification on the Physicochemical, Rheological Characteristics, Microbiological and Acceptability of Yam Flour Paste (Amala)

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Abstract

Amala flour was produced from two yam varieties (*D. rotundata* and *D. alata*) and theses were fortified with cowpea at 20, 30, 40% supplementation respectively. Effect of cowpea fortification was investigated and the parameters determined include: proximate composition, mineral element, water absorption capacity, pasting properties, *in vitro* protein digestibility and microbial count. The results show a statistically significant increase in % moisture, crud fiber, at all the levels of fortification when compared with control. Carbohydrate content was decrease as the proportion of the cowpea supplementation is increased by 10%. The *in vitro* protein digestibility increased with an increase in cowpea fortification. White yam tissue at 6 hrs.

Keywords: *Yam; Amala; Fortification; Cowpea*

Introduction

Yam is one of the staple foods in Nigeria and a crop of economic, social and cultural importance in many tropical countries particularly in West Africa, South Asia, and Caribbean [1]. It is an important source of carbohydrate for about 300 million people throughout the world [2]. The yam tuber from which flour is made consists mostly of carbohydrate, and has very low protein content which raises major concern in relation to its consumption alone. As a result of this; a lot of research work has been carried out to improve the nutritional composition and qualities of yam and its products [3]. The use of soybean to increase the protein content of cassava has been explored [4,5,6,7].

In Nigeria, there have been several attempts at overcoming the nutritional deficiency of cassava based diets by fortifying with legume (soy), which has high protein content of good quality [8]. Results of previous studies on fortification of cassava and plantain flours using legumes has shown that fortification improves nutritional quality of resulting meals, [9]. This present work attempted to develop and evaluate the quality of the fortified yam with a plant legume cowpea.

Materials and Methods

Source of raw materials

Yam tubers of *D. rotundata* local cultivar and the *D. alata* was obtained from farm gate at Zing town in Taraba state, while the improved variety of cowpea seeds was obtained from Lake Chad Research Institute (LCRI) Nigeria respectively.

Preparation of Yam Flour

The yam flour was produced from the whole yam and its peel; this was prepared by the method described by [10].

Procedure

The yam tuber was washed, peeled and cut into thin slices of less than 3 mm thick and parboiled for 10 min at 98°c. This batch served as the fresh unfermented sample. For the preparation of fermented sample, sterile tap water was added to a 500g batch of parboiled yam slices in a yam/water ratio 1:2 (w/w). The soaked yam slices were incubated at room temperature for 24 hrs. Both samples (fermented and unfermented) were dried for 24 hours at 70˚C in a hot air oven. The dried chips were milled in a laboratory mill and passed through USNO 0.40 sieves and packed in air tight container and stored at 40°c until use for fortification and analysis.

Preparation of Cowpea

Cowpea seeds was sorted, cleaned of dirt and soaked in clean tap water for 20 minutes. The cowpea seeds were dehulled using a mortar and a pestle. The seeds were washed to separate the coat and dried to a constant weight. The dried seeds were roasted and ground into a fine powder. The ground seeds were sieved using a 1 mm pore sieve and packed in air tight container and stored at 40°c until use for fortification and analysis [11]

Blend Formulation

Four blends (each of yam and cowpea flour) were prepared by mixing the proportion of 100:0; 80:20; 70:30; 60:40 [11].

Preparation of the Amala

The stiff dough (amala) was prepared by adding flour into 500 ml of boiled water. The mixture was stirred thoroughly with a wooden spoon to avoid lumps and cooked for 15 min to form soft dough. It was removed from the fire and served [12].

Chemical Analysis

Proximate composition

Proximate composition of the raw, processed and fortified mixture was determined by the standard methods of [13].

Determination of Moisture Content

Moisture was determined by oven drying method. 1.5g of well-mixed sample was accurately weighed in clean, dried crucible (W_1). The crucible was allowed in an oven at 100-105˚C for 6 - 2h until a constant weight was obtained. Then the crucible was placed in the desiccators for 30 min to cool. After cooling, it was weighed again (W_2). The percent moisture was calculated by the following formula.

$$\%\, moisture = \frac{W_1 - W_2}{weight\ of\ sample}$$

W_1 = Initial weight of crucible + sample
W_2 = Final weight of crucible + sample

Determination of Ash

For the determination of ash, clean empty crucible was placed in a muffle furnace at 600°c for an hour cooled in desiccators and then weight of empty crucible was noted (W_1). One gram of each of sample was taken in crucible (W_2). The sample was ignited over a burner with the help of blowpipe until it is charred. Then the crucible was placed in muffle furnace at 550˚C for 2 - 4 hours. The appearance of gray white ash indicates complete oxidation of all organic matter in the sample. After ash, furnace was switch off. The crucible was cooled and weighed (W_3). Percent ash was calculated by the following formula.

$$\%\, ash = \frac{Difference\ in\ weight\ of\ ash}{Weight\ of\ sample} \times 100$$

Difference in wt. of Ash = $W_3 - W_1$

Determination of Crude Fat

Dry extraction method for fat determination was implied. It consists of extracting dry sample with some organic solvent, since all the fat materials e.g. fats, phospholipids, sterols, fatty acids, carotenoids, pigments, chlorophyll etc., are extracted together, therefore the results are frequently referred to as crude fat. Fat was determined by intermittent Soxhlet apparatus. Approximately 1g of moisture free sample was wrapped in filter paper, placed in fat free thimble and then introduced in the extraction tube. Weighed, cleaned and dried the receiving beaker was filled with petroleum ether and fitted into the apparatus. Water and heater was turned on to start extraction. After 4-6 siphoning ether was then allowed to evaporate and beaker been disconnected before the last siphoning. The extract was then transferred into clean glass dish with ether washing and evaporated ether on water bath. Then the dish was placed in an oven at 105°C for 2 hrs and cooled in a desiccator. The percent crude fat was determined by using the formula.

$$\% crude\ fat = \frac{Weight\ of\ eather\ extract}{Weight\ of\ sample} \times 100$$

Determination of Crude Fiber

A moisture free and ether extracted sample of crude fiber made of cellulose was first digested with dilute H2SO4 and then with dilute KOH solution. The undigested residue was collected after digestion, then was ignited and loss in weight after ignition was registered as crude fiber.

Procedure

0.153g sample (W_0) was weighed and transferred to porous crucible. The crucible was then placed into Dosi-fiber unit and valve kept in off position. After that, 150 ml of preheated H_2SO_4 solution was added and some drops of foam suppresser to each column. Then open the cooling circuit and turn on the heating elements (power at 90%). When it starts boiling, the power at 30% is been reduced and left for 30 min. Valves was opened for drainage of acid and rinsed with distilled water thrice to completely ensure the removal of acid from sample. The same procedure was used for alkali digestion by using KOH instead of H_2SO_4 sample was dried in an oven at 150°C for 1hr. Sample was allowed to cool in a desiccator and weighed (W_1). Sample was placed in crucibles, in muffle furnace at 55oC for 3-4hrs. It was cooled i.e. the sample in desiccator and weighed again (W_2). Calculation was done by using the formula.

$$\% Crude\ Fiber = \frac{W_1 - W_2}{W_0} \times 100$$

Determination of Crude Protein

Protein in the sample was determined by Kjeldahl method. 0.5-1.0g dried sample was taken in digestion flask. 10-15 ml of concentrated H_2SO_4 was added and 8g of digestion mixture i.e. $K_2SO_4CuSO_4$ (8:1) the flask was swirled in order to mix the contents thoroughly then place on heater to start digestion till the mixture become clear (blue green in colour). It needs 2 hours to complete. The digest was cooled and transferred to 100 ml volumetric flask and volume was made up to make by addiction of distilled water. Distillation of the digest was performed in mark am still distillation tube, then 10 ml of 0.5N NaOH was gradually added through the same way. Distillation was continued for at least 10 min and NH_3 produced was collected as NH_4OH in a conical flash containing 20 ml of 40% boric acid solution with few drops of modified methyl indicator. During distillation yellowish color should appear due to NH_4OH. The distillate was then titrated against standard 0.1N HCl solution till the appearance of pink colour. A blank was also run through all steps as above. Percent crude protein content of the sample was calculated by using the following formula.

$$\%\ crude\ protein = 6.25^* \times \% N\ (^*Correction\ factor)$$

$$\% N = \frac{(S - B) \times N \times 0.014 \times D \times 100}{Weight\ of\ the\ sample \times V}$$

Where

S = Sample titration reading

B = Blank titration reading

N = Normality of HCl

D = Dilution of sample after digestion

V = Volume taken for distillation

0.014 = Milli equivalent weight of Nitrogen

Mineral Elements Analysis

The mineral elements contents of the sample were determined using atomic absorption spectrometry (AAS: Model; analysis 400) with computer readout after digestion (victor, 2000), this was carried out for sodium, magnesium, potassium, calcium and phosphorus.

Procedure for Digestion

Part, 0.2g of sample was weighed and oven dried at 60˚C in a digestion flask which was previously washed with distilled water and 10 ml of mix 4% Per Chloric acid added under fume cupboard. The mixed content was heated strongly on a digestion block under Per Chloric acid fume hood. Reaction was allowed to cool and then 50 ml distilled water added. Solution was being transferred into a 100 ml Pyrex volumetric flask and distilled water added to make up volume. Solution was stored for the determination of Sodium (Na), Magnesium (Mg), Potassium (K), Calcium (Ca) and Phosphorus (P) [14].

Functional Properties of Yam Flour

Water Absorption Index Determination

Water absorption index was determined using the modified method of [15]. Flour sample (2.5g) was suspended in 30 ml distilled water at 30˚C in a Centrifuge tube, stirred for 30 minutes intermittently and then centrifuged at 300rpm for 10 minutes. The supernatant was decanted and the weight of the gel formed recorded. The water absorption index (WAI) was calculated as gel weight per gram dry sample.

$$Water\ absorption\ index\,(WAI) = \frac{Bound\ water\,(g)}{Weight\ of\ sample} \times 100$$

Pasting Property Determination of Yam Flour

Pasting characteristics was determined with a Rapid Visco Analyzer (RVA), (ModelRVA3D+, Network Scientific, and Australia). First, a flour sample (2.5g) was weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister well fitted into the RVA as recommended. The slurry was heated from 50˚C to 95˚C with a holding time of two minutes followed by cooling to 50˚C with 2 minutes holding time. The rate of heating and cooling was at a constant rate of 11.25˚C per min. Peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature was read from the pasting profile with the aid of thermos cline for windows software connected to a computer [16].

Determination of *in vitro* Protein Digestibility

The *in vitro* protein digestibility of the samples was determined according to the method as described by [17]. One milliliter (1 ml) of

11% trypsin was introduced into 3 test tubes, 4 ml of phosphate buffer at pH 7.5 was added into each test tube and 1 ml of 1% sample was added to all the test tubes (labeled as digestibility at o hour, 1 hour and 6 hours). The reaction in each test tube was stopped with 5 ml of neutralized formalin at 1 hour and 6 hours. The content of the test tubes was then filtered using filter papers. The filter paper was then dried in an oven at 180°C for 3 hours. The nitrogen of the undigested sample was determined by *Kjeldahl* method.

$$\%\, in\; vitro\; protein\; digestibility = \frac{Cp_1 - Cp_2}{Cp_1} \times 100$$

Where

Cp_1 = Total protein of unprocessed sample

Cp_2 = Total protein after digestion with trypsin.

Microbiological Analysis

The microbial analysis of the sample was done according to the method described by [18]. Appropriate dilution of the samples were enumerated for counts of bacteria and yeasts using nutrient agar, Sabouraud dextrose agar and blood agar base. Inoculated plates were counted and expressed as colony forming units (CFU/g), colonies of bacteria and yeast were isolated and sub cultured to obtain pure cultures.

Media preparation

Nutrient agar

This is a good purpose medium which may be enriched with 10% blood or other biological fluid. It supports the growth of a wide range of microorganism and contains sufficient nutrient for the organisms.

Procedure

Twenty grams (20g) of nutrient agar (oxoid) was weighed and dissolved in 1.0L of distilled water in a clean conical flask. It was brought to boil to dissolve completely and then sterilized by autoclaving at 121°c for 15 minutes. It was allowed to cool to 50°C - 55°C and then poured aseptically into sterile petri dish and allowed to set.

Mac Conkey Agar

This is a differential medium for the isolation of coliforms and intestinal pathogens in water, dairy and biological specimens.

Procedure

Fifty-two grams (52g) of Mac Conkey agar was weighed into 1.0L of distilled water in a conical flask. This was brought to boil to dissolve completely and sterilized by autoclaving at 121°C for 15 minutes. It was aseptically poured into sterile petri dish. The surface of the gel was dried before inoculation.

Blood agar base

Forty-two grams (42g) of nutrient agar was dissolved in 1.0L of distilled water. It was dissolved and sterilized in an autoclave at 121°C for 15 minutes. On cooling, 10 ml of blood was added and poured aseptically into sterile petri dishes.

Sabouraud Dextrose Agar (SDA)

This is a general purpose medium for the cultivation of yeasts and molds.

Procedure

Sixty-five grams (65g) of SAD was suspended in 1.0L of distilled water. It was boiled to completely dissolve and autoclaved at 121˚C for 15 minutes and then cooled and aseptically poured into petri dishes.

Determination of total viable count

After inoculation, the plates were inoculated at 37˚C for 24 hours. The colonies obtained were counted on an electric colony counter (Galen Kamp colony counter).

Isolation and Identification

A loop full of the sample was smeared over one corner of the solidified medium which was sufficiently dried. A non-chrome wire loop was sterilized over a spirit lamp then cooled and used to make parallel streaks from the main inoculums. The plates were then inoculated at 37˚C for 24 hours.

The colonies were well spread from one another based on the difference of colony monopoly. One of the separated colonies was then taken using a sterilized wire loop and inoculated in another media then incubated for 24 hours at 37˚C. Colonies were obtained after 24 hours.

Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) using SPSS version 16.00 and Means were separated using Duncan's Multiple Range Test (DMRT).

Results

Proximate Composition

The proximate composition of the fortified and unfortified yam flour obtained, from different processing method is presented in [Tables 1, 2, 3 and 4]. There was an increase in crude fiber for the processed samples when compared to the control, also an increase in crude fiber was recorded in the fortified samples, however water yam at 40% fortification had the highest crude fiber content. There was significant difference in the moisture content for the processed sample when compared to the control. The moisture content for the fortified sample tends to be higher when compared to the unfortified samples; these may be as a result of the processing technique used. There was also reduction in dry matter for the fortified mixture when compared to the unfortified. There was no significant difference in ash and fat for both the fortified and unfortified samples. The protein content is higher in white yam (9.20 ± 0.49) fortified with 40% cowpea. The protein content was improved in all the treatments.

Treatments	% Dry Matter	%Moisture Content	% Crude protein	% Fat	% Crude Fiber	% Ash	% Carbohy-drate	Energy (K. Cal)
Control (1) WY	97.70 ± 0.56^{a}	2.30 ± 0.24^{d}	3.67 ± 0.07^{b}	1.00 ± 0.13^{a}	3.00 ± 0.45^{bc}	2.00 ± 0.14^{ab}	88.03 ± 0.57^{de}	375.08^{cd}
Control (2) WAY	97.00 ± 0.60^{a}	3.00 ± 0.40^{cd}	2.97 ± 0.46^{bc}	1.00 ± 0.05^{a}	2.00 ± 0.30^{cd}	1.00 ± 0.11^{b}	90.03 ± 0.78^{b}	381.00^{bc}
Processed WYF	95.29 ± 0.63^{b}	4.82 ± 0.33^{b}	1.40 ± 0.21^{cd}	2.00 ± 0.06^{a}	4.00 ± 0.21^{ab}	3.00 ± 0.23^{a}	84.90 ± 0.47^{f}	363.20^{e}
Processed WYPF	95.40 ± 0.72^{b}	4.60 ± 0.27^{bc}	1.22 ± 0.11^{d}	1.00 ± 0.05^{a}	3.00 ± 0.36^{bc}	1.00 ± 0.05^{b}	89.18 ± 0.63^{bc}	370.60^{d}

Processed WYP	96.90 ± 0.84^{a}	3.10 ± 0.38^{cd}	2.97 ± 0.45^{bc}	1.00 ± 0.10^{a}	2.00 ± 0.13^{cd}	2.00 ± 0.20^{ab}	88.93 ± 0.45^{cd}	376.60^{cd}
Processed WAYP	97.90 ± 1.00^{a}	2.10 ± 0.05^{d}	1.22 ± 0.13^{d}	1.00 ± 0.05^{a}	2.00 ± 0.26^{cd}	1.00 ± 0.10^{b}	92.68 ± 0.70^{a}	384.40^{b}
Processed WAYPF	94.90 ± 0.44^{b}	5.10 ± 0.41^{b}	1.05 ± 0.23^{d}	2.00 ± 0.22^{a}	2.00 ± 0.37^{cd}	2.00 ± 0.19^{ab}	87.85 ± 0.66^{e}	373.60^{d}
Processed WAYF	93.00 ± 0.54^{c}	7.00 ± 0.37^{a}	1.75 ± 0.20^{cd}	1.00 ± 0.10^{a}	5.00 ± 0.38^{a}	1.00 ± 0.05^{b}	84.25 ± 0.54^{f}	353.00^{f}

Table 1: *Proximate Composition for Yam Flour Fortified with Cowpea in The Ratio Of 100:0.*

Values are Mean ± SD

Means followed by the same superscript within the same column are not significantly different at $p \le 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	% Dry Matter	% Moisture Content	% Crude Protein	% Fat	% Crude Fiber	% Ash	% Carbohydrate	Energy K. Cal
WY	92.50 ± 0.56^{ab}	7.50 ± 0.15^{d}	4.90 ± 0.05^{ab}	1.00 ± 0.05^{b}	9.00 ± 0.46^{b}	1.00 ± 0.06^{b}	76.96 ± 0.55^{cd}	335.00^{b}
WYF	92.20 ± 0.46^{ab}	7.80 ± 0.44^{c}	4.20 ± 0.50^{ab}	1.00 ± 0.05^{b}	7.00 ± 0.25^{c}	1.00 ± 0.10^{b}	79.00 ± 0.52^{a}	341.80^{a}
WYPF	91.90 ± 0.51^{ab}	8.10 ± 0.19^{b}	4.55 ± 0.25^{a}	1.00 ± 0.05^{b}	12.00 ± 0.23^{a}	1.00 ± 0.29^{b}	73.00 ± 1.31^{e}	320.60^{d}
WYP	93.00 ± 0.53^{a}	7.00 ± 0.33^{e}	2.27 ± 0.53^{c}	2.00 ± 0.10^{a}	9.00 ± 0.33^{b}	2.00 ± 0.43^{a}	77.73 ± 1.21^{b}	338.00^{b}
WAY	92.00 ± 0.62^{ab}	8.00 ± 0.31^{b}	4.72 ± 0.21^{ab}	1.00 ± 0.05^{b}	12.00 ± 0.84^{a}	1.00 ± 0.05^{b}	73.28 ± 0.84^{c}	321.00^{d}
WAYP	93.60 ± 0.84^{ab}	7.40 ± 0.09^{d}	4.20 ± 0.45^{ab}	1.00 ± 0.13^{b}	15.00 ± 0.18^{a}	1.00 ± 0.05^{b}	71.40 ± 0.39^{f}	311.40^{e}
WAYPF	92.20 ± 0.65^{ab}	7.80 ± 0.24^{c}	4.72 ± 0.39^{ab}	1.00 ± 0.05^{b}	8.00 ± 0.23^{b}	1.00 ± 0.14^{b}	77.48 ± 0.95^{bc}	337.80^{b}
WAYF	91.50 ± 0.98^{b}	8.50 ± 0.39^{a}	3.85 ± 1.31^{b}	1.00 ± 0.10^{b}	9.00 ± 1.00^{b}	1.00 ± 0.05^{b}	76.65 ± 0.86^{d}	331.00^{c}

Table 2: *Proximate Composition for Yam Flour Fortified with Cowpea in The Ratio of 80:20.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \le 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	% Dry Matter	% Moisture Content	% Crude Protein	% Fat	% Crude fiber	% Ash	% Carbohydrate	Energy k. Cal
WY	91.90 ± 0.67^{c}	8.10 ± 0.44^{c}	7.30 ± 0.34^{d}	2.00 ± 0.21^{a}	6.00 ± 0.17^{g}	1.00 ± 0.10^{b}	75.60 ± 0.68^{b}	349.60^{a}
WYP	92.20 ± 0.70^{b}	7.80 ± 0.23^{d}	6.65 ± 0.33^{e}	2.00 ± 0.35^{a}	10.00 ± 0.15^{b}	1.00 ± 0.05^{b}	72.55 ± 0.43^{d}	334.80^{e}
WYF	91.80 ± 0.57^{c}	8.20 ± 0.32^{c}	6.47 ± 0.26^{f}	1.00 ± 0.11^{b}	7.00 ± 0.05^{f}	1.00 ± 0.05^{b}	76.33 ± 0.60^{a}	340.20^{b}
WYPF	92.20 ± 0.45^{b}	7.80 ± 0.45^{d}	8.92 ± 0.50^{a}	2.00 ± 0.10^{a}	11.00 ± 0.22^{c}	2.00 ± 0.12^{a}	68.28 ± 0.55^{f}	326.80^{d}
WAY	91.50 ± 0.78^{d}	8.50 ± 0.47^{b}	8.22 ± 0.43^{c}	1.00 ± 0.05^{b}	8.00 ± 0.19^{e}	1.00 ± 0.05^{b}	73.28 ± 0.43^{c}	335.00^{c}
WAYP	92.41 ± 0.67^{a}	7.60 ± 0.22^{d}	7.70 ± 0.36^{g}	1.00 ± 0.11^{b}	19.00 ± 0.26^{a}	1.00 ± 0.10^{b}	63.70 ± 0.51^{h}	294.60^{g}
WAYF	90.20 ± 0.71^{e}	9.80 ± 0.24^{a}	6.12 ± 0.21^{b}	1.00 ± 0.05^{b}	11.00 ± 0.22^{c}	2.00 ± 0.05^{a}	70.08 ± 0.45^{e}	313.80^{f}
WAYPF	91.40 ± 0.56^{d}	8.60 ± 0.20^{b}	8.57 ± 0.31^{b}	2.00 ± 0.13^{a}	12.00 ± 0.36^{b}	2.00 ± 0.05^{a}	66.83 ± 0.57^{g}	319.60^{e}

Table 3: *Proximate Composition for Yam Flour Fortified with Cowpea in The Ratio of 70:30.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

% Treatment	% Dry Matter	% Moisture Content	%Crude Protein	% Fat	% Crude Fiber	% Ash	% Carbohydrate	Energy K. Cal
WY	92.70 ± 0.45^b	7.30 ± 0.58^c	9.20 ± 0.36^a	1.00 ± 0.05^b	7.00 ± 0.45^g	1.00 ± 0.10^a	75.65 ± 0.57^b	343.80^a
WYF	92.30 ± 0.60^c	7.70 ± 0.23^b	7.60 ± 0.32^g	2.00 ± 0.17^a	11.00 ± 0.43^f	1.00 ± 0.05^a	72.70 ± 0.19^c	331.82^b
WYP	93.00 ± 0.47^a	7.00 ± 0.19^d	8.05 ± 0.49^e	1.00 ± 0.05^b	13.00 ± 0.44^d	1.00 ± 0.05^a	68.90 ± 0.63^d	321.23^c
WYPF	92.30 ± 0.68^c	7.70 ± 0.43^b	8.92 ± 0.4^5b	1.00 ± 0.10^b	17.00 ± 1.06^b	1.00 ± 0.10^a	64.38 ± 0.71^f	302.20^e
WAY	92.53 ± 0.56^b	7.40 ± 0.44^c	8.32 ± 0.53^d	1.00 ± 0.11^b	20.10 ± 0.33^a	1.00 ± 0.05^a	63.68 ± 0.59^f	291.00^f
WAYP	92.50 ± 0.57^{bc}	7.50 ± 0.56^{bc}	7.75 ± 0.51^f	1.00 ± 0.05^b	16.00 ± 0.33^c	1.00 ± 0.05^a	67.15 ± 0.60^e	307.00^d
WAYF	91.50 ± 0.63^d	8.50 ± 0.34^a	6.60 ± 0.23^h	1.00 ± 0.05^b	12.00 ± 0.20^e	1.00 ± 0.10^a	71.90 ± 0.57^c	319.00^c
WAYPF	92.70 ± 0.83^b	7.30 ± 0.33^c	8.65 ± 0.21^c	1.00 ± 0.05^b	7.00 ± 0.33^g	1.00 ± 0.05^a	77.75 ± 0.55^a	343.80^a

Table 4: *Proximate Composition for Yam Flour Fortified with Cowpea in The Ratio of 60:40.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam pee; Wayf: Water yam fermented

Mineral Element Composition

The mineral element contents of the blend obtained is presented in [Tables 5a, 5b, 5c and 5d]. The calcium level in white yam tends to be higher at 20% and 40% fortification with the values (0.40 ± 0.05 and 0.40 ± 0.05) when compared with the control. A decrease in the amount of calcium was seen in the fortified sample for white yam fermented when compared to the unfortified and processed sample. However white yam peel at 40% fortification had an increase in calcium level from 0.30 ± 0.05 to 0.50 ± 0.05 when compared with the unfortified. White yam peel and fermented had a decrease in calcium content, at 20% and 30% fortification. However, at 40% fortification value remains as the same as that of the unfortified sample. Water yam had an increase in the calcium level in the entire fortified sample, when compared to the unfortified sample and control, with 20% fortification of the water yam having the highest calcium level of about 0.40 ± 0.05. Water yam fermented had a higher calcium level at 30% and 40% fortification. Water yam peel had a higher calcium level at 40% fortification. The magnesium level of the fortified and unfortified sample ranges from (0.00 to 0.03) white yam fermented and water yam, all at 30% fortification had the highest level of magnesium.

Treatments	Ca	Mg	K (0%)	Na	P
C1 Wy	0.20 ± 0.05[c]	0.00 ± 0.00[c]	0.93 ± 0.05[h]	0.17 ± 0.03[e]	0.07 ± 0.05[a]
C2 Way	0.20 ± 0.03[c]	0.00 ± 0.00[c]	1.10 ± 0.05[e]	0.21 ± 0.04[c]	0.07 ± 0.05[a]
Wyf	0.40 ± 0.05[a]	0.10 ± 0.03[b]	1.85 ± 0.05[b]	0.29 ± 0.05[b]	0.10 ± 0.06[a]
Wyp	0.30 ± 0.05[b]	0.10 ± 0.05[b]	0.93 ± 0.06[h]	0.13 ± 0.05[f]	0.08 ± 0.01[a]
Wypf	0.40 ± 0.05[a]	0.00 ± 0.00[c]	2.00 ± 0.05[a]	0.35 ± 0.04[a]	0.10 ± 0.05[a]
Wayf	0.30 ± 0.05[b]	0.10 ± 0.03[b]	1.78 ± 0.05[c]	0.21 ± 0.05[c]	0.10 ± 0.05[a]
Wayp	0.30 ± 0.05[b]	0.00 ± 0.00[c]	0.95 ± 0.05[g]	0.21 ± 0.05[c]	0.08 ± 0.05[a]
Waypf	0.20 ± 0.05[c]	0.20 ± 0.05[a]	1.28 ± 0.06[d]	0.19 ± 0.05[d]	0.10 ± 0.03[a]

Table 5a: *Mineral Element Analysis of the Various Ratio Of Yam Flour.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Wayp f: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Ca	Mg	K (20%)	Na	P
C1 Wy	0.40 ± 0.05[a]	0.00 ± 0.00[c]	0.85 ± 0.05[f]	0.32 ± 0.06[c]	0.09 ± 0.05[a]
C2 Way	0.40 ± 0.05[a]	0.20 ± 0.03[a]	1.93 ± 0.05[a]	0.22 ± 0.05[f]	0.10 ± 0.05[a]
Wyf	0.20 ± 0.05[c]	0.10 ± 0.06[b]	0.85 ± 0.06[f]	0.15 ± 0.05[g]	0.08 ± 0.05[a]
Wyp	0.40 ± 0.05[a]	0.10 ± 0.03[b]	1.63 ± 0.06[b]	0.36 ± 0.05[b]	0.06 ± 0.05[a]
Wypf	0.20 ± 0.03[c]	0.10 ± 0.05[b]	0.93 ± 0.07[e]	0.41 ± 0.05[a]	0.07 ± 0.06[a]
Wayf	0.20 ± 0.05[c]	0.10 ±0.05[b]	1.00 ± 0.03[d]	0.22 ± 0.05[f]	0.08 ± 0.05[a]
Wayp	0.30 ± 0.05[b]	0.00 ± 0.00[c]	1.00 ± 0.03[d]	0.29 ± 0.05[d]	0.10 ± 0.05[a]
Waypf	0.30 ± 0.05[b]	0.00 ± 0.00[c]	1.25 ± 0.07[c]	0.25 ± 0.05[e]	0.06 ± 0.05[a]

Table 5b: *Mineral Element Analysis of the Various Ratio Of Yam Flour.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Ca	Mg	K (0%)	Na	P
Wy	0.20 ± 0.05[c]	0.20 ± 0.03[b]	1.13 ± 0.06[b]	0.29 ± 0.05[b]	0.05 ± 0.03[a]
Wyf	0.20 ± 0.05[c]	0.30 ± 0.05[a]	1.78 ± 0.06[a]	0.37 ± 0.05[a]	0.19 ± 0.05[a]
Wyp	0.30 ± 0.05[b]	0.20 ± 0.05[b]	0.98 ± 0.06[c]	0.21 ± 0.05[bc]	0.06 ± 0.05[a]
Wypf	0.30 ± 0.05[b]	0.00 ± 0.00[d]	0.90 ± 0.05[d]	0.20 ± 0.05[c]	0.09 ± 0.06[a]
Way	0.30 ± 0.05[b]	0.30 ± 0.05[a]	1.75 ± 0.06[a]	0.26 ± 0.05[bc]	0.15 ± 0.05[a]
Wayf	0.40 ± 0.05[a]	0.00 ± 0.00[d]	1.20 ± 0.06[b]	0.24 ± 0.03[bc]	0.12 ± 0.05[a]
Wayp	0.30 ± 0.05[b]	0.10 ± 0.05[c]	1.00 ± 0.05[c]	0.23 ± 0.05[bc]	0.12 ± 0.05[a]
Waypf	0.40 ± 0.05[a]	0.20 ± 0.05[b]	1.05 ± 0.05[c]	0.26 ± 0.05[bc]	0.12 ± 0.05[a]

Table 5c: *Mineral Element Analysis of The Various Ratio Of Yam Flour.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at p ≤ 0.05

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Ca	Mg	K (0%)	Na	P
Wy	0.40 ± 0.05[b]	0.00 ± 0.00[c]	1.10 ± 0.05c	0.16 ± 0.05[bc]	0.10 ± 0.05[c]
Wyf	0.30 ± 0.05[c]	0.10 ± 0.05[b]	1.30 ± 0.06[a]	0.16 ± 0.05[bc]	0.08 ± 0.05[e]
Wyp	0.50 ± 0.05[a]	0.10 ± 0.03[b]	1.90 ± 0.05[a]	0.24 ± 0.05[ab]	0.12 ± 0.05[a]
Wypf	0.40 ± 0.05[b]	0.10 ± 0.05[b]	1.63 ± 0.07[a]	0.24 ± 0.05[ab]	0.11 ± 0.04[b]
Way	0.30 ± 0.05[c]	0.00 ± 0.00[c]	1.28 ± 0.05[b]	0.17 ± 0.06[bc]	0.10 ± 0.05[c]
Wayf	0.40 ± 0.05[b]	0.20 ± 0.05[a]	1.58 ± 0.06[ab]	0.28 ± 0.05[a]	0.09 ± 0.05[d]
Wayp	0.40 ± 0.05[b]	0.20 ± 0.06[a]	1.75 ± 0.05[a]	0.19 ± 0.04[bc]	0.08 ± 0.05[e]
Waypf	0.20 ± 0.05[d]	0.00 ± 0.00[c]	0.65 ± 0.05[c]	0.12 ± 0.03[c]	0.09 ± 0.05[d]

Table 5d: *Mineral Element Analysis of the Various Ratio of Yam Flour.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at p ≤ 0.05

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Potassium present in the fortified and unfortified sample ranges from 0.65 ± 0.05 for water yam peel fermented at 40% fortification to 2.00 ± 0.05 for white yam peel fermented at 0% fortification.

Sodium was higher in white yam peel fermented at 20% fortification with the value (0.41 ± 0.05 and lower in water yam peel fermented and at 40% fortification with the value 0.12 ± 0.03.

Phosphorus level in the fortified and unfortified ranges from 0.05 ± 0.03 for white yam to 0.19 ± 0.05 for white yam fermented and all at 30% fortification.

Water Absorption Index Determination

The water absorption index is presented in table 6, it measures the extent of water retention in yam flour, and this affects the ability of the yam flour to form paste. It was determined using the modified method of [15]. The water absorption index for the control range from (410.13 ± 0.58 and 420.32 ± 0.64) %, for the processed (402.09 ± 0.45 to 497.61 ± 0.55) and the fortified samples (315.02 ± 0.19 to 910.86 ± 0.45) %. Results shows that the fortified samples had a higher water absorption index when compared with the control. However white yam at 40% fortification had a water absorption index of (421.02 ± 0.45) % which is significantly the same as the control. Water yam peel fermented and at 20% fortification had the highest water absorption index of (910.86 ± 0.45). The water absorption indexes of the processed and fortified sample were statistically significant at p ≤ 0.05. (Table-6)

Treatments	0%	20%	30%	40%
Control (1) wy	420.32 ± 0.64	478.03 ± 0.87^{a}	399.20 ± 0.71^{b}	421.02 ± 0.45^{bcd}
Control (2) way	410.13 ± 0.58^{c}	400.00 ± 0.05^{a}	385.60 ± 1.03^{b}	508.00 ± 0.68^{a}
Processed wyf	497.61 ± 0.5^{5}a	462.40 ± 0.39^{a}	468.00 ± 0.54^{a}	408.00 ± 0.71^{cd}
Processed wypf	462.41 ± 1.02^{b}	315.02 ± 0.19^{a}	354.40 ± 0.68^{b}	468.80 ± 0.44^{ab}
Processed wyp	404.00 ± 0.43^{c}	422.40 ± 0.66^{a}	531.20 ± 0.67^{b}	450.40 ± 1.03^{a}
Processed wayp	402.09 ± 0.45^{c}	414.08 ± 0.68^{a}	399.00 ± 0.36^{b}	496.34 ± 0.71^{a}
Processed waypf	436.83 ± 0.55^{bc}	910.86 ± 0.45^{a}	493.00 ± 0.23^{a}	414.77 ± 0.40^{cd}
Processed wayf	412.74 ± 0.37^{c}	680.34 ± 0.68^{a}	465.40 ± 0.45^{a}	357.920 ± 89^{d}

Table 6: *Water Absorption Index for Fortified and Unfortified Yam Flour.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at p ≤ 0.05

W: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Pasting Properties of Yam Flour

In [Tables 7, 8, 9, and 10] variations were observed in the pasting properties, pasting characteristic (peak viscosity, and final viscosity) decreased significantly in most of the treatments as proportion of cowpea flour increases above 10%. The peak viscosities for the fortified samples ranges from (147.00 ± 0.75 to 317.20 ± 0.45) RVU and were significantly different (p ≤ 0.05) from each other. The peak values of the fortified sample were considerably low compared to the control and processed unfortified samples. Breakdown of the yam flour for the fortified and unfortified flour samples which ranges from (10.05 ± 0.66 to 132.78 ± 0.43) RVU were significantly different (p ≤ 0.05). The highest breakdown for the fortified sample was 93.46 ± 0.44RVU (white yam fermented) at 20% fortification and for the unfortified 132.78 ± 0.43RVU (white yam). The setback values ranged from (23.25 ± 0.26 to 140.78 ± 0.56) RVU there is significant difference p ≤ 0.05 in the setback of the yam flour samples. The unfortified sample (white yam) in particular had the highest setback value of 140.78 ± 0.56RVU while water yam at 20%fortification had the lowest setback value of 23.25 ± 0.26RVU. Peak time ranges from (3.76 ± 0.62 to 6.37 ± 0.71) min. water yam at 0% fortification had the highest peak time and white yam peel fermented had the lowest peak time at 30% fortification. The pasting temperature ranges from (61.00 ± 0.59 to 62.89 ± 0.58)°C with water yam at 40% fortification having the highest pasting temperature of (62.89 ± 0.58)°C. The pasting temperature is not significantly different (p ≤ 0.05). However higher temperatures were observed in white yam peel and fermented at 40% fortification (62.68 ± 0.35)°C, water yam peel and at 40% fortification (62.74 ± 0.60)°C, white yam fermented at 0% fortification (62.67 ± 0.55)°C, water yam at 0% fortification (62.40 ± 50.34)°C, water yam peel at 20% fortification (62.00 ± 50.23)°C.

Treatments	Peak	Trough	Breakdown	Final Viscosity	Set back	Peak time	Pasting Temp (^{0}C)
Control (1) Wy	372.40 ± 0.45^a	239.62 ± 0.57^a	132.78 ± 0.43^a	388.35 ± 0.53^a	140.78 ± 0.56^a	4.73 ± 0.23^{de}	61.09±0.56^c
Control (2) Way	250.53 ± 0.98^f	147.28 ± 0.55^g	103.25 ± 0.69^b	171.63 ± 0.78^f	34.35 ± 0.71^h	6.37 ± 1.03^a	61.00 ± 0.66^c
Processed Wyf	226.76 ± 0.76^g	142.44 ± 0.88^h	84.32 ± 0.34^c	236.77 ± 0.67^e	41.97 ± 0.45^e	4.40 ± 0.34^e	62.67 ± 0.55^a
Processed Wypf	268.58 ± 0.47^e	223.47 ± 0.55^c	35.11 ± 0.54^f	260.44 ± 0.57^c	37.41 ± 0.55^g	5.43 ± 0.31^{cd}	61.85 ± 0.47^b
Processed Wyp	270.41 ± 0.70^b	235.57 ± 0.71^b	34.84 ± 0.23^f	260.45 ± 0.44^c	40.42 ± 1.17^f	5.49 ± 0.55^{bcd}	61.90 ± 0.68^b
Processed Wayp	211.39 ± 0.83^h	187.52 ± 0.71^f	23.87 ± 0.56^g	167.04 ± 0.79^g	40.42 ± 1.17^f	4.93 ± 0.22^{de}	62.45 ± 0.34^a
Processed Wapf	261.00 ± 0.45^d	222.45 ± 0.67^d	38.55 ± 0.41^e	259.54 ± 0.56^d	45.55 ± 0.34^d	6.23 ± 0.56^{ab}	61.90 ± 0.13^b
Processed Wayf	267.53±0.56^c	219.57±0.78^e	47.96 ± 0.45^d	277.34 ± 0.57^b	46.60 ± 0.44^c	5.71 ± 0.71^{abc}	61.83 ± 0.23^b

Table 7: *Pasting Property of Yam Flour At 0%.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak time (Mins)	Pasting Temp (^{0}C)
Wy	317.20 ± 0.45^a	235.62 ± 0.75^a	81.58 ± 0.43^b	374.83 ± 0.66^a	111.02 ± 0.41^a	4.76 ± 0.60^c	61.87 ± 0.35^b
Wyf	216.96 ± 0.78^d	122.50 ± 0.55^e	93.46 ± 0.44^a	162.42 ± 0.74^f	28.91 ± 0.05^g	4.68 ± 0.50^c	61.87 ± 0.43^b
Wypf	250.58 ± 0.67^b	214.38 ± 0.45^b	36.12 ± 0.44^b	260.79 ± 0.56^b	36.41 ± 0.78^e	5.41 ± 0.55^b	61.95 ± 0.37^b
Wyp	240.71 ± 0.55^c	214.33 ± 0.88^b	26.37 ± 0.47^f	258.50 ± 0.57^c	44.17 ± 0.14^b	5.49 ± 0.45^b	61.90 ± 0.45^b
Way	150.83 ± 0.89^f	138.08 ± 0.23^d	12.75 ± 0.61^g	161.33 ± 0.45^g	23.25 ± 0.26^h	6.37 ± 0.71^a	61.62 ± 0.38^b
Wayp	191.79 ± 0.55^e	120.62 ± 0.45^e	71.16 ± 0.66^c	158.04 ± 0.31^h	37.42 ± 0.33^d	4.93 ± 0.07^c	62.05 ± 0.23^b
Wapf	250.58 ± 0.98^b	213.93 ± 0.57^c	36.66 ± 0.88^d	255.50 ± 1.14^d	31.58 ± 0.44^f	5.44 ± 0.57^b	61.87 ± 0.37^a
Wayf	250.58 ± 0.37^b	214.33 ± 0.65^b	36.25 ± 0.55^e	254.60 ± 0.50^e	40.40 ± 0.31^c	5.42 ± 0.43^b	61.86 ± 0.67^b

Table 8: *Pasting Property of Yam Flour at 20% Fortification.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wyp: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (Mins)	Pasting temp (^{0}c)
WY	215.34 ± 0.58^{bc}	173.53 ± 0.71^{ab}	41.81 ± 1.17^{abc}	221.99 ± 0.43^{b}	53.33 ± 0.55^{b}	4.79 ± 0.40^{ab}	61.59 ± 0.43^{a}
WYF	215.35 ± 0.67^{bc}	173.54 ± 0.50^{ab}	41.81 ± 0.80^{abc}	222.01 ± 0.66^{b}	53.34 ± 0.47^{b}	4.79 ± 0.74^{ab}	61.59 ± 0.57^{a}
WYPF	282.64 ± 0.57^{a}	223.98 ± 0.38^{a}	58.66 ± 0.67^{abc}	276.37 ± 0.35^{a}	118.51 ± 0.08^{a}	3.76 ± 0.62^{b}	60.97 ± 0.37^{a}
WYP	233.19 ± 0.45^{ab}	153.80 ± 0.56^{ab}	79.39 ± 0.58^{a}	218.46 ± 0.45^{b}	63.71 ± 0.38^{b}	5.58 ± 0.33^{a}	61.74 ± 0.58^{a}
WAY	237.60 ± 0.78^{ab}	175.51 ± 0.55^{ab}	62.09 ± 0.77^{ab}	205.77 ± 0.77^{b}	37.83 ± 0.34^{b}	4.80 ± 0.41^{ab}	61.69 ± 0.71^{a}
WAYP	217.89 ± 0.43^{bc}	207.84 ± 0.88^{ab}	10.05 ± 0.66^{bc}	239.53 ± 0.47^{ab}	42.12 ± 0.57^{b}	5.00 ± 0.45^{ab}	61.88 ± 0.84^{a}
WAPF	167.84 ± 0.55^{c}	161.07 ± 0.67^{ab}	6.77 ± 0.36^{c}	174.69 ± 0.68^{b}	42.51 ± 0.57^{b}	4.78 ± 0.61^{ab}	61.92 ± 0.47^{a}
WAYF	164.82 ± 0.57^{c}	125.87 ± 0.37^{ab}	38.95 ± 0.34^{abc}	145.74 ± 0.87^{b}	27.38 ± 0.35^{b}	5.06 ± 0.44^{ab}	61.96 ± 0.35^{a}

Table 9: *Pasting Property of Yam Flour at 30% Fortification.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (Mins)	Pasting temp (^{0}c)
Wy	236.76 ± 0.69^{b}	214.64 ± 0.65^{a}	22.12 ± 0.31^{f}	341.67 ± 0.58^{a}	98.45 ± 0.55^{a}	4.62 ± 0.72^{a}	61.32 ± 0.58^{b}
Wyf	211.70 ± 0.78^{d}	121.07 ± 0.77^{b}	90.63 ± 0.44^{a}	144.37 ± 0.45^{e}	36.23 ± 0.45^{g}	4.54 ± 0.65^{a}	61.38 ± 0.45^{b}
Wypf	245.58 ± 0.43^{a}	190.87 ± 0.58^{d}	54.71 ± 0.23^{c}	221.58 ± 0.64^{d}	40.78 ± 0.60^{e}	4.44 ± 0.45^{a}	62.68 ± 0.35^{a}
Wyp	197.67 ± 0.58^{e}	145.67 ± 0.78^{e}	52.00 ± 0.81^{d}	233.77 ± 0.57^{c}	44.41 ± 0.78^{d}	4.56 ± 0.32^{a}	61.45 ± 0.29^{b}
Way	147.00 ± 0.75^{h}	135.07 ± 0.47^{f}	11.93 ± 0.08^{g}	137.43 ± 0.78^{f}	33.67 ± 0.54^{h}	4.66 ± 0.13^{a}	62.89 ± 0.58^{a}
Wayp	166.80 ± 0.57^{g}	111.56 ± 0.74^{h}	55.24 ± 0.45^{c}	121.41 ± 0.62^{g}	46.82 ± 0.45^{b}	3.98 ± 0.06^{a}	62.74 ± 0.60^{a}
Wapf	234.64 ± 0.45^{c}	211.23 ± 0.34^{c}	23.41 ± 0.71^{e}	240.01 ± 0.89^{b}	46.03 ± 0.33^{c}	4.42 ± 0.71^{a}	61.43 ± 0.35^{b}
Wayf	187.49 ± 0.65^{f}	123.43 ± 0.56^{g}	64.04 ± 0.37^{b}	233.55 ± 0.47^{c}	36.61 ± 0.40^{f}	4.38 ± 0.09^{a}	61.00 ± 0.59^{c}

Table 10: *Pasting Property of Yam Flour at 40% Fortification.*

Table 10: Pasting Property of Yam Flour at 40% Fortification.

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wy: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Time (Hours)		
	0	1	6
Control 1 wy	46.25 ± 0.57[a]	55.61 ± 0.48[a]	65.28 ± 0.70[a]
Control 2 way	42.84 ± 0.47[a]	53.06 ± 0.60[a]	58.86 ± 0.60[a]
Processed wyf	46.26 ± 0.34[a]	55.62 ± 0.60[a]	65.28 ± 0.45[a]
Processed wypf	46.26 ± 0.45[a]	55.62 ± 0.33[a]	45.29 ± 0.05[a]
Processed wyp	42.09 ± 0.25[a]	45.94 ± 0.47[a]	49.78 ± 1.01[a]
Processed wayf	27.49 ± 0.60[a]	36.57 ± 0.37[a]	48.07 ± 0.74[a]
Processed waypf	41.06 ± 0.47[a]	63.37 ± 0.55[a]	65.01 ± 0.58[a]
Processed wayp	53.04 ± 0.47[a]	61.99 ± 0.71[a]	70.56 ± 0.64[a]

***Table 11a:** In vitro Protein Digestibility 0%.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Treatments	Time (Hours)		
	0	1	6
Control 1 wy	64.26 ± 0.58[a]	71.45 ± 0.56[ab]	75.09 ± 0.35[ab]
Control 2 way	68.61 ± 0.71[a]	75.23 ± 1.02[ab]	80.24 ± 0.45[ab]
Processed wyf	64.25 ± 0.45[a]	71.44 ± 0.68[ab]	75.09 ± 0.68[ab]
Processed wypf	51.24 ± 0.38[a]	60.14 ± 0.42[c]	55.79 ± 0.60[c]
Processed wyp	61.76 ± 0.57[a]	66.42 ± 0.70[bc]	69.34 ± 0.70[b]
Processed wayf	57.19 ± 0.45[b]	75.03 ± 0.65[ab]	81.65 ± 0.52[a]
Processed waypf	67.68 ± 0.54[a]	72.46 ± 0.35[ab]	77.62 ± 0.57[ab]
Processed wayp	66.77 ± 0.55[b]	78.49 ± 0.77[a]	83.28 ± 0.33[a]

***Table 11b:** In vitro Protein Digestibility 20%.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Sample	Time (hours)		
	0	1	6
Wy	64.40 ± 0.47[f]	76.52 ± 0.87[d]	75.10 ± 0.35[g]
Way	68.84 ± 0.23[b]	78.28 ± 1.06[b]	80.98 ± 0.37[b]
Wyf	64.37 ± 0.45[g]	75.71 ± 0.57[e]	76.60 ± 0.44[d]
Wypf	72.53 ± 0.34[a]	74.55 ± 0.41[f]	76.45 ± 0.22[e]
Wyp	62.74 ± 0.61[h]	74.61 ± 0.71[g]	75.60 ± 0.61[f]
Wayf	66.25 ± 0.73[e]	66.53 ± 0.23[h]	69.50 ± 0.47[h]
Waypf	68.55 ± 0.68[c]	77.08 ± 0.28[c]	78.96 ± 0.45[c]
Wayp	66.78 ± 0.55[d]	79.85 ± 0.57[a]	85.30 ± 0.31[a]

Table 11c: *In vitro Protein Digestibility 30%.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Sample	Time (hours)		
	0	1	6
Wy	65.34 ± 1.04[h]	77.67 ± 0.75[f]	89.63 ± 0.58[a]
Way	71.09 ± 0.57[c]	85.35 ± 1.13[a]	85.63 ± 0.31[c]
Wyf	71.31 ± 0.71[b]	84.09 ± 0.66[c]	76.72 ± 0.57[f]
Wypf	81.77 ± 0.34[a]	83.78 ± 0.41[d]	84.68 ± 0.31[d]
Wyp	64.81 ± 0.66[g]	82.63 ± 0.45[e]	76.69 ± 0.45[g]
Wayf	67.24 ± 0.05[f]	67.24 ± 0.05[f]	68.66 ± 0.56[h]
Waypf	69.29 ± 0.45[e]	77.39 ± 1.20[g]	79.32 ± 1.05[e]
Wayp	70.00 ± 0.56[d]	84.54 ± 0.67[b]	89.24 ± 13[b]

Table 11d: *In vitro Protein Digestibility 40%.*

Each reading is the mean of triplicate determination ± SD

Means followed by the same superscript within the same column are not significantly different at $p \leq 0.05$

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

In vitro Protein Digestibility

Microbiological Analysis

[Table 12] shows the microbial counts and total mold count. The total bacteria count ranged between 9.0×10^3cfu to 84×10^3

Treatments	Total bacteria count (CFU)				Total mould count (CFU)			
	0	20	30	40	0	20	30	40
Control (1) WY	11 x 10^3	10 x 10^3	15 x 10^3	13 x 10^3	5 x 10^3	1 x 10^3	3 x 10^3	2 x 10^3
Control (2) WAY	20 x 103	20 x 10^3	16 x 10^3	26 x 10^3	2 x 10^3	0 x 10^3	2 x 10^3	2 x 10^3
Processed WYF	43 x10^3	57 x 10^3	21 x 10^3	35 x 10^3	1 x 10^3	5 x 10^3	3 x 10^3	3 x 10^3
Processed WYPF	23 x 10^3	68 x 10^3	32 x 10^3	68 x 10^3	0 x 10^3	2 x 10^3	6 x 10^3	0 x 10^3
Processed WYP	23 x 10^3	9 x 10^3	29 x 10^3	28 x 10^3	2 x 10^3	2 x 10^3	4 x 10^3	3 x 10^3
Processed WAYP	13 x 10^3	18 x 10^3	27 x 10^3	18 x 10^3	2 x 10^3	1 x 10^3	3 x 10^3	0 x 10^3
Processed WAYPF	78 x 10^3	43 x 10^3	84 x 10^3	46 x 10^3	7 x 10^3	7 x 10^3	11 x 10^3	3 x 10^3
Processed WAYF	87 x 10^3	39 x 10^3	78 x 10^3	42 x 10^3	5 x 10^3	0 x 10^3	6 x 10^3	0 x 10^3

Table 12: *Microbiological Analysis Carried Out On the Fortified and Unfortified Sample.*

CFU= Colony forming unit

Wy: White yam; Way: Water yam; Wyf: White yam fermented; Wayp: Water yam peel; Wypf: White yam peel fermented; Waypf: Water yam peel fermented; Wyp: White yam peel; Wayf: Water yam fermented

Bacterial Isolated from the Samples

Proteus species, *Carynobacteria species*, *Aspergillus niger*, *Aspergillus flavum*, was isolated from cowpea. *Carynobacteria* species, *Bacillus subtilis*, *Aspergillus niger* was isolated from water yam at 0% fortification. *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus album*, *Aspergillus niger* was isolated from water yam peel at 0% fortification. *Staphylococcus album*, *Carynobacteria* species *Aspergillus niger*, *Rhizopus* was found in white yam at 0% fortification. *Bacillus subtilis*, *Aspergillus flavum*. *Carynobacteria* species was isolated in white yam peel at 0% fortification.

Staphylococcus album, *Carynobacteria* species *Aspergillus niger*, *Aspergillus flavum* was isolated in water yam and at 30% fortification. *Staphylococcus aureus*, *Streptococcus pyogene*, *Carynobacteria* species, *Aspergillus niger*, *Aspergillus flavus* was isolated in water yam peel at 30% fortification. *Carynobacteria* species *Aspergillus niger*, *Rhizopus*. *Bacillus subtilis* was isolated in white yam at 30% fortification. *Escherichia coli, Carynobacteria* species, *Staphylococcus aureus, Aspergillus niger, Rhizopus*, was isolated in white yam peel at 30% fortification. *Streptococcus pyogene, Bacillus subtilis, Aspergillus niger*, was isolated in water yam at 40% fortification. *Staphylococcus albus, Carynobacteria* species was isolated in water yam peel at 40% fortification. *Bacillus subtilis, Carynobacteria* species, *Aspergillus niger* was isolated in white yam at 40% fortification, *Carynobacteria* species *Aspergillus niger, Rhizopus* was isolated in white yam peel at 40% fortification. Staphylococcus albus, Carynobacteria species was isolated in water yam at 20% fortification, *Staphylococcus albus*, *Carynobacteria* species *Aspergillus niger* was isolated in water yam peel and at 20% fortification, *Carynobacteria* species, *Aspergillus flavus, streptococcus pyogene*, was isolated in white yam and at 20% fortification. *Staphylococcus albus*, *Carynobacteria* species, *Bacillus subtilis* was isolated in white yam peel at 20% fortification, *Carynobacteria* species *Aspergillus niger*, *Rhizopus, Lactobacillus*, was isolated in water yam fermented at 0% fortification, *Lactobacillus, Carynobacteria* species, *Aspergillus flavus, streptococcus lactis* was isolated in water yam peel fermented at 0% fortification. *Lactobacillus, Carynobacteria* species, *Aspergillus flavus, Aspergillus niger* was isolated in white yam fermented at 0% fortification. *Lactobacillus*, *Carynobacteria* species was isolated in white yam peel and fermented at 0% fortification, *Staphylococcus albus, Lactobacillus, Aspergillus niger, Aspergillus flavus streptococcus lactis* was isolated in water yam fermented at 30% fortification, *streptococcus albus, Lactobacillus, Aspergillus niger, Rhizopus* specie was isolated in water yam peel and fermented at 30% fortification. *Carynobacteria species, Streptococcus lactis, Lactobacillus, Aspergillus niger,* was isolated in white yam fermented at 30% fortification. *Escherichia coli, Lactobacillus, Carynobacteria species, Aspergillus flavus, Aspergillus niger*, was isolated in white yam peel and fermented at 30% fortification *Carynobacteria* species, was isolated in water yam fermented at 40% fortification, *Lactobacillus, Carynobacteria* species, *Rhizopus, Aspergillus niger*, was isolated in water yam peel and fermented at 40% fortification, *Lactobacillus, Streptococcus lactis, Aspergillus niger* was isolated in white yam fermented at 40% fortification. *Carynobacteria species, Streptococcus pyogene* was isolated in white yam peel fermented and at 40% fortification

Lactobacillus, Carynobacteria specie, Aspergillus flavus, Aspergillus niger was isolated from water yam fermented and at 20% fortification, *Lactobacillus, Carynobacteria* species, *Aspergillus flavus, Aspergillus niger, Staphylococcus albus* was isolated in water yam peel fermented and at 20% fortification, *Staphylococcus albus, Lactobacillus, Carynobacteria* species was isolated in white yam fermented and at 20% fortification, *Lactobacillus, Carynobacteria species, Aspergillus niger, Streptococcus pyogene*, was isolated in white yam peel fermented and at 20% fortification.

Discussion

Yam flour was made from its whole (the white part) and its peel. Two varieties of the yam flour (*D. rotundata* and *D. alata*) were used. The yam and cowpea were been Processed and the subsequently the composite flour produced after drying and milling. The sample i.e. yam flour and cowpea flour were fortified in the following ratios 100:0, 80:20, 70:30, and 60:40.

The chemical analysis was calculated using standard method, also evaluated were the functional properties of yam flour, mineral element, *in vitro* protein digestibility and microbiological analysis.

The result of chemical composition for the treatments shows protein content of white yam at 40% with the value 9.20 ± 0.36% to be higher and significantly different $p \leq 0.05$ from other sample as well as the control. The protein content increased with increase in cowpea substitution (Table 1, 2, 3 and 4). Also the fat content of the sample were not significantly different, fat supplies most of the energy required by man. White yam fermented had higher value (3.00%) in ash content. The result indicates that the flour could be a source of mineral element having nutritional importance Ashaye., *et al*. (2001) reported an increase in protein content (7.28%) and ash (3.58%) when yam flour was substituted with 40% cowpea flour while Achi (1999) reported an increase in protein content from 3.5% in the control (yam flour) to 19.7% for yam flour fortified with 40% soybeans flour. There was an increase in crude fibre for the fortified mix; this indicates that yam flour is a good source of dietary fiber. Fiber has useful role in providing roughages that aid digestion [19]. Fiber consumption also soften stool and lower plasma cholesterol level in the body [20]. Carbohydrate content varied and decreased with addition of cowpea flour, this was in agreement with the findings of Jimoh and Olatidoye who reported a decrease in carbohydrate content with increase in soybean flour fortification. According to [21] the low moisture content of the samples would hinder the growth of microorganism and the storage life would be high.

The result of the mineral elements composition is presented in Tables 5a, 5b, 5c and 5d. The Sodium (Na) content for the fortified and unfortified ranges from 0.12% to 0.37%. Sodium is an important mineral that assist in the maintenance of electric potential in the body tissue. The World Health Organization (WHO) recommended intake of sodium per day is 0.50% (500 mg) for adult and 0.40% (400 mg) for children [22]. The result indicates that sodium content was below WHO recommended standard, however white yam peel fermented at 20% fortification was able to meet up with the recommended dosage for children. The potassium (K) Content of the sample range from 0.85% to 2.00%, potassium is important in the regulation of heart beat, neurotransmission and water balance of the body. The WHO recommended intake of potassium per day for adult is 2% that is of heart beat, neurotransmission and water balance of the body. The WHO recommended intake of potassium per day for adult is 2% that is 1000mg, for children is 1.60% (1600mg). This study revealed that potassium content of some of the treatment for the various blend were within WHO standard. Phosphorus content for the various blend range from 0.05% to 0.19%, daily allowance for phosphorus (P) is 0.80% (800mg/ day). The values were below recommended standard. The magnesium content ranges from 0.00% to 0.30%. Magnesium plays essential role in calcium metabolism in bones and also involve in prevention of circulatory diseases. It helps in regulating blood pressure and insulin releases [23]. Recommended daily allowance (RDA) for Magnesium in adult is 0.35% (350 mg/ day), while that of children is 0.17% (170 mg/ day). Result shows that most of the treatments in 30% fortification were able to meet up with the recommended dose for children. Also white yam peel fermented at 20%, water yam peel fermented at 0%, water yam fermented at 40% and water yam peel at 40%, were all able to meet the recommended dose for children. Calcium is an important mineral required for bone formation and neurological function of the body. The calcium content for the various blend range from 0.20% to 0.50%. the recommended daily intake of calcium by WHO is 0.80% (800 mg/ day) for adult and children. This study indicates that yam flour for the various blends and processing method was far below WHO standard.

Water absorption index ranged between 315.02% to 910.86% in yam fortified and unfortified with cowpea flour. These values were much higher than values reported for locust bean seeds [24] and kola seeds [25]. Water absorption index is considered a critical function of protein in viscous food; it there for implies that these samples could be used for viscous food formulation.

Pasting characteristic (peak viscosity, and final viscosity) decreased significantly in most of the treatments as proportion of cowpea flour increases above 10%. The peak values of the fortified sample were considerably low compared to the unfortified samples. Breakdown of the yam flour for the fortified and unfortified flour samples which ranges from (10.05 ± 0.66 to 132.78 ± 0.43) RVU were significantly different ($p \leq 0.05$). The higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and the shear stress during cooking [26]. The breakdown of yam flour sample is the difference in the peak viscosity and trough viscosity [16]. The final viscosity is the most commonly used parameter to define a particular sample quality [27]. There is significant difference $p \leq 0.05$ in the setback of the yam flour samples. The unfortified sample (white yam) in particular had the highest setback value of 140.78 ± 0.56RVU while water yam at 20% fortification had the lowest setback value of 23.25 ± 0.26RVU. The higher the setback value, the lower the retro gradation during cooling and the lower the rate of staling in yam flour [28]. The pasting temperature which is the temperature at which viscosity first increases by 25 RVU over 20 seconds [16]. The pasting temperature is not significantly different ($p \leq 0.05$). However higher temperatures were observed in white yam peel and fermented at 40% fortification (62.68 ± 0.35)˚C, water yam peel and at 40% fortification (62.74 ± 0.60)˚C, white yam fermented at 0% fortification (62.67 ± 0.55)˚C, water yam at 0% fortification (62.40 ± 50.34)˚C, water yam peel at 20% fortification (62.00 ± 50.23)˚C this implies higher gelatinization and lower swelling power of starch due to high degree of association between starch granules [29].

Samples of fortified and unfortified yam flour were assayed for the *in vitro* protein digestibility. Results range from 27.49 ± 0.60% to 70.56 ± 0.64% for the processed and unfortified samples which shows a significant different when compared with the control; however, the *in vitro* protein digestibility was higher in the fortified mixture when compared with the control and processed samples. White yam in 40% fortification and at 6-hour digestibility has a higher *in vitro* protein digestibility of 89.63 ± 0.58. The processing method used for some of the yam flour failed to improve the *in vitro* digestibility of the yam flour particularly in the processed and unfortified samples when compared with the control [30] reported the presence of anti-nutritional factors such as trypsin inhibitors and chemo trypsin inhibitors in legumes covers the digestibility of legume protein. Other anti-nutritional factors such as tannins, phytate, impart bitter or unacceptable taste to the legumes prevent protein digestibility and decrease the absorption of divalent metal ions such as Fe^{2+} and Zn^{2+} in the intestine.

The microbial analysis presented in (Table 12) shows predominance of *Staphylococcus aureus, Aspergillus* species and *Escherichia coli* in all samples. Coliform were observed to be present in all the processing water in the fermented fortified yam flour, the total bacteria count ranged between ($11x10^3$ and $20x10^3$) CFU for the control, (13x103 to 43x103) CFU for the processed sample and ($10x10^3$ to $68x10^3$) CFU for the fortified samples. The majority of the micro-organism involved in the spoilage of yam flour was found to be *Aspergillus niger.*

Conclusion

From the forgoing analyzed result it can be deduced that white yam at 40% fortification had the greater increase in protein content and at the same time recorded the highest digestibility (6hr) at 40% fortification. In conclusion this study has shown that a highly nutritious and acceptable yam flour (Amala) can be produced best in 40% fortification which is a better option for processing yam flour (Amala).

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