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Quality Attributes of Stiff Dough Made from Blends of White, Water and Cocoyam Flour

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Abstract

Quality attributes of Stiff dough made from blends of white, water and cocoyam flour was studied. Nine (9) samples blends comprising: A-100% white yam; B-100% water-yam; C-100% cocoyam; D-80% white yam, 10% water-yam, 10% cocoyam; E-70% white yam, 20% water-yam, 10% cocoyam; F-70% white yam, 10% water-yam, 20% cocoyam; G-60% white yam, 20% water-yam, 20% cocoyam; H-50% white yam, 30% water-yam, 20% cocoyam; and I-50% white yam, 20% water-yam, 30% cocoyam respectively were prepared. Proximate composition, physicochemical, pasting and sensory characteristics of the samples were evaluated. The proximate composition was (3.59 - 11.77%) moisture, (4.87 - 4.98%) ash, (0.41 - 1.7%) crude fat, (7.80 - 8.30%) protein, (2.37 - 2.44%) crude fibre and (72.01 - 79.44%) carbohydrate, with significant differences observed in the moisture, fat, carbohydrate and the calorific values. The bulk density, water absorption capacity and dispersibility of the samples were (0.62 - 0.87 g/ml), (41.40 - 56.80 g/ml), (3.85 - 4.29%) respectively, and were significant, while the measured swelling property and colour were not significant. The colour range was 4.74 to 4.95, while the pasting properties measured were all significant. Sample H (50% white yam, 30% water-yam, 20% cocoyam) was the most preferred for sensory, showing that water-yam and cocoyam can be good substitutes for white yam in stiff dough production.

***Keywords:** White-Yam; Water-Yam; Cocoyam; Stiff Dough; Pasting Properties; Physicochemical Properties*

Introduction

Root and tuber crops are starchy staples in developing countries of the world and second in importance to cereals. They are important plant parts with excellent source of carbohydrates, protein and minerals. Root and tuber crops in the Sub-Saharan Africa were estimated by FAO, 2013 [1] to be 254 million tonnes/annum with cassava (*Manihot esculenta*), Yam (*Dioscorea* spp.), and sweet-potato (*Ipomoea batatas*) estimated at 132, 56 and 17 million tonnes/annum respectively [2].

Yams are perennial herbaceous vines cultivated for the consumption of their starchy tubers worldwide [3]. They are roughly and cylindrical in shape, brown skinned with flesh that is usually white and firm, and a good source of income to numerous rural farmers [4,5]. However, post-harvest losses from handling to processing amount to between 10 and 60% [6]. The losses cover quantity and quality, which could range from physical damage, physiological and/or pathological in nature. Common flesh of yam tuber is white, though some species are yellow coloured, while processed flour ranged from cream-white to dark brown colour depending on handling and drying, with changes associated with enzymatic browning engineered by polyphenol oxidase [7]. Onwuka and Ihuma [8] reported that world consumption of yam is 18 million tons, with 15 million of it taken place in West Africa, where the yams are traditionally consumed as boiled, roasted, fried, or processed into pounded yam and *Amala* (glutinous dough). Yams could be exported or utilised for health or medicinal purposes [9,10] and these yam tubers are usually processed into flour by peeling, slicing, parboiling at varied time before drying and milling [11]. The flour is processed into a thick paste called "*Amala*" in the Yoruba speaking area of Nigeria by stirring in boiling water, which is then swallowed with a preferred soup [9].

Water-yam (*Dioscorea alata*), also referred to as greater yam or Asian greater yam (majorly cylindrical in shape), is known for its high nutritional content, with crude protein content of 7.4%, starch (75 - 84%) and vitamin C content ranging from 13.0 to 24.7 mg/100g [10]. Water-yam tubers, by FAO, 2001, vary in number from 1 to 5, and the flesh colour ranged from white to purplish. They are less firm in texture as that of white Yam (watery in texture), and less suitable for the preparation of most popular food products from yam (pounded yam most especially). Water-yam, as against yam, is a major staple food in Cote d'Ivoire, where it constitutes about 65% of the yams grown, and in West Indies, Papua New Guinea and New Caledonia, where they are equally the major yam grown and consumed by the people [12]. The properties of processed flour vary considerably with botanical source, environmental condition, composition and structure of starches of the yams. Investigation by Babajide., *et al*. [11] showed that about 3.4% of local processors use water-yam for the production of "gbodo" in some areas because of its cheapness and most especially, during the off season of yam (*D. rotundata*).

Cocoyam is an herbaceous perennial plant that belongs to the *Araceae* family. It constitutes one of the six most important root and tuber crops world-wide [13]. The most popular and widely consumed species of Cocoyam are *Colocasia*, *xanthosoma, alocasia, caryotosperma, chamissonis* and the *amophophallus*, with (*Colocasia esculenta* (taro) and (*Xanthosoma sagifittifolium* (tannia) being the very important species. They are grown primarily for their edible starch laden corms and cormels. Their leaves are used as vegetable [14] and accounts for over 50% of the caloric intake of people of the south (coastal or savannah). Although they are less important to other tropical roots (yam, cassava and sweet potato), they are a major staple in some parts of the tropics and sub-tropics [15].

Cocoyam's corms has about 25% starch, 7 - 9% protein, while yam has less than 6% protein, cassava (< 3%), and sweet potatoes, very poor in protein, but fair in B-vitamins. Cocoyam is believed to have some nutritional advantages over other root and tuber crops [16] and as a result, most suitable for several food products, especially food for allergic infants, and persons with gastro-intestinal disorders [17]. Though cocoyam production in Nigeria is about 26.58 million tonnes annually [18], they are still regarded as an underutilized tuber requiring more studies, partly because of the preference for yam consumption. Major problems with cocoyam utilization are the bitter, astringent taste and scratchiness being experienced in the mouth and throat, as well as the high content of calcium oxalate crystals. Oxalates precipitate calcium and make it unavailable for use by the body. This can however be reduced by peeling, grating, soaking, and fermenting during processing. However, cocoyam flour has the added advantage of high digestibility, which makes it a good raw material for the invalids and baby food products [19]. In spite of all these importance and the nutritive qualities highlighted in water-yam and cocoyam, their industrial potentials and contributions to food security have been grossly under-estimated [19], as they were regarded as "poor man's food" or "women's crop.

The use of water-yam and cocoyam flour for "*Amala*" production and other products is not common. The under-utilization of these crops led to the high wastages, reduced planting and loss of revenue being experienced by farmers, which has led to evaluating their attributes in this aspect.

Materials and Methods

White-yam *(Dioscorea rotundata),* water-yam *(Dioscorea alata),* and cocoyam *(Colocasia esculenta)* tubers were obtained from some local farms within Ilorin, Kwara State.

Production of white yam flour

The white yam sourced was processed into chips called "gbodo" in Yoruba land of Nigeria by the method of Babajide., *et al*. [11] (See figure 1).

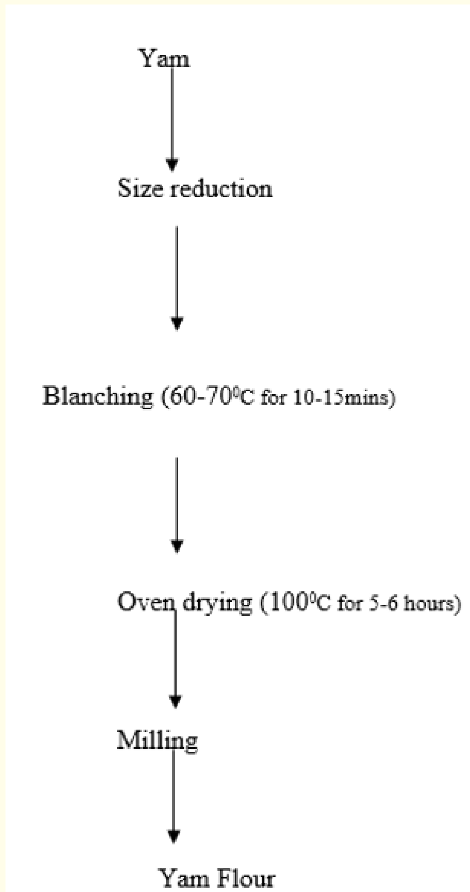

Figure 1: *Flow chart for production of white yam flour.*
Source: Babajide., et al [11].

Production of water yam flour

Water-yam tubers sourced were peeled manually and cut into thin slices of 2.0 cm thickness for faster cooking and drying. The slices were preserved from browning reaction by blanching at 60^{0}C for 5 minutes before drying, milling and packaging in ziploc bags and stored as shown in figure 2 [9].

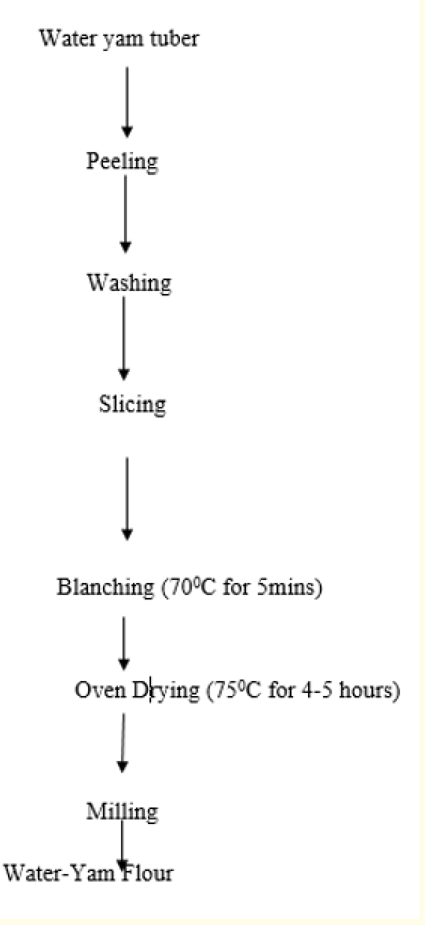

Figure 2: *Flow chart for production of water yam flour.*
Source: Babajide., et al [9].

Production of cocoyam flour

Fresh corms were processed like that of water-yam with slight changes (Figure 3).

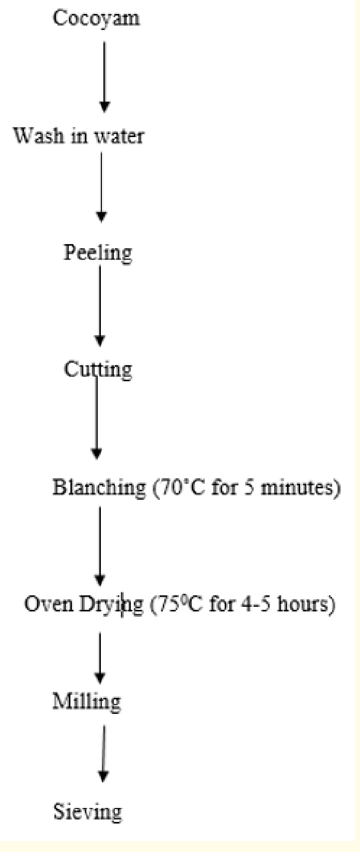

Figure 3: *Flow chart for preparation of cocoyam flour.*
Source: Babajide., et al [11].

Nine flour samples (with six composite) were prepared from yam, water-yam and cocoyam as shown in table 1.

Colour determination of flour

1g each of the flour sample was weighed into 100 ml beaker spectrophotometer cuvette. Methanol was added to extract the colour by shaking and homogenizing with glass rod for 30 minutes. The mixture was allowed to stand for 10 minutes after which it was filtered through whatman filter paper. Reading was taken at absorbance wavelength of 420 nm and 520 nm on a Cecil 200 colorimeter, and intensity was the sum of the absorbance readings.

Mathematically, colour intensity= Absorbance at 420 nm + Absorbance at 520 nm.

$$\%\text{yellow/cream} = \frac{\text{Absorbance at 420 nm} \times 100}{\text{Colour intensity}}$$

$$\%\text{Red or brown} = \frac{\text{Absorbance at 520 nm} \times 100}{\text{Colour intensity}}$$

Functional properties of flour

Determination of bulk density of the flour

The bulk density was determined using the procedure of Adebowale., *et al* [20]. A known amount of the sample was weighed into 100 ml capacity graduated measuring cylinder. The bottom of the cylinder was gently tapped severally on the laboratory bench until no further diminution noticed, and then made up to the 10 ml mark. The bulk density was calculated thus:

$$\text{Bulk density (g/ml or gcm}^3) = \frac{\text{Weight of the sample}}{\text{Vol. of the sample after tapping}}$$

Determination of swelling power of the flour

Swelling power was determined by the method of Ukpabi and Ndimele [21]. 1g of flour sample was weighed into 100 ml centrifuge tube. 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at (70, 80, 90 and 100˚C) respectively for 15 minutes. During heating, the slurry was stirred gently to prevent clumping of the flour. After 15 minutes, the tube containing the paste was centrifuged at 2200 rpm for 15 minutes. Supernatant was immediately decanted and the weight of the sediment recorded. The moisture content of the sediment gel was used to determine the dry matter content of the gel.

$$\text{Swelling power} = \frac{\text{Weight of wet mass sediment}}{\text{Weight of dry matter in gel}}$$

Determination of dispersibility of the flour

Dispersibility of the flour was determined using the method described by Kulkarni., *et al* [22]. 10g of the flour sample was weighed into 100 ml measuring cylinder, distilled water was added to each volume of the 100 ml. The set up was stirred vigorously and allowed to stand for three hours. The volume of the settled particles was recorded and subtracted from 100. The differences reported as percentage dispersibility.

% Dispersibility = 100 - volume of settled particle

Determination of water absorption capacity of the flour

Water absorption capacity was determined using the modified method of Ruales., *et al* [23]. 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 300 rpm for 10 minutes. The supernatant was decanted and weight of the gel formed was recorded.

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

Determination pasting properties of the flour

Pasting characteristics were determined using a Rapid Visco Analyzer (RVA), (Model RVA3D$^+$, Network scientific and Australia). Flour sample (3g) was weighed into a dried empty canister. 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister fitted into the RVA as recommended. The slurry was heated from 50°C to 95°C with a holding time of two minutes, which was followed by cooling to 50°C with another two minutes holding time. Peak viscosity, trough, breakdown, final viscosity, set back, peak time, and pasting temperature were read from the pasting profile with the aid of thermocline from a windows software connected to a computer.

Analysis of the proximate composition of the samples

Determination of moisture content

The method of AOAC [24] was adopted. It was calculated thus:

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

W_1 = Weight of empty petri-dish; W_2 = Weight of petri-dish plus sample before drying; W_3 = Weight of petri-dish plus oven dried sample; $W_2 - W_3$ = Total loss in weight; $W_2 - W_1$ = Weight of sample.

Determination of ash

The standard method by AOAC [24] was adopted, and calculated thus:

$$\% \text{ Ash} = \frac{\text{Weight of crucible + ash- weight of crucible} \times 100}{\text{Weight of sample}}$$

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

Determination of crude fat

The standard method of AOAC [24] (soxhlet) was adopted and calculated thus:

$$\% \text{ crude fat} = \frac{\text{Weight of ether extract}}{\text{Original weight of sample}} \times 100$$

Determination of crude fibre

Standard AOAC [24] method was adopted.

$$\% \text{ Crude Fibre} = \frac{\text{Dry wt. of residue before ashing - Wt. of residue after ashing} \times 100}{\text{Weight of sample}}$$

Determination of crude protein

Protein content was by kjeldahl method of AOAC [24] and calculated thus:

% Crude Protein = 6.25* × %N (*correction factor)

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

Where; S = Sample titration reading; B = Blank titration reading; N = Normality of HCl; D = Dilution of sample after digestion; V = Volume taken for distillation; 0.104 = Milli equivalent weight of Nitrogen.

Determination of carbohydrate

This was calculated by difference.

% Total Carbohydrate = 100 - (%moisture content + % crude protein + % crude lipid + % total ash + % crude fibre).

Sensory evaluation and data analyses

Stiff doughs produced were subjected to sensory evaluation by the method of Ihekoronye and Ngoddy [25]. Hedonic scale was used to measure the acceptance of the stiff doughs based on appearance, taste, moldability and aroma. Thirty untrained panellists, but regular consumers evaluated the stiff doughs through questionnaires, with a 9-point hedonic scale. Score 1= Dislike extremely, while score 9= Like extremely. Data generated were subjected to Analysis of Variance (ANOVA) using SPSS and means separated using Duncan's Multiple Range Test (DMRT).

Results

Samples	White yam flour %	Water yam flour %	Cocoyam flour %
A	100	0	0
B	0	100	0
C	0	0	100
D	80	10	10
E	70	20	10
F	70	10	20
G	60	20	20
H	50	30	20
I	50	20	30

Table 1: *Blending ratios of the flour samples.*

Samples	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Protein (%)	CHO (%)	Crude Fibre (%)	Calorific Value (KJ/100g)
A	11.77a ± 1.28	4.93a ± 0.01	0.41d ± 0.14	8.23a ± 0.14	72.24ab ± 1.31	2.39a ± 0.01	1359.80c ± 14.15
B	10.44b ± 0.57	4.95a ± 0.01	1.65ab ± 0.08	8.15a ± 0.49	72.39ab ± 0.96	2.39a ± 0.01	1407.75b ± 10.99
C	8.44d ± 1.28	4.94a ± 0.01	1.81a ± 0.48	8.30a ± 0.14	74.09a ± 1.47	2.40a ± 0.02	1444.35ab ± 9.15
D	9.07c ± 0.87	4.94a ± 0.01	0.41d ± 0.14	8.17a ± 0.47	75.01a ± 0.33	2.37a ± 0.04	1405.14b ± 18.86
E	7.94 ± 0.63	4.93a ± 0.04	1.97a ± 1.44	8.05a ± 0.27	74.64ab ± 0.84	2.44a ± 0.05	1455.50ab ± 40.58
F	10.54b ± 1.13	4.91a ± 0.10	1.63ab ± 0.17	8.25a ± 0.37	72.33ab ± 1.37	2.30a ± 0.02	1407.55b ± 11.03
G	5.54e ± 0.55	4.87a ± 0.10	0.91c ± 0.56	7.80ab ± 0.21	78.48a ± 0.78	2.37a ± 0.04	1475.51ab ± 11.73
H	9.09c ± 1.28	4.92a ± 0.01	1.01c ± 0.59	8.16a ± 0.41	74.40ab ± 1.09	2.39a ± 0.01	1417.36b ± 33.93
I	3.59f ± 0.29	4.98a ± 0.09	1.47b ± 0.39	8.13a ± 0.28	79.44a ± 0.47	2.39a ± 0.01	1517.83a ± 15.06

Table 2: *Proximate composition of the flour samples.*

**Means within column with superscripts indicates significant difference ($P \leq 0.05$).*

Key: A: 100% white yam flour; B: 100% water-yam flour; C: 100% cocoyam flour.

D: 80% white yam flour, 10% water-yam flour, 10% cocoyam flour.

E: 70% white yam flour, 20% water-yam flour, 10% cocoyam flour.

F: 70% white yam flour, 10% water-yam flour, 20% cocoyam flour.

G: 60% white yam flour, 20% water-yam flour, 20% cocoyam flour.

H: 50% white yam flour, 30% water-yam flour, 20% cocoyam flour.

I: 50% white yam flour, 20% water-yam flour, 30% cocoyam flour.

Samples	Bulk Density (g/ml)	WAC (g/ml)	Swelling Property (g/g)	Dispersibility (%)	Colour
A	0.64b ± 0.13	46.15b ± 1.17	0.05a ± 0.00	3.85b ± 0.17	4.95a ± 0.01
B	0.64b ± 0.13	44.56b ± 0.95	0.06a ± 0.01	3.91b ± 0.21	4.87a ± 0.03
C	0.64b ± 0.13	41.82bc ± 2.52	0.05a ± 0.00	4.29a ± 0.59	4.74a ± 0.04
D	0.67b ± 0.62	51.71a ± 1.57	0.05a ± 0.00	3.89b ± 0.14	4.80a ± 0.16
E	0.75a ± 0.16	49.88ab ± 3.22	0.05a ± 0.00	4.27a ± 0.14	4.95a ± 0.01
F	0.73a ± 0.49	47.68b ± 0.97	0.05a ± 0.00	4.38a ± 0.25	4.91a ± 0.18
G	0.62b ± 0.04	56.87a ± 1.34	0.06a ± 0.01	3.93b ± 0.14	4.88a ± 0.09
H	0.87a ± 0.64	47.03b ± 0.66	0.06a ± 0.01	3.77b ± 0.04	4.77a ± 0.12
I	0.69b ± 0.20	41.40bc ± 0.42	0.06a ± 0.01	3.88b ± 0.13	4.87a ± 0.03

Table 3: *Functional properties and colour of the flour samples.*

Mean value of two replicates. Sample means followed by the same superscript in a column are not significantly different (p>0.05).

Key: A: 100% white yam flour; B: 100% water-yam flour; C: 100% cocoyam flour.

D: 80% white yam flour, 10% water-yam flour, 10% cocoyam flour.

E: 70% white yam flour, 20% water-yam flour, 10% cocoyam flour.

F: 70% white yam flour, 10% water-yam flour, 20% cocoyam flour.

G: 60% white yam flour, 20% water-yam flour, 20% cocoyam flour.

H: 50% white yam flour, 30% water-yam flour, 20% cocoyam flour.

I: 50% white yam flour, 20% water-yam flour, 30% cocoyam flour.

Samples	Peak Viscosity (Cp)	Trough (Cp)	Breakdown (Cp)	Setback (Cp)	Final Viscosity (Cp)	Pasting Temp. (°C)	Peak Time (min.)
A	4338.00b ± 0.00	3797.50a ± 95.46	540.50d ± 15.46	1401.00bc ± 22.03	5198.50a ± 12.57	84.0a ± 1.20	6.47a ± 0.66
B	3875.50c ± 17.68	3034.00b ± 48.08	841.50b ± 30.41	1907.50a ± 10.61	4076.00c ± 18.69	83.6a ± 0.57	5.07c ± 0.01
C	4597.00a ± 18.39	3197.50b ± 24.75	1399.50a ± 43.13	1753.00a ± 24.04	4950.50a ± 18.79	84.83a ± 0.11	4.93c ± 0.00
D	3615.50c ± 16.26	3063.00b ± 36.77	552.50d ± 20.51	1434.50b ± 14.55	4497.50b ± 7.78	82.65d ± 0.64	5.70b ± 0.14
E	3364.50cd ± 53.03	2914.00c ± 42.43	449.50e ± 95.46	1234.00c ± 16.23	4148.00c ± 19.79	83.08c ± 0.04	5.60b ± 0.00
F	3351.00cd ± 31.11	2855.50c ± 17.68	495.50e ± 13.44	1220.50c ± 0.71	4076.00c ± 18.69	83.6a ± 0.57	5.83ab ± 0.05
G	2841.00e ± 45.26	2457.00d ± 52.33	384.00 ± 97.38	952.00d ± 13.52	3409.00d ± 19.19	83.1c ± 0.07	5.87ab ± 0.19
H	3199.50d ± 17.68	2590.50d ± 70.00	609.00c ± 52.33	1386.00c ± 13.94	3976.50c ± 16.06	82.68d ± 0.60	5.53b ± 0.00
I	2541.00f ± 13.45	2358.00e ± 19.79	183.00f ± 65.05	736.50d ± 13.30	3094.50e ± 11.50	83.95a ± 0.07	6.23a ± 0.24

Table 4: *Pasting properties of the flour samples.*

**Means within column with superscripts indicates significant difference (P ≤ 0.05).*

Key: A: 100% white yam flour; F: 70% white yam flour, 10% water-yam flour, 20% cocoyam flour.

B: 100% water-yam flour; G: 60% white yam flour, 20% water-yam flour, 20% cocoyam flour.

C: 100% cocoyam flour; H: 50% white yam flour, 30% water-yam flour, 20% cocoyam flour.

D: 80% white yam flour, 10% water-yam flour, 10% cocoyam flour; I: 50% white yam flour, 20% water-yam flour, 30% cocoyam flour.

Samples	Appearance	Aroma	Taste	Moldability	Overall Acceptability
A	6.50c ± 1.50	6.87a ± 1.59	6.80a ± 1.83	7.13ab ± 1.32	7.30ab ± 1.37
B	7.23ab ± 1.48	7.17a ± 1.59	6.73a ± 1.98	6.23d ± 2.11	7.13b ± 1.41
C	6.23d ± 1.69	6.39a ± 1.36	6.74a ± 1.44	6.71c ± 1.07	6.68c ± 1.08
D	6.31d ± 1.44	6.48a ± 1.35	6.69a ± 1.14	6.10d ± 1.50	6.69c ± 1.14
E	7.23ab ± 1.48	6.73a ± 1.29	6.53a ± 1.41	6.80b ± 1.26	7.07b ± 1.11
F	7.30a ± 0.92	6.90a ± 1.24	7.03a ± 1.49	6.80b ± 1.26	7.13b ± 1.07
G	6.67c ± 1.63	6.83a ± 1.18	7.03a ± 1.49	7.13ab ± 1.32	6.97b ± 1.22
H	7.67a ± 1.49	7.13a ± 1.38	7.40a ± 1.10	7.83a ± 1.62	7.77a ± 1.31
I	7.17b ± 1.32	6.90a ± 1.06	7.03a ± 1.49	6.90b ± 1.65	7.33ab ± 0.92

Table 5: *Sensory evaluation of the stiff dough made from the flour.*

**Value is duplicate determination; means within row having different superscripts differ significantly (P ≥ 0.05).*

Key: A: 100% white yam flour; B: 100% water-yam flour; C: 100% cocoyam flour.

D: 80% white yam flour, 10% water-yam flour, 10% cocoyam flour.

E: 70% white yam flour, 20% water-yam flour, 10% cocoyam flour.

F: 70% white yam flour, 10% water-yam flour, 20% cocoyam flour.

G: 60% white yam flour, 20% water-yam flour, 20% cocoyam flour.

H: 50% white yam flour, 30% water-yam flour, 20% cocoyam flour.

I: 50% white yam flour, 20% water-yam flour, 30% cocoyam flour.

Discussion

Proximate analysis of the flour samples

The proximate composition of the flour samples in table 2 showed variations in percentage composition, which may be due to genetic composition of the varieties and environmental conditions [26]. The moisture content of the flour samples varied (at $p < 0.05$) from 3.59% to 11.77%. Sample A (pure white yam flour) had the highest moisture content, while sample I (50% White yam flour, 20% Water-yam flour, 30% Cocoyam flour) had the lowest value. All the samples had moisture content below 13%, which was within the standard for dry food samples according to Obadina., *et al* [27]. The differences noticed were similar to that reported by Obadina., *et al* [27]. Low moisture content in flour depicts shelf stability, reduced microbial attack and less cakiness/lumpiness. There was no significant difference (at $p < 0.05$) in the ash content of the samples. The values ranged from 4.87% to 4.98%, comparable to that reported by Olopade and Akinyanju [28] for the blend of water-yam and soybean flour (3.95% - 4.04%), and that the flour produced could be a good source of essential micro-nutrients.

The fat content of the flour samples ranged from 0.41% - 1.97%. Sample E (70% White yam flour, 20% Water-yam flour, 10% Cocoyam flour) had the highest value, while samples A and D (pure white yam flour and 80% White yam flour, 10% Water-yam flour, 10% Cocoyam flour) had the lowest, which was similar to that reported by Olopade and Akinyanju [28] on water-yam soybean flour (0.39% to 2.15%). Fat stored as energy in the body is broken down to release glycerol and free fatty acids. The glycerol can be converted to glucose by the liver and used as a source of energy [29]. Crude protein content showed no significant difference (at $p < 0.05$) with values between 7.80% and 8.30%, but was higher than that reported by Adewale., *et al*. [26] (0.88% - 1.51%). The variation may be due to climatic, maturation and storage time, which could be responsible for the differences observed in the protein content [26].

The crude fibre ranged from 2.30% to 2.44%, with no significant difference at ($p < 0.05$), but these values were similar to the findings of Patience., *et al.* [30] on yam cowpea fortified flour (2.0% to 4.0%). Dietary fibre reduces the risks of cardiovascular diseases and the reduction in the incidence of certain diseases such as diabetes, coronary heart disease etc. [31].

The carbohydrate content, which was obtained by difference, ranged from 72.24% to 79.44%. Carbohydrates supply energy to the cells such as the brain, muscles and blood; contributes to fat metabolism and spares proteins as an energy source, as well as acts as mild natural laxative for humans and equally increase the bulk of diet. Also, the blended samples had higher carbohydrate and energy contents, showing that water-yam and cocoyam can be good substitute for white yam.

Functional properties and colour of the flour samples

Table 3 showed the results of the functional properties and colour of the flour samples. The composition and nature of the macronutrients in the food materials could affect their functionality [32]. The bulk density of the samples ranged from 0.62 g/ml to 0.87 g/ml, which was significant at $p < 0.05$. The values were, however, comparable to that reported by Babajide and Olowe [7]; Babajide., *et al*. [11] respectively. These researchers reported between 0.56 g/ml and 0.68 g/ml on water-yam cassava flour and yam varieties, as well as 0.71 - 0.79 g/ml reported by Adepeju., *et al*. [33] on the blend of yam and breadfruit. Bulk density depends on water intake of the flour, and it was observed to reduce as the soaking time increases. Plaami [34] reported that bulk density being influenced by polymers of starch structure, is attributable to the differences in their drying treatments.

Water absorption capacity (WAC) affects the rate at which the granules swell during constitution of the flour. The results obtained showed that there were significant differences ($p < 0.05$) in the water absorption capacities of the flour, with values ranging from 41.40% to 56.87%. Sample G had the highest value (56.87%), while sample I had the lowest value (41.40%). The values obtained were lower to that of Babajide and Olowe [7] (61.67% - 88.17%) and 100.4 - 269.70% reported by Adepeju., *et al*. [33] for yam and breadfruit blend. The WAC contributes to the acceptance of the stiff dough and gives an indication of the amount of water available for gelatinization [35].

The swelling power (0.05 to 0.06) was not significant at $p < 0.05$. The swelling power depicts the presence of amylase, which influences the quantity of amylose and amylopectin present in the flour. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water. High amylose content has been linked to low swelling power and greater reinforcement of the internal network by amylose molecules [36]. The dispersibility of a mixture in water indicates its ability to reconstitute i.e. the higher the dispersibility of a mixture, the better its reconstitution property. The values (3.77 to 4.29%) were significantly different at $p < 0.05$. The more the cocoyam flour incorporated, the higher the dispersibility.

Colour of the flour samples ranged from 4.77 to 4.95 with no significant differences at $p < 0.05$. The implication of the results could be likened or linked to the report of Ukpabi., *et al*. [12], who reported that darkish or brownish colouration observed in flour samples may be due to their respective phenolic content and/or phenolase activity.

Pasting properties of the flour samples

In table 4, variations were observed in the properties of the samples. Heating starch-based foods in the presence of water lead to series of changes known as gelatinization and pasting that influenced quality and aesthetic appeal, texture and digestibility of the starchy foods [5]. Peak viscosity indicates viscous load of the cooked starch and reflects the ability of the starch to swell freely before physical breakdown [14]. The results ranged from 2541.00 to 4338.00RVU and were significantly different at ($p < 0.05$), though higher than the values reported by Patricia., *et al*. [37] (212.00 to 362.07RVU).

The minimum viscosity at constant temperature phase of the RVA profile and the ability of the paste to withstand breakdown during cooling (trough) was reported [26,38]. The breakdown viscosity is the difference in the peak and trough viscosity, which is also an index of starch stability. Breakdown, which ranged from 183.00 to 1399.50 RVU were significantly different at $p < 0.05$ with sample C (100% cocoyam) having the highest breakdown (1399.50) RVU. This implies lesser granule rupture in the starches, which resulted in lower ability to withstand heating and shear stress during cooking [39].

Final viscosity is the change in the viscosity after holding cooked starch at 50˚C i.e. the ability of the material to form a viscous paste after cooking and cooling and the resistance of the paste to shear force during stirring [38]. The values ranged from 3094.50 to 5198.50 RVU, with the white yam flour having the highest value. The setback viscosity is the difference between the maximum viscosity during cooling and the lowest viscosity after heating. Values obtained ranged from 736.50RVU to 1907.50 RVU with significant difference (at $p < 0.05$). High set back viscosity resulted in lower retrogradation during the cooling and lower rate of staling in flour products [37]. The water yam flour had the highest value, but lowest staling rate. The peak time which is a measure of the cooking time ranged from 4.93 minutes to 6.46 minutes and was significantly different at $p < 0.05$. Sample A (100% white yam) had the highest peak time of 6.46 minutes, while sample C had the lowest peak time of 4.93 minutes. Blending of the flour definitely lowers the cooking time.

The pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured and characterized by the initial change due to the swelling [40]. The pasting temperature ranges from 82.67˚C to 84.82˚C with significant difference at $p < 0.05$. Higher pasting temperature implies higher gelatinization and lower swelling power of the starch due to high degree of association between the starch granules. The pasting temperature obtained for all samples were similar to 79.80˚C - 83.60˚C reported by Adewale., *et al*. [26] for plain yam flour.

Sensory evaluation of the flour samples

Table 5 showed the result of the sensory evaluation carried out on the stiff dough prepared from the flour samples. Sample H (50% White yam Flour, 30% Water-yam Flour and 20% Cocoyam Flour) was rated the best in appearance, while the lowest was sample C (100% Cocoyam Flour). For aroma and taste, there were no significant differences among the samples at $p < 0.05$. The moldability of the stiff dough showed significant differences among some of the samples. Samples A, G and H were not significant from one another, though rated higher. However, moldability of sample H was the most accepted, as well as being the most preferred [41].

Conclusion

The study showed stiff dough could be made from water-yam and cocoyam flour judging by the results obtained. Sample H (50% White yam Flour, 30% Water-yam Flour and 20% Cocoyam Flour), which was the most accepted, showed a stiff dough with high moldability, good aroma, appearance and taste. Utilizing water-yam and cocoyam for stiff would enhance their economic importance, reduce the high dependence on white yam, and equally provide varieties in stiff dough production.

Research Highlights

Some of the highlights of this work include:

- Cocoyam and water yam could be properly utilised in the production of stiff dough in Nigeria, as they are more nutritious than white yams.
- Cocoyam and water yams, which are underutilized, could be cultivated the more to increase farmers' income and job creation.
- Proper processing would help reduce any limitations to their utilization of coco-yam and water-yam.

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