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Physicochemical and Antioxidant Properties of Cocoyam, African Yam Bean and Watermelon Rind Flour Blends and Consumer Acceptability of its Cake

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Abstract

This study aimed to determine the quality of the flour blends and cakes developed from underutilized indigenous crops supplemented with food processing waste. The variables were cocoyam flour (CF), African yam bean flour (AYBF) and watermelon rind powder (WMRP) with their constraints 65-80%, 5-30% and 5-15%, respectively. Sixteen samples were generated using design expert software and subjected to proximate analysis. The best three samples were selected based on the highest protein and crude fibre content and were further evaluated for antioxidant, antinutrient, functional properties and pasting properties. Cakes were also developed and assessed for sensory properties. The incorporation of AYBF and WMRP significantly ($p<0.05$) led to the increase in ash, crude protein and crude fibre. The antioxidant properties in the flour blend samples showed significant ($p<0.05$) increase. The higher foaming capacity and stability of the samples were observed as well as final viscosity of the flour blends. Cake made from 70.71% CF, 24.29% AYBF and 5% WMRP (Sample 7) had the highest overall acceptability and competing favourably with cake made from wheat flour (control).

Keywords: *Watermelon rind powder, antioxidants, flour blends, cake, processing, underutilized*

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Introduction

Formulation of nutritious cakes product from local and readily available raw material have received a lot of attention in many developing countries due to malnutrition which has been known as a major problem especially to infants as a result of lack of several essential nutrients in the food product (Offia-Olua, 2014). Cocoyam (*Colocasia esculenta*) is one of the edible aroids distributed throughout the world, particularly in the tropics (Falade and Okafor, 2015). Cocoyam tubers are important sources of carbohydrates as an energy source and are used as staple foods in tropical and subtropical countries (Macharia *et al*., 2014. Compared to most root and tuber crops including cassava and yam, cocoyam provides digestible starch and contains relatively high levels of protein (Afolabi *et al*., 2015). Cocoyam deteriorates rapidly as a result of its high moisture and has been estimated to have a shelf-life of up to one month if undamaged and stored in a shady area. Cocoyam also contains some antinutrients which limit its utilization. However, these antinutritional factors can be removed or reduced upon application of heat. Several studies have been carried out on partial or total replacement of wheat flour with cocoyam flour to produce cake (Alozie and Chinma, 2015).

African yam bean (*Sphenostylis stenocarpa*) (AYB) is a legume plant belonging to the family *Fabaceae*, and is indigenous to the people of Africa. It consists of the seeds and the tubers which are both edible. AYB is a rich source of nutrients such as protein, vitamins, dietary fibre and important minerals such as calcium, iron, zinc, magnesium amongst others with values higher or comparable to soy and common bean (Adamu *et al*., 2015). Because AYB is rich in protein and other nutrients, it has been used in the development of foods (George *et al*., 2020). Aside from the high nutrient content, the bean has been reported to also be a source of bioactive compounds that offer health benefits such as the mitigation of lifestyle diseases to consumers (Soetan *et al*., 2018). AYB is a good crop for the development of new functional foods for consumer healthiness. Therefore, more attention needs to be given to this underutilized, nutritionally rich legume (Adegboyega *et al*., 2020).

Watermelon (*Citrullus lanatus*) is a member of the *Cucurbit* family (*Cucurbitaceae*). It is a vegetable crop which is large and oval round in shape. It has a smooth skin with pale green stripes. It is highly cultivated worldwide. According to Ho *et al*. (2018) watermelon acts as a vital reservoir of valuable phytochemicals with high nutrient potentials. It contains the juicy flesh, the seeds and the tough rind. Watermelon rind is the tough outer green layer of the fruit which is hard and less juicy, thus making it less appealing and palatable and as a result people discard the rinds rather than consume them. Watermelon rinds are good sources of vitamins and minerals. Previous works have reported the incorporation of watermelon rind to enrich pan bread (El-Badry, 2014). Therefore, this study aimed to determine the proximate composition, antinutrients, antioxidant, pasting and functional properties of the flour blends and thereafter evaluate the physical and sensory attributes of the developed cake.

Materials and Methods

Procurement of Raw Materials

Cocoyam corms, African yam bean seeds, watermelon and other baking materials such as margarine, sugar, baking powder, eggs were purchased from Akpan-Andem market in Uyo, Akwa-Ibom State, Nigeria.

Preparation of Samples

Preparation of cocoyam flour

Fresh corms were thoroughly washed with tap water to remove adhering debris, peeled using a stainless-steel knife, rewashed and sliced to about 0.5 cm thickness. The slices were blanched for 15 min to inactivate enzymes and prevent browning. The slices were then dried to a constant weight in an oven (NAAFCO BS oven OVH-102) set at 60 °C for 9 h before milling into flour using a grinder fitted with a 500 µm mesh sieve. Flour obtained was packed in Ziploc bags (Njintang *et al*., 2015).

Preparation of African yam bean flour

The preparation of African yam bean flour was carried out following the method described by Igbabul *et al*. (2015). African yam bean seeds were removed from the pods. The seeds were cleaned by winnowing and then soaked in water at a ratio of 1:3 w/v for 3 days. After 3 days the water was drained, the seeds were dehulled manually. Dehulled seeds were dried in the oven at 60 °C for 10 h before milling into flour. The flour was then sieved and package in Ziplock bags.

Preparation of watermelon rind flour

Whole fresh watermelons were washed to remove dirt. The watermelon was cut into portions and pulp was separated from the rind using a stainless-steel knife. The rinds were then cut into smaller sizes and dried in an oven at a temperature of 50 °C for 24 h. The dried rinds were milled, sieved and packaged in Ziplock bags.

Experimental Design and Flour Blends Formulations

Flour blends were formulated using a D-optimal design expert software, model 12. The variables with their constraints were cocoyam flour (65-80%), African yam bean flour (5-30%) and watermelon rind flour (5-15%). These mixtures generated sixteen (16) runs (samples) as shown in Table 1.

Table 1: Flour blends formulation

Sample	CF (%)	AYBF (%)	WMRP (%)
1	65.00	22.73	12.27
2	80.00	5.00	15.00
3	74.75	10.25	15.00
4	65.00	30.00	5.00
5	80.00	15.00	5.00
6	80.00	10.11	9.89
7	66.38	25.65	7.97
8	69.75	20.99	9.26
9	65.00	30.00	5.00
10	65.00	22.73	12.27
11	69.67	15.33	15.00
12	70.71	24.29	5.00
13	69.67	15.33	15.00
14	73.61	17.14	9.25
15	80.00	5.00	15.00
16	80.00	15.00	5.00

CF = Cocoyam flour, AYBF = Africa yam bean flour, WMRF = Watermelon rind flour.

Preparation of Cake Samples

The cake was prepared by mixing the margarine (400 g) and sugar (200 g) together for about 20 min. The flour (300 g), egg, and baking powder were added and mixed together until a smooth batter was gotten. The baking pan was then greased with margarine and the batter poured into the baking pan. The pan was placed in the oven and allowed to bake at a temperature of 190 °C for 15 min. The cake was then removed from the oven, allowed to cool and packaged in aluminum foil.

Determination of Proximate Composition of the Individual Flour and Flour Blends

The standard method of AOAC (2006) was used to determine the moisture, ash, crude fat and crude fibre content. The total carbohydrate content was estimated as the difference between 100 and the total sum of moisture, fat, protein, crude fiber and ash.

Determination of Functional and Pasting Properties of the Flour Blends

The water absorption capacity, oil absorption capacity and bulk density were determined according to the method described by Onwuka (2018). Foaming capacity, foaming stability and gelatinization temperature of the flour samples were determined following the method described by Abbey and Ibeh (1988).

Pasting properties were determined using the Rapid Visco Analyser (RVA Model 42000) manual. Three (3) g of flour sample was turned into slurry by mixing with 25 mL of water inside the RVA can. The can was inserted into the tower, which was then lowered into the system. The slurry was heated from 50 °C to 95 °C and cooled back to 50 °C within 14 min. Parameters estimated were peak, trough, final, breakdown and setback viscosities, pasting temperature, and time to reach peak viscosity.

Evaluation of Antinutritional Factors of Flour Blends

Phytate, oxalate, alkaloid and tannin content were determined using the method described by Abulude (2004).

Evaluation of Antioxidant Properties of Flour Blends

The FRAP (Ferric reducing antioxidant power) was estimated spectrophotometrically following the procedure of Nilima and Hande (2011). The ability to scavenge DPPH free radicals was determined according to the method of Ukom *et al*. (2014). The concentration of flavonoid and phenol were determined following the method described by Ezeonu *et al*. (2016).

Sensory Properties of Cake Samples

The sensory attributes of the cakes were carried out using untrained 20-member panel. The panel was comprised of a broad cross section of adult population (student and staff) of the University of Uyo, with panelist spread across a wide range of age, education and income groups. Cake samples were presented in coded white microwaveable plastic container. Samples was served in a randomized order on a tray with potable water for rinsing of mouth in between tasting of samples to minimize rating errors due to carry over of perceived attributes of previous samples. The 9 - point hedonic scale with a scale ranging from one to nine with one representing the least score (dislike extremely) and nine the highest score (like extremely) was used to collect data.

Statistical Analysis

Mean scores of the results and their standard mean of error were reported. Data generated were subjected to analysis of variance (ANOVA). Duncan's new multiple range test was then used to separate the means at $p<0.05$ using SPSS version 20.

Results and Discussion

Proximate Composition of Cocoyam Flour, African Yam Bean Flour and Watermelon Rind Powder and Their Blends

The proximate composition of the individual flour and their blends are presented in Table 2. The moisture content of the flours ranged between 4.88-6.75% while that of the flour blends ranged from 3.93-5.27%. The flour samples had a low moisture content which is adequate for its keeping quality. The crude protein content of flours ranged between 5.61-21.04% with sample B having the highest value. Sample 4 (65% CF, 30% AYBF and 5% WMRP) had the highest crude protein content (10.68%) and differed significantly ($p<0.05$) from all other flour blends. It is evident that flour blends with higher percentages of African yam bean flour (AYBF) recorded higher protein contents while those with lower percentages of AYBF recorded lower protein contents. This corroborates with findings of Inyang and Ekop (2015). The protein content of the composite flour significantly ($p<0.05$) increased with increasing levels of AYBF substitution. The ash and fibre content ranged from 1.98-9.49% and 0.18-5.93%, respectively for flours and from 3.35-4.46% and 0.11-1.48%, respectively for flour blends. Sample 2 had the highest ash and crude fibre content which were not significantly ($p>0.05$) different from sample 15 but differed significantly ($p<0.05$) from every other sample. However, sample 12 had the lowest ash and crude fibre content.

Table 2: Proximate composition of cocoyam flour, African yam bean flour and watermelon rind powder and their blends

	Moisture (%)	Crude protein (%)	Ash (%)	Crude fibre (%)	Crude fat (%)	Carbohydrate (%)
CF	4.88^{c} ± 0.01	5.61^{c} ± 0.02	3.28^{a} ± 0.03	1.04^{b} ± 0.06	0.71^{c} ± 0.03	84.48^{a} ± 0.04
AYBF	5.72^{b} ±0 .01	21.04^{a} ± 0.01	1.98^{b} ± 0.01	0.18^{c} ± 0.03	7.90^{b} ± 0.03	63.17^{b} ± 0.00
WMRP	6.75^{a} ± 0.01	12.09^{b} ± 0.03	9.49^{a} ± 0.02	5.93^{a} ± 0.03	9.51^{a} ± 0.02	56.22^{c} ± 0.00
1	3.98^{i} ± 0.00	8.31^{d} ± 0.01	3.75^{bcd} ± 0.00	0.89^{d} ± 0.01	10.00^{a} ± 0.13	73.05^{k} ± 0.12
2	4.23^{g} ± 0.02	6.64^{h} ± 0.01	4.46^{a} ± 0.55	1.48^{a} ± 0.00	5.60^{d} ± 0.00	77.21^{f} ± 0.02
3	5.12^{b} ± 0.00	6.83^{g} ± 0.01	4.11^{ab} ± 0.02	1.10^{b} ± 0.01	4.59^{f} ± 0.01	78.22^{c} ± 0.09
4	4.81^{d} ± 0.02	10.68^{a} ± 0.00	3.35^{f} ± 0.01	0.11^{h} ± 0.03	4.87^{e} ± 0.01	76.17^{g} ± 0.04
5	4.75^{e} ± 0.01	7.72^{f} ± 0.03	3.58^{cde} ± 0.03	0.88^{d} ± 0.01	3.86^{h} ± 0.03	79.22^{a} ± 0.06
6	4.62^{f} ± 0.00	6.56^{i} ± 0.03	3.91^{bcd} ± 0.01	0.21^{g} ± 0.01	6.89^{c} ± 0.01	77.81^{e} ± 0.03
7	5.27^{a} ± 0.02	10.02^{b} ± 0.05	3.43^{ef} ± 0.03	0.79^{e} ± 0.01	4.61^{f} ± 0.01	75.87^{h} ± 0.05
8	4.25^{g} ± 0.00	9.19 ^{c} ± 0.02	3.43^{ef} ± 0.03	0.48^{f} ± 0.01	4.60^{f} ± 0.03	78.06^{d} ± 0.00
9	4.81^{d} ± 0.02	10.67^{a} ± 0.00	3.35^{f} ± 0.01	0.11^{h} ± 0.03	4.87^{e} ± 0.01	76.18^{g} ± 0.04
10	3.98^{i} ± 0.00	8.31^{d} ± 0.01	3.76^{bcd} ± 0.00	0.89^{d} ± 0.01	10.10^{a} ± 0.13	72.94^{k} ± 0.12
11	5.01^{c} ± 0.01	7.72^{f} ± 0.03	3.93^{bc} ± 0.01	0.80^{e} ± 0.03	6.80^{c} ± 0.01	75.74^{i} ± 0.03
12	4.13^{h} ± 0.02	9.25^{c} ± 0.03	3.53^{de} ± 0.00	0.80^{e} ± 0.02	7.70^{b} ± 0.02	74.57^{j} ± 0.01
13	5.01^{c} ± 0.01	7.72^{f} ± 0.03	3.93^{bc} ± 0.01	0.80^{c} ± 0.03	6.80^{c} ± 0.01	75.73^{i} ± 0.03
14	3.93^{j} ± 0.03	7.89^{e} ± 0.02	4.04^{ab} ± 0.02	0.99^{c} ± 0.00	4.38^{g} ± 0.01	78.75^{b} ± 0.00
15	4.23^{g} ± 0.02	6.64^{h} ± 0.01	4.45^{a} ± 0.56	1.48^{a} ± 0.01	5.60^{d} ± 0.00	77.21^{f} ± 0.02
16	4.73^{e} ± 0.05	7.72^{f} ± 0.03	3.58^{cde} ± 0.03	0.88^{d} ± 0.01	3.86^{h} ± 0.03	79.22^{a} ± 0.06

Values are presented as means ± standard deviation of two (2) replicates. Data in the same column bearing different superscript differed significantly ($p < 0.05$). CF= cocoyam flour, AYBF= African yam bean flour, WMRP= watermelon rind powder.

This high level of ash and fibre content in samples 2 and 15 can be attributed to the high percentage of watermelon rind flour (WMRP) in the blend. This is in line with findings from Ho *et al*. (2018) who reported an increase in crude fibre content on replacement of part of wheat flour with WMRP. Crude fat content of the flours ranged 0.71-9.51% with sample C having the highest fat content. For the flour blends, sample 10 had highest (10.1%) crude fat and was significantly ($p<0.05$) different from the other samples. Samples 5 and 16 had the lowest value (1.86%). Fat content of the flour blends depend on the percentage of individual flours incorporated into the blends. The mechanical properties of baked food such as flavour and soft texture of food is dependent on fat composition. The decrease in fat content observed in samples could be attributed to a decrease in the percentage composition of AYBF (which helped in handling, processing and storage of the flour) and increase in cocoyam flour (CF). The fat content of this study is comparably lower than the values (16.55-24.60%) reported by Peter-Ikechukwu *et al*. (2019) for cocoyam-wheat soybean sausage. However, higher level of fat is undesirable in food products because they could lead to rancidity in food. Carbohydrate content of the samples ranged 56.22-84.48% for flours and 72.94-79.22% for flour blends. Sample 5 and 16 had the highest carbohydrate levels and were significantly ($p<0.05$) different from the other samples. This can be attributed to the high percentage of CF and AYBF. Cocoyam is known to be a veritable source of carbohydrate (Bamidele *et al*., 2020). Sample 10 was observed to have the lowest carbohydrate content.

Selection of Flour Blend Samples for Further Studies

Samples 4, 7 and 15 were selected following proximate analysis of the flour blends (16 runs) based on their higher contents of crude protein and fibre. Further analyses were then carried out on them.

Antinutrient Composition of Cocoyam, African Yam Bean and Watermelon Rind Flour Blends

Antinutritional factors are compounds which act to reduce nutrient utilization and/or food intake thus, preventing optimal exploitation of nutrients present in food and decreasing their nutritive value (Odo *et al*., 2014). Phytate content significantly ($p<0.05$) ranged from 2.34-3.01 mg/100g (Fig.1). Phytic acid is the main phosphorus stored in mature seeds with strong binding capacity (Adeyanju *et al*., 2021), it is considered an antinutrient because it forms insoluble complexes with minerals. Phytate chelates minerals (especially calcium and zinc) form poorly soluble compounds which are not voluntarily absorbed from the intestine, thus interfering with the bioavailability of these essential minerals as well as the enzymatic digestion of both starch and proteins. The phytate content was higher in all the flour samples, this is due to the increase in cocoyam and watermelon rind powder content of the flour. However, total removal of phytates may not be desirable due to the presence of high fiber, they also help in the reduction of cholesterols and other lipids (Adegboyega *et al*., 2020). Oxalate had the lowest values ranged between 0.49 mg/100g (sample 4) and 0.95 mg/100g (sample 15). Studies have proven that oxalate is considered poisonous at high concentrations and harmless when present in small amounts (Adeyanju *et al*., 2021). The decrease in oxalate content of this study could be a result of soaking AYB in water for 72 h. The present finding is lower than the findings (0.66-1.60mg/100g) of Olaye and Obidegwe (2018). The alkaloid content was significantly ($p<0.05$) different. The highest alkaloid (1.95 mg/100g) was observed in sample 7 and could be as a result of the increase in CF and AYBF. Tannin content showed no significant difference ($p>0.05$) for samples 4 (2.44 mg/100g) and 7 (2.86 mg/100g) with sample 15 having the highest concentration of 4.08 mg/100g. Tannins are water-soluble phenolic compounds that have the ability to bind or precipitate proteins from aqueous solutions. This could be as a result of increase in CF and WMRP. Studies have shown that the tannins also exhibit anti-microbial, antioxidant and anti-inflammatory properties. The usage of tannins rich food has lots of remedial and beneficial effects on human being and can be used as drugs to heal the burning injury as it is helpful to stop bleeding from cuts (Feyera, 2020).

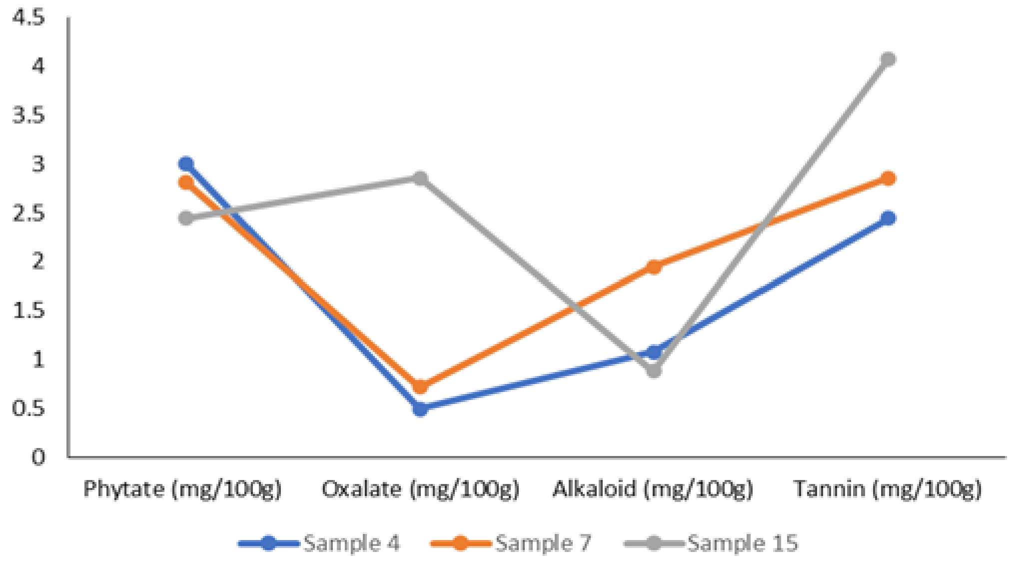

Figure 1: Antinutrient composition of cocoyam, African yam bean and watermelon rind flour blends.
Sample 4= 66.38% CF, 25.65% AYBF, 7.97% WMRP; Sample 7= 70.71% CF, 24.29% AYBF, 5% WMRP; Sample 15= 80% CF, 5% AYBF, 15% WMRP. CF= Cocoyam flour, AYBF= African yam bean flour, WMRP= Watermelon rind powder.

Antioxidant Properties of Cocoyam, African Yam Bean and Watermelon Rind Flour Blends

The antioxidant properties of the three selected flour blends are shown in Fig. 2. The antioxidant capacities and its activities in the flour blend samples showed significant ($p<0.05$) increase. They ranged from 18.82-19.50 mg/g, 6.49-22.30%, 0.37-1.02% and 24.48-40.83 mg GAE/g for FRAP, DPPH, flavonoid and total phenolic content, respectively, with sample 15 having the highest antioxidant content. FRAP and total phenolic content were the most abundant antioxidants in the flour blend samples. Their increase could be attributed to the increase in WMRP in the blends which is a good source of natural antioxidants (Rezagholizade-shirvan *et al*., 2023). The DPPH is a rapid and widely used method to measure the ability of compounds to act as free radical scavengers or hydrogen donors and to evaluate the antioxidant activity of foods (Enujiugha *et al*., 2012). The DPPH value in the present study is higher compared to the values (3.50–10.78) reported by Forgarasi *et al*. (2018) for watermelon-blueberry-buckhorn jam. There was no significant ($p>0.05$) difference in the flavonoid content of the flour blend samples. Flavonoids are secondary metabolites (Panche *et al*., 2016). They show a broad range of biological activities such as antioxidant, antiallergic, antimicrobial and anti-inflammatory properties. Various studies have proven that flavonoids possess several protective functions such as preventing the development of atherosclerosis because they help in the oxidation of low-density lipoprotein, prevent antineurogeneration associated with Parkinson's disease and prevent injury caused by free radical scavengers (Akansha, 2019).

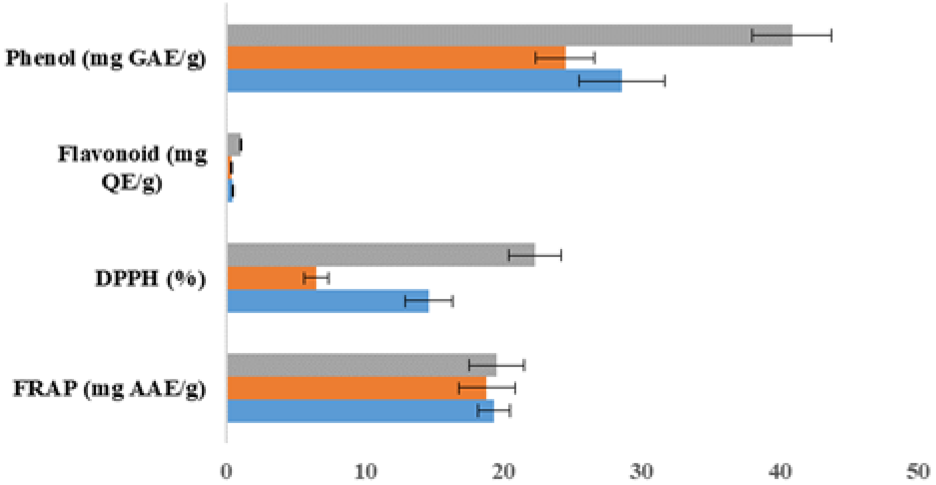

Figure 2: Antioxidant properties of cocoyam, African yam bean and watermelon rind flour blends. Sample 4= 66.38% CF, 25.65% AYBF, 7.97% WMRP; Sample 7= 70.71% CF, 24.29% AYBF, 5% WMRP; Sample 15= 80% CF, 5% AYBF, 15% WMRP. CF= Cocoyam flour, AYBF= African yam bean flour, WMRP= Watermelon rind powder.

Functional Properties of Cocoyam, African Yam Bean and Watermelon Rind Flour Blends

The functional properties of the three selected flour samples are shown in Table 3. Functional properties describe the behaviour of food during preparation and determine how they will affect their finished product (Chandra *et al*., 2014). Water absorption capacity (WAC) represents the ability of the product to associate with water under conditions when water is limiting (Awolu *et al*., 2017). The WAC of flour samples had values ranging from 1.77-2.03% with sample 15 having the highest value (2.03%) which differed significantly ($p<0.05$) from samples 4 and 7. Increase in percentage of WMRP led to increase in WAC. Sample 15 had the highest percentage of WMRP addition and exhibited highest capacities for water absorption. The oil absorption capacity (OAC) ranged between 1.00-1.10% with sample 7 having the highest value which did not significantly ($p>0.05$) different from sample 4 and 15. OAC is useful in formulation of foods such as bakery products (Awolu *et al*., 2017). All samples had OAC within the same range. The bulk density ranged from 0.82-0.88 g/ml with sample 15 exhibiting the highest value which differed significantly ($p<0.05$) from samples 4 and 7. The bulk densities of all the samples were low which fell within the same range. The low bulk density reported for all the samples in this study shows that flour could be an advantage in the preparation of complementary foods. The density of flour is important as it affects mixing, packaging, and transportation. Nutritionally, low bulk density is advantageous because it engenders consumption of more quantity of lighter food items and this will translate into more nutrients for the consumer (Ocheme *et al*., 2018). The swelling capacity of the flour samples ranged between 4.05-7.03%. Sample 7 had the highest value and was significantly ($p<0.05$) different from samples 4 and 15. This increase could be due to the incorporation of higher proportion of AYBF. This observation agrees with the finding of Dada et al. (2023) for wheat, African yam bean and tigernut flour blends. The foaming capacity and stability of the samples ranged between 5.33-7.00% and 10.45-14.58%, respectively. Sample 4 had the highest value which differ significantly ($p>0.05$) from samples 7 and 15. The increase observed in sample 4 could be responsible for the higher proportion of AYBF as CF has been reported to contain low foaming capacity of 1.90% (Bello *et al*., 2022). Sample 7 had the highest gelatinization temperature (83 °C) which did not differ significantly ($p>0.05$) from sample 15 but was significantly ($p<0.05$) different from sample 12. All samples recorded high gelatinization temperatures but sample 15 had the lowest temperature which could be attributed to its high percentage of CF.

Table 3: Functional properties of cocoyam, African yam bean and watermelon rind flour blends

	Sample 4	Sample 7	Sample 15
Water absorption capacity (g/mL)	1.83^b±0.06	1.77^b±0.06	2.03^a± 0.06
Oil absorption capacity (g/mL)	1.06^a±0.11	1.10^a±0.00	1.00^a±0.00
Bulk density (g/mL)	0.82^b±0.0	0.84^b±0.02	0.88^a±0.01
Swelling capacity (mL/g)	4.05^b±0.05	7.03^a±0.06	4.08^b±0.07
Foaming capacity (mL/g)	7.00^a±1.00	6.33^a±1.15	5.33^a±1.53
Foaming stability (%)	14.58^a±2.08	12.41^a±2.26	10.45^a±2.99
Gelatinization temperature (^{0}C)	82.67^a±0.57	83.00^a±0.00	81.67^b±0.58

Values are presented as means ± standard deviation of two (2) replicates. Data in the same row bearing different superscript differed significantly ($p<0.05$). Sample 4= 66.38% CF, 25.65% AYBF, 7.97% WMRP; Sample 7= 70.71% CF, 24.29% AYBF, 5% WMRP; Sample 15= 80% CF, 5% AYBF, 15% WMRP. CF= Cocoyam flour, AYBF= African yam bean flour, WMRP= Watermelon rind powder.

Pasting Properties of Cocoyam, African Yam Bean and Watermelon Rind Flour Blends

Pasting properties of flour refer to the changes that occur in the food as a result of application of heat in the presence of water (Ocheme *et al*., 2018). All the properties determined were significantly ($p<0.05$) increased with an increase in watermelon rind powder except peak time and pasting temperature (Table 4). The peak viscosity ranged from 485.00-917.50 RVU. Sample 15 (80% CF, 5% AYBF and 15% WMRP) had the highest value while samples with higher AYBF (sample 4) recorded a lower value. The observed increase in peak viscosity with increasing levels of WMRP and a higher proportion of CF might be linked to a higher content of carbohydrate which has been reported to increase paste viscosity. Trough viscosity values ranged from 470.50-851.50 RVU for samples 4 and 15, respectively. Reduction in sample 4 value has been responsible for the inclusion of AYBF due to starch-lipid complex which inhibits starch swelling. However, the increase in trough value shows that sample 15 possesses a greater ability not to break down during cooling. Breakdown viscosity ranged between 14.50 RVU and 66.00 RVU with sample 15 having the highest value. The low breakdown viscosity observed in sample 4 shows the capacity of the sample paste to withstand heat and shear stress when cooling. The final viscosity which indicates the stability of cooked starch after cooking ranged between 648.00-1349.50 RVU. The highest value was in blends with a higher proportion of CF and WMRP. Setback viscosity ranged between 177.50-498.00 RVU. It is the difference between the final viscosity and trough viscosity. The lower setback recorded for sample 4 indicates higher resistance of the paste to retrogradation. This finding agrees with the observation of Abioye *et al.* (2022) for yellow cassava grit flour incorporated with AYB flour. Peak time and temperature ranged from 6.76-7.00 min and 44.00-88.47 ^{o}C, respectively, with sample 15 having the highest value. No significant (p>0.05) difference was observed from samples 4 and 7. Pasting temperature indicates the minimum temperature needed when cooking a food sample. Lower pasting temperature results in shorter pasting time which requires less energy consumption as observed in sample 15.

Table 4: Pasting properties of cocoyam, African yam bean and watermelon rind flour blends

	Sample 4	Sample 7	Sample 15
Peak Viscosity (RVU)	485.00^{c}±42.45	792.50^{b}±50.43	917.50^{a}±61.33
Trough Viscosity (RVU)	470.50^{b}±46.33	773.50^{a}±45.49	851.50^{a}±45.77
Breakdown Viscosity (RVU)	14.50^{b}±2.12	19.00^{b}±3.07	66.00^{a}±5.55
Final Viscosity (RVU)	648.00^{b}±60.44	1099.50^{a}±53.86	1349.50^{a}±68.81
Setback Viscosity (RVU)	177.50^{b}±20.11	326.00^{a}±76.36	498.00^{a}±23.03
Peak Time (min)	7.00^{a}±0.00	6.94^{a}±0.09	6.76^{a}±0.23
Pasting Temperature (°C)	88.47^{a}±1.66	88.12^{a}±2.23	64.03^{b}±2.26

Values are presented as means ± standard deviation of two (2) replicates. Data in the same row bearing different superscript differed significantly (p<0.05). Sample 4= 66.38% CF, 25.65% AYBF, 7.97% WMRP; Sample 7= 70.71% CF, 24.29% AYBF, 5% WMRP; Sample 15= 80% CF, 5% AYBF, 15% WMRP. CF= Cocoyam flour, AYBF= African yam bean flour, WMRP= Watermelon rind powder.

Sensory Evaluation of Cocoyam, African Yam Bean and Watermelon Rind Flour Blend Cakes

The sensory scores of cakes produced from the selected flour samples are presented in Fig. 3. The scores for taste ranged between 6.30 and 7.50. Control (RC) had the highest value for taste and significantly (p<0.05) different from other cake samples.

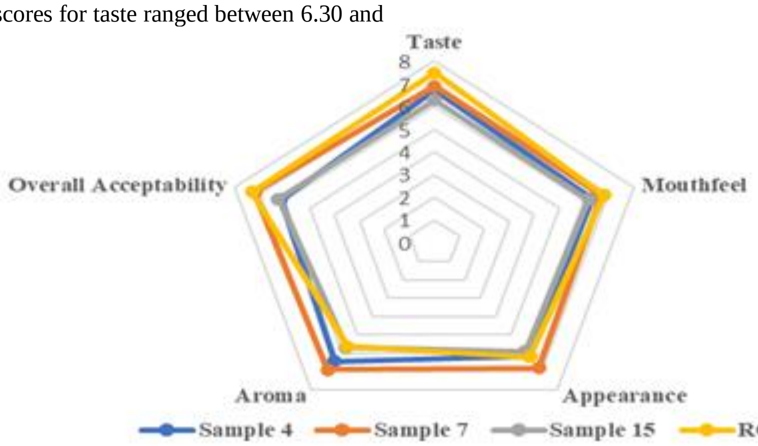

Figure 3: Sensory scores of cakes made form cocoyam, African yam bean and watermelon rind flour blends
Sample 4= 66.38% CF, 25.65% AYBF, 7.97% WMRP; Sample 7= 70.71% CF, 24.29% AYBF, 5% WMRP; Sample 15= 80% CF, 5% AYBF, 15% WMRP. CF= Cocoyam flour, AYBF= African yam bean flour, WMRP= Watermelon rind powder

Mouthfeel of the samples ranged from 6.20-6.80. The highest value was observed in RC and was not significantly (p>0.05) different from sample 7. Appearance of the samples had scores ranging from 5.90 to 6.80 with Sample 7 having the highest rating. The scores for aroma range between 5.70 to 6.90. Sample 7 had the highest score and was significantly (p<0.05) different from other cake samples. This could be attributed to the AYBF because during the processing of African yam bean seeds to flour, a sweet aroma was observed. Samples 7 had the highest score for overall acceptability in the formulated cake samples and not significantly (p<0.05) different from RC. Hoque and Iqbal (2015) incorporated watermelon rind powder at 10%, 20% and 30% to produce cake. The cake with high overall acceptability was that with 10% rind incorporation and this supports the findings of my present study.

Conclusion

The study successfully formulated flour blends from cocoyam, African yam bean, and watermelon rind. The findings showed that incorporating cocoyam, African yam bean, and watermelon rind into cake formulations can significantly improve the nutrient composition, offering higher protein and fiber as well as low antinutrient contents. The antioxidant properties of these blends also suggest the beneficial role in health promotion. Additionally, sensory evaluations showed overall acceptability of the developed cakes especially sample 7 made from 70.71% cocoyam flour, 24.29% African yam bean flour and 5% watermelon rind powder, competing favourably with the control. This study has demonstrated the potential of utilizing flour blends from these ingredients to produce nutrient-rich cakes, thereby contributing to food security and dietary diversification, particularly in regions where these crops are indigenous.

Declarations

Competing Interest

The authors declare no competing interest.

Authors' Contributions

All listed authors contributed equally to the research process, literature writing, review and editing of the article.

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