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# Composition and Sensory Properties of Wheat, Plantain and Cocoyam Flour Doughnuts

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## Abstract

This study was carried out to investigate proximate composition, functional properties and sensory evaluation of wheat, plantain and cocoyam flour blended doughnuts at different levels of plantain and cocoyam flour substitution for consumption. A whole wheat doughnuts and composite doughnuts were prepared in duplicates at 0, 12, 15, 30, 35% and 0, 8, 25, 25 and 50% levels of plantain and cocoyam flours substitution respectively and evaluated for proximate composition using AOAC Methods. The results reveal that moisture, ash, crude fiber and carbohydrate contents of the composite doughnuts increased significantly ($p<0.05$) while the protein and fat contents decreased significantly with progressive increase in the cocoyam and plantain flour substitution. The proximate composition of the various doughnut samples ranged from moisture, 16.29-20.15, ash, 1.49-2.6, protein, 4.54-9.36, fat, 38.35-46.35, fibre, 0.34-3.12 and carbohydrate, 42.20-49.18 g/100g. Results obtained from the functional properties of the composite flour revealed significant increase ($p < 0.05$) in water absorption capacity (118.78-135.61) and bulk density (0.58-0.70) as the levels of the plantain and cocoyam flours increased while the oil absorption capacity (68.21-96.44), emulsion ability (48.16-64.16) and foaming capacity (6.23-13.05) of the whole wheat flour increased. The sensory scores for the entire doughnut samples were above average, implying that the doughnut samples were highly acceptable based on the parameters assessed. The study concludes that Cocoyam and plantain flours could be blended with wheat flour up to 8% and 12% in doughnuts and other pastries preparation with no apparent difference in taste, aroma, or acceptability.

**Keywords:** Wheat flour, composite flour, doughnuts, functional properties, nutritional composition, sensory characteristics

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## INTRODUCTION

Dropped doughnuts are made from flour, water, egg, oil, sugar, and milk (Hatae et al., 2003). They are typically flour products that are ball-like shaped and are deep fried and can be garnished with sugar, chocolate, or maple glaze to create different varieties. Doughnut and other baked products consumption is increasing in Ghana and the entire continent as a result of urbanization (Adeyeye and Akingbala, 2015). Doughnuts are also one of the most popular foods, frequently consumed due to their ready-to-eat nature, high nutritional quality, high satisfaction and inexpensive nature (Adeleke and Odedeji, 2010; Adeyeye and Akingbala, 2015). People are becoming increasingly health-conscious and concerned about their diets because of that they require foods that are convenient, tasty, affordable, and have a positive nutritional image.

Wheat (*Triticum aestivum)* is an imported product in Africa and one of the most significant staple food crops in various countries throughout the world (Van iltersumet al., 2016). It provides more calories and proteins to the global diet than other commonly consumed grains (Kumar et al., 2011). Wheat grain is nutrient-dense, with protein levels ranging from less than 6% to more than 20% (Koehler and Wieser, 2013). It can be made into a variety of foods, such as semolina, bread, scones, noodles, and other confectionery goods (Kumar et al., 2011; Sramkovaet al., 2009). Wheat, because of the presence of gluten which is essential for given dough the ability to rise properly is a superior choice for baked goods than other cereals (Shewry and Hatford, 2002). Wheat is not a tropical crop, and only a few African countries have the climatic conditions to support its growth. As a result, significant sums of money are spent each year in Africa to import wheat to meet the expanding demand for wheat-based products (Ahmed et al., 2013). Wheat flour is the preferred flour for making doughnuts and other flour products; however, it is highly expensive when compared to flours made from underutilized crops like cocoyam and plantain. As a result, composite flours could be made from local crops, lowering the cost of doughnuts and other baked goods. According to Akobundu et al. (1998), while choosing components for composite flour blends, materials should be widely available, culturally acceptable, and have higher nutritious potential. According to the FAO (1995), composite flours made from grains and legumes have an advantage of boosting one's nutritional value. Chinma et al. (2007) also pointed out that composite flours made from legumes and tubers have high protein content as well as a high calorie value.

The herbaceous plants of the genus Musa are known as plantains. In Central and West Africa, plantain (*Musa paradisiaca*) is a common staple meal. It is a staple food crop and a low-cost energy source (Faturoti et al., 2007; Adeniyi et al., 2006). Plantain was listed as one of the key starchy staples in several Ghanaian and West African food consumption surveys (Odenigbo, 2012; Okeke et al., 2008; Ogechi et al., 2007). Plantains are high in dietary fibre (8.82%), resistant starch (16.2%), protein and fat contents (Ayodele and Erema, 2011). Dietary fiber lowers serum cholesterol and lowers the risk of heart attack, colon cancer, obesity, blood pressure, appendicitis, and a variety of other disorders in humans (Rehinan et al., 2004). The feasibility of baking with wheat/plantain composite flour has been investigated (Bamidele et al., 1990; Mepba et al., 2007; Idoko and Nwajiaku, 2013). With higher quantities of plantain supplementation, the composite flours' water absorption capacity and dough development time reduced (Bamidele et al., 1990).

The amount of wheat flour needed to create a specific impact in composite flours is highly dependent on the quality and quantity of wheat gluten present, as well as the nature of the product. Plantain flour, according to Akubor (1998), has a good potential for usage as a functional agent in baking products due to its high water absorption capacity.

Cocoyam is a key staple food in many African, Asian, and Pacific-Ocean countries. It is especially important in Sub-Saharan Africa. The crop's annual production and per capita consumption were expected to be 1.3 million MT and 40 kg, respectively, in 2014 (SRID, 2015). When compared to other root and tuber crops, cocoyam is said to have a greater crude protein content (6.4%) and digestible starch (Okpala and Okoli, 2011). Cocoyam is still used on a limited scale in Africa, ranking third behind other key roots and tuber crops such as yam and cassava (Wanyakha, 2016). Unlike cocoyam and other root harvests such as cassava and sweet potato, have been extensively researched in flour manufacturing (Mepba et al., 2007). They have been used to manufacture composite flour with wheat flour for a variety of pastry goods, and they have helped to reduce wheat imports by a small amount (Sanful and Darko, 2010).

The nutritional value of cocoyam is said to be superior to that of other root and tuber crops, particularly in terms of protein digestibility and mineral composition (Boakye et al., 2017). Cocoyam is key food security crop for many people in many tropical places, especially smallholder farmers. In terms of proximate and mineral content, cocoyam has surpassed taro (a similar aroid) (Matthews, 2002). For economic, nutritional, and/or health reasons, the quest for alternatives to partially or entirely replace wheat flour in bakery and other culinary applications has become imperative. Wheat prices on the global market have become erratic, according to Rodrick (2008), with prices doubling between 2005 and 2007, and increasing by 26% between October 2011 and October 2012. The commodity's price volatility puts a pressure on developing economies, which rely significantly on imports to meet their wheat demands. Using flours from root and tuber crops to partially substitute wheat flour has been offered as a potential solution to this problem. These root and tuber crops are widely available and reasonably priced. Their flours have the ability to improve the nutritious profile of the composite flour produced. Furthermore, consumers who are allergic to wheat gluten or have celiac disease will benefit because exposure to this wheat protein is reduced when non-gluten flour is used. The addition of cocoyam and plantain flour to doughnuts would improve the nutritional content of the product while also increasing the use of these underutilized crops. The purpose of the study was to evaluate the characteristics of wheat, plantain and cocoyam flour blends in doughnuts preparation.

## MATERIALS AND METHODS

### Source of raw materials

Prior to processing into flour, mature red cocoyam (*Xanthosoma sagittifolium*) and unripe plantain were purchased from a farm gate, sorted, cleaned, and stored in jute bags at room temperature. Soft wheat flour and other bakery ingredients were procured from Kumasi Central Market.

**Preparation of cocoyam flour**

Fresh cocoyam crowns were rinsed with water, peeled with a stainless steel knife, rewashed, and cut to a thickness of 0.5 cm. The slices were dried for 12 hours at 60°C in a mechanical dryer (Apex, UK). The dried cocoyam slices were crushed into flour with a hammer mill (Christy and Norris Ltd., Surrey, UK) and sieved at 250 μm before being packaged in flexible HDPE bags for subsequent usage.

**Preparation of plantain flour**

Plantains (*Musa paradisiaca*) were manually peeled using stainless steel kitchen knives, and the pulp was sliced into uniform sizes of around 1.5mm thickness according to the procedure of Adeniji et al., (2007). The slices were dried to a consistent weight in a 105°C oven for 24 hours before being milled into flour using Philip's grinder. The flour was then sieved in 500-mesh sieve to obtain fine smooth textured flour. The flour was packaged in plastic bags and stored at 4° C until it was time to make composite flours.

**Preparation of composite flour**

Composite flour was prepared by mixing proportions of the three component flours (wheat, cocoyam, and plantain), according to (Hugo, 2002) present in Table 1. Blends of the mixture were A (wheat flour, 100%), B (wheat 80%, Plantain 12% and Cocoyam 8%), C (wheat 60%, Plantain 15% and Cocoyam 25%), D (wheat 40%, Plantain 35% and Cocoyam25%) and E (wheat 20%, Plantain 30% and Cocoyam 50%). One hundred percent (100%) of wheat flour was used as control. The flours were packed in plastic containers until the preparation of the products and analysis.

**Table 1.** Formulation of Composite and wheat Flour for doughnuts Production

| | **SAMPLES** | | | | |
|---|---|---|---|---|---|
| **Ingredients** | **A** | **B** | **C** | **D** | **E** |
| Wheat flour (soft) (g) | 100 | 80 | 60 | 40 | 20 |
| Plantain flour (g) | 0 | 12 | 15 | 35 | 50 |
| Cocoyam flour (g) | 0 | 8 | 25 | 25 | 30 |
| Margarine (g) | 30 | 30 | 30 | 30 | 30 |
| Sugar (g) | 40 | 40 | 40 | 40 | 40 |
| Vanilla essence (ml) | 2 | 2 | 2 | 2 | 2 |
| Salt (g) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Baking powder (g) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Milk (ml) | 30 | 30 | 30 | 30 | 30 |
| Water (ml) | 15 | 15 | 15 | 15 | 15 |
| Egg | 1 | 1 | 1 | 1 | 1 |
| Vegetable oil (ml) | 250 | 250 | 250 | 250 | 250 |

A (100% wheat flour), B (wheat 80%, Plantain 12% and Cocoyam 8%), C (wheat 60%, Plantain 15% and Cocoyam 25%), D (wheat 40%, Plantain 35% and Cocoyam25%) and E (wheat 20%, Plantain 30% and Cocoyam 50%)

**Preparation of doughnuts**

Prior to the production of doughnut, cocoyam and plantain flour were blended with wheat flour as shown in Table 1. The doughnut samples were produced with slight modification to the method of Paraggon Book Service (2013). The basic formulation consists of 100% wheat flour, fat, 30g, egg, 1, sugar, 10g, yeast, 10g, and milk, 20ml. The weighed wheat–cocoyam-plantain flour used was poured into a mixing bowl with the margarine and baking powder. It was then rubbed-in to a fined breadcrumbs texture. Salt, sugar, vanilla essence and egg were added to the diluted milk and were mixed together with rotary whisk. The mixture was incorporated into the flour and was again mixed to a thick batter consistency. A scoop was used to fetch the thick batter into the oil so as to obtain the same size and weight. Doughnuts were checked and removed. This method was repeated for each flour blend to obtain different samples of doughnut.

**Proximate Analysis**

AOAC (1995) techniques were used to determine the proximate composition of the whole wheat and composite doughnut samples. The moisture content (% MC) of samples was evaluated by drying them for 24 hours at 105°C. With the Kjeltec 8400 analyzer unit (FOSS, Sweden), the crude protein percentage (%CP) was calculated using the Kjeldahl method No 920.87 (AOAC, 1995) and the percentage nitrogen obtained was used to calculate the percentage of CP using the formula: percentage of CP = percent N X 6.25. The percentage ether extract (percent EE) was calculated using the Soxhlet system HT-extraction technique AOAC (1995) method, and the percentage (%) of ash was calculated by incinerating the samples at 550°C for four (4) hours in a muffle furnace. The ash was weighed after cooling in a desiccator. Dilute acid and alkali hydrolysis was used to measure the crude fibre percentage (% CF). Difference was used to compute carbohydrate (AOAC, 1995).

**Determination of functional properties of the flour samples**

Determination of water and oil absorption capacity

The method described by Okezie and Bello (1988) was used to determine the water and oil absorption capacities. In a flask shaker, one gram (1.0 g) of each sample was mixed with 20 ml distilled water (for water absorption capacity) and 20 ml oil (for oil absorption capacity) and centrifuged for 1 hour at 2,000 rpm. The difference between the initial and final volumes of water/oil absorbed by samples was computed. The averages of duplicates were calculated and reported.

Oil absorption capacity (% OAC) = $\frac{(y-z)\times d}{x} \times 100$

Where y= initial volume of oil added

Z= volume of supernatant collected

X= initial weight of (dried) sample taken

d= density of oil

y-z =volume of water retained by the sample after centrifugation

Water absorption capacity (% WAC) = $\frac{y-z}{x} \times 100$

Where y= initial volume of water added

Z= volume of supernatant collected
X= initial weight of (dried) sample taken
y-z =volume of water retained by the sample after centrifugation

**Determination of bulk density**

With minor modifications, the bulk density was calculated using Onwuka's (2005) approach. Fifty grams (50g) of each sample were placed in a clean 100 ml graduated measuring cylinder and gently tapped several times until no more decrease occurred. It was measured in volume, and the bulk density was computed using the following formula:

$$\text{Bulk density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (mL)}} \times 100$$

**Determination of emulsion stability**

Acuna et al., (2012) method of determining the emulsion capacity was used. Five milliliters (5 ml) flour dispersion in distilled water (10 mg/mL) was homogenized for 1 minute with 5 mL oil. The emulsion was centrifuged for 5 minutes at 1,100 rpm. The height of the tube's emulsified layer (EL) and total content (TC) were both measured. Emulsion capacity was calculated as follows:

$$EC = \frac{EL}{TC} \times 100$$

**Determination of foaming capacity and stability**

Foaming capacity and stability were studied as described by Narayana and Narasinga (1982). At 302oC, two grams (2g) of each flour sample were mixed with fifty milliliters (50 ml) distilled water. The whipped mixture was poured into a graduated cylinder with a capacity of 100 ml. The suspension was correctly combined and shaken to froth, and the volume of the foam was measured after 30 seconds. The foaming capability was measured in terms of volume increase as a percentage. To evaluate the foaming stability as a percentage of the initial foam volume, the foam volume was measured 1 hour after whipping.

Calculation of the capacity and stability is as follows:

$$\%\text{foaming capacity} = \frac{(volafterhomogenization) - (volbeforehomogenization)}{volbeforehomogenization} \times 100$$

$$\%\text{foam stability} = \frac{foamvolumeaftertime(t)}{initialfoamvolume} \times 100$$

## Sensory Evaluation

Sensory evaluation was done to decide which doughnuts were the most preferred. A 50-member panel comprised of semi-trained Hospitality Management students evaluated the doughnuts. Colour, flavour, taste, hardness, and general acceptability were all considered when judging the doughnut variants. To disguise diverse qualities of the doughnut samples and so prevent bias, panelists worked in partitioned booths with no air flow, no noise or odours, and under off white light. The variations between the doughnut samples were measured using a nine-point hedonic scale.

## Statistical data analysis

Data obtained were analyzed using statistical package for social sciences (SPSS version 20). To examine the variations in proximate composition, functional properties, and sensory qualities of the doughnut samples, a one-way ANOVA was used. Fisher's Least Significant Difference test (LSD) at $p \leq 0.05$ was used to separate the means.

## RESULTS AND DISCUSSION

The moisture content of the doughnuts ranged from 16.29 to 20.15%. Doughnuts produced in 20% wheat, 30% Plantain and 50% Cocoyam doughnuts have the highest moisture content (20.15%) compared to other studies (Idoko and Nwajiaku, 2013; Ketiku, 1973; Asiedu, 1987) reported range of 49.40 to 62.0%. The close formation of composite doughnuts have shown that moisture increases as the rate of composite flour increases and this may be due to the ability of plantain and cocoyam flours to absorb more water than wheat flour as shown in Table 2. It was noted that the moisture of doughnut samples increased significantly ($p < 0.05$) as its substitution of cocoyam and plantain flour increased. This result differs from that (9.37–10.03%) reported by Echendu et al. (2004) of biscuits made from a mixture of pigeon flour. Low moisture is helpful because it will reduce product decay by improving its shelf life while the high moisture content is a conduit for microbial perforation (Nnam, 2002).

Crude ash was between 1.49-2.60% (Table 2), which was lower than previously reported (Lazos, 1986). Each treatment significantly ($P < 0.05$) increased the levels of crude ash as cocoyam and plantain flours increased. The control sample (100% wheat flour) has a small amount of ash (1.49%) while the sample mixture of combination E (wheat 20%, Plantain 30% and Cocoyam 50%), has a high ash content (2.60%). The increase in ash content could be credited to the higher levels of ash in the cocoyam and plantain flours as compared to wheat flour. The contents of the ashes are an indication of the minerals contained in the doughnuts.

The protein content also decreased significantly ($p < 0.05$) with an increase in the rate of non-wheat flour substitution in the samples but generally lower than the 100% wheat flour doughnuts produced. Raw protein was 9.36% for 100% wheat doughnuts (control), 8.64% for 80% wheat 12% Plantains and 8% cocoyam flour; 7.36% for 60% wheat, 15% plantain and 25% cocoyam flour, 6.35% for doughnuts produced from 40% wheat, 35% plantain and 25% cocoyam flour and 4.54% for 20% wheat, 30% plantain and 50% cocoyam flour blends respectively.

Fat content values were 46.35% in 100% wheat doughnuts (control), 44.36% in 80% wheat, 12% Plantain and 8%, cocoyam flour mixtures; 43.74% wheat 60% 15% plantain and 25% cocoyam flour, 41.65% for 40% wheat 35% plantain and 25% cocoyam flour and 38.35% for 20% wheat, 30% plantain and 50% cocoyam flour. It was noted that protein and fat were significantly reduced as the amount of cocoyam and plantain flour increased. The results also show that 100 g of doughnuts can provide more than one-third of the recommended daily protein (IOM, 2005) for a healthy adult when eaten.

The crude fibre content of all doughnut samples ranged from 0.34 to 3.12%, with the composite doughnuts sample E (wheat 20%, plantain 30%, and cocoyam 50%) having the highest fibre content. The fibre level was low (0.34%) in the 100% wheat flour doughnuts and thus, differs from that found by Kayode et al 1995 in bread made from 100% wheat flour. Fibre has numerous health advantages (Rehinan et al., 2004). According to Rehinan et al., (2004), the crude fibre content of plantain and cocoyam flours indicate that when included into a human diet, they can help lower serum cholesterol, reduce the risk of heart attack, colon cancer, obesity, blood pressure, appendicitis, and many other ailments.

The carbohydrate content of doughnut samples ABCDE ranged from 43.20 to 49.18%, with doughnut sample E (20% wheat, 30% Plantain and 50%Cocoyam flour blends) having the highest mean value (49.18%) while doughnut sample A (100 percent wheat flour) recorded the lowest (43.20%). The composite samples and the control sample differed considerably ($p<0.05$). It was discovered that increasing the amount of cocoyam and plantain flour in the doughnuts resulted in a comparable rise in carbohydrate content. The carbohydrate levels discovered in this study are lower than those reported by Eke et al. (2008) for cakes marketed in Port Harcourt. These variations could be attributable to variances in recipe composition and preparation methods. Furthermore, the high carbohydrate content of cocoyam and plantain may explain the considerable rise in carbohydrate with increasing cocoyam and plantain substitution levels. In roots and tubers, glucose predominates over all other solid nutrients (Enwere, 1998)

**Table 2** Proximate composition of doughnuts

| **Samples** | **Moisture** (g/100g) | **Ash** (g/100g) | **Protein** (g/100g) | **Fat** (g/100g) | **Fibre** (g/100g) | **CHO** (g/100g) |
|---|---|---|---|---|---|---|
| **A** | 16.29$^{a}$ | 1.49$^{a}$ | 9.36$^{e}$ | 46.35$^{a}$ | 0.34$^{a}$ | 42.20$^{c}$ |
| **B** | 17.23$^{b}$ | 1.95$^{b}$ | 8.64$^{d}$ | 44.36$^{b}$ | 0.82$^{a}$ | 42.64$^{a}$ |
| **C** | 18.63$^{c}$ | 2.30$^{c}$ | 7.36$^{c}$ | 43.74$^{c}$ | 1.42$^{c}$ | 43.13$^{b}$ |
| **D** | 18.71$^{d}$ | 2.54$^{d}$ | 6.35$^{b}$ | 41.65$^{d}$ | 2.56$^{d}$ | 46.15$^{e}$ |
| **E** | 20.15$^{e}$ | 2.60$^{e}$ | 4.54$^{a}$ | 38.35$^{e}$ | 3.12$^{e}$ | 49.18$^{e}$ |

*Values represent means and standard deviation replicate readings for various parameters. Values in the same column with different superscripts are significantly different ($p>0.05$). Keys: A (100% wheat flour), B (wheat 80%, Plantain 12% and Cocoyam 8%), C (wheat 60%, Plantain 15% and Cocoyam 25%), D (wheat 40%, Plantain 35% and Cocoyam 25%) and E (wheat 20%, Plantain 30% and Cocoyam 50%)*

The water absorption capacity of wheat, plantain, and cocoyam flour blends, as well as 100% wheat flour, is shown in Table 3 at various ratios. The water absorption capacity of the flours ranged from 118.78 to 135.61 g/g, with wheat flour having the lowest value (118.78 g/g) and composite flour sample E (20% wheat, 30% plantain, and 50% cocoyam) flour blends having the highest WAC (135.61).

Carbohydrates and proteins, which contain hydrophilic elements such as polar or charged chains, are the main chemical components that improve flours' water absorption ability (Lawal and Adebowale, 2004). At varied ratios, there was a significant ($p<0.05$) difference in WAC between composite flour samples and the control (100% wheat flour). This is not surprising given that cocoyam flour has larger carbohydrate content than wheat flour and starch plays a substantial role in water absorption. The rise in WAC, on the other hand, has been linked to an increase in amylose leaching and starch crystalline structure degradation (Chandra et al., 2015). The higher carbohydrate value of cocoyam and plantain flour blends in the proximate composition supports this. Other investigations have found that cocoyam flour has a high WAC (Oke and Bolarinwa, 2011). A high WAC is important since it maintains product consistency while also increasing yield and consistency (Osundahunsiet al., 2003). This is an important metric in the value-added industry, and it suggests that cocoyam and plantain flours could be used in the preparation of dough and pastries.

With increasing amounts of cocoyam and plantain flours, the oil absorption capacity (OAC) of the flours declined, ranging from 68.21 to 96.44 g/g. Sample A had the highest OAC value of 96.44 g/g, whereas sample E had the lowest OAC value of 68.21 g/g (20 percent wheat, 50 percent plantain, and 30 percent cocoyam flour). The presence of more hydrophobic proteins, which exhibit dominance in binding lipids, may be the source of the increase in OAC. Intrinsic factors such as protein structure, amino acid, and surface divergence influence the OAC (Shrestha and Srivastava, 2017). The composite flours used in this study could be advantageous in food application such as flavour retention, increased palatability, and shelf-life extension in pastries and bread products where fat absorption is desired (Aremu et al., 2007). The results differed from those of Kaushal et al. (2012), who looked at taro (Colocasia esculenta), rice (Oryza sativa), and pigeon pea (Cajanus cajan) flour. The bulk density and emulsion capacity of the pure flours and their composites, respectively, ranged from 0.58 to 0.70 and 52.35 to 64.16. Bulk density is a property of proteins that is impacted by protein quantity and quality (Akubor, 2013; Ocloo et al., 2010), whereas emulsion capacity is a property of proteins that is influenced by protein content and quality. The results show that cocoyam and plantain flour blends were significantly bulkier in sample E (20% wheat, 30% plantain, and 50% cocoyam flour) (0.70) than the 100% wheat flour (0.58), implying that adding more cocoyam and plantain flours to the composite resulted in an increased in its density. High bulk, according to Udensi and Eke (2000), reduces paste thickness. Wheat flour had substantially higher emulsion ability (64.16%) than the composite flour samples. The emulsion capacity was reduced when a portion of wheat flour was replaced with cocoyam and plantain flours.

Foaming capacity (FC) is a measurement of flour's ability to foam, which is determined by the presence of flexible protein molecules that lower water surface tension (Asif-Ul-Alam, et al., 2014). The foaming capacity of the flours ranged from 6.23 to 13.05%, with wheat flour having the highest foaming capacity (13.05%) and sample E (20% wheat, 50% plantain and 30% cocoyam flour) had the lowest foaming capacity (6.23%). As the amount of cocoyam and plantain flours was raised, the foaming capability fell. Because flexible proteins have strong foaming capacity, foaming capacity is thought to be reliant on the configuration and type of protein molecules (Graham and Philips, 1976). The high foaming capability of 100% wheat flour could indicate that it can help improve textural and leavening properties. Food ingredients with good foaming power and stability, according to Akubor et al. (2000), can be employed in bread products. The low protein content of cocoyam and plantain flours has been blamed for their low foaming potential (Ibebuchi and Uzoegbu, 2002).

Heat treatment of cowpea resulted in a similar reduction in foaming capacity (Abbey and Ibeh, 1988). Kiin-Kabari, et al., (2015) found that when the substitution of bambara groundnut increased in wheat/plantain flours, the results varied (23.5 percent–65.0%).

**Table 3.** Functional Properties of wheat/plantain/cocoyam flour blends

| Sample | WAC | OAC | BD | EA | FC |
|---|---|---|---|---|---|
| **A** | 118.78 ± 0.66[e] | 96.44 ± 3.01[a] | 0.58 ± 0.03[a] | 64.16 ± 1.77[e] | 13.05 ± 0.00[a] |
| **B** | 120.97 ± 0.88[d] | 85.30 ± 1.48[b] | 0.63 ± 0.01[e] | 60.34 ± 1.69[a] | 12.43 ± 0.00[b] |
| **C** | 124.63 ± 1.50[c] | 78.63 ± 0.29[b] | 0.65 ± 0.00[d] | 58.42 ± 1.27[b] | 9.45 ± 0.00[c] |
| **D** | 128.10 ± 1.69[b] | 75.24 ± 1.90[b] | 0.67 ± 0.00[c] | 54.73 ± 1.18[c] | 7.13 ± 0.00[d] |
| **E** | 135.61 ± 2.29[a] | 68.21 ± 1.52[b] | 0.70 ± 0.05[b] | 48.16 ± 0.69[d] | 6.23 ± 0.00[e] |

*Values represent means and standard deviation replicate readings for various parameters. Values in the same column with different superscripts are significantly different (p>0.05). WAC = Water Absorption Capacity, OAC = Oil Absorption Capacity, BD = Bulk Density, EA = Emulsion Ability, FC = Foaming Capacity*

The sensory features of the cocoyam-wheat-plantain composite doughnut samples are shown in Table 4. The doughnut samples had significant differences in texture (crispiness), aroma, colour, taste and overall acceptance (p<0.05). The texture score ranged from 4.15-8.30 with sample A (100% wheat flour) scoring the highest (p<0.05), followed by sample B (80% wheat, 12% cocoyam, and 8% plantain flours), which scored 8.26 and 4.15 for sample E (20% wheat, 30% Plantain and 50% Cocoyam) respectively. Aroma scores varied from 6.81 to 8.45, with significant (p<0.05) variations between the samples. The panelists found no significant difference in colour, taste, or overall acceptability between the composite doughnuts with up to 12% and 8% cocoyam and plantain flour substitutions and the control, but they did differ significantly in texture, flavour, colour, taste and acceptability from the 100% wheat doughnuts at all levels of substitution. The average sensory scores for the entire doughnut samples were above average, implying that the doughnut samples were highly acceptable based on the parameters assessed. This finding matches that of Echendu et al. (2004), who used maize and pigeon pea flour blends to make doughnuts and biscuits. Table 4 shows that as the percentage of cocoyam and plantain flours in the doughnut samples increased, the doughnut samples scored low in colour, taste, aroma, texture, and acceptability.

Doughnut samples prepared from the 100% wheat doughnut as well as 8% Cocoyam and 12% plantain flour blends doughnuts were accepted since there were no significant (p>0.05) difference between the control and the composite sample B.

**Table 4.** Sensory attributes of the wheat, plantain and cocoyam flour doughnuts

| Samples | Texture | Aroma | Colour | Taste | Overall Acceptability |
|---|---|---|---|---|---|
| **A** | 8.30 | 8.45 | 9.60 | 10.50 | 10.63 |
| **B** | 8.26 | 8.40 | 9.53 | 10.48 | 10.59 |
| **C** | 8.20 | 8.34 | 8.47 | 9.50 | 9.35 |
| **D** | 5.26 | 7.15 | 7.92 | 7.60 | 9.10 |
| **E** | 4.15 | 6.81 | 7.47 | 7.54 | 8.05 |

*Values represent means and standard deviation replicate readings for various parameters. Values in the same column with different superscripts are significantly different (p>0.05). Keys: A (100% wheat flour), B (wheat 80%, Plantain 12% and Cocoyam 8%), C (wheat 60%, Plantain 15% and Cocoyam 25%), D (wheat 40%, Plantain 35% and Cocoyam25%) and E (wheat 20%, Plantain 30% and Cocoyam 50%)*

## CONCLUSIONS

Cocoyam and plantain flours have been demonstrated to have high levels of proteins, ash, lipids, and carbohydrates, making them a valuable source of these nutrients when used to partially replace wheat flour in cooking. At all levels of substitution, nutritional analysis of the various composite doughnuts revealed that they have nutritious value that compares favorably to 100% wheat flour doughnuts and commercially available doughnuts. Its functional qualities made it a good candidate for use in composite flour blends. The study concludes that Cocoyam and plantain flours could be blended with wheat flour up to 8% and 12% in doughnuts and other pastries preparation with no apparent difference in taste, aroma, or acceptability.

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