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EFFECT OF CASSAVA, MAIZE AND SOYBEAN FLOUR MIXES ON COMPOSITION, PHYSICAL AND SENSORY PROPERTIES OF GLUTEN-FREE BREAD

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Abstract
This study evaluated composition, physical and sensory properties of gluten-free (non-wheat bread) bread produced with blends of cassava, maize and soybean flours. Flours were produced from cassava roots (7.kg), maize grains (1.5kg), soybeans (1.5kg) and wheat grains (2kg). Four composite flours; SF2 (12C:5M: 3S), SF3 (10C:7M: 3S), SF4 (8C:9M: 3S), SF5 (6C:11M: 3S) were blended from cassava (C), maize (M), and soybeans (S) flours. Bread samples were produced with the composite flours and 100% wheat flour (SF1, as control) using straight dough method. Bread samples were analysed for composition, physical and sensory properties. There was no remarkable difference in appearance of the composite and wheat breads. The gluten-free (composite flour) breads were comparably rich in protein (12.29 – 13.07%), minerals (6.1mg/100g Zn – 194.12mg/100g P) and vitamins (0.64mg/100g B_2 – 35.93mg/100g vit. C). The wheat bread had 12.52% protein, 1.85 – 101.2mg/100g minerals, and 0.91 – 27.73mg/100g vitamins, and had safe levels of anti-nutrients. However, wheat bread had anti-nutrients and higher specific volume than the gluten-free bread. The gluten-free bread; SF5 and SF4, had higher sensory scores than the 100% wheat bread, but SF4 was more preferred. Based on nutrient composition and sensory scores, cassava-maize-soybean breads could replace 100% wheat bread and its associated celiac disease, high cost and scarcity in Nigeria.

Keywords: Cassava, maize, soybean, composite bread, quality

Introduction

Bread is an important baked staple food highly cherished by all age groups and classes in Nigeria. In recent times, wheat; the base ingredient for bread production is posing many challenges globally (Bernardo and Peña, 2012; Catassi *et al*., 2013; Volta *et al.,* 2013). Wheat is a temperate crop, and not much is grown in Nigeria. Most wheat consumed in Nigeria is imported from temperate countries with high foreign expenditure. The resent recurrent cases of celiac disease among regular wheat consumers has lead to slow but steady increase of consumer interests for gluten-free diets (GFD). Celiac disease is an immune-meditated genetic disorder triggered by consumption of gluten, and is estimated to affect 0.5-1% of the world population (Lovis, 2003). Gluten is a wheat protein which is composed of glutenin and gliadin and is insoluble in water. However, it forms gel-like matrix when mixed with water to form dough or batter. Common symptoms include but not limited to diarrhea, fatigue and abdominal pains (Gujral *et al*., 2012). Celiac disease has no cure but can be controlled by removing gluten from the diet (Watkins and Zawahir, 2017). Many researchers have tried substitution of gluten with ingredients capable of mimicking gluten functional properties. Several hydrocolloids were added for high volume and soft crumb breads (Moor *et al*., 2004); and legumes, carob germ, zein, dairy and protein concentrates/isolates included to improve structure, gas-retaining batter/dough and nutritional quality (Osella, 2014; Ziobro *et al*., 2016). Nigeria is endowed with many promising tuber, root, legume and cereal crops that could be exploited for gluten-free bread. This will reduce high cost of importation of wheat and the gluten-associated celiac disease. Also, this will encourage value addition and exploitation of indigenous crops for bakery products. This study produced bread from cassava, maize and soybean composites, and evaluated its composition and sensory properties in comparison with wheat bread.

Materials and Methods

Materials

Fresh cassava roots (*Manihot esculenta*), variety TMS 98/1632 were obtained from National Root Crops Research Institute, Umudike. Soybeans, yellow maize grains and bakery ingredients were purchased from commercial stockers at Ubani Market, Ubani, Abia State, Nigeria. Wheat grains were purchased from a commercial stocker at Lafia Main Market, Lafia. All the reagents used for analysis in this study were of analytical grade.

Methods

***Processing of cassava flour*:** Fresh harvested cassava roots (7.5kg) were washed, peeled, sliced into chips and milled into mash using a commercial grinding machine. The mash was dewatered with a hydraulic jack, pulverized. Fibrous materials were removed and flour dried in a hot air oven at 55°C for 12h.

***Processing of maize flour*:** Dry maize grains (1.5kg) were freed from extraneous materials and equilibrated for moisture in a hot air oven (Shellab model VWR=1370G) at 55°C for 2h. Grains were tempered by spraying and mixing with 1% (50ml) water (v/w), and re-dried for another 4h at 55°C; milled lightly with Hammer mill (Betsch 5657 GmbH, Germany) to detach bran from grains. Bran was winnowed away (Sastry *et al.*, 1974); and maize kernels milled into fine powder in an Attrition Mill (model GX 160). The powder was sieved through a 300μm mesh to obtain fine flour.

***Processing of soybean flour*:** Dry soybeans (1.5kg) were cleaned and washed thoroughly in excess clean water. Seeds were drained out of water, dried at 55°C for 18h in a hot air oven (Shellab model VWR=1370G), and milled lightly with Hammer mill (Betsch 5657 GmbH, Germany) to detach hulls from nibs. The hulls were winnowed away (Sastry *et al.*, 1974), and the nibs milled into fine powder in a disk attrition mill (Agrico Model 2N, New Delhi, India).

Processing of whole wheat Flour: Wheat grains (2kg) were freed from extraneous material, washed, drained and oven dried for 18h at at55 °C. Dried grains were milled in a hammer mill (Betsch 5657 GmbH, Germany) into fine powder for further use.

***Formulation of composite flours*:** Four composite flours were formulated from different blends of cassava, maize and soybean flours. The composites are shown in Table 1.

Table 1: Formulation of gluten-free composite flours (%)

Samples	Wheat flour	Cassava flour	Maize flour	Soy-bean flour
SF1(100 whole wheat)	100	0	0	0
SF2(12C:5M:3S)	0	60	25	15
SF3(10C:7M:3S)	0	50	35	15
SF4(8C:9M:3S)	0	40	45	15
SF5(6C:11M:3S)	0	30	55	15

C= cassava flour, M= maize flour, S= soy flour

***Bread making process*:** The bread recipe were flour (100g), shortening (5g), yeast (3g), sugar (2g), salt (1.5g), tragacanth (1.5g), *Achi* (*Brachystagia eurycoma* seed powder) (1.5g), liquid egg (6.3g), calcium propionate (1.0g), and water (60ml). Dry yeast was pre-hydrated in 60ml of lukewarm water for 5min to allow for adequate dispersion during mixing with other dry ingredients. Other dry ingredients were blended homogenously; and the liquid egg and shortening added. The yeast mixture was added and the batter mixed at a lowest speed for 120s and then slowed down. Mixing was repeated for an additional 180s at a higher speed. For each bread loaf, 150g of batters were placed in greased bread pans. Pans with batter were proofed for 45min in warm proof chamber before baking for 30min at 230 ±5 °C in the baking oven. After baking, loaves were removed from pans and cooled for about 2h at room temperature. Loaves were packaged and kept aside for further use.

***Determination of dough expansion capacity*:** Dough expansion capacity was determined using the method of Maeda and Caperuto *et al*. (2000). Dough sample were made by mixing 50g of flours with 40ml of lukewarm water. Dough were divided into five balls of appropriately 10g each and baked at 200°C for 25min in an electric oven. Diameters of each dough ball were measured with a veneer calliper before and after baking. Dough expansion capacity was calculated from the initial average diameters of dough balls before and after baking.

***Determination of proximate composition of bread samples*:** Moisture, crude protein, fat, crude fibre and ash contents of bread samples were determined according to AOAC method (AOAC, 2010). Carbohydrate content was estimated by difference [100% – {protein (%) + fat (%) + crude fibre (%) +Ash (%)}].

***Determination of mineral composition of bread samples*:** Mineral contents were determined using dry ash extraction method (James, 1995). Five grams of each bread sample was burnt to ash and dissolved in 5ml of dilute 0.1M HCL acid solution, and made up to 100ml in volumetric flask. Extract of ash samples were used for mineral analysis. Potassium (K) content was analyzed by flame photometric method. Phosphorus (P) content was analyzed by the molybdo-vandate colorimetric method. Calcium (Ca), iron (Fe), zinc (Zn) and magnesium (Mg) contents were determined using atomic Absorption Spectrophotometer (Carpenter and Hendricks, 2003).

***Vitamin content determination*:** Ascorbic acid (vitamin C), thiamine (B_1), riboflavin (B_2), folic acid (B_9) and niacin (B_3) contents of the flours were determined using the method of AOAC (2010). Beta carotene content of samples was determined using a UV-VS spectrophotometer (Spectrum 23A, Gallemcamp, England) as described by Harbone (1973).

***Analysis of phyto-nutrients in bread samples*:** Oxalate, Phytate and hydrogen cyanide (HCN) were determined as outlined by the AOAC method (AOAC, 2010). Tannin contents were determined using the method outlined by Kirk and Sawyer (1991).

***Determination of loaf weight, volume and specific volume (LSV)*:** Loaf specific volume was determined by seed displacement method as described by Nwosu *et al*. (2014). A wooden box was filled with equilibrated millet grains until overflow above the brim. A straight edge ruler was used to edge off and discard all the grains above the box rim such that the grains formed a plateau with the rim. The grains were poured out, weighed and the box volume also recorded. The box was filled to 1/3 of its volume with the grains; the loaf was weighed and laid flat on top at the centre of the box and the box filled to the rim with the grains to form a plateau as before. All the displaced grains were collected, poured again into the box and the volume recorded. Volume occupied by the displaced grains corresponds to volume of the loaf. The loaf specific volume (ml/g) was calculated thus:

Plate I: SF1 (100 % whole wheat bread, control

Plate II: SF2 (60 % cassava, 25 % maize and 15 % soybean)

Plate III: SF3 (50 % cassava, 35 % maize and 15 % soybean)

Plate IV: SF4 (40 % cassava, 45 % maize and 15 % soybean)

Plate V: Sample SF5 (30 % cassava, 55 % maize and 15 % soybean)

Proximate composition of bread samples

Table 2 shows proximate composition of the samples; 100 % wheat bread (SF1) had lowest moisture content (12.72 %), while, gluten-free bread (SF5) had the highest moisture content (13.66%). Moisture content increased with increasing maize content in composite bread. Low moisture content in 100% wheat bread implies longer shelf life (Oluwafemi and Seidu, 2017). Protein content of the bread samples ranged from 12.29% in SF2 to13.07% in SF5; and decreased with increasing content of cassava in the flours. The 100% wheat bread had higher protein (12.52%). Oluwafefmi and Seidu (*ibid*), reported protein content of 10 – 11% in breads made from blends of wheat, cassava, plantain and soybeans. Proteins play vital roles in almost all biological processes, including enzymatic catalyses, transport and storage, immune protection, generation and transmission of nerve impulse, and control of growth and differentiation (Anuma, 2008). Fat content was significantly ($p< 0.05$) higher (12.17%) in 100% wheat bread than in gluten-free breads; and ranged from 7.68% in SF5 to 8.18% in SF2 among the gluten-free bread samples. Fat content decreased with increasing proportion of maize flour in the composite flours. Fat content as high as 21.52% was reported in bread made from wheat, cassava, plantain and soy bean composite flours (Oluwafemi and Seidu, 2017). Fat helps to retain air in batter, and aids in increased bread loaf volume (Pareyt *et al.,* 2011). In addition, fat aids as lubricant, imparts tenderness, moistness, flavour, colour and anti staling in bread (Ayele *et al.,* 2017).

The 100 % wheat bread had the highest fibre content of 1.69%, followed by SF5 (1.55 %) and lastly SF2 (1.27%). This may be because maize has higher fiber content than cassava. The 100% whole wheat and composite breads had low fibre content compared to 3.64% in wheat-cassava-soybean bread as reported by Ayele *et al*. (2017) and 9.25% in composite bread from wheat, cassava, plantain, maize and soybean flour blends as reported by Oluwafemi and Seidu (2017). Fibre helps to prevent constipation, bowel problems and piles (Inagbe *et al.,* 2006). Thus bread produced with whole wheat flour and SF5 will prevent constipation more than others. Ash content ranged from 1.34% in SF2 to 1.61% in SF5, but 2.22% in 100% whole wheat bread. Similar values of 1.81% - 2.14% were obtained by Oluwafemi and Seidu (2017). The whole wheat and gluten-free bread samples had high carbohydrate content (58.69) in whole wheat bread (SF1) to 63.53% in SF2. The energy value (Kcal) ranged from 371.1 in SF5 to 394.33 in SF1. Dry matter content of the bread samples was high and ranged from 86.34% in SF5 to 87.28% in SF1. Both energy value and carbohydrate content decreased as cassava content decreases in the gluten-free bread samples; this could be linked to the high carbohydrate content of cassava.

Table 2: Proximate composition of bread samples

Samples	MC (%)	CP (%)	Fat (%)	CF(%)	Ash (%)	CHO (%)	EV (Kcal)	Dm (%)
SF1	$12.72^{d}\pm0.03$	$12.52^{c}\pm0.03$	$12.17^{a}\pm0.02$	$1.69^{a}\pm0.02$	$2.22^{a}\pm0.03$	$58.69^{e}\pm0.01$	$394.33^{a}\pm0.02$	$87.28^{a}\pm0.03$
SF2	$12.39^{c}\pm0.01$	$12.29^{d}\pm0.01$	$8.18^{b}\pm0.01$	$1.27^{e}\pm0.01$	$1.34^{e}\pm0.01$	$63.53^{a}\pm0.01$	$376.90^{b}\pm0.13$	$86.61^{b}\pm0.01$
SF3	$13.43^{c}\pm0.01$	$12.52^{c}\pm0.01$	$8.11^{c}\pm0.01$	$1.38^{d}\pm0.01$	$1.43^{d}\pm0.01$	$63.13^{b}\pm0.01$	$375.59^{c}\pm0.01$	$86.57^{b}\pm0.01$
SF4	$13.51^{b}\pm0.01$	$12.85^{b}\pm0.01$	$7.87^{d}\pm0.01$	$1.43^{c}\pm0.01$	$1.52^{c}\pm0.01$	$62.84^{c}\pm0.01$	$373.51^{d}\pm0.01$	$86.49^{c}\pm0.01$
SF5	$13.66^{a}\pm0.01$	$13.07^{a}\pm0.01$	$7.68^{e}\pm0.01$	$1.55^{b}\pm0.01$	$1.61^{b}\pm0.01$	$62.43^{d}\pm0.01$	$371.12^{e}\pm0.13$	$86.34^{d}\pm0.0$

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). MC= moisture content, CP= crude protein, CF= crude fibre, EV= energy value, Dm= dry matter, C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S ; SF5=6C: 11M: 3S

Mineral composition of bread samples

Table 3 shows mineral composition of bread samples. The composite breads were relatively better sources of minerals (Ca, Mg, K, P, Fe and Zn) evaluated in this study than the wheat bread; as these minerals were significantly higher ($p<0.05$) in the composite breads. There were higher values of the minerals in the composite breads than in the wheat bread. Ca (mg/100g) ranged from 73.46 - 74.44 in composite breads but was 34.19 in wheat bread; Mg (mg/100g) from 89.13 – 93.67 in composite breads, but 18.71 in wheat bread; K (mg/100g) from 120.08 – 140.91 in composite breads, but 101.82 in wheat bread; and P (mg/100g) from 192.61 – 194.12 in composite breads, but 22.66 in wheat bread. Also, Fe and Zn had similar trends in comparison with wheat bread. Ca, Mg, and Zn increased, while, K, P and Fe decreased with increasing maize content in the composite flours and breads. Similar results were reported by Ndife *et al.* (2011) and Abebe *et al*. (2017) on Fe and Zn in composite flours containing wheat and 100% wheat bread samples. Calcium aids in physiological functions and maintenance of bone tissues throughout life (Abebe *et al., ibid*). Magnesium aids in treating diarrhoea, duodenal cancers, secondary coronary heart disease and congested heart failure (FAO, 2001). Potassium lowers blood pressure in humans, reduces risk of stroke (Okaka, 2010; Ogbuji *et al.,* 2016). Iron aids in oxygen binding with haemoglobin and acts as cofactor in many enzyme activities (Geissler and Power, 2005).

Table 3: Mineral composition of bread samples (mg/100g)

Samples	Ca	Mg	K	P	Fe	Zn
SF1	34.19^{e}±0.01	18.71^{e}±0.01	101.82^{e}±0.01	22.66^{e}±0.25	1.85^{e}±0.01	4.98^{e}±0.01
SF2	73.46^{d}±0.01	89.13^{d}±0.01	140.91^{a}±0.01	194.12^{a}±0.01	8.04^{a}±0.01	6.81^{d}±0.01
SF3	73.85^{c}±0.01	90.57^{c}±0.01	130.4^{b}±0.01	193.76^{b}±0.01	7.88^{b}±0.01	6.96^{c}±0.01
SF4	74.05^{b}±0.02	91.92^{b}±0.01	122.27^{c}±0.01	193.05^{c}±0.01	7.69^{c}±0.01	7.09^{b}±0.01
SF5	74.44^{a}±0.02	93.67^{a}±0.01	120.08^{d}±0.01	192.61^{d}±0.01	7.58^{d}±0.01	7.28^{a}±0.01

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S; SF5=6C: 11M: 3S

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Samples	Ca	Mg	K	P	Fe	Zn
SF1	34.19^{e}±0.01	18.71^{e}±0.01	101.82^{e}±0.01	22.66^{e}±0.25	1.85^{e}±0.01	4.98^{e}±0.01
SF2	73.46^{d}±0.01	89.13^{d}±0.01	140.91^{a}±0.01	194.12^{a}±0.01	8.04^{a}±0.01	6.81^{d}±0.01
SF3	73.85^{c}±0.01	90.57^{c}±0.01	130.4^{b}±0.01	193.76^{b}±0.01	7.88^{b}±0.01	6.96^{c}±0.01
SF4	74.05^{b}±0.02	91.92^{b}±0.01	122.27^{c}±0.01	193.05^{c}±0.01	7.69^{c}±0.01	7.09^{b}±0.01
SF5	74.44^{a}±0.02	93.67^{a}±0.01	120.08^{d}±0.01	192.61^{d}±0.01	7.58^{d}±0.01	7.28^{a}±0.01

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S; SF5=6C: 11M: 3S

Vitamin composition of bread samples

Table 4 show composition of various vitamins analysed in the samples. The whole wheat bread was significantly ($p< 0.05$) lower in these vitamins than the composite breads. This suggested that some of the constituent of the composite flours were richer in these vitamins than wheat. However, both the wheat and composite breads were poor in the B vitamins (less than 1.5mg/100g). Pro-vitamin A ranged from 9.02mg/100g in SF2 to10.01mg/100g in SF5, but 6.67 mg/100g in the wheat bread. Also, vitamin C ranged from 35.63mg/100g in SF2, to 35.93mg/100g in SF5, but 27.73mg/100g in wheat bread. Vitamin C aids formation, iron absorption and wound healing (Okaka, 2010). Vitamin B_2 was less than 1.00mg/100g in the bread samples. Similar values of 0.64mg/100g for B_1, 0.2mg/100g for B_2 and 1.78/100g for B_3 were obtained from maize-soybean bread by Edema *et al.* (2005). The B vitamins aid in many biochemical activities in the body; and are interdependent with minerals and other vitamins and enzymes in their actions (Okaka, 2010). All the vitamins increased with increasing maize content in the composite flours and breads. This was due to high content of these minerals in maize than every other component of the composite flours.

Table 4: Vitamin composition of bread samples (mg/100g)

Samples	Pro-vitamin A	B_1	B_2	B_3	B_9	Vit. C
SF1	6.57^{e}±0.01	0.91^{e}±0.01	0.56^{e}±0.01	1.18^{e}±0.01	0.91^{e}±0.01	27.73^{e}±0.01
SF2	9.02^{d}±0.01	1.13^{d}±0.01	0.64^{d}±0.01	1.27^{d}±0.01	1.11^{d}±0.01	35.63^{d}±0.01
SF3	9.45^{c}±0.01	1.27^{c}±0.01	0.71^{c}±0.01	1.40^{c}±0.01	1.19^{c}±0.01	35.76^{d}±0.01
SF4	9.76^{b}±0.01	1.38^{b}±0.01	0.86^{b}±0.01	1.51^{b}±0.01	1.27^{b}±0.01	35.84^{b}±0.01
SF5	10.01^{a}±0.01	1.44^{a}±0.01	0.95^{a}±0.01	1.59^{a}±0.01	1.35^{a}±0.01	35.93^{a}±0.01

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S; SF5=6C: 11M: 3S

Anti-nutrient composition of bread samples

Table 5 shows the composition of tannin, hydrogen cyanide, phytate and oxalate contents of the bread samples. These anti-nutrients could be fatal at high concentrations, but their concentrations were low. The minimum infective concentration (MIC) of oxalate is 4-5g of oxalate (Doughari, 2012); and of tannin is 560mg (Emmanuel-Ikpeme *et al*., 2012.). The wheat bread had significantly lower content of these anti-nutrients than the gluten-free composite bread. These anti-nutrients ranged from 0.01 – 0.08mg/100g in wheat bread, tannin from 0.45 – 0.61mg/100g, phytate from 1.19 – 2.07mg/100g, and oxalate from 0.03 – 0.11mg/100g in the composite bread samples. Oxalates form insoluble calcium oxalate with calcium, preventing calcium absorption and utilization. This could lead to rickets and oesteomalacia (Ladeji *et al.,* 2004). Phytate is not digested by humans and can bind iron, zinc, calcium and magnesium to form insoluble complexes that is not readily absorbable by the gastrointestinal track (Agbairer and Emoyan, 2012). The 0.18 – 0.42mg/g tannin was reported in composite bread from wheat, fruits, breadnuts and wheat blends. The HCN was 0.01mg/100g in wheat bread, but ranged from 2.54 – 4.02mg/00g in composite bread samples. The high HCN in composite flours was mostly from the cassava flour as this decreased with decreasing cassava content. High tannin content binds and inhibits iron absorption and interferes with vital protein activities (Akindahusi and Salawu, 2005). Low hydrogen cyanide content controls cardiac, neuronal rhythm activity, epilepsy and neuropathic pain (Ndukwe and Ikpeama, 2013). The four phytonutrients decreased with increasing maize and decreasing cassava contents in the composite bread.

Table 5: Anti-nutrient composition of bread samples

Samples	Tannin (mg/100g)	HCN (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)
SF1	$0.01^{e}\pm0.00$	$0.01^{e}\pm0.00$	$0.02^{e}\pm0.00$	$0.08^{ab}\pm0.01$
SF2	$0.61^{a}\pm0.01$	$4.02^{a}\pm0.01$	$2.07^{a}\pm0.00$	$0.11^{a}\pm0.01$
SF3	$0.54^{b}\pm0.01$	$3.87^{b}\pm0.01$	$1.78^{b}\pm0.01$	$0.07^{bc}\pm0.01$
SF4	$0.45^{c}\pm0.01$	$3.11^{c}\pm0.00$	$1.35^{c}\pm0.01$	$0.04^{cd}\pm0.01$
SF5	$0.36^{d}\pm0.01$	$2.54^{d}\pm0.01$	$1.19^{d}\pm0.01$	$0.03^{d}\pm0.01$

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; S F4=8C: 9 M: 3S; SF5=6C: 11M: 3S

Physical properties of bread samples

Table 6 shows expansion of dough and physical properties of the bread samples. Dough expansion of the 100% wheat bread was significantly higher ($p < 0.05$) than those of the gluten-free dough. This depicts high expansion and elasticity of gluten in the wheat bread. Similar trend was obtained for specific volume of bread samples. Among the gluten-free bread sample, these values decreased from SF2 through SF4, but become significantly higher ($p < 0.05$) for SF5 than SF4. Also, bread produced with blends of wheat and oil bean (Nwosu *et al.*, 2014), and with blends of wheat and defatted or undefatted soybean (Ndife *et al.,* 20011) had reduced specific volume. This was due to high density of the experimental breads.

Table 6: physical properties of bread samples

Samples	Dough Expansion (cm)	Specific Vol (cm^3)
SF1	$415.21^{a}\pm0.01$	$0.83^{a}\pm0.01$
SF2	$370.32^{b}\pm0.01$	$0.61^{b}\pm0.01$
SF3	$342.44^{c}\pm0.01$	$0.45^{c}\pm0.01$
SF4	$150.69^{e}\pm0.01$	$0.35^{d}\pm0.01$
SF5	$220.09^{d}\pm0.01$	$0.42^{c}\pm0.01$

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S; SF5=6C: 11M: 3S.

Sensory properties of bread samples

Table 7 shows sensory properties of the bread samples. There were low sensory scores, ranging from 4.05 for taste to 6.25 for crumb appearance, for all the bread samples. The 100% wheat bread was not significantly ($p < 0.05$) better than the gluten-free bread samples in all the sensory attributes; taste, aroma, crumb and crust appearance and crumb texture. The gluten-free bread samples were acceptable as or even preferred to the 100% wheat bread. Among the gluten-free bread samples, sample SF4 was the most acceptable, followed by SF5. Thus, cassava, soy-bean and maize composite flour can be used to produce acceptable bread with good organoleptic properties compared to 100% wheat bread.

Table 7: Sensory properties of bread samples

Samples	Taste	Aroma	Crust appearance	Crumb texture	Crumb appearance
SF1	4.35^{ab}±1.69	4.50^{b}±1.47s	5.20^{b}±1.91	5.20^{ab}±1.67	5.65±^{ab}1.73
SF2	4.05^{b}±1.82	5.50^{a}1.61	6.50^{a}±1.47	6.20^{a}±1.36	6.25^{a}1.25
SF3	4.35^{ab}±2.13	5.65^{a}±1.76	5.45^{ab}±1.73	4.95^{b}±2.19	5.05^{b}±1.81
SF4	5.25^{a}±1.16	5.55^{a}±0.94	6.15^{ab}±1.60	5.15^{ab}±1.50	5.85^{ab}±1.81
SF5	4.90^{ab}±1.52	5.85^{a}±1.23	6.40^{a}±1.50	5.25^{ab}±1.55	5.95^{ab}±1.79

Values are mean ±standard deviation for three determinations. Values with different superscripts on the same column are significantly different (p<0.05). C = cassava flour, M= maize flour and S=soy flour, SF1=100% whole wheat flour. SF2=12 C: 5M: 3S; SF3= 10C: 7M: 3S; SF4=8C: 9 M: 3S; SF5=6C: 11M: 3S

Conclusion

The gluten-free bread samples were relatively rich in protein, carbohydrate, minerals and vitamins; they have anti-nutrients at safe levels. The gluten-free bread SF5 and SF4 had higher sensory scores than the 100% wheat bread. This suggests that the non-wheat bread samples if consumed in sufficient amount would contribute greatly to human nutrition requirement for normal growth, and adequate protection against diseases arising from malnutrition. With these findings, gluten-free bread based on cassava, yellow maize and soy flours composites could replace 100% wheat bread and its associated celiac disease, high cost and scarcity in Nigeria.

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