Assessment of the Nutritional Composition, Physical Properties and Sensory Quality of Composite Bread Baked with High-Quality Cassava Flour from Biofortified and White-Fleshed Cassava Roots

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Abstract: With proper processing and utilization, biofortified cassava may contribute to the nutritional status of the consumers, thus, the need for this study. High-quality cassava flour from white- (TME 419) and biofortified (TMS 01/1368) cassava varieties were produced at a commercial processing factory, after which the flour is composite with wheat flour to produce bread. The nutritional composition, physical properties and sensory quality of the composite bread were analyzed using standard methods. Results showed that composite bread from 20% biofortified cassava flour (20-YCF) had a higher value of total β-carotene (0.74 µg/g), moisture (37.83%) and ash (2.29%) contents. The fat (3.72%) and protein (12.83%) contents were higher in 20% white cassava flour (20-WCF) composite bread. The 20-YCF composite bread had the highest loaf volume (3286.2 cm^3), elasticity (6.32), chewiness (40.51 N) and gumminess (6.41), 20-WCF composite bread had higher specific volume (3.59 cm^3/g) and hardness (176.50 N). The 100% wheat bread had higher cohesiveness (0.10) and loaf weight (932.35 g). A significant negative correlation (r = - 0.98, $p \leq 0.05$) exist between bread hardness and protein content. The composite bread compared favourably with the 100% wheat bread in terms of weight and aroma, but, the 100% wheat bread was more acceptable.

Keywords: white- and biofortified cassava flour; bread; nutritional composition; physical properties; sensory properties

1. Introduction

Wheat bread is one of the most important fast foods consumed in Nigeria. Nigeria is one of the highest importers of wheat in the world [1, 2, 3]. The expenditure on wheat importation is negatively affecting public investment in development and human welfare. Hence, Nigeria is seriously looking for ways to process locally sourced flours that can be used to produce bread that meets the sensory quality characteristics desired by the population. High-quality cassava flour (HQCF) produced from white-fleshed cassava roots (WCF) has been demonstrated to be a suitable partial substitute to WF for making composite bread and other confectionaries [4, 5, 6, 7, 8, 9, 10]. However, studies are rare on the use of high-quality cassava flour from biofortified (yellow-fleshed) cassava varieties (YCF) as a partial substitute for WF.

National and international research centers such as the International Institute of Tropical Agriculture (IITA) and the National Root Crop Research Institute (NRCRI) in Nigeria have developed biofortification programs to increase vitamin A, iron and zinc in crops such as cassava, maize, beans and potatoes to reduce micronutrient deficiency in Sub-Sahara Africa

[11]. The consumer acceptability of some traditional food products from biofortified crops, especially cassava (e.g. *gari* and *fufu*) has been demonstrated [11, 12, 13].

The retention of pro-vitamin A carotenoids (pVAC) during industrial processing to flour for bread baking has received little attention. Chavez *et al.* [14] using different laboratory drying methods, found that the highest β-carotene retention in YCF was obtained by oven-drying (72%), followed by shade-drying (59%), and sun-drying (38%). The study concluded that the large drastic reduction in β-carotene in sun-drying suggests a significant detrimental effect of light on the stability of the carotenoids. Hence the established low-cost procedure to produce WCF may not be suitable to produce the YCF. On the other hand, the industrial processing of WCF in Nigeria involves the use of pneumatic dryers that operate at the high-temperature short time period (110 ^{o}C for 5 sec.).

Consequently, evaluating the amount of pVAC (β-carotene) during commercial processing of biofortified cassava roots to the flour and subsequent baking of bread from the flour will contribute to our understanding of the potential use of pVAC biofortified cassava varieties for the manufacture of nutrient-enhanced food items, to contribute to the increased nutrition of the population. Therefore, this study aimed at assessing the nutritional composition, physical properties and sensory attributes of composite bread baked with cassava flour from biofortified and white-fleshed cassava roots.

2. Materials and methods

2.1 Materials

The cassava varieties (TME 419 and TMS 01/1368) were obtained from the cassava farm of IITA Ibadan and used to produce HQCF. Artificial bread colourant (egg yellow powder (Preema International Ltd. Uk) and other bread baking ingredients such as sugar, margarine, yeast, improver (ethylene diamine tetra-acetic acid), salt, and WF (Golden Penny brand) were purchased from a local market in Ibadan, Oyo state. The texture profiling of the bread was carried using a texture analyzer (TA-XT Plus texture analyzer, Stable Micro Systems Serial No. 5014 England).

2.2 Methods

2.2.1 Production of high-quality cassava flour and the 20% composite flour

The high-quality cassava flour from white- (TME 419) and biofortified TMS 01/1368) cassava varieties (WCF and YCF respectively) were produced at a commercial cassava processing factory according to the method described by Onabolu et al. [15] (Fig. 1). Drying was achieved using a pneumatic dryer (Single cyclone dryer, Niji Lucas Ltd., Nigeria) set at a temperature of about 110 ^{o}C for 5 min. The cassava roots were weighed separately with a weighing balance and then peeled manually using a stainless steel knife. The peeled cassava roots were then washed with clean water and transferred to a grating machine for grating. The grated cassava (mash) was dewatered using a hydraulic press to about 40% moisture to form a cake. The cake was pulverized and then flash dried. This was then followed by milling using a hammer mill (Niji Lucas company). The fine HQCF from both the white-fleshed (WCF) and biofortified (YCF) cassava roots were allowed to cool to room temperature, and separately packaged in a high-density polyethylene bag, prior to further use.

The WCF (20%) (20-WCF) and YCF (20%) (20-YCF) were separately weighed and mixed with WF (80%) using a stainless-steel blender, and separately packaged (100 g) in opaque hermetically sealed high-density polyethylene bags. Additionally, 0.45 g of egg yolk powder (used as colourant) was added to 100 g of 100% WF and packed in opaque hermetically sealed high-density opaque polyethylene bags. Another 100 g of 100% WF (without colourant) was packed in hermetically sealed high-density opaque polyethylene bags.

2.2.2 Baking of bread

Bread doughs were produced by homogeneously mixing sugar (100 g), margarine (50 g), yeast (7 g), improver (3 g) and salt (16 g), with 1 kg of flour of each of 20% WCF + 80% WF, 20% YCF + 80% WF, 100% WF with colorant, and 100% WF without colorant, with the addition of water (555 ml). The doughs were allowed to proof for 2.5 h, kneaded, cut into shape, placed in labelled lubricated baking pans and baked at 200 ^{o}C for 30 min [16]. The bread loaves were subsequently coded.

2.2.3 Nutritional composition of samples

2.2.3.1 Determination of total β-carotene

Approximately 15 g of each coded sample (flour and bread), plus 3 g of Celite 454 (Tedia, Ohio, USA), were weighed. Successive additions of 25 ml of acetone were performed to obtain a paste, which was transferred into a sintered funnel (5 µm) coupled to a 250 ml Buchner flask and filtered under vacuum. This procedure was repeated three times until the sample became colourless, and the extract was transferred to a 500 ml separation funnel containing 40 ml of petroleum ether. The acetone was removed through the slow addition of ultrapure water (Millipore) to prevent emulsion formation. The aqueous phase was discarded, and this procedure was repeated four times until no residual solvent remained. The extract was then transferred through a funnel containing 15 g of anhydrous sodium sulphate and made up a volume of 50 ml with petroleum ether [17]. For the identification and quantification of β-carotene, 2 mL was removed from the extract and dried in an amber flask under nitrogen flow. The sample was diluted in 100 µl of acetone under shaking in a vortex mixer (Genie 2-Scientific Industries) and transferred to a 2-ml amber flask for High-Performance Liquid Chromatography (HPLC) analysis. The concentration of β-carotene was then calculated as reported by Carvalho *et al.* [17].

$$\mathrm{C}\ (\mu\mathrm{g/g}) = \frac{\mathrm{A_x} * \mathrm{C_s}\ (\mu\mathrm{g/ml}) * \mathrm{V}\ (\mathrm{ml})}{\mathrm{A_s} * \mathrm{P(g)}}$$

Where *Ax* = carotenoid peak area, *Cs* = standard concentration, *As* = standard area, *V*= total extract volume, and *P* = sample weight.

The retinol activity was then calculated as the percentage of the total β-Carotene content divided by 3.7 [18].

2.2.3.2 Moisture content

The moisture content (MC) was determined using AOAC [19] method. About 3 g of sample was weighed into a pre-weighed clean dried dish, after which the dish was placed in a well-ventilated oven (draft air Fisher Scientific IsotempR Oven model 655F) maintained at 103 ± 2 °C for 24 h. The loss in weight was recorded as MC.

$$\%\mathrm{MC} = \left(\frac{\mathrm{M_1 - M_2}}{\mathrm{M_1 - M_o}}\right) \times 100$$

Where M_o = Weight in g of dish

M_1 = Weight in g of dish and sample before drying

M_2 = Weight in g of dish and sample after drying

2.2.3.3 Ash content

This was determined using the method of AOAC [19]. This involves burning off moisture and all organic constituents from 3 g of the sample at 600 °C for 5 h in a furnace (VULCAN$^{\mathrm{TM}}$ furnace model 3-1750). The weight of the residue after incineration was then recorded as the ash content.

$$\%\text{Ash content} = \left(\frac{\mathrm{w_3 - w_1}}{\mathrm{w_2}}\right) \times 100$$

W_3 = Wt. of crucible+ ash

W_2 = Wt of the sample only

W_1 = Wt. of the crucible

2.2.3.4 Protein content

The crude protein was determined by a Kjeldahl method using Kjeltec^{TM} model 2300 protein analyzer, as described in the Foss Analytical Manual, AB. [20]. About 0.2 g of sample was digested at 420 ^{o}C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulphate. The ammonia in the digest (ammonium sulphate) was then distilled off into a boric acid receiver solution and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein (displayed on the screen of the protein analyzer).

2.2.3.5 Fat content

Fat was determined using AOAC [19] method. Crude fat was extracted from 3 g of the sample with hexane using a fat extractor (Soxtec System HT-2 fat extractor), and the solvent was evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

$$\%\ \text{Fat content} = \left(\frac{\text{Wt.of flask+fat}-\text{Wt.of the sample after drying}}{\text{Wt. of the sample before drying}}\right) \times 100$$

2.2.4 Physical properties of bread samples

2.2.4.1 Loaf weight, volume, specific volume, and density

The loaves of bread from the flour samples were weighed after proper cooling for 50 min using a digital balance of about 0.01 g accuracy [21]. The loaf volumes were determined using the rapeseed displacement method [21] but with a slight modification which involves the use of sorghum seed instead of the rapeseed. The density and the specific volume of each of the loaf were then calculated as:

$$\text{Density } (\text{g}/cm^3) = \left(\frac{\text{Loaf weight}}{\text{Loaf volume}}\right)$$

$$\text{Specific volume } (cm^3/\text{g}) = \left(\frac{\text{Loaf volume}}{\text{Loaf weight}}\right)$$

2.2.4.2 Texture profile analyses of the bread samples

The texture parameters determined for each of the bread samples were hardness, stickiness, elasticity, cohesiveness, chewiness, and gumminess. The texture analysis was performed on a cylinder of 2.5 cm diameter and 2 cm thickness using the TA-XT Plus texture analyzer (Stable Micro Systems Serial No. 5014 England) according to the method described by Steffe [22]. The analyzer equipped with a compression cell of 30 kg and a matrix of 50 mm in diameter, was operated at a speed of 2 mm/s and a distance of 5 mm. The texture analyses were carried out using the original software provided by Stable Micro System automatically and performed by two sequential compression events (compression depth 40%, probe speed 2 mm/s, trigger force 5 g) and the force-deformation curve was recorded. Hardness (maximum force during the first penetration cycle; N); stickiness (area under the negative peak as probe withdraws after the first compression), elasticity (length to which the sample recovers in height during the time that elapses between the end of the first compression cycle and the start of the second compression cycle; unitless); cohesiveness (ratio of the positive force area of the second peak to that of the first peak; unitless); chewiness (product of hardness times cohesiveness times elasticity; unitless) and gumminess (product of hardness times cohesiveness; unitless) were calculated automatically by texture analyzer integrated macro functions.

2.2.5 ***Sensory evaluation of bread samples***

The sensory evaluation of the bread samples was done by 12 semi-trained panellists, chosen based on their interest. The sensory attributes assessed included the crust colour, weight, aroma, mouthfeel, crumb colour, taste, crumb texture, crust appearance, crust texture, and overall acceptability, using the 9-point hedonic scale as reported by Iwe [23]. The panellists were asked to rank the samples based on the highly-preferred sample in order of 1 to 9, 1-

corresponds to disliked extremely and 9-liked extremely. Data generated were then analyzed statistically.

2.2.6 Statistical analysis

Analysis of variance (ANOVA) and separation of the mean values (using Duncan's Multiple Range Test at $p<0.05$) were calculated using Statistical Package for Social Scientists (SPSS) software (version 21.0).

3. Results and Discussions

3.1 Nutritional composition of flour blends and bread produced from white- and biofortified high-quality cassava flour

Table 1 depicts the nutritional compositions of flour blends and bread produced from 20-WCF, 20-YCF and 100% WF with and without colourant. Results showed that the 20-YCF had the highest total β-carotene (10.69 µg/g) and ash (1.53%) contents. Fat content was highest in the 20-WCF (1.51%). Moisture (12.44%) and protein (16.43%) contents were highest in 100% WF. Also, bread produced from 20-YCF composite had the highest total β-carotene (0.74 µg/g), moisture (37.83%) and ash (2.29%) contents, while the fat and the protein contents were higher in 20-WCF composite (3.72%) and 100% wheat bread without colorant (12.83%) respectively.

The biofortified (yellow-fleshed) cassava flour (YCF) had the highest total β-carotene content of 10.69 µg/g while cassava flour from white-fleshed roots (WCF) had the least (0.06 µg/g). Similarly, 20-YCF (2.01 µg/g) had the highest total β-carotene content while WFc (0.13 µg/g) the lowest. The dough (20-YCF-D) and bread (20-YCF-B) from YCF have a higher value of the total β-carotene contents of 0.95 µg/g and 0.74 µg/g respectively, compared to those of the WF (0.26 µg/g and 0.24 µg/g respectively), which were lower.

This implied that a significant ($p<0.001$) reduction was observed in the total β-carotene contents from the flours to the bread. This could be attributed to the mixing and baking process, as the flours will be exposed to atmospheric oxygen and light during mixing in the formation of dough, and high temperature during baking [24, 25]. The reduction in the total β-carotene contents in the bread may also be associated with the wheat lipoxygenase enzyme activity on the carotenoid pigment during baking [26]. Furthermore, bread consumers can only utilize this β-carotene when bioconverted to retinol in the body. Consequently, IITA [18] stated that 3.7 µg of β-carotene from cassava are converted into 1 µg of retinol, which is also the same as the retinol activity equivalent (RAE). This refutes the previous estimate of about 12 µg of β-carotene in cassava being equivalent to 1 µg of retinol proposed by the United State Institute of Medicine [27]. Considering the daily pro-vitamin A intake recommended by the FAO, which is 250 to 400 retinol equivalents (RE) for children, 575 to 725 RE for adolescent and 750 RE for adults [28], the RAE/100 g of the breads was very low, using IITA [18] standard. This is because the RAE/ 100 g (calculated as the percentage of the total β-Carotene content divided by 3.7) of the bread ranged from 6 to 20 RAE/ 100 g (Figure 2), with bread from 20-YCF having the highest value and that from 100% WF the lowest. Though the RAE of the 20-YCF composite bread is low, it may still contribute to the daily pro-vitamin A intake recommended by the FAO if consumed with foods rich in vitamin A, compared to the 100% wheat bread.

It was reported by Onwuka [29] that moisture content is an important attribute in food processing and preservation as many biochemical and physiological changes depend very much on it. The higher moisture content of the dough (43.17%) could be attributed to the water added during the mixing of the flour as cassava flour tends to absorb more water than wheat flour (WF) [30], and which was reduced to 33.71% in the bread after baking due to high baking temperature (175 °C to 200 °C) and baking time (≥ 20 min). There was no significant difference ($p>0.05$) in the moisture content of the whole flour and the composite, but the moisture content of the bread produced from 20-YCF was significantly different ($p<0.01$) from the others including that of the WCF (Table 1). The 20-YCF bread (37.83%) had the highest moisture content compare to that of WF (31.27%), which was lower (Table 1). The moisture content of the bread in this study agreed with that of other researchers [7, 10, 31]. The difference in the moisture content may be attributed to differences in the moisture content of the raw materials, water added during dough formation and the baking time and temperature.

The ash content of food material is a measure of its total inorganic mineral content [32]. The 20% cassava flour inclusion significantly ($p<0.001$) increased the ash content of the WF from 0.71% to 0.80% in 20-WCF and 0.86% in 20-YCF. Similarly, the ash content was higher in YCF-B (2.29%) and 20-WCF-B (2.02%) compared with that of the 100% WF (1.92%). The higher ash content in the composite flour may be attributed to the high amount of ash present in the cassava flours (YCF=1.53%, WCF=1.15%, Table 1). The increase in the ash content of the 20% composite bread compared to that of the 100% WF supports the observations reported by Kent and Evers [33], Eddy et al. [7], Oluwamukomi et al. [34], Masamba and Jinazali [31], and Iwe et al. [10] that cassava flour has more mineral than wheat flour, but differ from that of Eleazu et al. [32] that found out lower ash content in cassava composite bread as the substitution level of cassava flour increased. The range of values (1.40 – 2.29%) obtained for the ash content of the bread samples in this study falls within the range reported by Iwe et al. [10] (1.37 – 2.55%) on the use of HQCF composite flour for bread and agrees with the ash content specification reported by Abass et al. [35]. However, the ash contents of the 20% HQCF composite bread reported by Eddy et al. [7] (1.72%) and Eleazu et al. [32] (1.40%) were lower than the values obtained in the present study.

Contrary to the observations of Eddy et al. [7], Eleazu et al. [32] and Iwe et al. [10] on the fat content of cassava flour composite bread, the fat content of the bread samples in this study increased with the 20% inclusion level from 3.18% in the 100% WF to 3.72% in 20-WCF composite and 3.61% in 20-YCF composite. This may be linked with the fat contents of the cassava flour (WCF=1.51%, YCF=1.49%, Table 1) compared with that of the 100% WF (1.39%). However, there was no significant difference ($p>0.05$) in the fat contents of the cassava flours and that of the 100% WF, thus, the high values of the fat in the bread may be attributed to the interactions between the cassava flour fat and the shortening added in the production of the bread. Significant differences ($p<0.001$) exist between the fat content of bread produced from the cassava flours and the 100% WF (Table 1).

The 20% inclusion of cassava flour into WF reduces the protein content of the bread samples from 12.83% for 100% WF to 10.65% for 20-WCF composite bread and 11.52% for 20-YCF composite bread. This result agrees with that of Defloor et al. [6], Eddy et al. [7], Shittu et al. [9] and Iwe et al. [10], on the use of cassava flour as a composite in WF for bread. The range of values of the protein contents (10.65 – 12.83%) of the bread samples reported in this study is slightly higher compared to that of Eddy et al. [7] (9.37 – 12.00%). The protein drop in the 20% composite bread may be due to a dilution effect of proteins caused by the 20% cassava flour added to the WF [36], as the protein content of the WCF is 0.25%, YCF 0.37% and 100% WF 16.43% (Table 1). This implied that the protein content of the cassava flours significantly ($p<0.001$) affected that of the bread samples.

3.2 Physical properties of bread loaves

The physical properties of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour is shown in Table 2. The mean of the properties is; loaf volume 3129.60 cm^3, loaf weight 915.34 g, specific volume 3.42 cm^3/g, density 0.29 g/cm^3, hardness

197.12, stickiness 3.38, elasticity 5.97, cohesiveness 0.04, chewiness 36.29 and gumminess 6.05. The loaf weight ($p \leq 0.05$), hardness ($p \leq 0.001$), cohesiveness ($p \leq 0.001$) and gumminess ($p \leq 0.05$) were significantly different between the bread samples, while the loaf volume, specific volume, density, stickiness, elasticity, and chewiness were not significantly different ($p > 0.05$).

It was reported by Shittu et al. [9] that loaf weight reduction during baking is an undesirable economic quality to the bakers as consumers often get attracted to bread loaf with higher weight and volume believing that it has more substance for the same price. This implied that in terms of volume, bread produced from 20-YCF composite (3286.20 cm^3) will be more attracted to the consumers compared to the 100% WF bread (3015.80 cm^3). Consumers may want to buy less of the 20-WCF composite bread (855.50 g) because of its lower loaf weight compared to the 100% WF bread (922.50 g), which is higher. Though, there was no significant statistical difference ($p > 0.05$) between the loaf weight of 20-YCF composite bread and that of the 100% WF bread, the 20-YCF composite bread may be highly patronized by the consumers. The high loaf volume of the 20-YCF composite bread may be attributed to the lower protein content of its flour compared to that of wheat. This is because a negative but not significant correlation ($r = -0.74$, $p > 0.05$) exist between the loaf volume and the protein content (Table 3). This agreed with the observation of Ragaee and Abdel-Aal [37]. However, the proofing time of the dough, as well as the difference in the rate of gas evolution and the extent of starch gelatinization, may also affect the loaf volume [9, 38]. The high loaf weight of the 100% WF bread may be attributed to the amount of moisture and carbondioxide diffused out of the loaf during baking [9]. However, baking temperature and time parameters affect the moisture retention capacity of breadcrumb [39].

The specific volume, which has been adopted as a more reliable measure of bread size [37], was higher in the 20% composite bread compared to that of the 100% WF ($p>0.05$). This result disagreed with the observations of other researchers [39, 40, 41, 42, 43]. Since specific volume and density are directly related, the 20% composite bread (0.28 g/cm^3) had a lower density compared to that of 100% WF (0.31 g/cm^3), but which is not statistically different ($p>0.05$) (Table 2). This observation negates that of Eriksson et al. [43], who reported that increasing the level of cassava flour in WF will give weaker and less elastic dough and a reduction in the leavening ability, resulting in bread with lower loaf volume and higher density.

An increase in bread hardness was observed in the 20-WCF composite bread (176.50 N) compared to the 100% WF bread (63 N). The lower hardness value of the 100% WF bread may be associated with its high protein content. This is because a significant negative correlation ($r = -0.98$, $p\leq0.05$, Table 3) exist between the bread hardness and the protein content. Since cassava is known to be very high in starch compared to wheat, the hardness of the 20-WCF composite bread may be attributed to the fact that as the bread cools after baking, starch retrogrades and gel within the inter-granular spaces, providing rigidity and resulting in bread hardening [44]. The result of this study agreed with that of Eriksson et al. [43], who reported that bread prepared from three cassava/wheat composite flours had a harder texture than that of 100% WF. This study also corroborates the outcome of the research carried out by Abdelghafor et al. [45] and Phattanakulkaewmorie et al. [46] on sorghum/wheat composite bread. The difference in the hardness value of the WCF and YCF bread may reflect the different extent of retrogradation of starches in the composite flours [43].

Rakkar [47] defined bread stickiness as a composite characteristic resulting from the balance between adhesive and cohesive forces of dough. Stickiness causes problems in commercial bakeries by choking production lines. Additionally, Dziedzic and Kearsley [48] reported that due to the high amylopectin content (87%) of cassava flour, and that amylopectin has a higher viscosity than amylose, cassava flour composite dough will become sticky. However, there was no significant statistical difference ($p>0.05$) in the stickiness of the 20% cassava flour bread compared to that of the 100% WF (Table 2). This may be linked to the level of inclusion of the cassava flour in the composite flour for bread. Similarly, there was no significant statistical difference ($p>0.5$) observed in the elasticity of the 20% cassava composite bread and that of the 100% WF. This may be attributed to the quantity and quality of gluten present in the flours and the level of substitution of the cassava flour. Gluten has been reported to be responsible for dough elasticity, and the inclusion of cassava flour beyond 20% has been observed to reduce dough elasticity [42, 43]. However, a negative but not significant correlation ($r= - 0.37$, $p>0.05$, Table 3) exist between elasticity and the protein content of the bread samples.

Cohesiveness characterizes the extent to which a material can be deformed before it ruptures, reflecting the internal cohesion of the material. Thus, bread with high cohesiveness is desirable because it forms a bolus rather than disintegrates during mastication, whereas low cohesiveness indicates increased susceptibility of the bread to fracture or crumble [49]. Lower cohesiveness value (0.04) was observed in the 20% cassava bread compared to that of the 100% WF (0.10), which implies that lower compression energy may be required during mastication, thus, the bread may be more easily crumbled. The reduction of the 20% composite bread cohesiveness may be related to the less adhesion between starch and gluten in the samples, as well as the formation of an uneven crumb [50]. This finding agreed with that of Houben et al. [51], who reported that gluten-free doughs are much less cohesive than wheat dough. It is also important to state that a significant negative correlation ($r= - 0.98$, $p\leq0.05$) exist between the bread cohesiveness and the fat content (Table 3).

The chewiness is the energy needed to masticate solid food to a state of readiness for swallowing, and it is directly related to hardness [52, 53]. A non-significant increase was observed in the chewiness (29.18 – 40.51 N) of the bread with the incorporation of 20% cassava flour into WF. Bread from 20-YCF (40.51 N) had the highest chewiness value compared to that of the 100% WF (34.60 N), which was lower. Gumminess, as reported by Szczesniak et al. [54], is mutually exclusive with chewiness, and it is often employed to characterize the energy to disintegrate semi-solid foods. The gumminess value significantly ($p\leq0.05$) increased from 5.90 for the 100% wheat bread to 6.41 for the 20-YCF composite bread (Table 2). The slight increase in the chewiness and gumminess of the bread was similar to the observation made by Abdelghafor et al. [45]. These researchers reported that gumminess increased with an increased amount of sorghum flours in the blends, which was associated with the weakening of the wheat gluten by the sorghum flour.

3.3 Sensory evaluation of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour

Table 4 showed the results of the sensory evaluation of bread produced from white- and yellow-fleshed high-quality cassava flour. Though the results depict that the mean of all the sensory parameters was within the likeness range (6.91 – 7.37), there was a significant difference in all the parameters except for bread weight and aroma, which were not significant ($p>0.05$). This implied that the 20% composite bread compared favourably well with the 100% WF bread in terms of weight and aroma. The sensory attributes of the 20-WCF bread compared to that of 100% WF disagreed with the observations of other researchers [5; 7, 42, 55]. These researchers reported that bread baked with 10 and 20 %

cassava-wheat composite flour were not significantly different in any sensory attributes. Additionally, bread from 20-YCF composite was significantly different ($p \leq 0.05$) from that of the 100% WF with an artificial colourant, but not significantly different ($p>0.05$) from the 100% WF bread without artificial colourant in terms of the overall acceptability. The indifference in the overall acceptability of the 20-YCF composite bread compared to the 100% WF bread may be attributed to the taste, crumb colour, mouthfeel, aroma, and weight, as these attributes were not significantly different ($p>0.05$) in the bread (Table 4). The significant difference in the crust colour, crumb texture, crust appearance and crust texture between the 20-YCF bread and the 100% WF bread may be associated with the protein content of the WF. This is because a positive correlation ($r > 0.85$) exists between protein content and these attributes, which although is not significant ($p>0.05$, Table 5). However, the 100% wheat bread with artificial colourant has the highest of all the sensory parameters including the overall acceptability.

4. Conclusion

This study revealed that the nutritional composition and the sensory properties (except weight and aroma), as well as the loaf weight, hardness, cohesiveness, and gumminess of the bread samples, differ significantly. Bread produced from 20% yellow- and white-fleshed composite flours have the highest of most of the nutritional composition except for the protein content which was higher in 100% wheat bread. The physical properties evaluated in the bread samples were also higher in the yellow- and white-fleshed HQCF bread except for the cohesiveness and loaf weight which were higher in 100% wheat bread without and with artificial colourant respectively. The 20% yellow- and white-fleshed composite bread compared favourably with the 100% wheat bread in terms of the weight and aroma, which were the attributes that are not significantly different out of all the sensory attributes. Though all the bread tasted was within the likeness range, the 100% wheat bread with artificial colourant has the highest of all the attributes including the overall acceptability.

Author Contributions

W.A., A.B.A., P.A., and G.N. designed the research and performed the experiment; W.A., A.B.A., P.A., and O.O. processed the data and prepared the manuscript.

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Conflict of interest

No conflict of interest

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Table 1. Nutritional composition of flour blends and bread loaves in dry basis

Samples	Total β-carotene content (µg/g)	Moisture content (%)	Ash content (%)	Fat content (%)	Protein content (%)
Whole flour					
YCF	10.69±0.04a	10.98±0.28e	1.53±0.04f	1.49±0.07gh	0.37±0.01j
WCF	0.06±0.01j	10.59±0.19e	1.15±0.01g	1.51±0.08gh	0.25±0.01j
WF	0.43±0.01e	12.44±0.07f	0.71±0.01j	1.39±0.01h	16.43±0.01a
Composite Flour					
20-YCF	2.01±0.03b	12.03±0.03e	0.86±0.02h	1.66±0.05g	13.48±0.37d
20-WCF	0.22±0.00i	12.10±0.01e	0.80±0.03hi	1.96±0.02f	12.72±0.02ef
WFc	0.13±0.00i	12.52±0.04e	0.75±0.02ij	0.84±0.08j	16.04±0.13a
Dough					
20-YCF-D	0.95±0.01c	44.75±0.05a	2.53±0.11a	2.50±0.02e	12.17±0.26g
20-WCF-D	0.30±0.00f	44.30±0.08a	2.27±0.00b	5.65±0.06a	11.91±0.06gh
WF-D	0.26±0.01g	40.99±0.01b	2.04±0.03d	0.85±0.05j	14.37±0.04c
WFc-D	0.25±0.01gh	42.65±0.04ab	2.14±0.02c	1.16±0.11i	14.86±0.00b
Bread					
20-YCF-B	0.74±0.01d	37.83±2.29c	2.29±0.04b	3.61±0.20bc	11.52±0.46h
20-WCF-B	0.26±0.01g	33.53±2.88d	2.02±0.04d	3.72±0.03b	10.65±0.34i
WF-B	0.24±0.01gh	31.27±0.03d	1.92±0.03e	3.18±0.01d	12.83±0.10e
WFc-B	0.23±0.00gh	32.23±1.40d	1.40±0.01de	3.46±0.08c	12.30±0.33fg
Groupings					
Whole Flour	3.72±5.40a	11.34±0.89c	1.13±0.37c	1.46±0.07c	5.68±8.33d
Composite Flour	0.79±0.95b	12.22±0.24c	0.80±0.05d	1.48±0.52c	14.08±1.57a
Dough	0.43±0.32c	43.17±1.58a	2.24±0.20a	2.54±2.03b	13.33±1.40b
Bread	0.37±0.23d	33.71±3.06b	1.64±0.65b	3.49±0.23a	11.82±0.92c
Mean	1.20	27.02	1.64	2.35	11.42
P level	***	**	***	***	***

**p<0.01, *** p<0.001, Means with the same letters on the same column are not significantly different at p≤0.05

WCF-White-fleshed cassava flour, YCF- Yellow-fleshed cassava flour, WF-100% Wheat flour, WFc-100% Wheat flour with a colourant, 20-WCF-20% WCF, 20-YCF- 20% YCF, D-Dough, B-bread

Table 2. Physical properties of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour

Samples	Loaf volume (cm^3)	Loaf weight (g)	Specific volume (cm^3/g)	Density (g/cm^3)	Hardness (N)	Stickiness	Elasticity	Cohesiveness	Chewiness (N)	Gumminess
20-WCF	3182.60±68.66a	885.50±12.02b	3.59±0.03a	0.28±0.00a	176.50±4.95a	3.50±0.71a	5.90±0.74ab	0.04±0.01cd	35.85±07.41ab	6.05±0.49a
20-YCF	3286.20±44.90a	921.00±7.07a	3.57±0.02a	0.28±0.00a	151.00±8.79a	4.00±0.00a	6.32±0.09a	0.04±0.00c	40.51±1.21a	6.41±0.10a
WFB	3015.80±194.17a	922.50±13.44a	3.27±0.25a	0.31±0.02a	63.00±1.41b	4.00±0.00a	5.87±0.05ab	0.10±0.01a	34.60±1.11ab	5.90±0.14ab
WFBc	3033.80±13.44a	932.35±0.49a	3.26±0.02a	0.31±0.00a	79.50±0.71b	3.00±0.00ab	5.35±0.21b	0.07±0.00b	29.18±2.55b	5.45±0.26b
Means	3129.60	915.34	3.42	0.29	197.12	3.38	5.97	0.04	36.29	6.05
P level	NS	*	NS	NS	***	NS	NS	***	NS	*

*$p\leq0.05$, ***$p\leq0.001$, NS-Not significant. Means with the same letters on the same column are not significantly different at $p\leq0.05$
20-WCF-B-20% white-fleshed cassava flour composite bread, 20-YCF-B-20% Yellow-fleshed cassava flour composite bread, WF-100% wheat flour bread without colourant, WFc-100% wheat flour bread with the colourant.

Table 3. Pearson correlation of the physical properties and nutritional composition of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour

	Loaf volume	Loaf weight	Specific volume	Density	Hardness	Stickiness	Elasticity	Cohesiveness	Chewiness	Gumminess
Total β-carotene	0.84	0.14	0.58	-0.62	0.45	0.54	0.80	-0.55	0.81	0.80
Moisture	0.94	-0.07	0.75	-0.78	0.66	0.39	0.76	-0.76	0.80	0.80
Ash	0.91	0.03	0.68	-0.71	0.58	0.39	0.74	-0.70	0.77	0.77
Fat	0.77	-0.62	0.85	-0.85	0.93	-0.24	0.28	-0.98*	0.35	0.39
Protein	-0.74	0.83	-0.91	0.90	-0.98*	0.08	-0.37	0.91	-0.44	-0.48

*$p\leq0.05$

Table 4. Sensory evaluation of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour

Samples	Crust Colour	Weight	Aroma	Mouthfeel	Crumb colour	Taste	Crumb Texture	Crust Appearance	Crust texture	Overall acceptability
20-WCF-B	6.73±2.10b	7.04±2.26a	6.41±2.13c	6.56±2.12c	6.06±2.13c	6.44±2.18c	6.40±2.12b	6.15±2.14b	6.29±2.0b	6.60±2.15c
20-YCF-B	6.85±1.87b	7.50±1.79a	6.64±2.06bc	6.86±1.85bc	6.59±1.74b	6.89±1.85bc	6.35±1.96b	6.66±1.96b	6.70±1.92b	7.10±1.73bc
WF-B	7.79±1.22a	7.20±1.38a	7.22±1.53ab	7.38±1.63ab	7.75±1.23ab	7.44±1.69ab	7.85±1.33a	7.37±1.31a	7.41±1.43a	7.62±1.18ab
WFc-B	7.87±1.68a	7.40±1.63a	7.38±1.77a	7.87±1.53a	7.84±1.58a	7.84±1.48a	7.76±1.45a	7.78±1.44a	7.60±1.46a	7.86±1.44a
Mean	7.31	7.29	6.91	7.37	7.06	7.15	7.09	6.99	7.00	7.30
P Sample	**	NS	NS	*	**	*	***	**	**	*

*$p \leq 0.05$, **$p \leq 0.01$, ***$p \leq 0.001$, NS-Not significant.

Means with the same letters on the same column are not significantly different at $p \leq 0.05$

20-WCF-B-20% white-fleshed cassava flour composite bread, 20-YCF-B-20% Yellow-fleshed cassava flour composite bread, WF-100% wheat flour bread without colourant, WFc-100% wheat flour bread with a colourant

Table 5. Pearson correlation of the sensory parameters, and the physical properties and nutritional composition of 20% composite bread produced from white- and biofortified cassava roots

	Crust Colour	Weight	Aroma	Mouthfeel	Crumb colour	Taste	Crumb texture	Crust appearance	Crust texture	Overall acceptability
Loaf volume	-0.91	0.24	-0.84	-0.77	-0.83	-0.75	-0.95*	-0.77	-0.8	-0.73
Loaf weight	0.75	0.78	0.83	0.84	0.84	0.89	0.65	0.88	0.87	0.91
Specific volume	-1.00**	-0.13	-0.98*	-0.93	-0.98*	-0.94	-1.00**	-0.95	-0.97*	-0.93
Density	1.00**	0.08	0.97*	0.91	0.97*	0.92	1.00**	0.93	0.95*	0.92
Hardness	-0.98*	-0.21	-0.97*	-0.89	-0.99*	-0.92	-0.97*	-0.93	-0.97*	-0.94
Stickiness	-0.31	0.03	-0.33	-0.48	-0.22	-0.38	-0.27	-0.36	-0.28	-0.27
Elasticity	-0.72	0.12	-0.69	-0.76	-0.62	-0.68	-0.71	-0.68	-0.64	-0.60
Cohesiveness	0.88	-0.09	0.82	0.68	0.86	0.72	0.92	0.74	0.81	0.75
Chewiness	-0.77	0.12	-0.74	-0.79	-0.67	-0.72	-0.77	-0.72	-0.69	-0.65
Gumminess	-0.8	0.09	-0.77	-0.82	-0.71	-0.75	-0.79	-0.75	-0.73	-0.68
Total β-carotene	-0.55	0.66	-0.44	-0.4	-0.4	-0.33	-0.63	-0.35	-0.37	-0.28
Moisture	-0.72	0.55	-0.61	-0.536	-0.59	-0.49	-0.8	-0.52	-0.56	-0.46
Ash	-0.65	0.62	-0.53	-0.458	-0.51	-0.41	-0.74	-0.43	-0.47	-0.38
Fat	-0.84	-0.05	-0.8	-0.65	-0.85	-0.71	-0.87	-0.73	-0.8	-0.76
Protein	0.91	0.33	0.92	0.822	0.95*	0.88	0.90	0.89	0.93	0.92

*$p \leq 0.05$, **$p \leq 0.01$

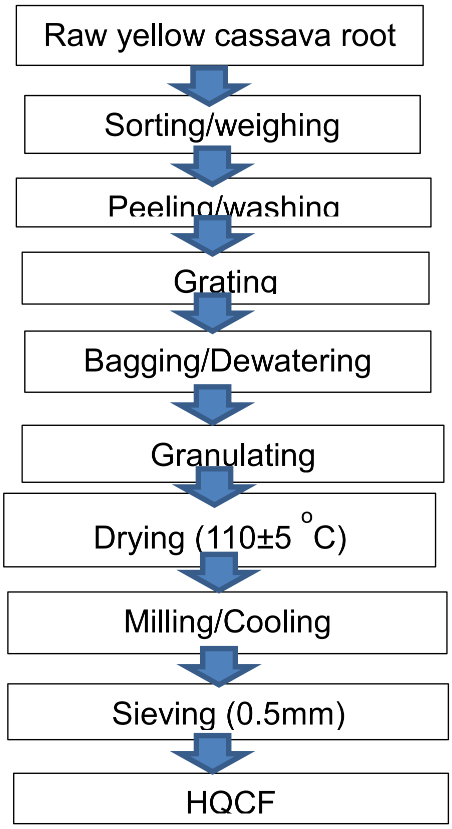

Figure 1: Production of high-quality cassava flour (HQCF) (Onabolu et al., 1998)

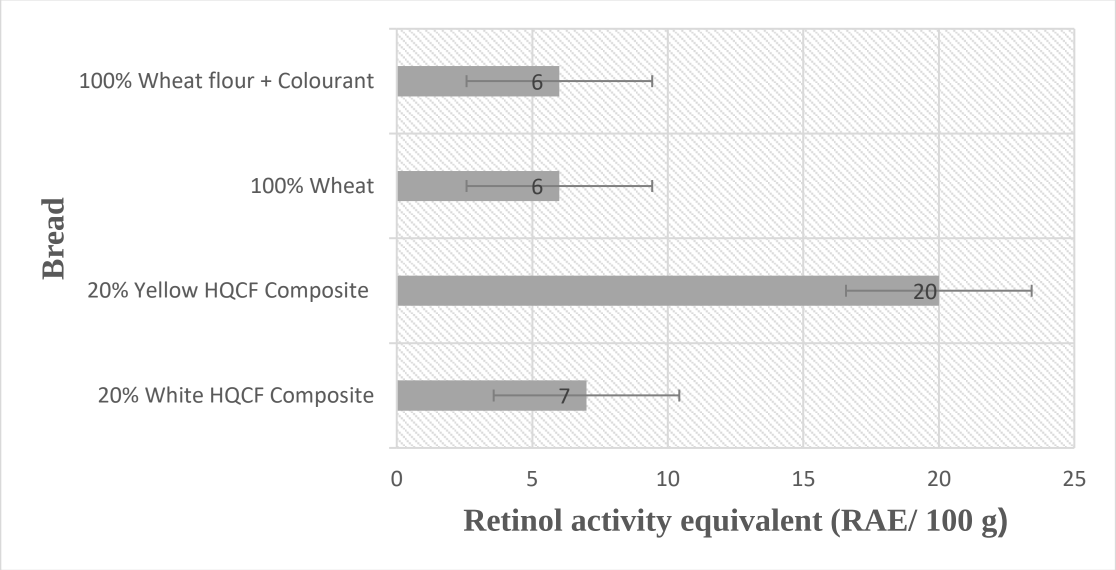

Figure 2. Retinol activity equivalent of bread produced from white- and biofortified (yellow-fleshed) high-quality cassava flour