Quality attributes of breads from high-quality cassava flour improved with wet gluten

Olaide A. Akintayo, Samson A. Oyeyinka, Aziz O. Aziz, Ibukunoluwa F. Olawuyi, Rowland M. O. Kayode, and Olayinka R. Karim

Abstract: This study investigated the physical, chemical, and sensory attributes of breads produced from preheated high-quality cassava flour (PCF) and its composite with wheat flour (CWF). Wet gluten was added to the PCF and CWF for production of bread, while bread from wheat served as the control. Flour functionality was determined prior to bread production. The moisture contents of the flour samples were in the range of 12.80 to 14.21%, and PCF exhibited water absorption capacity (1.12 mL/g) comparable to that of wheat flour (WF) (1.10 mL/g). There were significant ($P < 0.05$) differences in color characteristics, except in L^* values and breads produced from WF and CWF were similar in specific volume (3.85 to 4.21 mL/g) and firmness (2.04 to 2.64 N). Breads from WF and CWF exhibited similar crumb microstructure, though gas bubbles in the sample from PCF appeared less developed. Wheat bread had significantly ($P < 0.05$) higher calorie, crude protein and crude fat, but lower crude fiber, ash, and carbohydrate compared to other bread samples. Sensory evaluation showed that bread from PCF was not significantly different from 100% wheat bread in crust color, texture, and overall acceptability but was impaired in flavor. The study revealed the feasibility of bread baking from preheated cassava flour with added gluten extract. The bread produced had some quality attributes comparable to that of wheat bread.

Keywords: cassava bread, chemical, gluten, physical, sensory

Practical Application: Bread from wheat-cassava composite flour with added gluten was similar to wheat bread in specific volume and firmness while sample from cassava flour with added gluten compared favorably well with wheat bread in crust color, texture, and overall acceptability. Findings from the study present wheat gluten extract as a viable component to be used in nonwheat flours for bread making. This could be a basis to further add value to the gluten churned out as a by-product in the wheat starch industry.

1. INTRODUCTION

Production of bread from composite or nonwheat flours has been extensively researched for purposes such as reduced wheat importation, prevention of gluten-related health implications, and promotion of locally available indigenous crops. These have yielded varying (yet lower) levels of success in terms of expected bread quality attributes such as specific volume and texture. Among factors playing crucial roles in bread final qualities are flour type, starch and water content. Flour type is, however, arguably the major factor owing to variation in gluten content, which plays important roles in the appearance, structure, and texture of bread (Mir, Shah, Naik, & Zargar, 2016). This has informed the search for improving agents, such as emulsifiers and hydrocolloids, to compensate for the absence or insufficient amount of gluten in nonwheat flours (Pasqualone et al., 2010).

Bread quality has been found to vary according to flour type, processing conditions, as well as dough improver types. For example, the use of xanthan gum (Shittu, Aminu, & Abulude, 2009) was previously noted to improve the crumb texture and specific volume of breads produced from wheat-cassava composite flour. Eduardo, Svanberg, and Ahrné (2014) reported the incorporation of carboxymethyl cellulose and high methylated pectin along with diacetyl tartaric acid ester and lecithin, respectively, to composite flour containing up to 40% cassava. While all these efforts were aimed at improving the poor qualities of cassava bread as a result of its lack of gluten, the resulting breads are still far from being significantly comparable to 100% wheat bread. For example, Eduardo et al. (2014) obtained bread loaves that were approximately 40 to 48% lower in a specific volume and 150 to 200% firmer when compared with loaves from 100% wheat bread, in their trials with hydrocolloid-emulsifier blends as improvers. It is however interesting to note that, as far as literature reviewed is concerned, instead of using improvers, no study had investigated bread baking potentials of cassava flour with added gluten. Wheat gluten is available as an industrial by-product of wheat starch production (Kaushik, Kumar, Sihag, & Ray, 2015).

Gluten is responsible for the viscoelastic properties of wheat dough, helping in the entrapment of the carbon dioxide produced during proofing. This underlies the rising of the dough and the desired crumbliness and lightness of the resulting bread. It has been shown that gluten isolated from wheat has regeneration properties when reconstituted back to wheat starch components (Kaushik et al., 2015). Esteller, Pitombo, and Lannes (2005) investigated textural properties of hamburger buns produced from wheat flour having added gluten extract, and found general improvement, with

JFDS-2019-2062 Submitted 12/21/2019, Accepted 5/31/2020. *Authors Akintayo, Oyeyinka, Aziz, Kayode, and Karim are from Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria. Author Olawuyi is from School of Food Science and Biotechnology, Kyungpook National University, Daegu, South Korea. Author Oyeyinka is from School of Agriculture and Food Technology, University of the South Pacific, Apia, Samoa. Direct inquiries to author Akintayo (E-mail: akintayo.oa@unilorin.edu.ng).*

Journal of Food Science
A Publication of the Institute of Food Technologists

doi: 10.1111/1750-3841.15347

Table 1–Formulations of breads from wheat flour (g per 100 g flour), preheated HQCF and their blend (g per 100 g flour containing added gluten).

Ingredients	WB	CWB	CB
Wheat flour (g)	100.00	50.00	–
Preheated cassava flour (g)	–	45.00	90.00
Gluten (db) (g)	–	5.00	10.00
Fresh compressed yeast (%)	2.50	2.50	2.50
Sucrose (%)	15.00	15.00	15.00
Salt (%)	1.25	1.25	1.25
Hydrogenated fat (%)	10.00	10.00	10.00
Ascorbic acid (%)	2.00	2.00	2.00
Water (%)	65.00	80.00	90.00

Source: Pasqualone et al. (2010) with slight modifications.
Keys: WB: 100% wheat bread; CWB: Composite wheat-cassava bread; CB: 100% cassava bread.

wet gluten giving better textural quality than freeze-dried gluten. While this generally confirms the regeneration properties of extracted gluten in wheat flours, it suggests a promising potential, which can be used as an ingredient in the production of bread from cassava flour. Cassava flour demonstrates weak structure, making it incapable of trapping gas effectively during baking, resulting in defects of baked products (Nindjin, Amani, & Sindic, 2011).

However, preheating, among other physical treatments, has been reported to improve starch functionality, flour quality, and their baking potentials (Dudu, Li, Oyedeji, Oyeyinka, & Ma, 2019; Jyothi, Sajeev, & Sreekumar, 2010). Studies have also highlighted that preheated flour showed better functional properties and exhibited superior product qualities (Nurdjanah, Yuliana, Astuti, & Zukryandry, 2017). This study, therefore, investigated some physical, chemical, and sensory properties of breads from blends of preheated high-quality cassava flour (HQCF) and wheat gluten extract.

2. MATERIALS AND METHODS

HQCF was obtained from the International Institute for Tropical Agriculture (IITA), Nigeria. Wheat flour (Dangote) and other ingredients (Table 1) were obtained from a local market in Ilorin Metropolis, Nigeria.

2.1 Preheating of HQCF

The method described by Ratnayake and Jackson (2006) was used with slight modifications. Briefly, HQCF was moistened with distilled water (20:3 w/v) (to give 32% moisture content on dry basis), mixed (Felino AF.10.1 Portugal) vigorously to maximize uniform moisture distribution and minimize lump formation. The conditioned HQCF was then oven-dried at 60 °C for 15 min (following about 30 min of preheating in the oven to attain the desired temperature). This was then cooled at ambient temperature for 30 min, sieved (350 μm), packaged in a polyethene bag (Ziploc), and stored in a cool dry place for subsequent analyses and use.

2.2 Determination of the moisture contents of wheat and cassava flours and their blend

These were determined according to the method of Association of Official Analytical Chemists (A.O.A.C., 2000).

2.3 Determination of functional properties of wheat and cassava flours and their blend

2.3.1 Bulk density. The bulk density of each of the flour samples was determined according to the method described by Nwosu, Owuamanam, Omeire, and Eke (2014). Each of the flour samples was separately filled into a preweighed 10 mL centrifuge tube up to the mark, and then tapped repeatedly until no further change in volume was noticeable. The weights and final volumes (before and after tapping) of the flour samples were then taken and used to calculate their bulk densities as follows:

$$\text{Loose bulk density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample before tapping (mL)}};$$

$$\text{Packed bulk density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample after tapping (mL)}}.$$

2.3.2 Water and oil absorption capacities. These were carried out following the procedures previously adopted by Nwosu et al. (2014). For water absorption capacity (WAC), each of the flour samples (1 g) was weighed into a 20 mL centrifuge tube and to this, 10 mL of distilled water was added. The slurry was then vortexed for 2 min and allowed to stand for 30 min at room temperature. After 30 min, the slurries were then centrifuged (0502-1 Hospibrand, USA) at 2,000 × *g* for 45 min (Akintayo et al., 2019). The weights gained by the samples following the decantation of the supernatants were taken as the WAC. The oil absorption capacity (OAC) was determined following the same procedure, except that refined palm oil was used in place of distilled water.

2.3.3 Swelling index. Each of the flour samples was separately filled to the 10 mL mark of a 100 mL graduated measuring cylinder. Distilled water was then added to make 50 mL. The resulting suspensions were slightly swirled, left to stand and then swirled again after 2 min. The ratios of the final volumes to original volumes occupied by the samples were taken after another 8 min (Chandra, Singh, & Kumari, 2015).

2.4 Extraction of wet gluten from wheat flour

Gluten and starch components of the wheat flour were separated using the procedure previously described (Van Der Borght, Goesaert, Veraverbeke, & Delcour, 2005). The process involved mixing flour and water (approximately 50%) to form a dough, leaving the dough submerged in water for 1 hr, before washing the dough under running water, in order to separate the gluten from starch (which is carried by water). The wet gluten (68.75% moisture content on wet basis) obtained was used immediately for bread production.

2.5 Production of bread from wheat flour,preheated HQCF and their blend

Straight dough method as described by Eduardo (2015) was employed with slight modifications for the bread production. The various formulations are presented in Table 1. The flours were respectively mixed (Felino AF.10.1 Portugal) with other ingredients (Table 1) for 10 min for the formation of smooth viscoelastic doughs. The amounts of water added to the various flours were determined from preliminary trials. This was necessary if the different flour types were to form doughs of similar consistency (Pasqualone et al., 2010). Also, preliminary evaluation of the amount of gluten in the wheat flour used in the study informed the amount added to cassava and composite flours (to replace the amounts lost by wheat flour substitution by cassava flour). The various doughs formed were then left to proof at 30.0 ± 2.0 °C for 90 min, after which they were baked in the oven at 220 °C for 10 min. After 10 min, all the bread samples were allowed to sufficiently cool at ambient temperature, then packaged in polythene bags for subsequent analyses.

2.6 Determination of physical characteristics of breads produced from wheat flour, preheated HQCF and their blend

2.6.1 Crust color. Color parameters, L, a, and b, of the breads' crust were measured using a standardized chroma meter and were then used to calculate the Brownness Index (B.I.) as previously described by Eduardo, Svanberg, Olivera, and Ahrne (2013).

$$\mathrm{BI} = 100 \times \left(\frac{X - 0.31}{0.17}\right) \text{ where } x = \frac{(a + 1.75L)\,a}{(5.645L + a - 3.012b)}.$$

2.7 Loaf weight, volume, and specific volume

These were determined following the procedures previously described by Shittu, Raji, and Sanni (2007). Following sufficient cooling, the weighs of the bread loaves were measured using a digital scale of 0.01 g accuracy, while loaf volumes were determined using the rapeseed displacement method.

$$\text{Thus, specific volume} = \frac{\text{Loaf volume (mL)}}{\text{Loaf weight (g)}}.$$

2.7.1 Crumb firmness. The method described by Eduardo et al. (2013) was followed to determine the crumb firmness of the bread samples using an Instron Universal Testing Machine (UTM, model 5542). Slices (2.5 × 2.5 × 1.5 cm) taken from the centers of the bread loaves 6 hr after baking were compressed by a cylindrical probe (15 mm diameter) to about 40% depth at a test speed of 1.7 mm/s. Recording of compression curves was carried out automatically using a software (Merlin, version 5, Instron Corp., Canton, MA, USA) and readings presented as crumb firmness (N). Measurements were in quintuplicate.

2.7.2 Crumb microstructure. The bread samples were stained with Lugol's iodine solution, and the slurries were then smeared and dried. The samples were further examined with a Microphot FXA light microscope (Nikon, Tokyo, Japan) using a 10× and a 40× objective. Images were taken with an Altra 20 Sot Imaging System camera (Olympus, Tokyo, Japan) (Eduardo et al., 2013).

2.8 Proximate analysis of breads produced from wheat flour, preheated HQCF and their blend

The method previously described (A.O.A.C., 2000) was used to determine the proximate compositions of the bread samples.

2.9 Calorie determination of breads produced from wheat flour, preheated HQCF and their blend

Calorie contents of the various bread samples were determined from their protein, ether extract, and carbohydrate contents using the Atwater conversion factors as previously described (Ayele, Bultosa, Abera, & Astatkie, 2017).

$$\text{That is, Calorie (kCal/100g)} = (\%\text{protein} \times 4) + (\%\text{ether extract} \times 9) + (\%\text{carbohydrate} \times 4)$$

2.10 Sensory evaluation of breads produced from wheat flour, preheated HQCF and their blend

There was a prior review and approval of the study by the Department of Home Economics and Food Science, University of Ilorin. Also, the consent of each participant was obtained for their participation in the sensory evaluation.

A multiple paired comparison test was used for the sensory evaluation of the bread samples. A 50 member panel comprising staff and students of the Department of Home Economics and Food Science, University of Ilorin, Nigeria who are familiar with the quality attributes of bread were selected for this purpose. Prior to the evaluation, panelists were screened by their interest to participate, and the ability to discern sensory quality (Akintayo et al., 2019). Parameters assessed on the bread samples include appearance, color, aroma, taste, crumb texture, and overall acceptability. All parameters were assessed on a 9-point hedonic scale of preference, with 1 and 9 representing "dislike extremely" and "like extremely," respectively.

2.11 Statistical analysis

Results of the analyses described above were subjected to Analysis of Variance (ANOVA) to determine significant differences, and the means were separated with Duncan Test, using Statistical Package for Social Sciences (SPSS), version 20.0.

3. RESULTS AND DISCUSSION

3.1 Moisture contents and functional properties of wheat and cassava flours and their blend

HQCF showed higher WAC than other flour samples (Table 2). The higher WAC of native HQCF than that of wheat flour can be attributed to higher starch content of cassava, providing more hydrophilic constituents to bind with water molecules. Higher starch contents were found in flours from three cassava varieties studied than wheat flours by Eriksson, Koch, Tortoe, Akonor, and Baidoo (2014). Similarly, Iwe et al. (2017) recently attributed higher carbohydrate and lower protein contents for the higher WAC of HQCF than that of wheat flour. Higher amylopectin contents in cassava than in wheat has also been reported to be responsible for their higher WAC (Eriksson et al., 2014). However, it was found that preheated cassava flour showed lower WAC when compared to its native form but was similar in this respect to wheat flour (Table 2). This suggests that the starch granules of preheated cassava had less affinity for water intake than its native form. A similar finding was described by Rodriguez-Miranda et al. (2012). The authors observed that pregelatinized potato starch had restricted water absorption potential, and this was attributed to the alteration of starch granules brought about by pregelatinization. The WAC recorded in this study for wheat flour is lower than the 1.40 (140%) reported by Suresh (2013) but value as low as 0.319 (31.9%) has also been documented (Oladunmoye, Akinoso, & Olapade, 2010).

Native HQCF exhibited the highest OAC, suggesting the presence of more lipophylic potential than in other flour samples. The OAC of native cassava flour was higher than that of preheated cassava flour and wheat flour by approximately 18 and 41%, respectively (Table 2). This is an indication that the various flours had different levels of affinity for oil intake. Babu and Parimalavalli (2012) previously documented a link between OAC and lipophilic characteristics of starch granules. Breads produced from flours with different OAC might also exhibit different flavor characteristics. This is plausible since OAC is known to be associated with flavor retention in food (Iwe et al., 2017). Besides, fat is one of the major ingredients responsible for the flavor and mouthfeel of bakery products, including bread, therefore, the ability of a flour sample to absorb oil is critical (Tharise, Julianti, & Nurminah, 2014).

Table 2–Moisture contents and functional properties of wheat flour, HQCF and their blend.

Samples	Moisture (%)	WAC (ml/g)	OAC (mL/g)	SI	LBD (g/mL)	PDB (g/mL)
WF	$12.80^{b} \pm 0.80$	$1.10^{b} \pm 0.10$	$1.40^{b} \pm 0.30$	$1.45^{a} \pm 0.15$	$0.35^{b} \pm 0.04$	$0.67^{b} \pm 0.03$
CWF	$12.92^{b} \pm 0.95$	$1.10^{b} \pm 0.20$	$1.40^{b} \pm 0.27$	$0.89^{c} \pm 0.08$	$0.39^{ab} \pm 0.05$	$0.75^{a} \pm 0.05$
PCF	$14.21^{a} \pm 0.80$	$1.12^{b} \pm 0.09$	$1.00^{c} \pm 0.05$	$1.05^{bc} \pm 0.17$	$0.42^{a} \pm 0.03$	$0.69^{b} \pm 0.03$
CF	$12.93^{b} \pm 0.50$	$1.45^{a} \pm 0.15$	$1.70^{a} \pm 0.28$	$1.07^{b} \pm 0.19$	$0.37^{ab} \pm 0.05$	$0.62^{c} \pm 0.04$

Keys: WF = 100% wheat flour; CWF = composite wheat flour-preheated HQCF; PCF = 100% preheated HQCF; CF = 100% native HQCF; WAC = water absorption capacity; OAC = oil absorption capacity; SI = swelling index; LBD = loose bulk density; PDB = packed bulk density.
Values are means (n = 3) ± SD. Means with the same superscript within the same row are not significantly ($P < 0.05$) different.

Wheat flour exhibited a higher swelling index (SI) than other flour samples studied (Table 2). Factors, such as amylose-amylopectin ratio, starch granule size, as well as other structural variations, have been noted to influence SI of starchy food materials. Although the results in this study are at variance with some previous reports (Eriksson et al., 2014), literatures are also available where wheat flour had higher SI than cassava flour (Lagnika et al., 2019; Nwosu et al., 2014). Lagnika et al. (2019) attributed higher SI of the wheat flour to the presence of gluten. Furthermore, the different swelling indices demonstarted by the various flour samples may have resulted from different degree of associative forces in their starch granules.

Although the loose and packed bulk densities of the flour samples did not generally follow the same trend, preheated HQCF was generally higher in densities than native HQCF, implying less intergranular space within starch molecules. Rodriguez-Miranda et al. (2012) earlier opined that granules of potato starch become more compact when subjected to heating for pregelatinization. Data reported by Ratnayake and Jackson (2006) show that large starch granules begin to break apart at around 55 to 60 °C, indicating starch disintegration during gelatinization. It is, therefore, likely that similar modification took place in cassava starch in this study, since cassava starches have been reported to exhibit even lower onset gelatinization temperature than corn starches (Elgadir et al., 2009). The packed bulk density (0.62 g/mL) obtained for native HQCF in this study is within the range (0.55 to 0.77 g/mL) previously reported by Iwe et al. (2017) for HQCFs produced from five different cassava varieties. Bulk density of flour has been noted to influence the development of dough when reconstituted with water (Udoro, Kehinde, Olasunkanmi, & Charles, 2014). Higher bulk density implies less space requirement for packaging.

3.2 Physical properties of breads produced from wheat flour, preheated HQCF and their blend

The crust colors of the various bread samples showed no significant difference in lightness (Table 3), suggesting similar extents of browning during baking. Nwosu et al. (2014) observed a significant reduction in the crust color of breads when wheat flour was substituted with over 30% cassava flour and attributed this to lower protein content in cassava, which limited the extent of Maillard reaction. In this study, however, cassava breads containing gluten extract did not significantly differ in lightness from wheat bread. It is probable that some amylose molecules were released from preheated HQCF, thereby providing more available glucose ends for caramelization during baking (Eduardo et al., 2013). Eduardo et al. (2013) earlier reported similar crust colors between 100% wheat bread and bread from composite flour containing 40% roasted cassava flour.

The $L*$ values reported in this study are within the range (46.58 to 71.20) documented by Shittu et al. (2007) for wheat-cassava (90:10) breads baked at 215 °C for 20 to 45 min. Bread produced from preheated HQCF in this study recorded the highest *a* and *b* values, indicating redness and yellowness, respectively. The brownness indices (BI) are higher than the 38 reported for wheat-cassava (90:10%) bread baked at 215 °C for 20 min (Shittu et al., 2007), but are similar to values (43.2 to 63.4) reported for wheat-cassava breads baked at 220 °C for 7 min which is similar to the temperature-time regime (220 °C for 10 min) used in this study. This variation indicates the effect of the temperature-time combination on the BI of wheat-cassava bread. It may also be attributed to differences in the design and operational efficiency of the baking ovens used. Similar to the findings in this study, Eduardo et al. (2014) recorded higher BI (81.6 to 86.4) when wheat flour was partially replaced with roasted cassava flour.

The weights, volumes, and specific volumes of the various bread samples were in the ranges of 84.56 to 89.61 g, 340 to 356 mL, and 3.81 to 4.21 mL/g, respectively (Table 3). While bread samples from 100% HQCF and wheat-cassava composite flour were approximately 5 to 6% heavier than the sample from 100% wheat flour, the latter was approximately 3 to 5% bigger in volume. However, the decrease in volume obtained in this study is quite minimal when compared to the value (42%) reported by Nwosu et al. (2014) when wheat flour substituted with 50% cassava flour was improved with malted soybean flour. This implies the potential usefulness of gluten extract as an improver for cassava bread. Also, the specific volume of 100% wheat bread was found to be only 8.5 and 9.5% higher than those of wheat-cassava and cassava breads, respectively. Much higher decrease (40 to 48%) in specific volumes have been reported for breads, when wheat flour substituted with cassava flour up to 40% was improved with carboxymethyl cellulose and high methylated pectin (Eduardo et al., 2014). The role of gluten in bread making involes development of viscoelasticity, which in turn makes possible the entrapment of carbon dioxide and rising of dough during fermentation and subsequent baking. Bread weights and volumes are important parameters from an economic point of view but specific volumes, which are a function of both, are more generally used in literature to simply represent bread loaf sizes (Shittu et al., 2007).

Bread produced from composite wheat-cassava flour was similar in firmness with the sample from 100% wheat flour, but 100% cassava bread significantly differed in this respect (Table 3). While this again indicates the possible role of other property of wheat flour aside gluten content in the textural property of wheat bread, the percentage increases (29.4 to 70.6%) in firmness recorded with half-to-full replacement of wheat with cassava flour are lower than values previously documented in literatures for breads from composite flours. For example, Eduardo et al. (2014) recorded 150 to 200% firmer crumbs for breads made from composite flour containing 40% cassava when improved with hydrocolloids and emulsifiers. Similarly, an earlier study (Feili, Abdullah, & Yang, 2013) on wheat flour replacement with 5 to 15% jackfruit rind flour gave bread samples that were approximately 68 to 110% firmer. However, the values (2.2 to 2.4 N) recorded for wheat

Table 3–Physical attributes of breads produced from wheat flour, preheated HQCF and their blend.

Samples	*L*	*a*	*b*	Brownness Index	Weight (g)	Volume (mL)	Specific volume (mL/g)	Firmness (N)
WB	$59.69^{av} \pm 1.92$	$7.26^{b} \pm 0.16$	$15.25^{c} \pm 0.18$	$42.51^{c} \pm 6.42$	$84.56^{b} \pm 4.98$	$356^{a} \pm 15.06$	$4.21^{a} \pm 0.24$	$2.04^{b} \pm 0.69$
CWB	$57.50^{a} \pm 2.25$	$6.49^{c} \pm 0.57$	$17.54^{b} \pm 0.07$	$54.40^{b} \pm 7.28$	$88.46^{ab} \pm 6.65$	$345^{b} \pm 8.04$	$3.90^{ab} \pm 0.37$	$2.64^{b} \pm 0.44$
CB	$59.33^{a} \pm 2.60$	$10.37^{a} \pm 0.89$	$26.41^{a} \pm 1.40$	$79.34^{a} \pm 6.27$	$89.23^{a} \pm 5.33$	$340^{b} \pm 5.42$	$3.81^{b} \pm 0.05$	$3.48^{a} \pm 0.57$

Keys: WB = 100% wheat bread; CWB = wheat-cassava bread; CB = 100% cassava bread.
Values are means (n = 3) ± SD. Means with the same superscript within the same row are not.

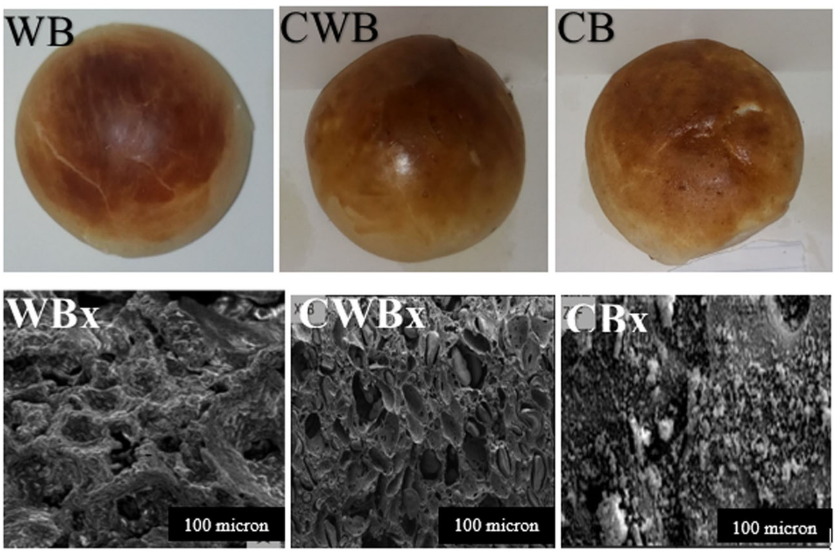

Figure 1–Pictures and crumb microstructures of breads produced from wheat flour, preheated HQCF and their blend. *Keys*: WB = 100% wheat bread; CWB = wheat-cassava bread; CB = 100% cassava bread;
WBx = crumb microstructure of 100% wheat bread; CWBx = crumb microstructure of wheat-cassava bread; CBx = crumb microstructure of 100% cassava bread.

breads by these authors are similar to the value (2.2 N) recorded for the same bread type in this study.

3.3 Microstructure of bread produced from wheat flour, preheated HQCF and their blend

While the sizes and distributions of gas bubbles in 100% wheat bread and wheat-cassava bread appear similar, the bubbles in 100% cassava bread were relatively less developed (Figure 1), despite the addition of gluten. The inherent distribution of gluten in wheat flour, as well as other compositional and structural properties of wheat flour, might play roles complementary to gluten content in overall bubble development and distribution. Shittu et al. (2007) stated that change in the composition of flour can affect the crumb structure of bread. The difference in the gelatinization properties of cassava compared to wheat may also be responsible for the relatively poorer bubble development in 100% cassava bread. This probably caused the dough to toughen rather more quickly, thereby, restricting the expansion of gas cells formed more quickly in the former than the latter. This is plausible as the starch content of flour has been noted as one of the main components influencing bread property (Upadhyay, Ghosal, & Mehra, 2012). The lower rate of gas bubble development and distribution due to cassava flour may explain the relatively lower specific volumes of bread (Table 3) produced from it.

3.4 Proximate compositions and calorie content of bread produced from wheat flour, preheated HQCF and their blend

There were significant differences ($P < 0.05$) in the proximate compositions of the various bread samples, except in moisture contents (Table 4). The significant differences can be justified by the different chemical compositions of wheat and cassava. However, the similar moisture contents (42.35 to 44.73%) obtained were not expected, since preheated HQCF or its composite with wheat flour, containing added gluten, required higher amounts of water (Table 1) during dough development. While the reason for the similar moisture contents noted in this study could not be yet ascertained, it appears evident that moisture migration out of the crumb of cassava breads was faster than from wheat bread. Though higher moisture contents have been reported for cassava breads than wheat breads by some authors (Eduardo et al., 2014; Pasqualone et al., 2010), in a study carried out by Nwosu et al. (2014), four of five bread samples containing between 10 and 50% cassava flour had lower moisture contents than 100% wheat bread. The moisture contents of all the bread samples in this study are, however, within some ranges reported in the literature (Eduardo et al., 2014; Pasqualone et al., 2010) but lower than those reported by Shittu et al. (2007). The variations obtained from these various studies may be attributed to the nature of the flours and type of the improvers used, in addition to the baking conditions (oven temperature and baking time).

Aside moisture, carbohydrate and protein were the major nutrients found in the various bread samples, with the sample from 100% wheat flour showing the lowest and highest values, respectively. The lower amounts of protein recorded for the cassava breads, despite the addition of gluten, indicate that wheat flour contains other protein than gluten. Lim, Mendes, and Chronakis (2019) reported that gluten accounts for about 80 to 90% of the protein in wheat. However, lower protein contents (1.3 to 5.3%) compared to values in this study were obtained in a similar study

Table 4–Proximate compositions (%) and calorie (kCal/100 g) of breads produced from wheat flour, preheated HQCF and their blend.

	Moisture	Crude protein	Ether extract	Crude fiber	Ash	Carbohydrate	Calorie
WB	44.73[a] ± 1.09	15.22[a] ± 0.10	2.88[a] ± 0.20	0.23[c] ± 0.04	0.22[c] ± 0.03	36.77[c] ± 0.10	234[a] + 2.60
CWB	44.26 [a] ± 1.05	12.36[b] ± 0.20	1.60[bc] ± 0.10	1.12[b] ± 0.03	1.30[b] ± 0.10	39.36[b] ± 0.20	221[c] + 2.50
CB	42.35 [a] ± 2.75	11.44[c] ± 0.20	1.55[c] ± 0.10	1.33[a] ± 0.02	1.56[a] ± 0.10	41.77[a] ± 0.20	227[b]+ 2.50

Keys: WB = 100% wheat bread; CWB = wheat-cassava bread; CB = 100% cassava bread.
Values are means (n=3) ± SD; means with the same superscript in the same row are not significantly ($P > 0.05$) different.

Table 5–Sensory properties of breads from wheat, preheated HQCF and their blend.

	Appearance	Crust color	Aroma	Taste	Texture	Overall acceptability
WB	8.18[a] ± 0.77	7.76[a] ± 0.87	7.24[a] ± 1.04	7.40[a] ± 0.93	7.42[a] ± 1.23	7.66[a] ± 1.10
CWB	6.42[c] ± 1.43	6.46[b] ± 1.39	7.02[ab] ± 1.17	7.22[ab] ± 1.18	6.88[a] ± 1.42	7.12[b] ± 1.15
CB	7.38[b] ± 1.46	7.42[a] ± 1.23	6.70[b] ± 1.02	6.68[b] ± 1.32	6.92[a] ± 1.34	7.22[ab] ± 1.08

Keys: WB = 100% wheat bread; CWB = wheat-cassava bread; CB = 100% cassava bread.
Mean ± SD. Means with the same superscript in the same row are not significantly ($P < 0.05$) different.

on nongluten cassava breads (Pasqualone et al., 2010). Similarly, the ether extract (crude fat) content of 100% wheat bread was the highest, presumably due to the inherent crude fat content of wheat flour as compared to cassava flour, as well as the higher oil absorption capacity of wheat flour (Table 2). On the contrary, however, breads from 100% cassava and wheat-cassava composite flours were higher in ash and crude fiber contents. These higher crude fiber contents may partly explain the lower specific volumes and higher firmness (Table 3) of the cassava breads (Rosell & Santos, 2010). This may be responsible for puncturing of bubble cell walls and ultimately collapse of gas bubble leading to poor leavening.

In spite of its lower carbohydrate content, wheat bread showed a significantly ($P < 0.05$) higher calorie content than both cassava and wheat-cassava bread samples (Table 4). Higher fat content of wheat bread could be responsible for its higher calorie content. Food products containing higher fat contents are likely to be more energy-dense. Similarly, the higher protein content of wheat bread can partly explain its higher calorie content.

Since the major contributing components to the calorie contents of the various bread samples differ, varying implications on possible glycaemic indices are possible. Wheat bread in this study will likely have lower glycaemic response than cassava breads, owing to lower carbohydrate and higher protein content (Meng, Matthan, Ausman, & Lichtenstein, 2017). However, the higher fibre content of cassava breads might have a positive effect on its glycaemic response as well. As reviewed by Scazzina, Siebenhandl-Ehn, and Pellegrini (2013), the main strategy to reduce the glycaemic index of bread is through the incorporation of fibre-rich flours.

3.5 Sensory properties of bread produced from wheat flour, preheated HQCF and their blend

Bread produced from 100% preheated HQCF was similar to sample from 100% wheat flour in terms of crust color, texture, and overall acceptability (Table 5). However, there was a significant difference in the overall acceptability of the composite bread when compared with 100% wheat bread. Although objective color analysis revealed no significant difference in the $L*$ values of the bread samples, the crust color of the composite bread was uneven when compared with the other bread samples (Figure 1). This might be the major reason why it was least accepted by the panelists. The unevenness in the crust color can be associated with the different extents of browning (Maillard and caramelization) in the two flour types (wheat and cassava). This is plausible since they had different carbohydrate and protein compositions. Other factors that might have possibly limited the overall acceptability of the composite bread are appearance and texture, where it was also rated lowest.

Despite the fact that partial-to-full replacement of wheat with cassava flour resulted in a steady decline in aroma and taste, the composite bread remained significantly similar to 100% wheat bread in this respect. This implies that even though cassava starch has been noted to impart unusual taste in bread (Horstmann, Lynch, & Arendt, 2017), this study has shown that when not beyond a critical level, replacement of wheat with cassava flour in bread making would not result to significantly notable impairment in flavor. This inference is consistent with the finding of Eduardo et al. (2014) who reported no significant difference between the flavor of bread from 100% wheat flour and those from composite flour substituted with 40% cassava flour. Oyeyinka et al. (2018), however, reported significant ($P < 0.05$) impairment in the flavor of nongluten cookies produced from fermented cassava flour, noting that panelists described this as chalky. Hence, the utilization of cassava flour in baking may require the use of additives for flavor improvement.

4. CONCLUSIONS

The study has revealed the potential of wheat gluten extract as an ingredient in the production of cassava bread. The specific volume of wheat bread was only slightly higher than those of cassava breads. Bread produced from composite flour comprising 50% wheat, 45% cassava, and 5% gluten extract showed no notable impairment in firmness when compared with wheat bread. Cassava breads had higher carbohydrates but were lower in protein and calories than wheat bread. The study also revealed similarity in the overall acceptability between bread samples from wheat and preheated cassava flours. Further researches may be necessary to address the flavor impairment in cassava breads. Also, future studies are recommended to study the effect of varied levels of gluten incorporation on the quality attributes of cassava breads, as well as investigate the role of other properties of wheat flour aside gluten content.

ACKNOWLEDGMENT

The authors acknowledge the service of Dr. Emeka Asogwa of the Central Research Laboratory, Ilorin, Nigeria, for the measurement of bread color and size characteristics. The study was funded by the authors.

AUTHOR CONTRIBUTIONS

Olaide Akintayo conceived the idea of the study and was involved in the design, execution, and report writing. Samson Oyeyinka was also involved in the design of the study and took part in data interpretation. Aziz Aziz carried out the production and experimental analyses and was involved in report writing. Ibukunoluwa Olawuyi was involved in the review editing. Rowland Kayode was involved in study design and review. Olayinka Karim was involved in study design and review.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

A.O.A.C. (2000). Association of official and analytical chemist. Official method of Analysis, Washington, DC.

Akintayo, O. A., Obadu, J. M., Karim, O. R., Balogun, M. A., Kolawole, F. L., & Oyeyinka, S. A. (2019). Effect of replacement of cassava starch with sweet potato starch on the functional, pasting and sensory properties of tapioca grits. *LWT—Food Science and Technology*, *111*, 513–519.

Ayele, H. H., Bultosa, G., Abera, T., & Astatkie, T. (2017). Nutritional and sensory quality of wheat bread supplemented with cassava and soybean flours. *Cogent Food & Agriculture*, *3*(1), 1331892.

Babu, A. S., & Parimalavalli, R. (2012). Functional and chemical properties of starch isolated from tubers. *International Journal of Agricultural and Food Science*, *2*(3), 77–80.

Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*, *52*(6), 3681–3688.

Dudu, O. E., Li, L., Oyedeji, A. B., Oyeyinka, S. A., & Ma, Y. (2019). Structural and functional characteristics of optimised dry-heat-moisture treated cassava flour and starch. *International Journal of Biological Macromolecules*, *133*, 1219–1227.

Eduardo, M. (2015). *Enhancing composite cassava bread quality effect of cassava pre-treatment and baking improvers*. (Ph.D.), Chalmers University of Technology, Göteborg, Sweden. Retrieved from http://publications.lib.chalmers.se/records/fulltext/213197/213197.pdf

Eduardo, M., Svanberg, U., & Ahrné, L. (2014). Consumers acceptance of composite cassava-maize-wheat breads using baking improvers. *African Journal of Food Science*, *8*, 390–401.

Eduardo, M., Svanberg, U., Olivera, J., & Ahrne, L. (2013). Effect of cassava flour characteristics on properties of cassava-wheat-maize composite bread types. *International Journal of Food Science*, *2013*, 1–10.

Elgadir, M. A., Bakar, J., Zaidul, I., Rahman, R. A., Abbas, K., Hashim, D., & Karim, R. (2009). Thermal behavior of selected starches in presence of other food ingredients studied by differential scanning calorimetery (DSC)—Review. *Comprehensive Reviews in Food Science and Food Safety*, *8*(3), 195–201.

Eriksson, E., Koch, K., Tortoe, C., Akonor, P., & Baidoo, E. (2014). Physicochemical, functional and pasting characteristics of three varieties of cassava in wheat composite flours. *International Journal of Food Science and Nutrition*, *3*(5), 64–70.

Esteller, M. S., Pitombo, R. N. d. M., & Lannes, S. C. d. S. (2005). Effect of freeze-dried gluten addition on texture of hamburger buns. *Journal of Cereal Science*, *41*(1), 19–21.

Feili, R., Abdullah, W. N. W., & Yang, T. A. (2013). Physical and sensory analysis of high fiber bread incorporated with jackfruit rind flour. *Food Science and Technology*, *1*(2), 30–36.

Horstmann, S. W., Lynch, K. M., & Arendt, E. K. (2017). Starch characteristics linked to gluten-free products. *Foods*, *6*(4), 29. https://doi.org/10.3390/foods6040029

Iwe, M., Michael, N., Madu, N., Obasi, N., Onwuka, G., Nwabueze, T., & Onuh, J. (2017). Physicochemical and pasting properties high quality cassava flour (HQCF) and wheat flour blends. *Agrotechnology*, *6*(2), 167. https://doi.org/10.4172/2168-9881.1000167

Jyothi, A. N., Sajeev, M. S., & Sreekumar, J. N. (2010). Hydrothermal modifications of tropical tuber starches. 1. Effect of heat-moisture treatment on the physicochemical, rheological and gelatinization characteristics. *Starch-Stärke*, *62*(1), 28–40.

Kaushik, R., Kumar, N., Sihag, M. K., & Ray, A. (2015). Isolation, characterization of wheat gluten and its regeneration properties. *Journal of Food Science and Technology*, *52*(9), 5930–5937.

Lagnika, C., Houssou, P. A., Dansou, V., Hotegni, A. B., AMOUSSA, A. M. O., Kpotouhedo, F. Y., . . . Lagnika, L. (2019). Physico-functional and sensory properties of flour and bread made from composite wheat-cassava. *Pakistan Journal of Nutrition*, *18*(6), 538–547.

Lim, L. T., Mendes, A. C., & Chronakis, I. S. (2019). Electrospinning and electrospraying technologies for food applications. *Advances in Food and Nutrition Research*, *88*, 167–234.

Meng, H., Matthan, N. R., Ausman, L. M., & Lichtenstein, A. H. (2017). Effect of macronutrients and fiber on postprandial glycemic responses and meal glycemic index and glycemic load value determinations. *American Journal of Clinical Nutrition*, *105*(4), 842–853.

Mir, S. A., Shah, M. A., Naik, H. R., & Zargar, I. A. (2016). Influence of hydrocolloids on dough handling and technological properties of gluten-free breads. *Trends in Food Science & Technology*, *51*, 49–57.

Nindjin, C., Amani, G., & Sindic, M. (2011). Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality. *Carbohydrate Polymers*, *86*(4), 1637–1645.

Nurdjanah, S., Yuliana, N., Astuti, S., & Zukryandry, Z. (2017). Physico chemical, antioxidant and pasting properties of pre-heated purple sweet potato flour. *Journal of Food and Nutrition Sciences*, *5*(4), 140–146.

Nwosu, J. N., Owuamanam, C., Omeire, G., & Eke, C. (2014). Quality parameters of bread produced from substitution of wheat flour with cassava flour using soybean as an improver. *American Journal of Research Communication*, *2*(3), 99–118.

Oladunmoye, O., Akinoso, R., & Olapade, A. (2010). Evaluation of some physical–chemical properties of wheat, cassava, maize and cowpea flours for bread making. *Journal of Food Quality*, *33*(6), 693–708.

Oyeyinka, S. A., Ojuko, I. B., Oyeyinka, A. T., Akintayo, O. A., Adebisi, T. T., & Adeloye, A. A. (2018). Physicochemical properties of novel non-gluten cookies from fermented cassava root. *Journal of Food Processing and Preservation*, *42*(11), e13819.

Pasqualone, A., Caponio, F., Summo, C., Paradiso, V. M., Bottega, G., & Pagani, M. A. (2010). Gluten-free bread making trials from cassava (Manihot esculenta Crantz) flour and sensory evaluation of the final product. *International Journal of Food Properties*, *13*(3), 562–573.

Ratnayake, W. S., & Jackson, D. S. (2006). Gelatinization and solubility of corn starch during heating in excess water: New insights. *Journal of Agricultural and Food Chemistry*, *54*(10), 3712–3716.

Rodriguez-Miranda, J., Delgado-Licon, E., Hernández-Santos, B., Reyes-Jaquez, D., Aguilar-Palazuelos, E., Medrano-Roldan, H., . . . Gómez-Aldapa, C. (2012). The effect of pregelatinized potato starch on the functional properties of an extruded aquafeed. *Journal of Animal Production Advances*, *2*(7), 335–344.

Rosell, C. M., & Santos, E. (2010). Impact of fibers on physical characteristics of fresh and staled bake off bread. *Journal of Food Engineering*, *98*(2), 273–281.

Scazzina, F., Siebenhandl-Ehn, S., & Pellegrini, N. (2013). The effect of dietary fibre on reducing the glycaemic index of bread. *British Journal of Nutrition*, *109*(7), 1163–1174.

Shittu, T., Raji, A., & Sanni, L. (2007). Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. *Food Research International*, *40*(2), 280–290.

Shittu, T. A., Aminu, R. A., & Abulude, E. O. (2009). Functional effects of xanthan gum on composite cassava-wheat dough and bread. *Food Hydrocolloids*, *23*(8), 2254–2260.

Suresh, C. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research*, *8*(38), 4849–4852.

Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. *International Food Research Journal*, *21*(4), 1641–1649.

Udoro, E. O., Kehinde, A., Olasunkanmi, S., & Charles, T. (2014). Studies on the physico-chemical, functional and sensory properties of gari processed from dried cassava chips. *Journal of Food Processing and Technology*, *5*(1), 1–8. https://doi.org/10.4172/2157-7110.1000293

Upadhyay, R., Ghosal, D., & Mehra, A. (2012). Characterization of bread dough: Rheological properties and microstructure. *Journal of Food Engineering*, *109*(1), 104–113.

Van Der Borght, A., Goesaert, H., Veraverbeke, W. S., & Delcour, J. A. (2005). Fractionation of wheat and wheat flour into starch and gluten: Overview of the main processes and the factors involved. *Journal of Cereal Science*, *41*(3), 221–237.