American Journal of Food Science and Technology, 2021, Vol. 9, No. 4, 142-148
Available online at http://pubs.sciepub.com/ajfst/9/4/5
Published by Science and Education Publishing
DOI:10.12691/ajfst-9-4-5

Physical and Microstructural Properties of Composite Cassava-wheat Bread Produced from Blend of Wheat and Low Postharvest Physiological Deterioration Cassava Flours

Ahemen Samuel Aondoaver[1], Alimi John Praie[2,*], Alimi Janet Omolola[3], Iluebbey Peter Oshiapi[4]

[1]Akperan Orshi Polytechnic, P.M.B. 181, Gboko, Benue State, Nigeria
[2]Nigerian Stored Products Research Institute, P.M.B. 5044, Onireke, Dugbe, Oyo State, Nigeria
[3]Microbiology Department, P.M.B 1, University of Ibadan, Oyo State, Nigeria
[4]International Institute of Tropical Agriculture, P.M.B. 5320. Ibadan, Oyo State, Nigeria
*Corresponding author: praise4palace2@gmail.com

Received September 15, 2021; Revised October 17, 2021; Accepted October 26, 2021

Abstract The physical and microstructural properties of bread are basic criteria in measuring and optimizing bread quality. This study investigated the physical and microstructural properties of composite cassava-wheat (CCW) bread produced with blend of wheat flour and low postharvest physiological deterioration (PPD) cassava flours. Wholesome four varieties of yellow-fleshed Low PPD cassava and one variety of high PPD cassava were processed into flour and composited with wheat flour. Composite breads produced were analyzed for physical and microstructural properties. Data obtained were subjected to one way analysis of variance using SPSS 25.0 and significant means were separated applying Duncan multiple range test. The CCW flours' water absorption, swelling power, solubility index, oil absorption, bulk density, lightness (*L**), redness (*a**), and yellowness (*b**) ranged from 13.53±0.05 - 13.73±0.05 %, 7.00±0.01 - 8.87±0.03 %, 8.27±0.01 - 9.55±0.06, 101.33±0.87 - 118.83±0.49 %, 0.55±0.01 - 0.62±0.01 g/cm^3, 93.95±0.28 - 96.01±0.34, 0.36±0.01 - 0.77±0.10 and 9.94±0.17 - 11.74±0.24, respectively. Oven spring, loaf volume, loaf weight, specific volume, softness index, springiness, crumb moisture, crumb density, solid density, crumb porosity, bread crust lightness (*L**), crust redness (*a**), crust yellowness (*b**), crumb lightness (*L**), crumb redness (*a**), crumb yellowness (*b**), browning index, total number of cells and percentage area ranged from 0.20±0.00 - 1.25±0.07 cm, 570.80±6.62 - 917.60±6.23 cm^{-3}, 245.33±0.43 - 255.83±0.45 g, 6.22±0.09 - 7.81±0.01 cm^3/g, 11.09±0.36 - 12.69±0.40, 0.70±0.01 - 0.84±0.01, 36.59±0.47 - 39.24±1.67 %, 0.15±0.00 - 0.64±0.71 g/cm^3, 1.14±0.86 - 1.94±0.09 g/cm^3, 0.89±0.01 - 0.93±0.01, 46.49±0.07 - 59.55±1.77, 13.35±0.76 - 17.26±0.04, 25.52±0.05 - 35.66±0.47, 71.72±0.40 - 89.40±0.25, -0.25±0.05 - 6.96±0.45, 20.45±0.08 - 30.88±0.26, 88.94±5.15 - 98.77±0.06, 227.00±2.83 - 1000.00±11.5 and 50.95±11.11 - 68.67±3.07 cm^2, respectively. Bread of desirable loaf qualities and microstructural properties comparable to 100% wheat flour bread were produced from low PPD cassava flour.

Keywords: *composite cassava-wheat bread, functional properties, bread microstructural properties, shelf stability, bread springiness, loaf volume*

Cite This Article: Ahemen S.A., Alimi J.P., Alimi J.O., and Iluebbey P.O., "Physical and Microstructural Properties of Composite Cassava-wheat Bread Produced from Blend of Wheat and Low Postharvest Physiological Deterioration Cassava Flours." *American Journal of Food Science and Technology*, vol. 9, no. 4 (2021): 142-148. doi: 10.12691/ajfst-9-4-5.

1. Introduction

The quest to add value and fortify a food crop such as cassava roots with essential nutrients such as protein and pro-vitamin A so as to enhance its nutritive value for domestic and industrial application has led to immense research efforts by scientists. Cassava has become a significant food security and industrial crop, contributing as food (consumed in tropical regions), feed and industrial biomass in Africa, Asia and South America [1]. Notably, cassava production rose from 132,200,764 tons to exactly 157,271,697 tons in 2010 to 2016, respectively, which was about 18.9% [2]. Also, the production share of cassava by region: Africa (60.7%), Americas (9.9%), Asia (29.3%) and Oceania (0.1%) from 2017 to 2018 [3]. The total production of cassava in Africa in 2018 was 169,673,737; Nigeria's share in this production was 50,485,047 tons [3]. Cassava is known to suffer a physiological disorder that takes effect in about 24-72 hours after the roots have been harvested which impairs its palatability even though it has propensity for increased productivity [4]. It's short postharvest life due to postharvest physiological deterioration (PPD) necessitate quick transportation of the roots to point of processing and this challenge has led to the screening of cassava varieties for extended shelf life, improvement in the nutritional composition and yield..

In countries and regions where wheat grain production is not supported due to unfavorable soil and climatic conditions required for optimum growth of wheat, such countries would largely depend on wheat importation. In Nigeria, flours from crops such as cassava and cowpea have been explored and prospected for use in replacing wheat flour up to 30% so as to reduce the over-dependence on wheat importation for use as food and industrial application [5]. The Nigerian Cassava Growers Association posited that if 20% cassava flour is introduced into bread that is consumed in the country, Nigeria would save ₦250bn annually from wheat importation [6]. The use of CF as partial substitute to wheat flour (WF) for baking purposes has received the support of the Federal Government of Nigeria, which mandated the flour mills to include up to 10% high quality cassava flour (HQCF) into wheat flour. There is an increasing interest in the use of cassava roots for food and industrial purposes especially in the baking industry in Nigeria. The International Institute of Tropical Agriculture (IITA) currently screened varieties of cassava for low PPD some of which were investigated in this study.

Previous works have indicated that varietal influence significantly affects physical, chemical and functional characteristics of cassava flour (CF), which could subsequently affect their food applications [7]. Bread is one of the most widely consumed food products in the world. It has relatively low cost and gives some of the nutrients missing in majority of carbohydrate foods [8]. Bread is mainly produced from wheat flour since it was introduced as food in Nigeria. The knowledge of the structure and properties of bread crumb is necessary to optimize its quality and consequently its acceptability. Important quality parameters determining the consumer acceptability and preference for the composite breads produced with blend of flours from varieties of low PPD cassava flours and wheat flour are not known until analyzed for physical and microstructural properties, therefore this study examined the physical and microstructural properties of composite cassava-wheat (CCW) bread produced with the blend of wheat flour and flour from low (delayed) postharvest physiological deterioration (PPD) cassava.

2. Materials and Methods

The materials used for the include cassava flours from five (5) varieties. The four (4) varieties screened for low postharvest physiological deterioration were: (IITA-TMS-IBA011368, IITA-TMS-IBA070593, IITA-TMS-IBA011412, IITA-TMS-IBA011371) while the one (1) variety of high postharvest physiological deterioration was (TMEB419). All the cassava varieties were obtained from International Institute of Tropical Agriculture (IITA), Ibadan while refined wheat flour was obtained from Honeywell Flour Mills, granulated sugar from Dangote Nigeria Plc., Lagos, Other materials used include Fermipan baking yeast (DSM bakery ingredient, Dordrecht-Holland), salt, Simas margarine (PT Intiboga Sejahtera, Jakarta, Indonesia) and Edlen Dough Conditioner (EDC 2000; Edlen International Inc., GA, USA).

2.1. Preparation of High Quality Cassava Flour (HQCF)

The high quality cassava flour was prepared by method described by [9]. Wholesome cassava roots obtained from the International Institute of Tropical Agriculture (IITA) were peeled using stainless steel knives and washed with clean water in a plastic bowl. The washed roots were then grated and pressed with screw jack press to dewater the mash. The dewatered mash was pulverized and subsequently dried with the aid of flash dryer at 120°C for 8 min. The flash dried cassava mash was then milled into flour with the aid of cyclone hammer mill fitted with a screen of 250 µm aperture size, cooled and packed into high density polyethylene bag. The sieved cassava flour was allowed to cool and packaged into high density polyethylene bag and subsequently sealed for further analysis.

2.1.1. Physical, Functional and Rheological Properties Of Composite Cassava-wheat Flour

The functional, physical and rheological properties of the composite cassava-wheat flours used for the study had been presented in [7]

2.1.2. Bread Baking

The straight dough method described by [10] for composite cassava-wheat bread was used in dough preparation. The two flours (wheat and cassava) were blended together in percentages as shown in Table 1. The bread dough was prepared using the main ingredients (cassava and wheat flour) in varying percentages while other ingredients are based on composite flour weight as shown in Table 1. The mixing was done with a DIOSNA mixer (Osnabrick, model no: 49086 Am, Germany) for 10 min prior to kneading, which was done manually for 5 min until smooth dough was obtained. The dough was then divided into uniform sizes. Proofing of the dough was done in the pan at ambient conditions (29 ± 2°C, 79% RH) for 2 h. Baking was done with an electric oven (Macadams, UK, model: Convecta B) at 180°C for 25 min. The bread samples were allowed to cool and packaged for subsequent analyses.

2.1.3. The Physical Properties of the CCW Bread

The weights of the loaves were determined with the aid of a weighing balance with accuracy of 3 d.p. (Mettler Toledo, Switzerland). The loaf volume was determined after baking process using volume displacement method in which millet seed was used. The volume of the millet seed was taken and this volume was then subtracted from the initial volume of the millet seeds to give the volume of the loaf. The specific volume of each loaf was then calculated as shown in Equation (1) below:

$$\text{Specific volume}\left(\frac{\text{cm}^3}{g}\right) = \frac{\text{Loaf volume}}{\text{Loaf weight}} \qquad (1)$$

Table 1. Dough recipe and formulation (composition) used for the baking experiment

ING (g).	C-C1371-W	C-C1368-W	C-C0593-W	C-C419-W	C-C1412-W	WHEAT
WF	900	900	900	900	900	1000
CF	100	100	100	100	100	-
Salt	10.0	10	10	10	10	10
Sug	100	100	100	100	100	100
Yea	15	15	15	15	15	15
Fat	50	50	50	50	50	50
EDC	3.0	3	3	3	3	3
Wat	62	62	62	62	62	62

Source: [10]
ING: Ingredient; WF: Wheat Flour; CF: Cassava flour; sug: sugar;
Yea: Yeast; Wat: water
C-C1371-W: Composite flour (CF 10%: 90% WF)
C-C1368-W: Composite flour (CF 10%: 90% WF)
C-C0593-W: Composite flour (CF 10%: 90% WF)
C-C419-W: Composite flour (CF 10%: 90% WF)
C-C1412-W: Composite flour (CF 10%: 90% WF)
100%WHEAT: Bread produced with wheat flour.

Oven spring was determined by recording the height of the fermented dough and height of the baked bread samples and estimating the difference. The tristimulus color parameters L* (lightness), a* (redness to bluishness), a* (yellowness to greenness) of the baked loaves crumbs were determined using a digital colorimeter (Color Tec PCM, Accuracy Micro Sensor Inc., USA). The instrument has spot diameter view of 15 mm. To determine the color of bread crust, the top crust was divided into three regions while the tristimulus color parameters L^*, a^*, b^* were determined at each point in duplicate. The brownness index (BI) was calculated as shown in Equation (2) and (3), in accordance to Maskan [11]:

$$\mathrm{BI} = \frac{100*(x-0.31)}{0.17} \tag{2}$$

$$\mathrm{x} = \frac{a+1.75*L}{5.645*L+a-3.012*b} \tag{3}$$

For crumb moisture determination, 1 g of bread was obtained from five different portion of a slice and weighed into a previously weighed Petri dish. The Petri dish and the samples were transferred into the oven set at 105°C dried to constant weight after which the Petri dish and sample were removed from the oven and transferred to desiccators, cooled and weighed. The crumb moisture was then calculated as shown in Equation (4) below:

$$\mathrm{x}(\%) = \frac{(\mathrm{M1}-\mathrm{M2})}{(\mathrm{M1}-\mathrm{Mo})}\mathrm{X100} \tag{4}$$

Where, Mo = Mass of moisture dish (g)
M1 = Mass of dish + fresh bread samples (g)
M2 = Mass of dish + dried bread samples (g)
X = Moisture Content (%)

The crumb density and porosity were determined by the method described by [10].

2.1.4. Textural Analysis of the Composite Cassava-wheat (CCW) Bread

The textural properties such as softness index and springiness of the CCW bread was determine using a textural analyzer (Win test^{TM} Machine model: 0500-10080).

2.1.5. Microstructural Analysis of the Composite Cassava-wheat (CCW) Bread

Digital image analysis was performed on the crumb grain by capturing images of the sliced breads using a flatbed Mercury Scanner 1200U (SCAMXX, Mercury, China; http://www.kobian. com). The images were scanned full scale at 300 dots per inch and analyzed in grey scale. A 200 x 200 pixel square field of view (FOV) was evaluated for each image. This FOV captured the majority of the crumb area of each slice. Seven digital images were processed and analyzed for each bread sample, giving a total of 70 images. Image analysis was performed using the Image J1.32j software (National Institute of Health, USA). All samples used throughout the analyses were replicated five times [8,10].

2.1.6. Statistical Analyses

Data obtained were subjected to one way analysis of variance and significant means were separated applying Duncan's Multiple Range Test at (P<0.05) using Statistical Package for Social Scientists (SPSS) software (version 25.0).

3. Results and Discussion

3.1. The Physical Properties of Composite Cassava-wheat (CCW) bread

The physical properties of the composite cassava-wheat bread are presented in Table 2a and Table 2b. The physical properties of the composite bread were significantly different (P≤0.05) from each other. The oven spring, loaf volume, loaf weight, specific loaf volume, softness index, springiness, crumb moisture, crumb density, solid density and crumb porosity ranged from 0.20±0.00 - 1.25±0.07 cm, 570.80±6.62 - 917.60±6.23 cm^{-3}, 245.33±0.43 - 255.83±0.45 g, 6.22±0.09 - 7.81±0.01 cm^3/g, 11.09±0.36 - 14.51±0.86, 0.70±0.01 - 0.84±0.01, 36.59±0.47 - 39.24±1.67 %, 0.15±0.00 - 0.64±0.71 g/cm^3, 1.14±0.86 - 1.94±0.09 g/cm^3 and 0.89±0.01 - 0.93±0.01, respectively.

Table 2a. Physical properties of the composite cassava-wheat (CCW) bread

PARAMETERS	C-C1371-W	C-C1368-W	C-C0593-W
Oven Spring (cm)	0.20±0.00^{a}	1.00±0.14^{d}	0.80±0.04^{cd}
Loaf Volume (cm^{-3})	781.60±8.25^{cd}	570.80±6.62^{a}	693.20±8.08^{b}
Loaf Weight (g)	245.33±0.43^{a}	255.83±0.45^{c}	249.68±1.92^{b}
Sp. L. V. (cm^3/g)	7.27±0.06^{cd}	6.22±0.09^{a}	6.79±0.25^{b}
Softness Index	11.09±0.36^{a}	12.03±0.14^{a}	12.69±0.40^{a}
Springiness	0.81±0.06^{ab}	0.79±0.04^{ab}	0.83±0.02^{ab}
Crumb Moist. (%)	38.39±3.80^{a}	39.24±1.67^{a}	36.67±0.59^{a}
Crumb den.(g/cm^3)	0.22±0.30^{a}	0.15±0.00^{a}	0.18±0.00^{a}
Solid dens. (g/cm^3)	1.94±0.09^{b}	1.74±0.09^{ab}	1.14±0.86^{a}
Crumb porosity	0.89±0.01^{a}	0.92±0.01^{bc}	0.89±0.00^{a}
Crust L	57.94±0.20^{bc}	56.08±0.63^{b}	59.55±1.77^{c}
Crust a	13.64±0.08^{ab}	14.16±0.14^{ab}	13.35±0.76^{a}
Crust b	35.66±0.47^{bc}	31.60±0.01^{bc}	31.24±0.22^{b}
Crumb L	80.45±0.52^{c}	75.09±0.57^{c}	79.55±0.41^{c}
Crumb a	-0.25±0.05^{a}	0.01±0.28^{a}	-0.08±0.01^{a}
Crumb b	21.16±0.30^{a}	21.61±0.11^{a}	20.45±0.08^{a}
Browning index	93.24±2.42^{ab}	98.15±0.01^{b}	88.94±5.15^{a}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter across a row are significantly different ($P \leq 0.05$) Sp. L. V.: Specific loaf volume; Crumb Moist..: Crumb moisture; Crumb den. : Crumb density; Solid dens. : Solid density; TNC: Total number of cells; Crust L: Bread Crust lightness; Crust a: Bread Crust redness; Crust b: Bread Crust yellowness; Crumb L: Bread crumb lightness; Crumb a: Bread crumb redness; Crumb b: Bread crumb yellowness.

Oven spring, which takes place in the early period of baking, is a measure of dough strength or stability. Expectedly, the oven spring was highest in the wheat bread (control) because of the gas retention ability of wheat protein (gluten) network structure, while the least was recorded in composite bread C1371-W. Oven spring basically is dependent on certain factors such as thermal regime (heating rate and duration), type of flour and ingredients used in dough formulation [5,8]. The observed significant difference in the oven spring could be attributed to the varietal differences in the flour used for the baking experiment since all the composite bread contained the same ingredient and were baked at the same thermal regime. The oven spring of the composite bread produced with varieties of low PPD flour followed the order C-C1368-W>C-C0593-W>C-C1412-W>C-C1371-W.

Table 2b. Physical properties of the composite cassava-wheat (CCW) bread

PARAMETERS	C-C419-W	C-C1412-W	WHEAT
Oven Spring (cm)	0.45±0.07^{b}	0.75±0.07^{c}	1.25±0.07^{e}
Loaf Volume (cm^{-3})	774.89±6.61^{c}	836.00±0.00^{d}	917.60±6.23^{e}
Loaf Weight (g)	250.31±0.01^{c}	248.21±1.15^{ab}	245.44±1.99^{a}
Sp. L. V. (cm^3/g)	7.09±0.04c	7.40±0.04^{d}	7.81±0.01^{e}
Softness Index	12.49±1.32^{a}	14.51±0.86^{b}	11.96±0.84^{a}
Springiness	0.80±0.04^{b}	0.84±0.01^{b}	0.70±0.01^{a}
Crumb Moist. (%)	37.55±0.56^{a}	36.59±0.47^{a}	37.17±0.04^{a}
Crumb den.(g/cm^3)	0.18±0.00^{a}	0.17±0.00^{a}	0.64±0.71^{a}
Solid dens. (g/cm^3)	1.65±0.06^{ab}	1.79±0.02^{ab}	1.86±0.04^{b}
Crumb porosity	0.89±0.00^{a}	0.91±0.01^{b}	0.93±0.01^{c}
Crust L	58.58±0.08^{c}	58.15±0.01^{c}	46.49±0.07^{a}
Crust a	15.69±0.06^{ab}	17.26±0.04^{b}	14.05±0.04^{ab}
Crust b	32.18±0.26^{c}	32.77±0.00^{d}	25.52±0.05^{a}
Crumb L	79.20±1.34^{c}	71.72±0.40^{a}	89.40±0.25^{b}
Crumb a	-0.03±0.13^{a}	5.81±1.05^{b}	6.96±0.45^{b}
Crumb b	20.80±0.40^{a}	21.32±1.05^{b}	30.88±0.26^{c}
Browning index	91.92±2.79^{ab}	97.57±0.08^{b}	98.77±0.06^{b}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter across a row are significantly different ($P \leq 0.05$)

Loaf volume is used as a criterion to measure the quality of fresh bread in research quality control in industry and by consumers [5]. Specific volume of loaves of bread provides a uniform basis for comparing results of various studies [8]. The loaf volume and the specific loaf volume were highest with wheat bread due to high content of gluten present 100% wheat flour used; in terms of loaf volume, the composite cassava-wheat (CCW) bread followed the order: C-C1412-W>C-C1371-W>C-C419-W>C-C0593-W>C-C1368-W (Tables 2a and 2b). The effect of variety of cassava flour used for baking on loaf size of composite cassava-wheat (CCW) bread is shown in Figure 1. There was no significant difference (P>0.05) in loaf weight of CCW bread C-C1371-W and 100% WHEAT; composite bread C-C1368-W and C-C419-W were not significantly different (P>0.05) in terms of loaf weight (Table 2a and Table 2b), which was expected because the dough were cut into same weight of 280 g each before proofing and baking.

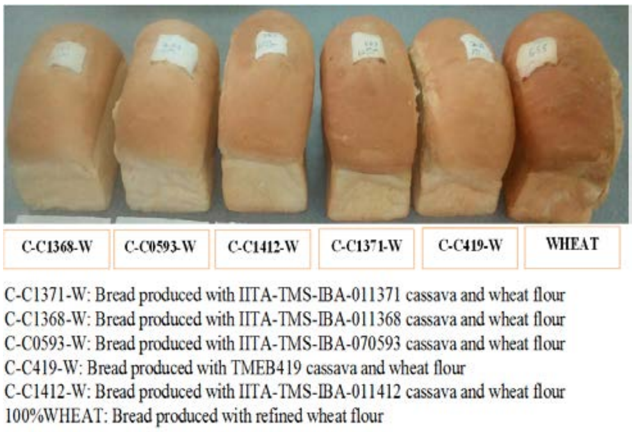


Figure 1. Effect of cassava variety on loaf size of composite cassava-wheat bread

The CCW bread samples were not significantly different (P>0.05) in terms of softness index, crumb moisture and crumb density (Table 2a and Table 2b). Bread baked with Wheat flour had least springiness when compared with the CCW bread simply because 100% wheat bread contains higher content of gluten which have been reported to be responsible for viscoelastic property of bread dough when compared with the composite, which had been diluted as a result of the 10% substitution of wheat flour with cassava flour. Gluten is a protein responsible for the viscoelastic property in wheat dough, excellent gas production and retention in the bread samples which upon application of external strain result into the collapse of the baked bread which expectedly resulted into low springiness observed in 100% wheat bread. Noteworthy, 100% wheat bread had highest crumb porosity (0.93) when compared with all the composite bread (Table 2a and Table 2b). The crumb cell analysis revealed that wheat bread exhibit uniformly distributed pores whereas the composite bread exhibit densely packed crumb cells which were not uniformly distributed (Figure 2).

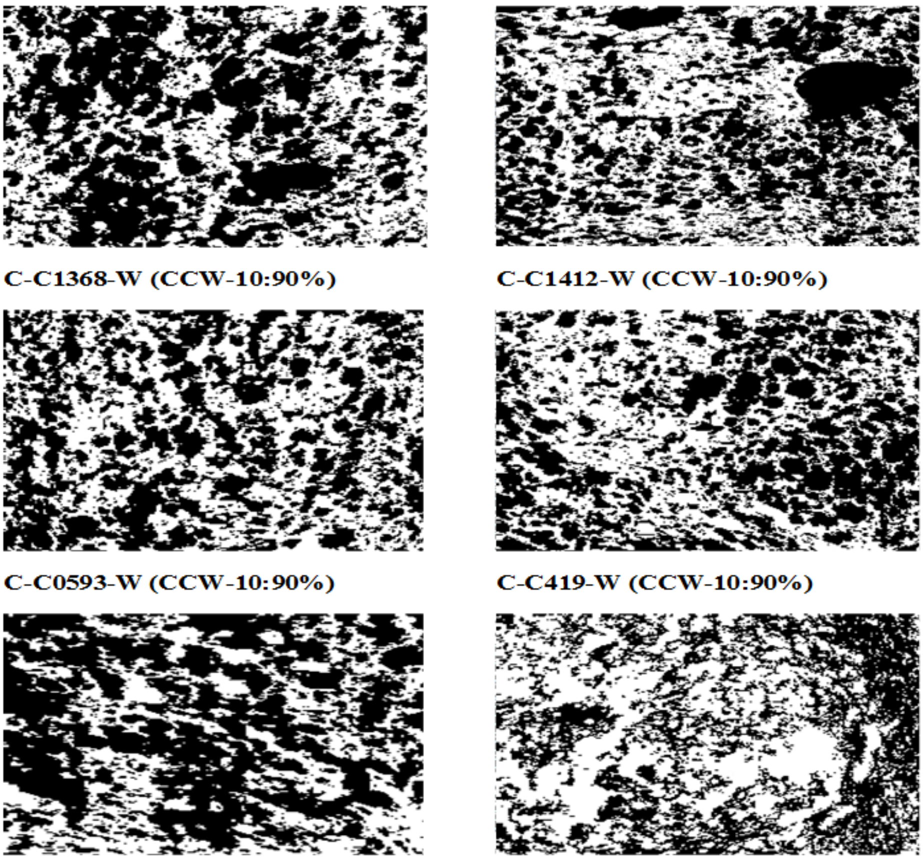
Determination of bread crust's color is important in determining its acceptability. Principally, the crust color exhibited in a bread loaf depends on a number of factors including dough formulation (i.e. type of flour, type and quantity of ingredient used), baking temperature and time etc. [5]. In this study, some of the physical properties were significantly different ($P \leq 0.05$) from each other and this could be attributed to varietal (genetic make-up) differences in the cassava flours used. The composite bread crusts' lightness (L^*), crust redness (a^*), crust yellowness (b^*), crumb lightness (L^*), crumb redness (a^*), crumb yellowness (b^*), browning index (BI) ranged from 46.49±0.07 - 59.55±1.77, 13.35±0.76 - 17.26±0.04, 25.52±0.05 - 35.66±0.47, 71.72±0.40 - 89.40±0.25, -0.03±0.13 - 6.96±0.45, 20.45±0.08 - 30.88±0.26 and 88.94±5.15 - 98.77±0.06, respectively.

The total number of cells and percentage area are presented in Figure 3 and Figure 4, respectively. Maillard browning is a non-enzymatic browning reaction between amino acids and reducing sugars which basically is responsible for the primary color formation reaction. Bread crust color is an important index for the initial acceptability of bread by the consumer. Unlike bread crumb color that may be similar to the color of the ingredients at dough formation, crust color is formed during baking as a result of Maillard and Caramelization reactions [12].

The results are expected, for bread crust lightness and browning index, simply because browning in composite bread samples where the wheat protein (gluten) was reduced as a result of wheat flour substitution, consequently, the observed higher crust lightness in composite bread and higher browning index (higher Maillard reaction) in 100% wheat bread sample. A darker color is a characteristic of the Maillard reaction, which could be attributed to the degree of polymerization and the presence of low molecular weight sugars in the formulation and the level of its contribution in the recipe [12]. Yellowness of the composite bread crust was relatively higher than that of 100% wheat bread because yellow fleshed cassava varieties were used for the production of the high quality cassava flours (HQCF) used in the preparation of the composite flour used in the baking experiment.

3.2. Crumb Structural Properties of Composite Cassava-wheat Bread

The knowledge of the structure and properties of bread crumb is necessary to optimize its quality and consequently its acceptability [5,8]. The averages of frequency of gray color intensity for each crumb area (200 x 200 squared pixels) were obtained while the coefficient of variation (CV) of GL intensity was taken as a measure of uniformity of crumb structure [5]. The crumb cell structure of the composite bread is presented in Figure 2.



C-C1371-W (CCW-10:90%) CONTROL (100%WHEAT)

CF: Cassava flour 10%; WF: Wheat flour 90%
C-C1371-W: Composite bread produced with (IITA-TMS-IBA-011371 CF 10%: 90% WF);
C-C1368-W: Composite bread produced with (IITA-TMS-IBA-011368 CF 10%: 90% WF);
C-C0593-W: Composite bread produced with (IITA-TMS-IBA-070593 CF 10%: 90% WF);
C-C419-W: Composite bread produced with TMEB419 CF 10%: 90% WF); C-C1412-W: Composite bread produced with IITA-TMS-IBA-011412 CF 10%: 90% WF); 100%WHEAT: Bread produced with refined wheat flour.

Figure 2. Gray images of bread crumb obtained from composite cassava-wheat flour

This approximation was assumed since there exist a relationship between cellular structures of bread crumb and the intensity of light reflected during image acquisition The region with finer structure reflect more light (lower gray level intensity) while regions with coarser texture reflect less light. Larger crumb cells that are many when compared with the 100% wheat bread that had smaller but numerous crumb cells (Figure 2). The gray image revealed that the 100% wheat bread exhibit higher porosity than all the composite bread, consequently the observed higher fluffiness in 100% wheat bread when compared with the composite breads.

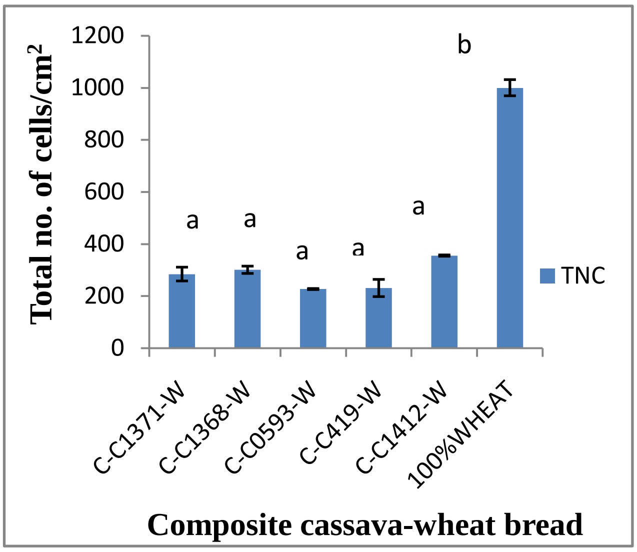


Figure 3. Effect of cassava variety on the crumb cell characteristics of composite cassava-wheat bread determined by digital image analysis of bread crumbs (n=6) (Chart bars having different letter on the top are significantly different ($P \leq 0.05$).)

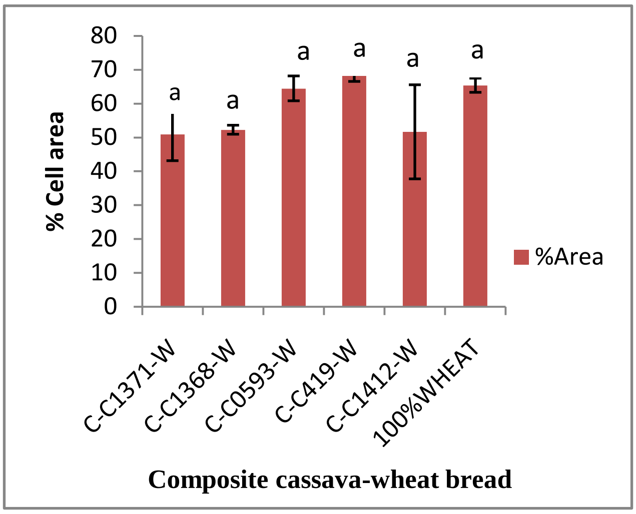


Figure 4. Effect of cassava variety on the % cell area of composite cassava-wheat bread determined by digital image analysis of bread crumbs (n=6) (Chart bars having different letter on the top are significantly different ($P \leq 0.05$))

The tendency for moisture migration from within the crumb to the surface of the crust was higher in 100% wheat bread due to the comparatively higher crumb porosity and smaller crumb cells when compared with the composite cassava-wheat breads; in the composite breads, the crumb cells are larger and relatively closely arranged or packed which could reduce the rate of moisture migration from the bread crumb (Figure 2). This implied that staling is occasioned to occur relatively faster in wheat bread than in the composite breads. The aforementioned point plays a critical role in shelf stability of bread. In terms of bread crumb porosity microstructurally, the order was: wheat bread>C-C419-W>C-C1412-W>C-C1368-W>C-C1371-W>C-C0593-W.

4. Conclusion

Composite cassava-wheat breads produced with low PPD cassava flour were comparable to 100% wheat bread in terms of loaf physical qualities such as crumb softness, crumb moisture, browning index, crumb density and microstructural characteristics which include crumb cells and crumb cell area. The tendency for moisture migration from within the crumb to the surface of the crust was higher in 100% wheat bread when compared with the with composite cassava-wheat breads due to the highly porous crumb cell structure of wheat bread whereas in the composite breads, the crumb cells are larger and relatively closely arranged or packed, consequently staling is occasioned to occur relatively faster in wheat bread than in the composite cassava-wheat breads. The aforementioned phenomenon determines the shelf stability of bread, hence, there is need to investigate the storage stability of the composite breads produced when wheat flour is composited with high quality cassava flour produced from varieties of low PPD cassava.

Acknowledgements

The authors are indebted to the Nigerian Stored Products Research Institute (NSPRI), Centre for Food Technology and Research (CEFTER) Benue State University, International Institute of Tropical Agriculture (IITA), for providing cassava roots and the Nigerian Eagle Flour Mills of Nigeria (NEFM) for providing the wheat flour and baking laboratory used for the study.

Statement of Competing Interests

Authors have no competing interests.

References

[1] Ayetigbo, O., Latif, S., Abass, A. and Müller, J. Comparing Characteristics of Root, Flour and Starch of Biofortified Yellow-Flesh and White-Flesh Cassava Variants, and Sustainability Considerations: A Review. *Sustainability*, 10: 3089. 2018.

[2] Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), "Cassava production statistics," 2018, http://www.fao.org/faostat/en/#data/QC.

[3] Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), "Cassava production statistics," 2020, http://www.fao.org/faostat/en/#data/QC/visualize.

[4] Zainuddin I, Fathoni M, Sudarmonowati AE, Beeching JR, Gruissem W, Vanderschuren H.. Cassava postharvest physiological deterioration: From triggers to symptoms. *Postharvest Biology and Technology*; 9(2): 55-60. 2017

[5] Alimi, J.P., Shittu, T.A., Oyelakin, M.O., Olagbaju, A.R., Sanu, F.T., Alimi, **J.O.**, Abel, O.O., Ogundele, B.A., Ibitoye, O., Ala, B.O. and Ishola, D.T. Effect of cowpea flour inclusion on the storage characteristics of composite wheat-cowpea bread. *Journal of Agricultural and Crop Research,* Vol. 4(4), Pp 49-59. April 2016.

[6] The Punch Newspaper (2019). Available online at https://punchng.com/nigeria-can-save-n250bn-through-cassava-bread-ncga/?amp=1.

[7] Alimi, J.P, Ahemen S.A., Alimi, J.O. and Iluebbey P.O. (In Press). Functional, Physical and Rheological Properties of Composite Cassava-Wheat Flour Produced from Low Postharvest Physiological Deterioration Cassava (Manihot esculenta Crantz). *Asian Food Science Journal*.

[8] Alimi, J.P., Alimi, J.O. *Effect of cowpea flour inclusion on composite dough and baking qualities*. Lambert Academic Publishing European Union, 2019, 1-10.

[9] Iwe, M.O., Michael, N., Madu, N.E., Obasi, N.E. and Onwuka, G.I. Physicochemical and Pasting Properties High Quality Cassava Flour (HQCF) and Wheat Flour Blends. *Agrotechnology*, 6(3): 167. 2017.

[10] Shittu TA, Dixon A, Awonorin SO, Sanni LO, Maxiya-Dixon B. Bread from composite cassava-wheat flour II: effect of cassava genotype and nitrogen fertilizer on bread quality. Food Res. *Int*.; 41: 569-578. March 2008.

[11] Maskan, M. Kinetics of colour change of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, 48, 169-175. 2001

[12] Juszczak, L., Witczak, T., Ziobro, R., Korus, J., Cieślik, E. and Witczak, M. Effect of 911 inulin on rheological and thermal properties of gluten-free dough. *Carbohydrate Polymers*. 90, 353-360. 2012.