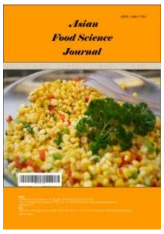

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Functional, Physical and Rheological Properties of Composite Cassava-Wheat Flour Produced from Low Postharvest Physiological Deterioration Cassava (*Manihot esculenta Crantz*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The functional, rheological and color (physical) properties of flours are quality attributes determining the usage, suitability and organoleptic characteristics of flours meant for industrial (baking and confectionery) application. This study investigated the functional, physical and rheological properties of composite cassava-wheat flour produced with low (PPD) cassava flours. Wholesome four varieties of yellow-fleshed Low PPD cassava and one variety of high PPD cassava were, washed, grated, pressed, pulverized, flash dried at 120 °C for 8 minutes, milled with cyclone hammer mill to which a screen having aperture size of 250 was affixed and subsequently cooled. The flours were subjected to analysis such as physical (color), functional and rheological. SPSS 25.0 was used to analyze pertinent data generated, significant means were separated applying Duncan multiple range test. The composite cassava-wheat (CCW) flours' water absorption, swelling power, solubility index, oil absorption, bulk density, lightness (L*),

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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. The water absorption, dough development time, dough stability, mixing tolerance index, dough consistency, farinograph quality number, breakdown time, water absorption for default moisture content and gluten content ranged from 60.70±0.00-63.70±0.14%, 1.28±0.00-1.32±0.00 min, 1.14±0.00-1.37±0.00 min, 75.00±0.00-104.00±0.00 BU, 424.00±0.00-518.00±0.00 mm, 23.00±0.00-26.00±0.00 mm, 2.10±0.00-2.38±0.00 min, 59.90±0.00-62.20±0.00% and 27.00±0.00-32.00±0.00, respectively. Comparable functional, rheological and physical properties to that of wheat flour was obtained from CCW flour prepared with blend of low PPD cassava flour and wheat which are suitable for application in the baking and confectionery industry.

Keywords: Composite cassava-wheat flour; functional properties; dough development time; mixing tolerance index; farograph quality number; water absorption capacity.

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 (*Manihot esculenta Crantz*) is a crop that people consume in the tropical regions [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 share in this production was 50,485,047 [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].

Cassava (*Manihot esculenta Crantz*) characteristically has short postharvest life and this is as a result of a phenomenon known as "postharvest physiological deterioration (PPD", which consequently reduce its market potential and makes the stakeholders in its value chain loose enthusiasm. This challenge requires that cassava is quickly transported to the point of processing and this has led to the screening of cassava varieties for extended shelf life, improvement in the nutritional composition and yield, thereby overcoming the major challenge confronting cassava value chain.

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 importation of wheat. In Nigeria, crops such as cassava, cowpea etc. and their flour has 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 [5,6]. Replacement of wheat with high quality cassava flour (HQCF) in making composite flour for baking purpose attracted the attention of the Nigerian Government, which necessitate that Nigerian flour mills should replace wheat flour with cassava flour up to 10%.

Development (screening) of some low PPD cassava varieties targeted at extending the shelf life of cassava root from two days (48hrs) to 5 days (120hrs) and enhancement of nutritional value with vitamin A or β-carotene is very important. Authors had established that varietal difference affects the quality parameters such as physical, functional and chemical properties of high quality cassava flour [7]. This consequently implies that the flour making properties of such roots and their food uses would also vary [5].

Physical quality such as color is an important organoleptic quality attribute of consideration when talking about acceptability of food products to the consumer. The eventual color of a baked product (e.g. bread, cake etc.) is dependent on the color of the constituent ingredients used in the product formulation [6]. The indices determining the usage of flour in food industry is known to be controlled by the functional, chemical and physical characteristics of such flour. The rheological properties of food material such as flour gives pertinent and underlining information about the flour and its' suitability for baking purpose. The behavior of the low PPD cassava flours in terms of the flow and handling properties (rheological), functional and physical properties cannot be predicted until they are subjected to relevant analysis, this study therefore investigated the functional, physical and rheological characteristics of composite flours prepared with the blend of wheat flour and high quality cassava flour (HQCF) produced from cassava variants screened for low (delayed) postharvest physiological deterioration (PPD).

2. MATERIALS AND METHODS

2.1 Materials

Flours from five varieties were used for the study. The four clones of the low postharvest physiological deterioration cassava used for the study were selected based on their flour yield potential. Four yellow fleshed varieties screened for low postharvest physiological deterioration are: IITA-TMS-IBA011368 (yellow), IITA-TMS-IBA070596 (yellow), IITA-TMS-IBA011412 (yellow), IITA-TMS-IBA011371 (yellow) and one variety of high postharvest physiological deterioration: TMEB419 (white) were provided by International Institute of Tropical Agriculture (IITA), Ibadan while the refined wheat flour was obtained from Nigerian Eagle Flour Mills of Nigeria, Ibadan.

2.2 Preparation of High Quality Cassava Flour (HQCF)

The unit operations involved in processing cassava tuber to high quality cassava flour (HQCF) as reported by Shittu et al. [5] was followed and is presented in Fig. 1. Wholesome four varieties of yellow-fleshed Low PPD cassava and one variety of high PPD cassava obtained from the International Institute of Tropical Agriculture (IITA) were peeled using stainless steel knives. The peeled cassava were washed, grated, pressed, pulverized and flash-dried at 120 °C for 8 minutes. The dried cassava grit was milled into fine high quality cassava flour (HQCF) with the aid of a cyclone hammer mill to which a screen having aperture size of 250 was affixed. The sieved cassava flour was allowed to cool and packaged into high density polyethylene bag, sealed, ready for subsequent analysis.

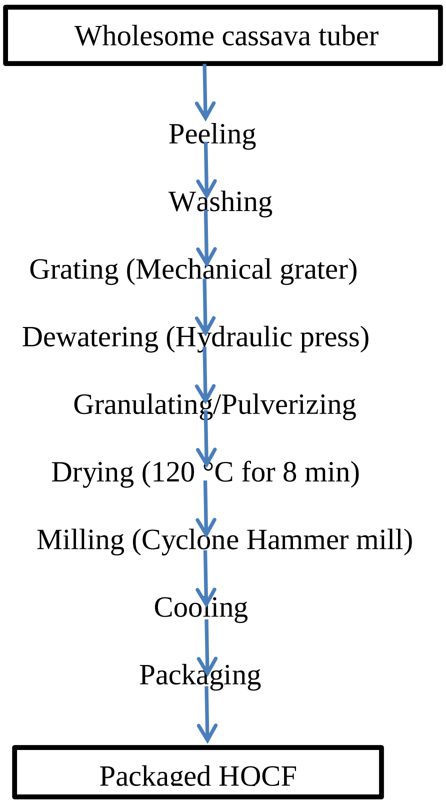

Fig. 1. Flow chart of the production of high quality cassava flour (HQCF)
Source: shittu et al. [5]

2.3 Composite Cassava-Wheat Blend

The high quality cassava flour (HQCF) prepared from low PPD cassava and wheat flour were blended as indicated in Table 1.

2.4 Physical and Functional Analysis of Composite Cassava-wheat *(CCW)* flour

The physical properties of CCW flour determined include the color parameters (*L** *a** **b***) and bulk density. The surface color of the CCW flours were determined objectively with the aid of a Colorimeter (ColorTec PCM^{TM} Acuracy microsensors Inc., USA). The bulk density of the CCW flour was estimated as the ratio of the mass of an untapped powder sample and its volume including the contribution of the interparticulate void volume. The functional properties of the CCW flours determined include water absorption capacity, swelling power, solubility index, oil absorption capacity. The water absorption capacity was determined as described by Kadan *et al*. [7] while oil absorption capacity was determined as described by Adebowale *et al*. [8] and Onwuka, [9]. Swelling power and solubility were determined as described by Oladele and Aina [10].

2.5 Rheological Properties of Composite Cassava-wheat (CCW) Flour

The Farinogram characteristics of dough made from the composite cassava-wheat flours were determined by approved method (AACC) [11], using Brabender Farinograph (Model T 150 E, Ohgduisburg, Germany).

2.6 Statistical Analysis

Statistical package for social sciences version 25.0 (IBM-SPSS Inc. USA) was used to analyze the pertinent data generated, one way analysis of variance was carried out and significant means were separated applying Duncan multiple range test.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Composite Cassava-wheat (CCW) Flour

The physical properties of the composite cassava-wheat (CCW) flours are presented in "Table 2". The physical properties were significantly different (*P*=.05) from each other owing to the difference in clones. The range of CCW flours' bulk density, lightness (*L**), redness (*a**), and yellowness (*b**) was 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. An important parameter determining the ease of packaging of food that has particle (particulate foods) is referred to as bulk density. The range of value (0.55-0.62 g/cm^3) for the bulk density, with C-C0593-W having the lowest value, while C-C1368-W had the highest value. The composite flour were significantly different (*P*=.05) in terms of the yellowness of the composite flour. All the cassava flours used in replacing wheat flour were essentially from yellow-fleshed cassava except composite flour C-C419-W that was whitish. The intensity of the color of the variety of cassava processed goes a long way in depicting the eventual color of the resulting flour prepared and baked product that would be produced, the yellow color look more appealing to the consumers and contribute to the consumer preference. This finding is in consonance with the results of similar study conducted by Eleazu and Eleazu [12].

3.2 The Functional Properties of Composite Cassava-wheat (CCW) Flour

The functional properties of the composite cassava-wheat (CCW) flour are presented in "Table 3". Quality parameters of importance that depicts the end use to which flour could be put to are known as the functional properties [5]. Difference in clone was responsible for the significant difference (*P*=.05) observed in the composite flour investigated. The CCW flours' water absorption, swelling power, solubility index, and oil absorption 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 %, respectively. It was observed that the composite flour C-C419-W which was prepared by replacing wheat flour with 10% high PPD cassava flour had the lowest water absorption while the composite flours prepared by replacing wheat flour with 10% low PPD cassava flours had higher water absorption. The composite flour C-C0593-W and C-C419-W had the highest swelling power and oil absorption capacity, respectively. The swelling power of composite flours followed the order: C-C0593-W>C-C1368-W>100%WHEAT> C-C1371-W>C-C419-W>C-C1412-W.

Table 1. Blending ratio of cassava and wheat flour used in the experiment

Composite flour	Cassava flour	Wheat flour	Total (%)
C-C1371-W	10	90	100
C-C1368-W	10	90	100
C-C0593-W	10	90	100
C-C419-W	10	90	100
C-C1412-W	10	90	100
Wheat flour	-	100	100

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

Table 2. Physical properties of composite cassava-wheat flour used in the study

Cassava Variety	Bulk d. (g/cm^3)	L^*	a^*	b^*
C-C1371-W	0.59±0.01^{a}	94.81±0.05^{ab}	0.39±0.02^{a}	11.74±0.24^{d}
C-C1368-W	0.62±0.01^{b}	95.32±0.01^{ab}	0.43±0.00^{a}	10.66±0.01^{b}
C-C0593-W	0.55±0.01^{c}	94.44±0.34^{ab}	0.36±0.01^{a}	11.34±0.10^{c}
C-C419-W	0.60±0.01^{a}	96.01±0.34^{b}	0.60±0.03^{b}	9.94±0.17^{a}
C-C1412-W	0.57±0.00^{d}	93.95±0.28^{a}	0.38±0.03^{a}	11.33±0.09^{c}
WHEAT FLOUR	0.59±0.01^{a}	95.58±1.67^{ab}	0.77±0.10^{c}	10.45±0.15^{b}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter within a column are significantly different ($P \leq 0.05$)
Bulk d.: Bulk density; L: flour lightness; a*: redness to greenness; b*: yellowness*
C-C1371-W: Composite flour (IITA-TMS-IBA-011371 CF 10%: 90% WF)
C-C1368-W: Composite flour (IITA-TMS-IBA-011368 CF 10%: 90% WF)
C-C0593-W: Composite flour (IITA-TMS-IBA-070593 CF 10%: 90% WF)
C-C419-W: Composite flour (TMEB419 CF 10%: 90% WF)
C-C1412-W: Composite flour (IITA-TMS-IBA-011412 CF 10%: 90% WF)

Oil absorption describes the emulsifying ability of a food substance. This ability is of great importance in improving the ability of a powdery food material to bind other substances in its structure. It enhances flavor retention and sensorial (organoleptic) perception such as mouthfeel. The ability of the composite flours to absorb and retain oil as measured by oil absorption capacity followed the order: C-C419-W>C-C1412-W>C-C0593-W>C-C1371-W> C-C1368-W>100% WHEAT. Generally, the functional properties of the composite flour revealed that C-C0593-W and refined wheat flour were not significantly different from each other in terms of water absorption, swelling power, solubility and oil absorption capacity. All the composite flours when compared with the refined wheat flour were not significantly different in terms of solubility.

3.3 Rheological Properties of Composite Cassava-wheat (CCW) Flour

The rheological properties of the composite cassava-wheat flour is presented in Table 4. Unit operations such as mixing, fermentation and baking practically are majorly the three basic operations to be employed in bread making. Mixing as a unit operation transforms the flour and water into cohesive viscoelastic mass (dough) and also incorporates air into the dough.

The gas cells into which the carbon dioxide produced by the yeast fermentation diffuses is made possible by incorporation of air. The flow of food material i.e. rheological properties are quantified or tested by rheometers, which have a resemblance of rapid visco anlyser, farinograph and alveograph that provides empirical information that have direct relationship with the actual product's quality. The Farinograph indices of composite cassava-wheat flour indicated that the water absorption, dough development time, dough stability, mixing tolerance index, dough consistency, farinograph quality number, breakdown time, water absorption for default moisture content and gluten content ranged from 60.70±0.00-63.70±0.14 %, 1.28±0.00-1.32±0.00 min, 1.14±0.00-1.37±0.00 min, 75.00±0.00-104.00±0.00 BU, 424.00±0.00-518.00±0.00 mm, 23.00±0.00-26.00±0.00 mm, 2.10±0.00-

2.38±0.00 min, 59.90±0.00-62.20±0.00% and 27.00±0.00-32.00±0.00, respectively.

The interactions between the cross link that existed in protein with the disulfide bonds during dough mixing operation is made possible by addition of water, the same applies for the hydration of protein fibrils in the flour matrix. Water is needed in adequate amount in order to develop a viscoelastic, firm (cohesive) dough and optimum gluten strength. This quantity of water necessary for the dough development differs from flour to flour, largely dependent on the amount and quality of protein and other dense particles present. Flour protein plays a critical role in the ability of particular flour to absorb water during mixing operation [13].

The inclusion of cassava flour increased the water absorption of the composite cassava-wheat flours. However, previous studies reported that when wheat is substituted with non-wheat flour, there was relative increase in the water uptake of the dough [14,15]. Therefore, at the baker’s end for example, inclusion of low PPD cassava flour in wheat for bread making purpose would increase the water absorption of flour which consequently would result into higher yield as noted and posited by Puhr and D`appolonia, [15] that flour with high water absorption capacity would result in high yield of product. The order of the water absorption capacity of the flours follows: C-C1371-W> C-C0593-W> C-C1368-W> C-C419-W> C-C1412-W>WHEAT.

Time of development (formation) of the dough is the time required for the formation of dough, i.e. until the consistency of 500 BU. The rheological characteristics exhibited by flour during mixing ‘Table 4” revealed that the composite flour C-C0593-W arrived at the consistency line in lowest possible time 1.28 min, whereas other blends and wheat flour arrived at relatively high times, indicating faster uptake of water and faster dough development [16]. Arrival time, (AT) was the time to the nearest one-half minutes required for the top of the curve to reach the point of greatest torque after the commencement of mixing (500 BU consistency line).

Worth pointing out, dough development time is; (i) directly proportional to proteolytcal degradation of protein and damaged starch content (ii) inversely proportional to starch granules (Thiele *et al.* [17]. It is a measure of the rate at which water was taken up by the flour [18]. The dough development time of the composite flour followed the order C-C0593-W <WHEAT<C-C1371-W<C-C419-W<C-C1368-W<C-C1412-W. The dough development time had negative significant (*P*=.05) correlation with mixing tolerance index and dough consistency but correlated significantly (*P*=.05) with Farinograph quality number (r=-0.700, *P*=.05; r=-0.640, *P*=.05; r=0.610, *P*=.05) “Table 5”.

Table 3. Functional properties of composite cassava-wheat (CCW) flour

Cassava Variety	W. abs, Cap. (%)	Swelling power (%)	Solubility index	Oil Abs. capacity (%)
C-C1371-W	13.73±0.05^{b}	7.19±0.17^{ab}	8.37±0.25^{a}	107.86±0.88^{c}
C-C1368-W	13.73±0.10^{b}	7.80±0.07^{c}	9.55±0.06^{a}	103.46±0.13^{b}
C-C0593-W	13.67±0.01^{ab}	8.87±0.03^{a}	8.27±0.01^{a}	107.52±0.37^{c}
C-C419-W	13.53±0.05^{a}	7.16±0.08^{ab}	8.64±1.51^{a}	118.83±0.49^{e}
C-C1412-W	13.60±0.05^{a}	7.00±0.01^{a}	9.02±0.16^{a}	115.19±0.83^{d}
WHEAT FLOUR	13.60±0.03^{ab}	7.26±0.10^{a}	9.22±0.04^{a}	101.33±0.87^{c}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter within a column are significantly different (P≤0.05)

W.abs: Water absorption; Oil Abs: Oil Absorption

C-C1371-W: Composite flour (IITA-TMS-IBA-011371 CF 10%: 90% WF)

C-C1368-W: Composite flour (IITA-TMS-IBA-011368 CF 10%: 90% WF)

C-C0593-W: Composite flour (IITA-TMS-IBA-070593 CF 10%: 90% WF)

C-C419-W: Composite flour (TMEB419 CF 10%: 90% WF)

C-C1412-W: Composite flour (IITA-TMS-IBA-011412 CF 10%: 90% WF)

Table 4. Rheological properties of composite cassava-wheat (CCW) flour

PARAMETER	C-C1371-W	C-C1368-W	C-C0593-W	C-C419-W	C-C1412-W	WHEAT
WA (%)	63.70±0.14^{d}	62.90±0.14^{b}	62.90±0.00^{c}	62.30±0.00^{b}	62.10±0.00^{b}	60.70±0.00^{a}
DDT (min)	1.30±0.01^{bc}	1.32±0.00^{d}	1.28±0.00^{a}	1.30±0.00^{c}	1.32±0.00^{d}	1.29±0.00^{b}
DSTA. (min)	1.27±0.00^{ab}	1.20±0.00^{a}	1.22±0.03^{ab}	1.14±0.00^{a}	1.37±0.00^{b}	1.36±0.10^{b}
MTI (BU)	85.75±0.36^{b}	92.00±0.00^{c}	102.00±0.00^{e}	98.00±0.00^{d}	75.00±0.00^{a}	104.00±0.00^{f}
D.CON (BU)	478.50±0.70^{e}	436.00±0.00^{c}	460.00±0.00^{d}	433.00±0.00^{b}	424.00±0.00^{a}	518.00±0.00^{f}
FQN (mm)	25.00±0.00^{a}	25.00±0.03^{a}	24.00±0.06^{a}	23.00±0.00^{a}	26.00±0.00^{a}	24.00±0.08^{a}
BRK.T (min)	2.31±0.00^{c}	2.30±0.00^{c}	2.25±0.00^{b}	2.10±0.00^{a}	2.38±0.00^{d}	2.25±0.10^{b}
WAM (%)	61.85±0.07^{e}	60.70±0.00^{c}	62.20±0.00^{d}	60.70±0.00^{c}	60.60±0.00^{b}	59.90±0.00^{a}
GC	28.00±0.12^{ab}	28.00±0.07^{ab}	27.00±0.00^{a}	27.00±0.00^{a}	27.00±0.00^{a}	32.00±0.00^{b}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter across a row are significantly different ($P \leq 0.05$)
WA: Water absorption; DDT: Dough development time; DSTA: Dough stability; MTI: Mixing tolerance Index; DCON: Dough consistency; FQN: Farinograph quality number; BRK.T: Breakdown time; WAM: Water absorption content for default moisture content; GC: Gluten content
CCW flour: Composite cassava-wheat flour
CF: Cassava flour; WF: Wheat flour
C-C1371-W: Composite flour (IITA-TMS-IBA-011371 CF 10%: 90% WF)
C-C1368-W: Composite flour (IITA-TMS-IBA-011368 CF 10%: 90% WF)
C-C0593-W: Composite flour (IITA-TMS-IBA-070593 CF 10%: 90% WF)
C-C419-W: Composite flour (TMEB419 CF 10%: 90% WF)
C-C1412-W: Composite flour (IITA-TMS-IBA-011412 CF 10%: 90% WF)
100%WHEAT: Bread produced with refined wheat flour

Table 5. The Pearson's correlation matrix among the rheological and functional properties of composite cassava-wheat (CCW) flour

VAR.	WA	DDT	DST	MTI	FQN	BKD	WAM	DCO	BD	WAC	SPO	WSO	OAC
WA	1.000												
DDT	-0.094	1.000											
DST	-0.423	0.100	1.000										
MTI	-0.343	-0.700*	-0.369	1.000									
FQN	0.173	0.610*	0.605*	-0.843**	1.000								
BKD.	0.173	0.575	0.628*	-0.836**	0.998**	1.000							
WAM	0.981**	-0.189	-0.333	-0.297	0.168	0.17	1.000						
DCO	-0.337	-0.640*	0.414	0.533	-0.243	-0.216	-0.174	1.000					
BD	0.022	0.32	0.315	-0.467	0.558	0.558	-0.047	-0.531	1.000				
WAC	0.476	-0.034	-0.114	-0.052	0.318	0.321	0.514	0.131	-0.096	1.000			
SPO	0.248	-0.487	-0.351	0.487	-0.216	-0.206	0.23	0.007	0.297	0.397	1.000		
WSO	-0.425	0.329	0.134	0.044	0.166	0.159	-0.469	-0.036	0.13	-0.05	0.010	1.000	
OAC	0.255	0.219	-0.288	-0.391	-0.121	-0.128	0.154	-0.684*	0.23	-0.565	-0.333	-0.299	1.000

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

WA: Water absorption; DDT: Dough development time; DST: Dough stability; MTI: Mixing tolerance Index; DCO: Dough consistency; FQN: Farinograph quality number; BKD: Breakdown time; WAM: Water absorption content for default moisture content; GC: Gluten content

Dough Stability Time (DST) indicated how much tolerance the flour has to over or under mixing (Schiller) [19]. Stability time is the point between arrival time and departure time and generally indicates the strength of flour [20,6]. Dough stability did not differ significantly by substituting wheat flour with cassava flour it was only composite flour C-C419-W (high PPD cassava flour) that had the lowest dough stability while C-C1412-W had the highest dough stability time value 1.37 min.

This finding is in agreement with the findings of other researchers [20-22, 6] that inclusion of non-wheat flour into wheat flour for dough development improves dough stability. Dough stability correlated significantly (*P*<0.05) with farinograph quality number and breakdown time (r=0.605, *P*=.05; r=0.628, *P*=.05) “Table 5”.

Mixing tolerance index (MTI) is used by bakers to determine the extent of softening dough will experience over a period of mixing [22,23,6]. The shorter or lower the value is, the better, the higher the MTI value, the weaker the flour [22]. The flexibility (pliability) and smoothness of the dough follows the order C-C1412-W<C-C1371-W<C-C1368-W<C-C419-W<C-C0593-W<WHEAT. Mixing tolerance index had negative correlation with both (*P*=.05) with farinograph quality number and breakdown time (r=-0.843, *P*=.05; r=-0.836, *P*=.05), respectively (Table 5).

Dough consistency ranged from 424.00-518.00 (BU), with composite flour C-C1412-W having the lowest while wheat flour had the highest but among the low PPD flour composite flour C-C1371-W had the highest. The lower the oil absorption capacity of the flour, the higher the dough consistency. Dough consistency had negative correlation with oil absorption capacity (r=-0.684, *P*=.05) “Table 5”.

Farinograph quality number (FQN) is an index for measuring the quality of the flour and is measured on the farinogram, on horizontally (in minutes) from the vertical axis of the consistency of the dough to the point where the center line of the curve meets the horizontal line lowered by 30 FU towards the peak of consistency, multiplied by 10. Farinograph quality number (FQN) of the composite flours varied insignificantly (*P*>0.05). Farinograph quality number correlated significantly (*P*=.05) with breakdown time (r=0.998, (*P*=.01) Table 5.

Breakdown Time (TBD) just like MTI is also an index of the relative strength of flours. The TBD values ranged from 2.10-2.38 min, with C-C419-W having the least while C-C1412-W had the highest. The composite flour C-C1412-W showed better resilience than wheat flour and other composite flours that were examined. Noteworthy, composite flour C-C419-W (high PPD) took the least time 2.10 min to breakdown as measured by breakdown time, meaning that the composite flour prepared with low PPD cassava flours were comparatively more stable. The gluten content of the composite flour was relatively reduced when compared with that of wheat flour because of the dilution of gluten present in wheat flour as a result of the substitution. The gluten is responsible for the viscoelastic property of wheat flour.

4. CONCLUSION

The functional properties of the composite flour studied revealed that C-C0593-W and refined wheat flour were not significantly different from each other in terms of water absorption, swelling power, solubility and oil absorption capacity. The relatively better resilience (high breakdown time) of flours produced from low PPD cassava when compared with flours from high PPD cassava indicates low tendency towards retrogradation of starch, this makes them suitable and promising in the baking industry, especially in bread baking where staling is occasioned. Comparable functional, rheological and physical properties to that of wheat flour was obtained from CCW flour prepared with blend of low PPD cassava flour and wheat flour which are suitable for application in the baking and confectionery industry.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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