Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper *DOI: 10.17508/CJFST.2023.15.1.09*

Effect of varietal differences on chemical and pasting properties of composite wheat-cassava flours produced from low postharvest physiologically deteriorated cassava roots (*Manihot esculenta Crantz*)

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

[1]*Nigerian Stored Products Research Institute, P.M.B. 5044, Onireke, Dugbe, Oyo State, Nigeria*
[2]*Akperan Orshi Polytechnic, Yandev, P.M.B. 181, Gboko, Benue State, Nigeri*
[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*

ARTICLE INFO

Article history:
Received: February 2, 2022
Accepted: June 27, 2022

Keywords:
composite wheat-cassava flour
pasting properties
chemical composition
postharvest physiological deterioration
flour blend

ABSTRACT

This study investigated the effect of varietal differences on the chemical and pasting properties of composite wheat-cassava flours produced with blend of wheat and high-quality cassava flour from low postharvest physiologically deteriorated (PPD) cassava roots. Wholesome four varieties of yellow-fleshed low PPD cassava roots and one variety of high PPD cassava root were, peeled, washed, grated, pressed, pulverized, flash dried at 120 °C for 8 minutes, milled with cyclone hammer mill fitted with a screen of 250 µm aperture size, cooled and packed into high density polyethylene bag. The high-quality cassava flours (HQCF) were composited with wheat flour and analyzed for chemical and pasting properties. Data obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS version 25.0) and significant means were separated applying Duncan multiple range test and Pearson's correlation was also determined. The results depict that moisture, protein, fat, ash, sugar, starch, dry matter and energy value ranged from 12.45 - 13.10 %, 10.30 - 11.65 %, 0.40 - 3.71 %, 0.58 - 0.62 %, 1.75± - 2.08 %, 70.94 - 74.40 %, 86.90 - 87.55 % and 1464.29 - 1531.66 KJ/kg, respectively. Peak, trough, breakdown, final, setback, peak time and pasting temperature ranged from 180.63 - 247.21 RVU, 95.84 - 129.00 RVU, 83.42 - 118.21 RVU, 139.29 - 253.71 RVU, 83.79 - 124.71 RVU, 5.90 - 6.17 min and 69.00 - 73.48 °C, respectively. Considering the relatively high dry matter content, energy value, peak viscosity, low breakdown viscosity and pasting time, flour blends C-C1368-W and C-C0593-W prepared with HQCFs from IITA-TMS-IBA-011368 and IITA-TMS-IBA-070593 cassava varieties could find application in baking and confectionery industry.

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 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 eat in the tropical regions (Ayetigbo et al., 2018). 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% (FAO, 2018). Also, the production share of cassava by region is the following: Africa (60.7%), Americas (9.9%), Asia (29.3%) and Oceania (0.1%) from 2017 to 2018 (FAO, 2020). The total production of cassava in Africa in 2018 was 169,673,737. Nigeria share in this

*Corresponding author E-mail: praise4palace2@gmail.com

production was 50,485,047 (FAO, 2020). Cassava root 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 (Zainuddin et al., 2017).

Cassava root characteristically has short postharvest life and this is a result of a phenomenon known as "postharvest physiological deterioration (PPD)", which consequently reduces 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 challenges confronting cassava value chain.

Countries and regions where wheat grain production is not supported due to unfavorable soil and climatic conditions required for the optimum growth of wheat, would largely depend on the importation of wheat. In Nigeria, crops such as cassava, cowpea etc., and their flour, 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 (Alimi et al., 2016; Punch Newspaper, 2019). Partial substitution of wheat with high quality cassava flour (HQCF) to make composite flour for baking purpose had attracted the attention of the Nigerian Government, which necessitates that Nigerian flour mills replace wheat flour with HQCF up to 10%.

Development (screening) of some low PPD cassava varieties aimed at extending the shelf life of cassava root from two days (48 h) to 5 days (120 h) and the enhancement of nutritional value with pro-vitamin A or β-carotene is very important (Alimi et al., 2021a). Authors found out that a difference in variety goes a long way to affect the quality parameters such as physical, functional and chemical properties of the HQCF (Shittu et al., 2008; Alimi et al., 2021a). This consequently implies that the flour making properties of such roots and the usage of their foods would also vary.

The proximate components in food are essential to the consumers to be informed on the nutritional benefits derivable in such food which also guide them in making knowledgeable decisions about their diet. Pasting characteristics of a food had been employed in food industry to match up the functionality of starch-based food ingredients in processing and production operations such as baking (Defloor et al., 1994; Idowu et al., 1996; Alimi et al., 2021b) and extrusion cooking (Ruales et al., 1993). This study, therefore, examined the effect of varietal differences on the chemical and pasting characteristics of composite flours produced with blend of wheat and flours from low postharvest physiologically deteriorated (PPD) cassava roots.

Materials and methods

The materials used for this study include flours from five (5) varieties. Four varieties screened for low PPD (IITA-TMS-IBA011368, IITA-TMS-IBA070596, IITA-TMS-IBA011412, IITA-TMS-IBA011371) and one variety of the high PPD (TMEB419) were sourced from the International Institute of Tropical Agriculture (IITA), Ibadan and refined wheat flour was from the Nigerian Eagle Flour Mills, Ibadan.

Preparation of high-quality cassava flour

Wholesome cassava roots (28.86 kg) obtained from 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 (12.22 kg) and subsequently dried with the aid of flash dryer (fabricated by Niji Lukas, Lagos, Nigeria) at 120 °C for 8 min. The flash dried cassava mash was then milled into flour with the aid of cyclone hammer mill (fabricated by Niji Lukas, Lagos, Nigeria) fitted with a screen of 250 µm aperture size, cooled and packed into high density polyethylene bag. The sieved HQCF (7.8 kg) was allowed to cool and packaged into high density polyethylene bag and subsequently sealed for further analysis (Alimi et al., 2021a).

Preparation of the composite wheat-cassava composite flours

The HQCF produced from one variety of high PPD cassava (TMEB419) and four varieties of cassava screened for PPD (IITA-TMS-IBA011368, IITA-TMS-IBA070596, IITA-TMS-IBA011412, IITA-TMS-IBA011371) were blended with wheat flour at ratio 90:10 (wheat flour WF 90; cassava flour CF 10), respectively as presented in Table 1.

The chemical analysis of the composite wheat-cassava flours

The moisture content, protein, ash, and fat content of the flour prepared from the flour blends were determined following the standard analytical procedures (AOAC, 2019). Starch and sugar content were determined according to Dubois et al. (1970). Energy value was calculated using Atwater factor Equation (1) (Etudaiye et al., 2009). The dry matter content was determined with Equation (2) (Etudaiye et al., 2009).

$$\text{Energy value (KJ/kg)} = (\text{Protein cont.} * 4) + (\text{Fat cont.} * 9) + (\text{Carbohydrate cont.} * 4) \quad (1)$$

$$\text{Dry matter content (\%)} = (100 - \text{Moisture content}) \quad (2)$$

The pasting analysis of the composite wheat-cassava flours

The pasting properties of the flour blends were determined with a Rapid Visco Analyzer (Model RVA-4C, Newport Scientific, Warriewood, Australia) interfaced with a personal computer equipped with the Thermoclined software supplied by same manufacturer. The heating and cooling cycles are programmed in the following manner: the slurry is held at 50 °C for 1 min, heated to 95 °C within 3 min and then held at 95 °C for 2 min. It is subsequently cooled to 50 °C within 3 min and then held at 50 °C for 2 min, while maintaining a rotation speed of 160 rpm. The viscosity is expressed as rapid viscosity units (RVU) (Newport Scientific, 2012).

Statistical analysis

The chemical composition and pasting properties data obtained were subjected to one-way analysis of variance (ANOVA) using SPSS 25.0 version (SPSS Inc. USA). Significant means were separated applying Duncan's multiple range test and Pearson's correlation was also determined.

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

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

(Source: Alimi et al., 2021a)
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)

Results and discussion

Chemical properties

The chemical properties of the composite wheat-cassava (CWC) flour as affected by the variety are presented in Table 2. The values of moisture, protein, fat, ash, sugar, starch, dry matter and energy value of the composite cassava-wheat (CWC) ranged from 12.45 - 13.10 %, 10.30 - 11.65 %, 0.40 - 3.71 %, 0.58 - 0.62 %, 1.75 - 2.08 %, 70.94 - 74.40 %, 86.90 - 87.55 % and 1464.29 - 1531.66 KJ/kg, respectively, and were significantly different ($p \leq 0.05$) from each other. The protein, moisture, fat contents and energy value decreased at 10% substitution of wheat flour with high quality cassava flour prepared from low and high PPD cassava and this could be attributed to dilution effect of HQCF on the wheat flour. This is in agreement with the findings of Ajatta et al. (2016), who observed that protein, moisture and fat contents of the composite flours decreased with the increasing level of wheat flour substitution with breadfruit flour. The ash, starch, sugar, and dry matter content of the composite flours increased when wheat flour was substituted with 10% HQCF prepared from varieties of low and high PPD cassava. This could be attributed to additive effect of HQCF on wheat flour.

The lower the moisture content of a product to be stored, the better the shelf stability of such product (Sanni et al., 2006; Alimi et al., 2021b). Hence, low moisture ensures higher shelf stability in dried products. Also, the moisture content of a food is indicative of the dry matter in that food. The range of value for moisture content of CWC flour investigated in this study is similar to that reported by Ogunlakin et al. (2014). The moisture content of the CWC flour correlated significantly with the protein content ($r=0.93$, $p \leq 0.01$) (Table 4).

The mineral element present in food as measured by ash content is very essential simply because it is a parameter needed in the milling industries to estimate the yield of flour expected and highly instrumental in the identification of the milling functionality of flour (Alimi et al., 2021b).

Table 2. Chemical composition of composite cassava-wheat flour made from low PPD cassava

CCW Flour Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Sugar (%)	Starch. (%)	Dry matter (%)	Energy V. (KJ/kg)
C-C1371-W	12.45±0.07^{a}	10.40±0.00^{b}	0.40±0.50^{a}	0.61±0.00^{b}	1.75±0.00^{a}	74.40±0.57^{d}	87.55±0.07^{d}	1464.29±2.23^{a}
C-C1368-W	12.60±0.00^{b}	10.40±0.00^{b}	2.13±0.10^{d}	0.61±0.00^{b}	2.08±0.06^{b}	72.28±0.04^{b}	87.50±0.00^{d}	1499.75±0.50^{b}
C-C0593-W	12.50±0.00^{a}	10.40±0.00^{b}	1.53±0.33^{cd}	0.58±0.00^{a}	1.86±0.07^{a}	73.13±0.25^{c}	87.40±0.00^{c}	1486.02±1.63^{b}
C-C419-W	12.60±0.00^{b}	10.30±0.00^{a}	0.68±0.35^{ab}	0.58±0.00^{a}	1.82±0.06^{a}	73.73±0,30^{cd}	87.30±0.00^{b}	1466.55±1.77^{a}
C-C1412-W	12.70±0.00^{c}	10.50±0.00^{c}	1.22±0.01^{bc}	0.62±0.01^{b}	1.84±0.07^{a}	71.58±0.15^{ab}	86.90±0.00^{a}	1470.40±0.09^{a}
WHEAT	13.10±0.00^{d}	11.65±0.07^{d}	3.71±0.28^{e}	0.58±0.00^{a}	1.77±0.06^{a}	70.94±0.34^{a}	87.40±0.00^{c}	1531.66±1.41^{c}

Results are expressed as mean ± standard deviation of 3 replicate. Mean values followed by different superscript letter within a column are significantly different ($p \leq 0.05$).
CCW flour: Composite cassava-wheat Flour; M. Content: Moisture content; 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)
WHEAT: Refined wheat flour

Table 3. Pasting properties of composite wheat-cassava flour made from low PPD cassava

CCW Flour	Peak Viscosity (RVU)	Trough (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temperature (°C)
C-C1371-W	223.52±2.83^{bc}	108.07±0.00^{b}	94.92±1.65^{ab}	191.75±1.41^{b}	83.79±1.12^{a}	6.17±0.05^{b}	70.16±1.10^{a}
C-C1368-W	202.67±2.35^{ab}	109.21±2.13^{b}	90.96±2.48^{ab}	196.50±2.26^{b}	88.96±4.77^{a}	5.99±0.05^{ab}	69.00±0.59^{a}
C-C0593-W	205.96±0.88^{ab}	112.50±0.00^{b}	83.42±0.83^{ab}	198.30±1.24^{b}	85.75±1.30^{a}	6.00±0.18^{ab}	70.18±1.17^{a}
C-C419-W	180.63±0.54^{a}	95.84±2.77^{a}	84.79±2.14^{a}	139.29±3.02^{a}	80.96±2.85^{a}	6.00±1.00^{ab}	73.48±0.04^{b}
C-C1412-W	210.59±0.23^{ab}	108.55±0.53^{b}	102.04±0.30^{b}	196.35±2.98^{b}	88.21±4.89^{a}	5.90±0.42^{a}	70.18±1.24^{a}
WHEAT	247.21±1.12^{c}	129.00±1.65^{c}	118.21±0.53^{c}	253.71±1.48^{c}	124.71±1.82^{b}	5.97±0.05^{ab}	69.33±0.04^{a}

Results are expressed as mean ± standard deviation of 3 replicate. Mean values followed by different superscript letter within a column are significantly different ($p \leq 0.05$).
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)
WHEAT: Refined wheat flour

The ash content ranged from 0.58-0.62% with the flour blends prepared with HQCF from TMEB419 and wheat flour (C-C419-W), IITA-TMS-IBA-070593 and wheat (C-C0593-W) having the lowest, while flour blend prepared with HQCF from IITA-TMS-IBA-011412 and wheat flour (C-C1412-W) had the highest. The trend of increased ash content of CWC flour investigated in this study was similar to that reported by Ajatta et al. (2016). The variation in the ash content of the CWC flour could be due to genetic make-up of the constituent HQCF from low and PPD cassava used in substituting wheat flour.

Protein forms the basic building block for cells and tissue repairs in the body, and can also be correlated to the finish product attributes such as texture and appearance. The protein content ranged from 10.30-11.65% with the composite flour prepared with HQCF from TMEB419 and wheat (C-C419-W) having the lowest, while wheat flour had the highest. The protein content of the CWC flour correlated significantly with the ash content ($r=0.60$, $p \leq 0.05$), but had negative significant correlation with the dry matter ($r=-0.93$, $p \geq 0.01$) (Table 4).

Fat supplies the body with energy. The fat content ranged from 0.40-3.71% with C-C1371-W the lowest, while wheat flour had the highest. The decrease in fat content observed in this study was similar to that reported by Ogunlakin et al. (2014) and Ajatta et al. (2016). The fat content of the CWC flour correlated significantly with the energy value ($r=0.99$, $p \leq 0.01$), but had negative significant correlation with the starch content ($r=-0.83$, $p \geq 0.01$) (Table 4).

Cassava storage root on a dry weight basis contains 74-85% starch. It determines the processing characteristics of food products. The starch content ranged from 70.94-74.40% with wheat flour having the lowest, while composite flour prepared with HQCF from IITA-TMS-IBA-011371 cassava and wheat flour (C-C1371-W) had the highest (Table 1). The sugar content of the CCW flour ranged from 1.75-

2.08 % with composite flour prepared with HQCF from IITA-TMS-IBA-011371 and wheat flour had the lowest, while flour blend prepared with HQCF from IITA-TMS-IBA-011368 and wheat flour (C-C1368-W) had the highest (Table 2).The starch content of the CWC flour had negative significant correlation with the energy value (r=-0.74, p≥0.01) (Table 4).

The dry matter of food is a measurement of the mass of such food material (i.e. carbohydrates, fats, proteins, vitamins, minerals and antioxidants) when completely dried. It indicates the economic value of food products (cassava) and this is of a particular interest to farmers and food industries as it represents the true biological yield and the chemical potential of the crop. The dry matter of the CWC flour varied and ranged from 86.90-87.55 % with composite flour prepared with HQCF from IITA-TMS-IBA-011412 and wheat flour (C-C1412-W) having the lowest while flour blend prepared with HQCF from IITA-TMS-IBA-011371 and wheat flour (C-C1371-W) had the highest (Table 2). The relative increase in the dry matter content of flour blends prepared with HQCF from low and high PPD cassava varieties could be attributed to additive effect of the HQCF and wheat flour, while the variation in the dry matter contents of the composite flours prepared with HQCF from the low PPD cassava could be attributed to varietal differences of cassava roots investigated.

The energy content is an important property of food. The energy content is the amount of heat produced by the burning of 1 gram of a substance, and is measured in J/g or KJ/kg. The energy value of the CWC flour ranged from 1464.29 - 1531.66 KJ/kg with composite flour prepared with HQCF from IITA-TMS-IBA-011371 and wheat flour (C-C1371-W) having the lowest, while wheat flour had the highest, which was expected, but among the composite flours prepared from low PPD flour, flour blend prepared with HQCF from IITA-TMS-IBA-011368 and wheat flour (C1368-W) had the highest. The variation in the energy value could be attributed to a large extent on the variety differences of the cassava and the method of determination.

Pasting properties

The characteristics of composite flours are dependent basically on the characteristics of the individual constituent flour. Hypothetically, some properties may be additive, while some may not. The most common objective method of assessing the cooking property of starch-based food products is through an amylograph pasting characteristics. Information obtained from the pasting characteristics of a food correspond to the functionality of starchy food ingredients used in production processes such as baking (Defloor et al., 1994; Idowu et al., 1996; Alimi et al., 2021b) and extrusion cooking (Ruales et al., 1993). The pasting properties of the CWC flours, as affected by variety, are presented in Table 3. The values for peak viscosity, trough, breakdown viscosity, final viscosity, setback, peak time and pasting temperature ranged from 180.63 - 247.21 RVU, 95.84 - 129.00 RVU, 83.42 - 118.21 RVU, 139.29 - 253.71 RVU, 83.79 - 124.71 RVU, 5.90 - 6.17 min and 69.00 - 73.48 °C, respectively. In this study, it was observed that the pasting properties such as peak viscosity, breakdown viscosity and peak time of the cooked composite wheat-cassava (CWC) flours showed the widest variation among other properties measured.

The peak viscosity is the quantification of the highest viscosity reached when the flour is subjected to the heating and cooling regimes. It takes place after substantial fraction of the granules that swells had stopped. The peak viscosity gives a clear picture of activity of enzymes such as alpha amylase and the degree of susceptibility of starch to amylase in starch-based foods (Watson, 1984; Meera, 2010; Alimi et al., 2021b). The cassava gel strength is depicted and described by the peak viscosity. It, therefore, means that a reduced (lower) diastatic activity corresponds to an increased (higher) value of peak viscosity and vice versa (Schiller, 1984; Alimi et al., 2021b). In this study, the peak viscosity ranged from 180.63 - 247.21 RVU (Table 3). The peak viscosity of wheat flour (247.21 RVU) was found to be significantly higher than all the composite flours, indicating a relatively lower diastatic activity and higher gel strength when compared with the composite flours. Substituting wheat flour with 10% HQCF from the low and high PPD cassava varieties investigated decreased the gel strength of the resulting flour blend and this observation could be attributed to the dilution effect of starch (amylose) from HQCF on the starch content of wheat flour (Alimi et al., 2016).

Noteworthy is the fact that amongst the composite flours, flour blend prepared with HQCF from TMEB419 and wheat flour (C-C419-W), which was the only composite flour composited with high PPD cassava flour, had significantly lower peak viscosity (180.63 RVU) indicating a higher diastatic activity and lower gel strength. Also, peak viscosities occur at equilibrium between swelling of the granules (that increases the viscosity) and the granule rupture and alignment (that reduces viscosity). The relatively high swelling capacity exhibited by the composite flour prepared with low PPD cassava flour may have resulted from a weak internal bonding in the starch granules. The peak viscosity of CWC flour prepared with low PPD cassava was similar to the range of value (119-240 RVU) reported by Iwe et al. (2017). The peak viscosity of the CWC flour correlated significantly with trough, breakdown and final viscosity (r=0.81, p≤0.01; r=0.82, p≤0.01; r=0.79, p≤0.01), but had negative significant correlation with the pasting temperature (r=-0.66, p≥0.05) (Table 4).

Stability of starch granules to heating is referred to as the holding strength or trough. The trough ranged from 95.84 - 129.00 RVU (Table 3). Expectedly, the starch granules of wheat flour had the highest ability (129.00 RVU) to maintain gelatinized structure than all flour blends prepared with HQCF from the low PPD cassava under study, indicating that substitution of wheat flour with HQCF from low PPD cassava reduced the stability of the composite flour. Notably, the ability of the composite flour prepared with low PPD cassava flours to maintain gelatinized structure follows this order: C-C0593-W>C-C1368-W>C-C1412-W>C-C1371-W>C-C419-W. Also, the composite flour produced with low PPD cassava flour had a holding strength that was higher than that of the composite flour prepared with high PPD cassava flour. This trend of result for trough viscosity is similar to the findings of Ajatta et al. (2016), who observed decreased holding strength of the composite flours produced when wheat flour was substituted with breadfruit flour. The trough viscosity of the CWC flours correlated significantly with breakdown, final viscosity setback viscosity, energy value and fat (r=0.78, p≤0.01; r=0.80 p≤0.01; r=0.88, p≤0.01; r=.77, p≤0.01; r=.77, p≤0.01), but had negative significant correlation with the pasting temperature and starch content (r=-0.63, p≥0.05; r=-0.61, p≥0.05) (Table 4).

The degree of starch disintegration is depicted by breakdown viscosity value. It reveals the hot paste stability of the starch. Therefore, the higher the paste stability, the smaller the breakdown viscosity value and vice versa (Hugo et al., 2000; Bakare et al., 2012; Alimi et al., 2021b). The breakdown viscosity ranged from 83.42 - 118.21 RVU (Table 3). Worth pointing out is the fact that the hot paste formed by both composite flour prepared using high and low PPD cassava flour was more stable than that of wheat flour, revealing the additive effect of HQCF from low and high cassava on hot paste stability of the resulting flour blends. Also, the order of the hot paste stability is: C-C0593-W>C-C419-W>C-C1368-W>C-C1371-W>C-C1412-W. This trend of hot paste stability in this study is similar to the findings of Ajatta et al. (2016) and Iwe et al. (2017). The observed variation in the breakdown viscosity value of the composite flour prepared with the cassava roots studied could be attributed to varietal difference in the cassava root investigated. The breakdown viscosity of the CWC flour correlated significantly with final viscosity, setback viscosity, fat and energy value (r=0.91, p≤0.01; r=0.87 p≤0.01; r=0.73, p≤0.01; r=0.69), but had negative significant correlation with the starch content (r=-0.72, p≥0.05) (Table 4).

The final viscosity (FV) is a major pasting parameter that determines the final product quality of starch-based foods. The final viscosity ranged from 139.29 - 253.71 RVU (Table 3). Expectedly, wheat flour had significantly higher final viscosity value (253.71 RVU) than the composite flours prepared with high and low PPD cassava flour indicating that it forms a firmer gel after cooking and cooling which is attributed to the gluten network structure that confers the viscoelastic nature on wheat when compared with the composite flour prepared with HQCF from high and low PPD cassava. Relative reduction in the ability of the flour blends to form firmer gels was due to the wheat substitution with 10% HQCF from low and high PPD cassava, which could be due to the dilution effect on the starch component of wheat flour. Also, amongst the composite flours, C-C419-W, which was the only composite flour prepared with high PPD cassava flour, had significantly lower final viscosity value (139.29 RVU) indicating greater propensity to form a loose paste or gel. The ability of the composite flours to form a relatively firmer gel or paste is: C-C0593-W>C-C1368-W> C-C1412-W>C-C1371-W>C-C419-W. The final viscosity of the CWC flour studied (191.75-198.30 RVU) was within the range of value reported by Iwe *et al*. (2017).

The final viscosity of the CWC flour correlated significantly with setback viscosity, fat and energy value (r=0.79, p≤0.01; r=0.78 p≤0.01; r=0.77, p≤0.01), but had negative significant correlation with the pasting temperature and starch content (r=-0.71, p≥0.01; r=-0.66, p≥0.05) (Table 4).

The setback viscosity, when measured, has been used to describe the retogradation tendency of starch or starch-based food product. The higher the setback viscosity of a starchy food product or material, the greater the tendency toward retrogradation of its starch. The setback viscosity value ranged from 83.79 - 124.71 RVU (Table 3).

Wheat flour had relative significantly higher setback value (124.71± RVU) indicating that the tendency for retrogradation of its starch would be relatively higher than all the composite flour under study, indicating that substituting wheat flour with HQCF from low and high PPD cassava at 10% level resulted in additive effect of the HQCF on the wheat flour.

Table 4. Pearson's Correlation matrix between the pasting and chemical properties of CCW flour made with low PPD cassava

VAR	PV	TRG	BRK	FV	STB	PTM	PTE	MC	PRO	ASH	FAT	SUG	STA	DM	EV
PV	1.00														
TRG	0.81**	1.000													
BRK	0.82**	0.78**	1.00												
FV	0.79**	0.80**	0.91**	1.00											
STB	0.74**	0.88**	0.87**	0.79**	1.00										
PTM	0.15	-0.04	-0.22	-0.22	-0.22	1.00									
PTE	-0.66*	-0.63*	-0.48	-0.71**	-0.44	0.20	1.00								
MC	-0.20	-0.15	0.14	-0.11	-0.08	-0.54	0.20	1.00							
PRO	-0.06	-0.14	0.16	-0.05	-0.12	-0.42	0.01	0.93**	1.00						
ASH	0.02	-0.17	-0.07	-0.01	-0.29	-0.03	-0.39	0.30	0.60*	1.00					
FAT	0.52	0.77**	0.73**	0.78**	0.88**	-0.44	-0.51	-0.10	-0.18	-0.31	1.00				
SUG	-0.32	-0.08	-0.34	-0.12	-0.18	-0.13	-0.28	-0.12	-0.05	0.31	0.12	1.00			
STA	-0.39	-0.61*	-0.72**	-0.66*	-0.73**	0.67*	0.46	-0.44	-0.38	-0.04	-0.83**	-0.17	1.00		
DM	0.20	0.15	-0.14	0.11	0.08	0.54	-0.20	-1.00**	-0.93**	-0.30	0.10	0.12	0.44	1.00	
EV	0.54	0.77**	0.69*	0.77**	0.87**	-0.34	-0.52	-0.25	-0.32	-0.36	0.99**	0.13	-0.74**	0.25	1.00

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

VAR: Variable; TRG: Trough; BRK: Breakdown; FV: Final viscosity; STB: Setback viscosity; PTM: Peak time; PTE: Pasting temperature; MC: Moisture content; PRO: Protein; SUG: Sugar; STA: Starch; DM: Dry matter; EV: Energy value

This implies that, if the flour blends are used for baking purpose for example bread baking, bread baked with wheat flour would experience retrogradation of its starch which predisposes such bread to staling relatively faster than the bread baked with these composite flours. There was no significant difference ($p>0.05$) between the high and low PPD cassava flours in terms of setback viscosity (retrogradation tendency). Worth pointing out is the fact that amongst the composite flours (both high and low PPD), the setback viscosity value of the flour blend prepared with HQCF from TMEB419 (high PPD) and wheat flour (C-C419-W) was the least implying relatively low retrogradation tendency especially when used in baked products such as bread. The setback viscosity of the CCW flour correlated significantly with fat and energy value ($r=0.88$, $p\leq0.01$; $r=0.87$ $p\leq0.01$), but had negative significant correlation with the starch content ($r=-0.73$, $p\geq0.01$) (Table 3).
Time to reach maximum (peak) viscosity is referred to as the peak time. The requisite time for starch portion of food material to cook is referred to as the peak time. The peak time ranged from 5.90 - 6.17 min, with composite flour prepared with HQCF from IITA-TMS-IBA-011412 and wheat flour (C-C1412-W) having the lowest, while composite flour prepared with HQCF from IITA-TMS-IBA-011371 and wheat flour (C-C1371-W) had the highest value (Table 3). Substituting wheat flour with HQCF from low and high PPD cassava at 10% slightly increased the requisite time for starch portion of the composite flours to cook. The composite flour prepared using HQCF from low PPD cassava IITA-TMS-IBA-011412 and wheat flour (C-C1412-W) at 10% level of substitution had significantly lower peak time value 5.90 min, from the energy conservation point of view, using C-C1412-W flour for baking purpose in confectionery industry saves energy which is of economic value. The range (5.90 - 6.17 min) peak time value for the CWC flour investigated was within the range of value (4.33-6.62 min) reported by Iwe et al. (2017). The peak time of the CCW flour correlated significantly with the starch content ($r=0.67$, $p\leq0.05$).
The temperature at which a notable increase in viscosity of starch or flour is first observed with simultaneous swelling is known as pasting temperature. It gives information on the minimum temperature and energy costs involved in such a production process. The pasting temperature of the composite flours ranged from 69.00 - 73.48 °C. Composite flours prepared when wheat flour was substituted with HQCF from low PPD cassava and wheat flour were not significantly different in terms of pasting temperature. The composite flour prepared with HQCF from TMEB419 and wheat (C-C419-W) had significantly higher pasting temperature of 73.48 °C and was the only variety that was high PPD cassava among all the varieties under investigation. All the composite flour prepared with the low PPD cassava varieties attained gelatinization at lower temperature when compared with composite flour C-C419-W. Generally, it was observed that the pasting viscosities of the composite flour prepared with HQCF from low PPD cassava were relatively higher than that prepared with HQCF from high PPD (C-C419-W) cassava. This could be a result of the screening for low PPD (screening effect) and or varietal differences.
The insignificant difference ($p>0.05$) in pasting temperature of the composite flours prepared with HQCF from low PPD cassava and wheat flour might be due to relatively smaller proportion of HQCF (10%) compared to wheat. The gelatinization properties of the CCW flours were nearer to that of wheat than cassava flours, probably due to the replacement of wheat with a smaller quantity of cassava flour (CF 10%: WF 90%) and the additive nature of the properties inherent in the constituent flours. However, from the previous works, it was concluded that attaining gelatinization at a lower temperature led to improved bread making quality (Defloor et al., 1994). The insignificant differences ($p>0.05$) in gelatinization temperatures of wheat flour and composite flours (C-C1371-W, C-C1368-W, C-C0593-W and C-C1412-W) revealed that they were comparable in terms of pasting temperature. High peak viscosity and low breakdown viscosity (i.e. stability) were also associated with cassava starch which produces acceptable bread (Adeyemi and Omotayo, 1984). Composite flours prepared using HQCF from IITA-TMS-IBA-011368 and wheat flour at 10% (C-C1368-W) and that prepared with HQCF from IITA-TMS-IBA-070593 and wheat flour at 10% (C-C0593-W) could find application for baking purposes in baking industry, considering their peak viscosity, low breakdown (stability) and pasting time.

Conclusions

The relatively high dry matter content, protein and energy value of composite wheat-cassava (CWC) flour prepared with low postharvest physiologically deteriorated (PPD) cassava varieties gives it the nutritional competitive advantage over composite flour prepared from the high PPD cassava varieties. Considering the relatively low breakdown viscosity (i.e. stability), pasting time and high peak viscosity, the composite flours C-C1368-W and C-C0593-W are suitable for baking purpose in food industry, especially bread and cake making. Wheat flour had relatively higher tendency towards retrogradation of its starch when compared with the composite flours prepared with HQCF from low PPD cassava as indicated by its significantly higher setback viscosity, implying that bread baked with wheat flour will experience staling (bread firming) relatively faster than those baked with the composite flours investigated. Varietal differences significantly affected the protein, starch and dry matter (chemical characteristics) and peak, trough, breakdown, final viscosity and pasting temperature (pasting properties) of composite flours produced with blends of wheat and low and high PPD flours.

Author Contributions: John Praise Alimi: Conceptualization, methodology and original draft preparation, Janet Omolola Alimi: Data curation and investigation, Peter Oshiapi Iluebbey: Supervision and validation, Samuel Aondoaver Ahemen: reviewing and editing.
Funding: This research received no external funding.
Acknowledgments: 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.
Conflict of interest: Authors have no competing interests.

References

Adeyemi, I. A., Omotayo, O. O. (1984): Utilization of cocoyam flour and starch for biscuit and cake making, *Nigerian Food J.* 8, 63-73.

Ajatta, M. A., Akinola, S. A., Osundahunsi, O. F. (2016): Proximate, functional and pasting properties of composite flours made from wheat, breadfruit and cassava starch, *Applied Tropical Agriculture* 21(3), 158-165.

Alimi, J.P, Ahemen, S.A., Alimi, J.O., Iluebbey, P.O. (2021a): Functional, Physical and Rheological Properties of Composite Cassava-Wheat Flour Produced from Low Postharvest Physiological Deterioration Cassava (*Manihot esculenta Crantz*), *Asian Food Sci. J.* 20(10), 62-72. https://doi.org/10.9734/AFSJ/2021/v20i1030362

Alimi, J.P., Ahemen, S.A., Ikeme, A.I., Iluebbey, P.O., Alimi, J.O. (2021b): Physical, proximate and pasting properties of flours from selected clones of low postharvest physiological deterioration cassava, *Res. J. of Chem. Sci.* 11(3), 24-32.

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., Ishola, D.T. (2016). Effect of cowpea flour inclusion on the storage characteristics of composite wheat-cowpea bread, *J. of Agric. and Crop Res.* 4(4), 49-59. Retrievable at http://sciencewebpublishing.net/jacr/archive/2016/June/pdf/Alimi%20et%20al.pdf

Ayetigbo, O., Latif, S., Abass, A., Müller, J. (2018): Comparing Characteristics of Root, Flour and Starch of Biofortified Yellow-Flesh and White-Flesh Cassava Variants, and Sustainability Considerations: A Review, *Sustainability* 10, 3089. https://doi.org/10.3390/su10093089

Bakare, H. A., Adegunwa, M. O., Osundahunsi, O. F., Olusanya, J. O. (2012): Composition and Pasting properties of Breadfruit (*Artocarpus communis* Forst) From South West States of Nigeria, *Negerian Food J.* 30, 11-17.

Defloor, I., De Geest, C., Schellekens, M., Martens, A., Delcour, J. A. (1994): Impact of genotype and crop age on the breadmaking and physiochemical properties of flour produced from cassava (Manihot esculenta Crantz) planted in the dry season, *Journal of the Sci. of Food and Agric.* 66, 193–202.

Dubois, M., Giles, K. A., Hamilton, J. K. Rebers, P. A., Smith, F. L. (1970): Colorimetric method for determination of sugars and related substances, *Anal. Chem*. 28, 350-356.

Etudaiye, H., Nwabueze, T., & Sanni, L. (2009): Quality of fufu processed from cassava mosaic disease (CMD) resistant varieties, *African J. of Food Sci.* 3, 061–067.

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

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

Hugo, L. F., Rooney, L. W., Taylor, J. R. N. (2000): Malted Sorghum as a functional ingredient in composite bread, *Cereal Chem*. 77, 428-432.

Idowu, M. A., Oni, A., Amusa, B. M. (1996): Bread and biscuit making potential of some Nigerian cocoyam cultivars, *Nigerian Food J.* 14, 1-12.

Iwe, M.O., Michael, N., Madu, N.E., Obasi, N.E., Onwuka, G.I. (2017): Physicochemical and Pasting Properties High Quality Cassava Flour (HQCF) and Wheat Flour Blends, *Agrotech*. 6(3), 167. https://doi.org/10.4172/2168-9881.1000167

Meera, K. (2010): Falling number in wheat-how is it calculated and what does it mean to Producers? USA: USDA, ARS, Soft wheat Quality Lab. Alpha amylase mkweon-FN-012810 [1], pdf. (Accessed 19 May 2020).

Newport Scientific (2012): Newport RVA. http://www.sciencescans.com/products/newport/newport_rva. Htm Adapted from RVA-4 Series Operation manual, Newport Scientific Pty. Ltd 1995. 8th Feb., 2018@2.20pm.

Official methods of analysis, AOAC (2019): Association of Official Analytical Chemists, Vol I, 21st Edition.

Ogunlakin, G. O., Abioye, V. F., Olewepo, M. O. (2014): Evaluation of the quality attibutes of wheat composites (wheat-cassava, wheat plaintain and wheat-rice) flours in bread making, *African Journal of Biotechn.* 13, 3907-3911. https://doi.org/10.5897/AJB2013.13169

Ruales. J., Valencia, S., Nair. B. (1993): Effect of processing on the physico-chemical characteristics of quinoa flour, *Starch/Starke* 45, 13-19.

Sanni, O.L., Adebowale, A.A., Filani, T.A., Oyewole, O.B., Westby, A. (2006): Quality of flash and rotary dryer dried fufu flour, *J. Food Agric. Environ*. 4, 74-78.

Schiller, G. W. (1984): Bakery flour specifications, *CFW* 29, 647–651.

Shittu, T.A., Dixon, A., Awonorin, S.O., Sanni, L.O., Maxiya-Dixon, B. (2008): Bread from composite cassava-wheat flour II: effect of cassava genotype and nitrogen fertilizer on bread quality, *Food Res. Int*. 41, 569-578.

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

Watson, C. A. (1984): An instrument for determining alpha – amylase activity, *CFW* 29, 507–509.

Zainuddin, I., Fathoni, M., Sudarmonowati, A.E., Beeching, J.R., Gruissem, W., Vanderschuren, H. (2017): Cassava postharvest physiological deterioration: From triggers to symptoms, *Postharvest Bio. and Tech.* 9(2), 55-60.