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Comparative study on chemical and functional properties of flours produced from selected clones of low and high postharvest physiological deterioration cassava (*Manihot esculenta* Crantz)

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Abstract
The industrial usage to which flour could be put to is essentially determined by its physical, chemical and functional characteristics. This study compared the chemical and functional properties of high quality cassava flours (HQCFs) produced from low and high postharvest physiological deterioration (PPD) cassava. Wholesome four varieties of Low PPD cassava and one variety of high PPD cassava were processed into HQCFs. The flours were analyzed for chemical and functional properties. Pertinent data generated were analyzed using SPSS 25.0, Duncan multiple range tests was applied to separate significant means. Sugar, starch, amylose, cyanogenic potential, total titratable acidity and total carotenoid ranged from 4.23±0.04-5.10±0.04%, 80.54±0.57-82.30±0.15%, 31.50±0.11-33.62±0.11%, 0.02±0.00-0.51±0.01 mg/kg, 0.04±0.00-0.06±0.01% and 0.34±0.01-3.14±0.06 µg/g. Water absorption, swelling power, solubility, starch damage, oil absorption, least gelation capacity and bulk density ranged from 416.01±2.70-547.56±2.15%, 9.03±0.04-14.02±1.23, 32.63±1.21-53.62±3.31%, 3.08±0.04-3.40±0.07%, 105.19±0.55-120.56±2.06%, 7.00±1.41-13.00±1.41% and 0.53±0.01-0.66±0.01 g/cm^3. Low PPD cassava flours studied had relatively higher water absorption, swelling power, starch solubility and high gel strength than flours from high PPD, and could find application in food industry as thickeners and pharmaceutical industry for drug delivery systems.

Keywords: Functional properties, bulk density, pulverization, screening, anti-oxidative effect

1. Introduction

Low postharvest postharvest physiological deterioration (PPD) cassava (*Manihot esculenta*) is a promising crop owing to its pasting (high gel strength, starch granule stability to heating, low peak time and tendency for retrogradation) characteristics and physical properties such as appealing yellow color that constitute appeal which could influence consumer preference when applied in baked food products such as cake, bread etc. [5]

The people in the tropical areas eat cassava and array of products prepared from cassava. 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) [14]. 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 (FAO, 2020) [15]. The total production of cassava in Africa in 2018 was 169,673,737 (FAO, 2020) [15]. Nigeria produced 50,485,047 out of 169,673,737 tons.

A physiological disorder occurs in cassava at 24-72 hours postharvest, which impairs cassava palatability (Zainuddin *et al.*, 2017; Alimi *et al.*, 2021) [37, 5]. Cassava is known to have a short postharvest or storage life and this is connected to a phenomenon regarded as "postharvest physiological deterioration (PPD)". This challenge necessitate quick transportation of cassava to processing point and this challenge warrant the screening of available cassava clones for low PPD or extended postharvest or storage life, improvement in the nutritional value, yield and functional properties, thereby providing solution to the constraints encountered in cassava value chain.

Unfavorable soil and climatic conditions had been identified as a constraint to optimum production of wheat in some regions, and as such, countries in those regions would largely depend on importation of wheat. The Nigerian Government mandated the flour mills to replace wheat flour with high quality cassava flour up to 10% (Shittu *et al.*, 2008; Alimi *et al.*, 2016) [30, 4].

Shittu *et al.* (2008) and Alimi *et al.* (2016) explored the partial replacement of wheat flour with flours from cassava and cowpea up to 30% for bread production respectively in order to minimize the over-reliance on wheat importation for industrial application [30, 4].

Screening of available clones of cassava for low PPD was considered a priority with the view to extending the postharvest life of cassava root from two days (48hrs) to 5 days (120hrs), enhancement of its nutritional value with pro-vitamin A or β-carotene and widening the functionality of its products (starch and flour). Researchers had established that clonal differences affects quality characteristics like physical, functional and chemical properties of high quality cassava flour, indicating that flour quality and uses also differs (Aryee *et al.*, 2006; Shittu *et al.*, 2008; Alimi *et al.*, 2021) [10, 30, 5].

Carotenoids have been found to improve the immune response of human health; with the propensity to decrease the possibility of eye diseases such cataracts, cancerous cells development and heart diseases. This has been made possible as a result of the production of substances that protects cells from the damage caused by free radicals (Olson, 1999; Alimi *et al.*, 2021b) [24, 6].

The indices determining the usage of flour in food industry includes the physical, chemical and functional characteristics of such flour. This study therefore compared the functional and chemical characteristics of flours produced from selected screened cassava varieties for delayed or low and high postharvest physiological deterioration (PPD).

2. Materials and Methods

2.1 Materials

The materials used for this study includes five clones of cassava from which high quality cassava flours (HQCFs) were produced. Four out of the five clones of cassava were basically yellow-fleshed low postharvest physiological deterioration cassava (IITA-TMS-IBA011368, IITA-TMS-IBA070596, IITA-TMS-IBA011412 and IITA-TMS-IBA011371) while one was white-fleshed which was of high postharvest physiological deterioration cassava (TMEB419). International Institute of Tropical Agriculture (IITA) Ibadan provided the cassava while the refined wheat flour was obtained from Nigerian Eagle Flour Mills of Nigeria, Ibadan.

2.2 Production of cassava flour used in the study

Wholesome cassava used for this study was provided by International Institute of Tropical Agriculture (IITA) and was used to produce the flour. The wholesome cassava roots were subjected to unit operations such as peeling, washing, grating, dewatering, granulating, drying, milling, cooling and packaging to produce high quality cassava flours (HQCFs). The processing of the roots into high quality cassava flours was done as described by Alimi *et al.* (2021) [5].

2.3 Chemical composition of the high and low PPD cassava flour

2.3.1 Carotenoid content determination

Carotenoids were manually extracted from samples using cold acetone and partitioned using Petroleum ether. The extraction with acetone was done using 10g of the representative flour samples was used. This was transferred to mortar, 50 mls of cold acetone was added, 2g of cellite was added and left to stay for 2 hours. The resulting solution was separated with suction via Buchner funnel using Whatmann 90mm paper. The separation process was done two times until the residue is colorless. Exactly 10ml of petroleum ether together with 5ml of water in a separating funnel was added to acetone extract. De-ionzed water of about 200ml gently was added, allowing it to flow down the sides (i.e. walls) of the funnel. The aforementioned separation operation resulted into two different phases, the upper and lower aqueous. Washing was done thrice using 100ml of water per time. 150ml of brine was added, the lower fraction was removed at the last washing. The petroleum ether (PE) phase, going through the solution via a small funnel containing anhydrous sodium sulphate. The extract made up to 25ml with petroleum ether and left to settle, subsequently the absorbance was read instrumentally with the aid of a spectrophotometer at 450nm (Rodriguez-Amaya and Kimura, 2004) [27].

Calculate total carotenoid (TC) using this formula:

$$TC\ (\mu g/g) = \frac{A \text{ x volume (ml)x DF x } 10^4}{A^{1\%}_{1cm} \text{ x weight of sample (g)}}$$

Where:
A signifies absorbance;
DF signifies dilution factor;
Volume is equivalent to the total volume of extract (25ml)
($A^{1\%}_{1cm}$) indicated absorption co-efficient of carotene present in petroleum ether

2.3.2 Cyanide Potential Determination (CNP)

Cyanide content of the high quality cassava flours was determined following the alkaline picrate procedure with slight modifications (Onwuka, 2005) [25].

2.3.3 Amylose, Starch and Sugar

Rapid colorimetric method was applied in estimating amylose value for the low PPD cassava flour (Williams *et al.*, 1970) [35]. Phenol-sulfuric method was followed in the determination of sugar and starch content (Dubois *et al.*, 1970) [13].

2.3.4 Degree of acidity

The pH of the low PPD cassava flours were evaluated by measuring a known quantity of flour sample specifically 10 g and was then introduced into a beaker containing 50 ml of water obtained from distillation process. The resulting solution which was based on 1:5 (w/w) ratio was left for 5 min to ensure proper dissolution. The degree of acidity or alkalinity was eventually determined using a digital type of pH meter with Model number 720A, produced by Orion Research Incorporation, United State of America.

2.3.5 Titratable acidity (TTA)

The total titratable acidity was estimated by measuring ten grams (10 g) of the flour which was introduced into water obtained from a distillation process. The resulting solution was left for 5 min, after which 10 mL aliquot was used for the titration with NaOH having normality of 0.1. After noting the titre value, TTA value was then estimated following the relationship below:

1 mL NaOH = 0.009mg lactic acid

2.4 Functional characteristics of low PPD cassava flour
2.4.1 Starch damage
The reduced destructive impact of processing stress on the integrity of starch granules as measured by starch damaged of cassava flour sample was evaluated adapting method described by McDermott (McDermott, 1980) [22].

2.4.2 Water absorption capacity, solubility and swelling power
Flour propensity to absorb water, put differently, the ease of the flour being soluble in water and the ability of the flour to be swollen after absorbing water were determined following the method of Ruales *et al.*, (1993) [29] using two and a half gram sample.

2.4.3 Oil absorption capacity
The capacity of low PPD cassava flours in absorbing oil as measured by oil absorption potential was evaluated following the protocols of Sosulski, Abbey and Ibeh's [32, 1].

2.4.4 Least gelation properties
The propensity of a flour food material to give gel which is referred to as gelation potential was evaluated (Adebowale *et al.*, 2005) [3].

2.4.5 Bulk density determination
The ratio of flour particle size to the volume they occupy as measured by bulk density was evaluated following the protocols of Narayana and Narasinga-Rao [23]. Low PPD cassava flour about 50 g was weighed and introduced into a measuring cylinder. Measuring cylinder was then tapped using fingers till no noticeable shift in the volume occupied by the flours. The initial weight and the eventual height denoting volume of HQCF in the measuring cylinder noted, weight, and volume difference were recorded, bulk density was then estimated in g/cm^3.

2.5 Statistical analysis
The chemical and functional characteristic data obtained were analyzed using SPSS 25.0 version (SPSS Inc. USA) and significant means were separated applying Duncan's multiple range test.

3. Results and Discussion
Chemical properties of low PPD cassava flours investigated are presented in Table 1. In cassava roots, sugars such as glucose, sucrose and maltose are present. In this study, the differences in the sugar content of low PPD cassava was significant ($p< 0.05$) and ranged from 4.23±0.04 to 5.10±0.04% with TMEB 419 having the minimum value while the maximum was recorded in IITA-TMS-IBA-070593. TMEB 419 variant being the only high postharvest physiological deteriorated cassava amongst the variant studied which had significantly lower sugar content. The result of this study is in consonance with the findings reported by Anggraini *et al.* (2009) [8] in which it was particularly noted that cassava variety having yellow flesh are sweet and added that the white cassava roots could be bitter or sweet. This phenomenon is variant-dependent. Sugar content of the high and low PPD cassava flours correlated significantly ($r=0.680$, $p\leq0.05$; $r=0.886$, $p\leq0.01$; $r=-0.680$, $p\geq0.05$; $r=-0.644$, $p\geq0.05$) with cyanogenic potential and propensity of the flours to absorb oil as indicated by oil absorption capacity, but correlated negatively with amylose content and least gelation capacity (Table 3).

Food industries found cassava starch important as a substance capable of forming gel, having ability to bind and maintain textural characteristics of food component (Gu *et al*., 2013; Fortuna and Gakowska, 2006; Leszczyñski, 2006) [17, 16, 20]. Cassava roots compositionally contains 74%–85% starch when dried (Rickard *et al.*, 1991) [26]. Almazan (1992), observed that the factors guiding the ease of processing and eating properties of food products are basically two namely starch and amylose composition of such food [7]. The cassava flours were not significantly different ($p> 0.05$) from each other with regard to starch content which ranged from 80.54±0.57 to 82.30±0.15%, IITA-TMS-IBA-011371 had the minimum and the maximum value was recorded in TMEB 419. The starch content of flours prepared from low postharvest physiological deteriorated cassava varied between 80.54 - 81.12%. Aniedu and Omodamiro (2012) [9] reported that yellow fleshed cassava roots had minimum starch content while that from white cassava roots had maximum values when averaged (Aniedu and Omodamiro, 2012; Maziya-Dixon *et al*, 2005) [9, 21]. Variation in the starch content of cassava roots could be due to clonal differences and age of cassava root when harvested (Maziya-Dixon *et al*, 2005) [21]. The noticeable relative decrease for starch content of low PPD (yellow) cassava roots in comparison with that of high PPD (white) could be adduced to the characteristic molecular structure such as branching enzymes for starch synthesis, and enzyme activities such as starch synthases that are soluble and starch synthase that are bound in the granule that had decreased activity in low PPD cassava (Kossmann and Lloyd, 2000) [19].

Worth mentioning is the fact that amylose and amylopectin has been noted to exhibit a functional and compositional roles in starch of crops especially that of cassava starch, showing tendencies to influence properties such as the extent of structural order in a food matrix, the gel forming propensity of starch, pasting behavior and realignment of amylose and amylopectin in a cooked starch. The variation in amylose content of the cassava flours were significant ($p<0.05$), it was between 31.50±0.11% and 33.62±0.11%, with IITA-TMS-IBA-070593 having the minimum while IITA-TMS-IBA-011412 had the maximum value.

Table 1: Chemical composition of low PPD cassava flour

Cassava. Var.	Sugar (%)	Starch (%)	Amylose (%)	CNP (mg/kg)	TTA (%)	TC (µg/g)	pH
011368	4.65±0.08^c	80.57±0.57^a	32.44±0.11^c	0.04±0.01^a	0.06±0.01^a	0.74±0.01^b	5.85±0.06^b
070593	5.10±0.04^d	81.12±0.29^a	31.50±0.11^a	0.51±0.01^c	0.05±0.01^a	2.62±0.01^c	5.58±0.01^a
011412	4.39±0.01^b	80.66±0.42^a	33.62±0.11^e	0.02±0.00^a	0.04±0.00^a	0.75±0.01^b	5.51±0.06^a
011371	4.33±0.05^{ab}	80.54±0.57^a	31.97±0.11^b	0.32±0.03^b	0.06±0.01^a	3.14±0.06^d	5.76±0.01^b
419	4.23±0.04^a	82.30±0.15^b	33.23±0.11^d	0.02±0.01^a	0.05±0.01^a	0.34±0.01^a	6.09±0.00^c

Results are expressed as mean ± standard deviation of 3 replicate. Mean values followed by different superscript letter within a column are significantly different ($p\leq0.05$).
Cassava var.: Cassava variety; CNP: Cyanogenic potential; TTA: Total titratable acidity;
TC: Total carotenoid; 011368: IITA-TMS-IBA-011368; 070593: IITA-TMS-IBA-070593; 011412: IITA-TMS-IBA-011412; 011371: IITA-TMS-IBA-011371; 419: TMEB 419

The extent of structural order in cassava starch having low amylose was found to be higher which stipulate a decreased amorphous band (Tukomane *et al.*, 2007) [33], and a high amylose starch realigns with ease (Rodrıguez-Sandoval *et al.*, 2008) [28].

The order of suitability of these cassava flours studied for baking purpose based on their amylose contents, their retrogradation tendencies was: **(**IITA-TMS-IBA-070593> IITA-TMS-IBA-011371> IITA-TMS-IBA-011368> TMEB419> IITA-TMS-IBA-011412) Table 1. Amylose content of the cassava flours correlated significantly with the bulk density (r=0.963, p≤0.01; r=-0.887, p≥0.01; r=-0.815, p≥0.01) but correlated negatively with cyanogenic potential (CNP) and total carotenoid, respectively (Table 3).

The values for the cyanogenic potential (CNP) of the low PPD HQCFs ranged from 0.02±0.00 to 0.51±0.01 mg/kg, two flours namely IITA-TMS-IBA-011412 and TMEB 419 had the minimum while the maximum value was recorded in flour prepared from IITA-TMS-IBA-070593. The cyanogenic potential of the cassava flours correlated significantly with the total carotenoid (TC) but correlated negatively with the bulk density (r=0.893, p≤0.01; r=-0.809, p≥0.01), respectively (Table 3).

High and low PPD cassava flours were not significantly different ($p>$ 0.05) from each other with regards to total titratable acidity, values ranged from 0.04±0.00 to 0.06±0.01%, IITA-TMS-IBA-011412 had the minimum and the maximum value was recorded in flour prepared from IITA-TMS-IBA-011368 and IITA-TMS-IBA-011371 respectively. The total treatable acidity of the flours correlated significantly with flour solubility (r=0.649, p≤0.05), respectively.

Carotenoids have been found effective in maintaining healthy metabolism and diseases prevention of the human body. Beta (β) carotene was found to be present in substantial quantity in yellow cassava than other carotenoids that takes part in the synthesis of the vitamins especially, vitamin A (Wolf, 1982) [36]. The low PPD cassava flours differed significantly ($p<0.05$) in total carotenoids (TC), the value ranged from 0.34±0.01 to 3.14±0.06 μg/g, TMEB419 (high PPD) had the minimum and flour prepared from IITA-TMS-IBA-011371 recorded the maximum (low PPD) value. The observed results on total carotenoids was expected in that all the yellow fleshed low PPD cassava contained varied carotenoid content except TMEB 419 which was cassava root with high PPD and was white in color (Table 2). This study recorded higher TC values than (0.6–0.88 μg/g) that which was reported by Aniedu and Omodamiro (2012) [9]. The concentrations of total carotenoid differed by variant (i.e. variety) when some production processes were applied (Tukomane *et al*., 2007) [33]. The total carotenoid of the flours correlated significantly with the ability of the flour to absorb water, swelling power of the HQCF but correlated negatively with bulk density of the HQCF (r=0.695, p≤0.05; 0.763, p≤0.05; -0.821, p≥0.01), respectively (Table 3).

The functional characteristics of HQCFs produced from five clones of cassava (low and high PPD) are presented in Table 2. Functional characteristics of a food material, especially flour are known to depict the usage of such food material [5].

The ability of cassava flour to absorb water as measured by water absorption capacity ranged from 416.01±2.70 to 547.56±2.15%, flour produced from TMEB 419 had the minimum and the flour prepared from IITA-TMS-IBA-011371 had maximum. The ability of low PPD cassava flour to absorb water ranged from 431.20±2.63 to 547.56±2.15%, and notably the low PPD cassava flours (yellow fleshed) had higher water absorption capacity than the high PPD (white flesh) cassava. The observed relatively high water absorption of low PPD cassava flour was alike that of Awoyale *et al*. (2015) [11]. The propensity of the flours to absorb water (water absorption capacity) had a significant correlation (r=0.706, p≤0.01) with swelling power, respectively (Table 3).

The absorption and subsequent binding of water by hydrogen bonds describes a phenomenon known as “starch swelling”, this has been explored and applied as substance to increase the consistency of food products (i.e. thickener) in industries, especially food industry. Substance having tendency to increase consistency in food (thickening effect) is essential in foods which includes but not limited to breakfast gruels and baby foods. The value 7.98±0.16 swelling power for TMEB419 (white fleshed) was significantly lower in comparison with the low PPD (yellow fleshed) cassava flour which ranged from 9.76±0.40 to 14.02±1.23. The difference in the flours’ ability to absorb and bind water between high and high PPD clones investigated, depends on the inherent genetic constituents of the cassava clones under consideration.

It is important to point out that the flours’ ability to absorb and bind water could be affected by an array of parameters such as the ratio of amylose to that of amylopectin, binding forces between the granules, the shape and size of the granules (Singh *et al.*, 2004) [31].

A situation whereby the ability of a starch to swell is restricted, the presence of amylose is suspected, the reason being that amylose starch is noted for its diluting effect (Hoover, 2001) [18]. The ability of the HQCF to swell had significant correlation ($p<0.05$) with the ability of flour’ solubility (r=0.873, p≤0.01) (Table 3).

Solubility of cassava starch has found application in degradable excipients in drug delivery systems. Solubility of the cassava flour ranged from 32.63±1.21 to 53.62±3.31%, flour from IITA-TMS-IBA-011412 had the minimum and the flour prepared from IITA-TMS-IBA-011371 recorded the maximum value. Solubility of cassava flour correlated negatively with the flour’ bulk density (r=-0.661, p≥0.05) (Table 3).

Starch damage of cassava flours ranged from 3.08±0.04 to 3.40±0.07%, flour prepared from IITA-TMS-IBA-011368 had the minimum while that prepared with IITA-TMS-IBA-011412 had the maximum value. Starch damage of high quality cassava flours prepared with clones of low PPD cassava ranged from 3.08±0.04 to 3.40±0.07%. The generally low levels of starch damage in the flours indicated that the processing had infinitesimal impairment on the integrity of the starch granules.

Oil absorption capacity is an important determinant of flavor retention and consequently improves the palatability of foods. The oil absorption capacity of HQCFs ranged from 105.19±0.55 to 120.56±2.06%, flour prepared from IITA-TMS-IBA-011368 had the minimum, whereas flour from IITA-TMS-IBA-011371 absorbed maximally. Flours from IITA-TMS-IBA-011368 and IITA-TMS-IBA-011412 were not significantly different ($p>$ 0.05), likewise flours from IITA-TMS-IBA-011371 and TMEB 419 were not significantly different in terms of oil absorption capacity.

Clonal differences of the cassava roots investigated could be adduced for the differences noticed in the ability of low postharvest physiological deteriorated cassava flours to retain flavor and improve palatability as measured by the oil absorption capacity. These low PPD cassava flours can find application in food formulation where moderate oil absorption capacity is required such as in pastries and bakery products production.

Table 2: Functional properties of low or delayed PPD cassava flour

C. Var.	Water Absorption C. (%)	Swelling Power	Solubility (%)	Starch Damage (%)	Oil Absorption C. (%)	Least Gelation C (%)	B. Dens. (g/cm^3)
011368	431.20 ± 2.63^{a}	9.76 ± 0.40^{b}	45.44 ± 2.91^{bc}	3.08 ± 0.04^{a}	105.19 ± 0.55^{a}	9.00 ± 1.41^{a}	0.57 ± 0.00^{b}
070593	476.08 ± 2.77^{b}	9.38 ± 0.50^{ab}	37.37 ± 2.10^{ab}	3.38 ± 0.04^{bc}	112.58 ± 0.33^{b}	13.00 ± 1.41^{b}	0.53 ± 0.01^{a}
011412	508.40 ± 3.86^{bc}	9.03 ± 0.04^{ab}	32.63 ± 1.21^{a}	3.40 ± 0.07^{c}	106.11 ± 1.13^{a}	7.00 ± 1.41^{a}	0.66 ± 0.01^{d}
011371	547.56 ± 2.15^{c}	14.02 ± 1.23^{c}	53.62 ± 3.31^{c}	3.30 ± 0.07^{bc}	120.56 ± 2.06^{c}	7.00 ± 1.41^{a}	0.53 ± 0.00^{a}
419	416.01 ± 2.70^{a}	7.98 ± 0.16^{a}	35.28 ± 2.65^{ab}	3.25 ± 0.00^{b}	118.47 ± 1.95^{c}	13.00 ± 1.41^{b}	0.62 ± 0.01^{c}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter within a column are significantly different ($p\leq0.05$).

C. var.: Cassava variety; Water Absorption C.: Water absorption capacity; Oil Absorption C.: Oil absorption capacity; Least Gelation C.: Least gelation capacity; B. Dens.: Bulk density; 011368: IITA-TMS-IBA-011368; 070593: IITA-TMS-IBA-070593; 011412: IITA-TMS-IBA-011412; 011371: IITA-TMS-IBA-011371; 419: TMEB 419

Table 3: Pearson's correlation matrix among the chemical and functional properties of the low PPD cassava flour

PAR	SUG	STA	AMY	TTA	CNP	TC	pH	WAC	SWE	SOL.	OAC	STD	LGC	BD.
SUG	1.000													
STAR	-0.204	1.000												
AMY	-0.680*	0.268	1.000											
TTA	0.229	-0.194	-0.477	1.000										
CNP	0.680*	-0.184	-0.887**	0.258	1.000									
TC	0.375	-0.379	-0.815**	0.374	0.893**	1.000								
Ph	-0.487	0.623	0.173	0.188	-0.413	-0.379	1.000							
WAC	-0.071	-0.481	-0.214	0.009	0.418	0.695*	-0.575	1.000						
SWE	-0.127	-0.601	-0.492	0.421	0.421	0.763*	-0.129	0.706*	1.000					
SOL.	-0.086	-0.553	-0.516	0.649*	0.272	0.559	0.151	0.292	0.873**	1.000				
OAC	0.886**	0.054	-0.384	-0.156	0.538	0.149	-0.517	-0.135	-0.435	-0.485	1.000			
STD	0.107	-0.023	0.023	-0.468	0.409	0.353	-0.607	0.548	0.033	-0.369	0.348	1.000		
LGC	-0.644*	-0.473	0.624	-0.294	-0.561	-0.241	-0.26	0.411	0.242	0.089	-0.58	0.081	1.000	
BD.	-0.533	0.257	0.963**	-0.622	-0.809**	-0.821**	0.036	-0.245	-0.608	-0.661*	-0.198	0.152	0.555	1.000

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

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

PAR: Parameter; SUG: Sugar; STA: Starch; AMY: Amylose; TTA: Total titratable acidity; CNP: Cyanogenic potential; pH: Degree of acidity; WAC: Water absorption capacity; SWE: Swelling power; SOL.: Solubility; OAC Oil absorption capacity; STD: Starch damaged; LGC: Least gelation capacity; BD.: Bulk density

One functional property of importance on which incorporation of an ingredient or substance is premised or dependent on in food product development is referred to as 'gelation capacity' (Adebowale *et al*., 2008) [2]. The least gelation capacity of the flours ranged from 7.00±1.41 to 13.00±1.41%, flours prepared from IITA-TMS-IBA-011412 and IITA-TMS-IBA-011371 had the minimum value whereas flour prepared from IITA-TMS-IBA-070593 and TMEB 419 recorded the maximum value. There was insignificant difference (p> 0.05) in the propensity of flours prepared from IITA-TMS-IBA-011368, IITA-TMS-IBA-011412 and IITA-TMS-IBA-011371 to absorb oil, the same applies to flours prepared from IITA-TMS-IBA-070593 and TMEB 419.

Gelling capacity of a food material as measured by least gelation capacity connotes that little quantity of flour is needed to make food gels of the same consistency and this considered a favorable economic impact. From the foregoing, flours prepared from IITA-TMS-IBA-011412 and IITA-TMS-IBA-011371 cassava has the ability to make food gels of same consistency with little quantity of flours. Inherent genetic constituents of the cassava roots studied could be adduced for the noticeable differences in gellying capacity of the high quality cassava flours prepared from low postharvest physiological deteriorated cassava.

Food materials that are particle-like in nature require that they are compact so as to make their transportation from one place to the other easy and this is referred to as the bulk density. The HQCFs prepared from low postharvest physiological deteriorated cassava had their bulk densities varied between 0.53±0.01 to 0.66±0.01 g/cm^3 (Table 2). Bulk density for HQCF prepared with the low PPD cassava flours was 0.53-0.66 g/cm^3. Flour prepared from clone IITA-TMS-IBA-011412 gave highest bulk density (0.66 g/cm^3), while cassava variety IITA-TMS-IBA-070593 had the least (0.53 g/cm^3) value. The range of value for bulk density in this present study of cassava flours is similar to the range reported by Aniedu and Omodamiro (2012) [9].

Generally, it is pertinent to remark that low PPD cassava flours investigated in this study had relatively higher and desirable functional properties (water absorption, swelling power, solubility and high gel strength) than the high PPD cassava flours which are of great importance in food and pharmaceutical industry. Noteworthy, screening of cassava varieties for low PPD gave rise to high quality cassava flours of improved chemical (sugar, amylose, CNP and TC) and functional characteristics when compared with flours from high PPD cassava.

4. Conclusion

Low postharvest physiological deteriorated (PPD) cassava flours investigated in this study had relatively higher and desirable functional properties (water absorption, swelling power, solubility and high gel strength) than the high PPD cassava flours and this is of great importance in industries such as food and pharmaceutical. The relatively high swelling power of the low PPD cassava flour over flours from high PPD could be prospected and used as substance that increase consistency (i.e. thickener) which is basically required in the formulation of baby foods, breakfast cereals and soups. The carotenoids content of low PPD flours from low PPD cassava could be of health benefits in improving body metabolism and prevent disease owing the ability to reduce oxidation.

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