Journal homepage: www.fia.usv.ro/fiajournal
Journal of Faculty of Food Engineering,
Ştefan cel Mare University of Suceava, Romania
Volume XXIII, Issue 4- 2024, pag. 57 - 73

FOOD AND ENVIRONMENT SAFETY

PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF FLOUR BLENDS FROM CASSAVA, WHEAT AND BAMBARA GROUNDNUT (*Vigna subterranea*)

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Received 3 May 2024, accepted 13 December 2024

Abstract: *High quality cassava flour from low postharvest physiologically deteriorated cassava variety (IITA-TMS-IBA011368) was blended with flour from wheat and Bambara groundnut and analyzed for physicochemical and functional properties to determine their suitability for use in baking industry. D-Optima design was used for combination of the flours. Data obtained were subjected to analysis of variance using SPSS 25.0 and significant means were separated using Duncan Multiple Range Tests. Results indicated the flour blends were not significantly ($p \geq 0.05$) different in flour lightness (L*), greenness (a*), yellowness (b*) but were significantly different in bulk density, with ranges: 33.32 to 49.90, -1.20 to -3.01, 5.81 to 7.79 and 0.70 to 1.00 g/ml, respectively. The physicochemical properties measured were significantly ($p \leq 0.05$) different. The swelling index, water absorption capacity, solubility index, least gelation capacity and oil absorption capacity of the flour blends ranged from 0.71 to 0.91%, 0.19 to 1.24%, 4.23 to 21.67%, 0.17 to 0.30% and 0.92 to 2.27%, respectively. The pasting properties of the flour blends varied significantly ($p<0.05$) and ranged from 110.67 to 162.84 RVU, 53.88 to 77.96 RVU, 51.25 to 84.88 RVU, 92.34 to 158.92 RVU, 37.29 to 80.96 RVU, 5.34 to 5.93 min and 74.35 to 95.13 °C for peak, trough, final, breakdown, setback viscosities, peak time and pasting temperature, respectively. Blending wheat flour with flours from cassava and Bambara groundnut improves the physical, functional and the pasting profile of the composite flour. Flour blends $HQCF_{10.00}WF_{61.88}BNF_{28.12}$, and $HQCF_{14.65}WF_{70.00}BNF_{15.35}$ are suitable bread and pastry production based on their pasting and functional properties.*

Keywords: *Bulk density, water absorption capacity, proximate composition, Zeleny, baking quality*

1. Introduction

Wheat has been the staple food of the major civilizations in Europe, Western Asia, and North Africa for 8,000 years. The composition of wheat flour includes moisture, protein, total ash, crude fiber and fatty acid with average values of 12.4%, 11.8%, 1.3%, 2.0% and 77 mg, respectively [1]. The typical functional properties of wheat include emulsification, water binding capacity, viscosity, foaming, solubility and gelation capacity. Wheat flour provides the structure of baked food products. It contains proteins that interact with each other when mixed with water, forming gluten [2]. Averagely, within the space of 2010 and 2020, Nigeria produced just 2.06 per cent of the total amount of wheat consumed which was infinitesimal, the aforementioned point possibly explains why the prices of wheat-base food products in Nigeria has been on the increase due to high cost of wheat

DOI: https://doi.org/10.4316/fens.2024.022

importation. Therefore, the need to prospect flour from other crops such as Bambara groundnut, cowpea and cassava is a right step in the right direction. One of such crops is cassava, from which gluten-free high quality cassava flour with promising food functional properties. The HQCF can be constituted into composite protein-enriched baking flour when blended with flour from Bambara groundnut. There is an increasing interest in the use of HQCF (gluten-free) for food and industrial purpose especially in the baking industry in Nigeria [1, 3]. HQCF is can be derived from low postharvest physiologically deteriorated cassava known to have carotenoid content that can improve the immune response of human health. High quality cassava flour from low postharvest physiologically deteriorated cassava is a promising in food industry owing to its pasting characteristics (high gel strength, starch granule stability to heating, low peak time and tendency for retrogradation) characteristics and physical properties such as appealing creamy color that constitute appeal which could influence consumer's acceptability and preference when applied in baked food products such as bread, cakes and biscuits [3]. The pasting profile of HQCF produced from selected varieties of low postharvest physiologically deteriorated cassava revealed that flour from IITA-TMS-IBA-011368 followed by IITA-TMS-IBA-070593 are suitable for baking purposes [3]. There is an undeniable fact that many African homes resort to Bambara groundnuts as their sole meal due to its significance as a highly nutritive food crop ranked next to cereals in caloric and protein content, an inexpensive food, and an essential leguminous food commodity after cowpea and groundnut [4, 5, 6]. Bambara is a potent nutraceutical having anti-diabetic and anti-cancer properties due to its content of vitamin C content. It has high soluble carbohydrate [5] and good water absorption capacity [6] that corresponds to an increased baking quality (loaf volume). Some of the proximate composition of Bambara groundnut includes 18–21% protein, 6–8% fat, 8–10% moisture, 1.2–2.6% ash and 54–60% carbohydrates [7]. Bambara groundnut flour is relatively low in carbohydrates when compared to maize, wheat, millet and cassava flours. The ability of food material to absorb oil as measured by oil absorption capacity determines the extent to which such a food material can retain or enhance flavor. This aforementioned functional property makes Bambara groundnut flour suitable for the development of ready-to-eat foods such as bread, biscuits, cookies, sausage and chinchin. High quality cassava flour from low postharvest physiologically deteriorated is gluten-free flour that could be beneficial for celiac patients [9]. Therefore, this study was conducted to assess the physicochemical and functional properties of flour blends from cassava, wheat and Bambara groundnut.

2. Materials and methods

2.1. Materials

Cassava roots (IITA-TMS-IBA-011368), Bambara groundnut, refined wheat flour was provided by Nigerian Eagle Flour Mills of Nigeria, Ibadan.

2.1.1 Methods

2.2. Production of high-quality cassava flour (HQCF)

Wholesome cassava roots used for this study and provided by IITA-TMS-IBA011368 were processed into high quality cassava flour (HQCF). About 143.20 g of cassava root (IITA-TMS-IBA011368) was peeled manually with stainless steel knives. The peeled cassava was washed, grated, pressed and pulverized. The weight after pulverization was 34.70 g and thereafter, flash drying was done at 120 °C for 8 minutes. The dried (22.22 g) cassava grit was milled into fine high quality cassava flour (HQCF) with the aid of a cyclone hammer mill to which a screen with aperture size of 250 was fixed for sieving; the weight after sieving was 21.92 g, while the spent chaff was 0.3 g. The sieved cassava flour was allowed to cool and packed into high density polyethylene bag, sealed, ready for subsequent analysis [3, 10].

2.3. Production of Bambara nut flour (BNF)

Wholesome Bambara groundnuts seeds were procured from Mokwa, Niger State. The seeds were manually sorted to remove broken, insect-infested seeds and other foreign materials. Bambara groundnut seeds were soaked for 24 h, and thereafter dried at 70 ºC for 14 h to obtain moisture content of maximum 12%. The soaking water was decanted at 6 h interval to facilitate dehulling, reduces nutrient loss associated with soaking, and also the anti-nutritional component from the nut into the soaking water. The soaking process was followed by sprouting for up to 72 h [11] purposely to reduce the carbohydrate and lipid content of the sprouts [12], enhance the protein content and amino acid profile.

The germinated nuts were allowed to drain properly, spread on the drying trays and dried using NSPRI parabolic shaped solar dryer (PSSD) at 60 ºC dried for 24 hours. The dried Bambara nuts were packed, allowed to cool, milled into fine flour, sieved with 250-micron mesh and packaged in high density polyethylene bags for subsequent analyses.

2.4. Wheat flour (WF)

The refined wheat flour used for this study was provided by Nigerian Eagle Flour Mills of Nigeria, Ibadan.

2.5. Experiment Design for the experiment

D-Optima design was used for the combination of the flours. Therefore, a total of 16 samples were generated while the control (wheat) sample was the seventeenth. High quality cassava flour was blended with wheat and Bambara groundnut flour as indicated in Table 1.

2.6. Composite flour preparation

The sixteen different blends of flour from cassava, wheat and Bambara flour (Table 1) as depicted by Design Expert are used in the composite cassava-wheat-bambara (CWB) flour production. The flour from cassava, wheat and Bambara flour were blended together using a mixer and were subsequently stored in an airtight container before use for analyses and baking experiment.

2.7. Physicochemical analyses on the composite flour

2.7.1. Physical properties of composite CWB flour:

The physical properties of composite flour determined include the color parameters (L*, a*, b*) and bulk density. The surface color of the flour blends was determined objectively with the aid of a Colorimeter (ColorTec PCMTM Accuracy microsensors Inc., USA) while the bulk density was determined by simply getting a graduated measuring cylinder of 10 mL weighed and fill the flour carefully into it. The cylinder at the bottom was gently tapped on the bench in the laboratory several times until there was no visible reduction in the sample level after filling to the mark of 10 mL. The bulk density is calculated as weight of sample (g)/ volume of sample (mL) [13].

2.8. Chemical properties of the flour blends

The physicochemical properties of the

Table 1

Composition of the flour blends

Sample /Run	HQCF	WF	BNF
1	14.65	70.00	15.35
2	10.00	61.88	28.12
3	28.62	61.38	10.00
4	15.00	50.00	35.00
5	24.97	53.16	21.87
6	14.65	70.00	15.35
7	24.97	53.16	21.87
8	28.62	61.38	10.00
9	32.87	50.00	17.13
10	15.10	63.67	21.23
11	40.00	50.00	10.00
12	17.46	55.18	27.36
13	22.90	60.26	16.84
14	22.08	67.92	10.00
15	15.00	50.00	35.00
16	10.00	61.88	28.12
***17**	0.00	100.00	0.00

composite CWB flour were determined instrumentally using Perten IM9520. 3 ± 0.00 g of the composite flour was weighed into a cuvette and placed into the holder in the machine connected to a display. The results of the parameters (moisture, ash, color, wet gluten, protein (wet), protein (dry) measured were displayed on the monitor attached to the instrument.

2.9. Functional properties of the flour blends

2.9.1. Swelling power and solubility index

The swelling power (SWP) and solubility index (SI) of the composite CWB flours were determined [17]. About 2.5% of aqueous flour was placed in centrifuge tubes, covered to avoid leaks, and heated for 30 minutes in a water bath (Precision Scientific Model 25 shaker) at 85 °C. After heating for 15 minutes at 3000 rpm with a centrifuge (Thelco GLC-1, 60647: Chicago, USA), the tubes were allowed to cool to ambient temperature. The paste and supernatant were separated, then the paste was weighed. At a temperature of 105 °C, the liquid above the sediment was evaporated in a hot air oven (Memmert GmbH Co.KG, Germany), and the residue was weighed. The SWP and SI were calculated using equations 1 and 2, respectively.

$$SWP = (Weight\ of\ starch\ paste) / (Weight\ of\ dry\ starch\ sample) \quad (1)$$

$$SI = \frac{Weight\ of\ soluble\ weight\ of\ sample}{Weight\ of\ dry\ starch\ sample} \quad (2)$$

2.9.2. Water absorption capacity

Water absorption capacity of the flour blends was determined as described by Onwuka [13]. One (1 g) of sample was weighed and placed into a conical graduated centrifuge tube. A waring whirl mixer was used to mix the sample thoroughly, 10 mL was added and sample was allowed to stay for 30 mins at room temperature and then centrifuged at 5000 × g for 30 mins.
The volume of the free water (supernatant) was read using 10 mL measuring cylinder. Water absorption was calculated as the amount of water absorbed (total minus free)

water) x 1 g/mL.

2.9.3 Least gelation capacity

The gelation capacity of the flour blends was determined by suspending the samples in 5 ml of distilled water which was inside the test tubes prepared using 2–20% (w/v). The sample test tubes were heated for 1 hour in a boiling water-bath followed by rapid cooling under running cold tap water. The test tubes were further cooled for 2 hours at 40 ºC. Then, the gelation capacity was determined for each sample as the least gelation concentration [13].

2.9.4. Oil absorption capacity

The oil absorption capacity (OAC) of the flour blends were measured [18] with slight modifications. In a centrifuge tube, one gram of the sample was combined with 10 mL of either distilled water. Using a flask shaker, the suspension was stirred for an hour before being centrifuged for 15 min at 2200 rpm. The volume of oil in the sediment was measured. According to the amount of oil absorbed per gram of the sample, the OAC were estimated and recorded.

2.10. Pasting properties of composite CWB flour

A Rapid Visco Analyser (RVA) (Model RVA 4500, Perten Instrument, Australia) which was equipped with a 1000 cmg sensitivity cartridge was applied in measuring the pasting properties of the flour blends. A known weight (3.5 g) of flour sample was introduced into a clean, dried, and empty canister and was subsequently filled with 25 mL of distilled water. After properly stirring the mixture, the canister was inserted into the RVA. The slurry was heated at a rate of 1.5 °C/min from 50 to 95 °C, maintained for 15 min, and then cooled to 50 °C. The attribute describing the pasting profile of the flour samples which were measured includes the Peak, trough, breakdown, final, and setback viscosities, peak time, and pasting temperature using Thermocline for Windows Software connected to a computer [19].

2.11. Statistical analysis

Pertinent data obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Scientists (SPSS 25.0) and significant means were separated using Duncan Multiple Range Tests (DMRTs).

3. Results and discussion

3.1. Physical properties of composite CWB flour

The physical properties of flour blends from cassava, Bambara groundnut and wheat are presented in Table 2. The physical property such as color constitute aesthetic and could influence acceptance and preference of food. The flour blends were not significantly (p>0.05) different in terms of flour lightness (L^*), greenness (a^*), yellowness (b^*) but were significantly different in bulk density, the ranges are 33.32 to 49.90, -1.20 to -3.01, 5.81 to 7.79 and 0.70 to 1.00 g/mL, respectively. The flour lightness (L^*) ranged from 33.32 to 49.90, with flour blend $HQCF_{15.00}WH_{50.00}BNF_{35.00}$ being the least light while the blend $HQCF_{14.65}WH_{70.00}BNF_{15.35}$ was the lightest in color. This observation is not unconnected with the fact that the quantity of flour from Bambara nut used was off-white in color while the HQCF was yellowish in color and relatively small in sample $HQCF_{14.65}WH_{70.00}BNF_{15.35}$ when compared with sample $HQCF_{15.00}WH_{50.00}$ $BNF_{35.00}$, in which BNF and HQCF were relatively higher, consequently the observed decreased flour lightness. The flour blends, with regards to greenness (a^*), had values ranging from -1.20 to -3.01, with flour blend $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ having lowest while the highest was recorded in blend $HQCF_{14.65}WH_{70.00}BNF_{15.35}$. Flour yellowness (*b**) had values ranging from 5.81 to 8.38, flour blend $HQCF_{32.87}WH_{50.00}$ $BNF_{17.13}$ having the minimum while the highest was recorded in sample $HQCF_{14.65}WF_{70.00}BNF_{15.35}$.

The inherent yellow pigment (color) in HQCF tends to have additive (masking) effect on the resulting color of the flour blends.

The bulk density of the flour blends varied significantly (p<0.05) and ranged from 0.70 to 1.00 g/mL, with blend $HQCF_{15.00}WH_{50.00}BNF_{35.00}$, having the lowest while sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ had the highest. It was observed that wheat content in each flour blend tends to exert a masking effect on other constituent flour, such that the higher the content of wheat in each blend, the high the bulk density of the composite flour. The range of value (0.70 to 1.00 g/mL) for bulk density in this study is slightly reduced than (0.54 to 1.75 g/mL) that reported by Bukuni et al. [20] which could probably be due to inherent properties such as the particulate nature and moisture content of the constituent flours.

The bulk density of flour is a major criterion of concern with relation to packaging requirement which is basically hinged on particle size and the moisture content of the constituent flour making up the composite flour.

It is important to point out that flour or composite flour with low bulk density are suitable in the design and development of weaning foods while high density composite flours present ease in packaging and transportation of food materials simply because it minimizes costs associated with production in food industry.

3.2. Chemical composition of the flour blends

The chemical properties of blends of flour from high quality cassava flour, Bambara nut flour and wheat flour are presented in Table 3. Moisture content is a major criterion that determines the storage stability of a food. Low moisture content of food intended for storage corresponds to better shelf life [21, 22]. The moisture content of the flour blends varied insignificantly (p>0.05) and ranged from 12.45 to 13.45%, with blends $HQCF_{15.00}WF_{50.00}$ $BNF_{35.00}$ having minimum while control sample $HQCF_{0.00}WF_{100.00}$ $BNF_{0.00}$ had the maximum value. The range (12.45-13.45%) of moisture content in this study is similar to (12.45-13.10%) that was reported by Alimi et al. [23] for composite cassava-wheat flour, a little higher than (8.60-11.90 %), (7.44-9.43%) reported by Iwe et al. [10] and Elochukwu, [23], respectively. This variation in moisture content could be attributed to moisture content of the constituent flours making up the composite flour. Mineral element presents in food as measured by ash content is an essential parameter in milling industries as it is instrumental in estimating the yield of flour and equally important in assessing milling functionality of flour [22]. The ash content of the flour blends varied significantly (p<0.05) and ranged from 0.44 to 0.77% with sample $HQCF_{14.65}WF_{70.00}BNF_{15.35}$ having the lowest while sample $HQCF_{32.87}WF_{50.00}BNF_{17.13}$ had the highest. Seventy percent (70%) of the flour blends had ash contents that were higher than that of wheat (control sample). This could be attributed to additive effect of ash contents of the constituent flours. The range of ash (0.44-0.77%) content recorded in this study was relatively higher than (0.58-0.61%) reported by Alimi et al. [9]; lower than range (0.42-4.00%) by Elochukwu, [23] for composite from cassava, Bambara groundnut and cashew seeds and close to (0.83-1.17%) reported by Iwe et al. [10] for composite cassava-wheat flour. The stretchability and viscoelastic property of dough formed by mixing composite flour with water is dependent on the gluten content of the constituent flour. The gluten contents of the flour blends varied significantly ($p<0.05$) and ranged from 17.95 to 31.10%, with blend $HQCF_{40.00}WF_{50.00}BNF_{10.00}$ having the lowest while sample $HQCF_{10.00}WF_{61.88}BNF_{28.12}$ had the highest. It was observed that the quantity of wheat and protein content of the constituent flour making up the composite flour tends to have dominant effect on gluten content of the flour blends.

Table 2.

Physical properties of the flour blends

Sample/blends	Lightness (L^*)	Greenness (a^*)	Yellowness (b^*)	Bulk density (g/mL)
$HQCF_{14.65}WF_{70.00}BNF_{15.35}$	38.66±0.22 ^{ab}	-2.13±0.20 ^{ab}	6.75±0.60 ^{ab}	0.84±0.00^{k}
$HQCF_{10.00}WF_{61.88}BNF_{28.12}$	39.36±2.39 ^{ab}	-2.18±0.35 ^{ab}	6.75±0.34 ^{ab}	0.72±0.00 ^{c}
$HQCF_{28.62}WF_{61.38}BNF_{10.00}$	43.91±3.08 ^{ab}	-1.93±0.24 ^{ab}	7.16±0.49 ^{ab}	0.81±0.00 ^{i}
$HQCF_{15.00}WF_{50.00}BNF_{35.00}$	42.04±9.03 ^{ab}	-1.99±0.97 ^{ab}	7.51±1.35 ^{ab}	0.70±0.00 ^{a}
$HQCF_{24.97}WF_{53.16}BNF_{21.87}$	42.73±1.62 ^{ab}	-1.65±0.21 ^{ab}	7.51±0.34 ^{ab}	0.76±0.00 ^{f}
$HQCF_{14.65}WF_{70.00}BNF_{15.35}$	49.90±1.54^{b}	-1.20±0.65 ^{b}	8.38±0.18 ^{b}	0.71±0.00 ^{b}
$HQCF_{24.97}WF_{53.16}BNF_{21.87}$	44.40±2.69 ^{ab}	-1.59±0.29 ^{ab}	6.91±0.32 ^{ab}	1.00±0.00 ^{l}
$HQCF_{28.62}WF_{61.38}BNF_{10.00}$	40.52±5.12 ^{ab}	-2.23±0.51 ^{ab}	6.73±0.82 ^{ab}	0.78±0.00 ^{h}
$HQCF_{32.87}WF_{50.00}BNF_{17.13}$	34.74±0.02 ^{ab}	-2.82±0.35 ^{ab}	5.81±0.13 ^{ab}	0.76±0.00 ^{f}
$HQCF_{15.10}WF_{63.67}BNF_{21.23}$	34.37±1.25 ^{ab}	-2.80±0.21 ^{ab}	6.14±0.09 ^{ab}	0.81±0.00 ^{j}
$HQCF_{40.00}WF_{50.00}BNF_{10.00}$	40.43±8.37 ^{ab}	-2.24±0.94 ^{ab}	6.98±1.02 ^{ab}	0.72±0.00 ^{d}
$HQCF_{17.46}WF_{55.18}BNF_{27.36}$	39.68±2.01 ^{ab}	-2.20±0.40 ^{ab}	6.75±0.24 ^{a}	0.77±0.00 ^{g}
$HQCF_{22.90}WF_{60.26}BNF_{16.84}$	41.14±0.84 ^{ab}	-1.94±0.18 ^{ab}	6.96±0.23 ^{ab}	0.84±0.00 ^{k}
$HQCF_{22.08}WF_{67.92}BNF_{10.00}$	36.19±1.29 ^{ab}	-3.01±0.31 ^{a}	6.05±0.26 ^{ab}	0.81±0.00 ^{j}
$HQCF_{15.00}WF_{50.00}BNF_{35.00}$	33.32±1.55^{a}	-2.89±0.28 ^{ab}	6.04±0.34 ^{ab}	0.75±0.00 ^{e}
$HQCF_{10.00}WF_{61.88}BNF_{28.12}$	45.11±12.4 ^{ab}	-1.86±1.16 ^{ab}	7.79±2.09 ^{ab}	0.72±0.00 ^{d}
$HQCF_{0.00}WF_{100.00}BNF_{0.00}$	37.63±3.23 ^{ab}	-2.36±0.51 ^{ab}	6.23±0.14 ^{ab}	0.84±0.00 ^{q}

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% (p≤0.05) level

The quality of flour meant for baking purposes as measured by zeleny value varied significantly (p<0.05) and ranged from 13.85 to 82.55 mL, with sample $HQCF_{15.00}WF_{50.00}$ $BNF_{35.00}$ having the minimum while sample $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ had the maximum. The protein (gluten) present in wheat and constituent flour making up the composite flour tends to influence the zeleny value (i.e. the suitability of flour for baking purpose). Flour blend $HQCF_{10.00}WF_{61.88}BNF_{28.12}$ and $HQCF_{10.00}WF_{61.88}BNF_{28.12}$ stood out amongst the flour blends and could find application in food industry especially in baking industry. Protein is an important chemical property in food; it is correlated significantly to the finished product attributes, especially texture and appearance [9]. The protein content of the flour blends on a dry and wet basis followed the same trend with ranges of values 8.46 to 14.16% and 7.33 to 12.24%, with blend $HQCF_{40.00}WF_{50.00}BNF_{10.00}$ having the lowest while control sample $HQCF_{0.00}$ $WF_{100.00}BNF_{0.00}$ had the highest, respectively. The trend observed for zeleny, stretchability and viscoelastic property applies to the protein contents of the flour blends. Expectedly, 100 % wheat flour had the highest protein content, and also the quantity of wheat and Bambara groundnut flour present in each flour blend influences the resultant protein content due to additive effect. The trend of increased protein content when wheat flour is replaced by flour from leguminous crop rich in protein as observed in this study is similar to what had been reported in past works [24, 23, 25, 33].

3.3. Functional properties of the flour blends

The functional properties of flour blends from high quality cassava flour, wheat and Bambara nut are presented in Table 4. The swelling index of the flour blends ranged from 0.71 to 0.91, with sample $HQCF_{17.46}WF_{55.18}BNF_{27.36}$ having the lowest while blend $HQCF_{10.00}WF_{61.88}BNF_{28.12}$ had the highest. The range (0.71 to 0.91) for swelling index in this study was relatively lower than range (0.07-1.07) reported by Bukuni et al. [20] for blends of flour from maize, Bambara groundnut and mango (MBM) flour. The range (0.19 to 1.24%) for swelling capacity in this study was relatively lower than (1.05-1.36%) reported by Bukuni et al. [20] and this could be attributed to relatively higher quantity (100, 90, 85, 75 etc.) of maize which is the base flour present in the formulation of the later when compared with the composite CWB flour. Legume starch usually exhibit a restricted-swelling pattern as reported by Alimi et al. [24], the formulation of composite CWB flour contained relatively higher Bambara groundnut flour than composite MBM flour, consequently the observed relatively lower swelling index and water absorption capacity in composite CWB flour. Water absorption capacity depicts the ability of the flour or starch to hold water against gravity and this could involve bound water. Water absorption capacity of the flour blends varied significantly (p<0.05) and ranged from 0.19 to 1.24%, with sample $HQCF_{24.97}WF_{53.16}BNF_{21.87}$ having the lowest while blend $HQCF_{15.10}WF_{63.67}BNF_{21.23}$ had the highest. It was observed that flour blends ($HQCF_{15.10}WF_{63.67}BNF_{21.23}$, $HQCF_{15.00}WF_{50.00}BNF_{35.00}$ and $HQCF_{10.00}WF_{61.88}BNF_{28.12}$) with relatively high protein contents had increased water absorption capacity. Flour from food crops rich in protein when blended with wheat tends to increase the water absorption capacity of the resulting composite flour, example of such crops include cowpea [24], winged bean flour (2.1 g/g flour), pigeon pea flour (138%) [26], chickpea flours (1.33–1.47 g/g) [27], and sunflower Flour (107%) [28], this observation of increased water absorption capacity could be attributed to increased amylose leaching, loss of crystalline starch structure and increased hydrophilic (polysaccharides) constituent. The solubility index of the flour blends varied significantly (p<0.05) and ranged from 4.23 to 21.67% in samples $HQCF_{15.00}WF_{50.00}BNF_{35.00}$ and $HQCF_{14.65}WF_{70.00}BNF_{15.35}$, respectively. It was observed that 81 % of the flour blends had higher solubility index than wheat flour. The observed increased solubility index could be attributed to the synergistic effect of inherent factors such as pH and presence of salts in HQCF and BNF, respectively since the constituent flours were at relatively same temperature. Blending wheat flour with HQCF and Bambara groundnut flour increased the water solubility index of the resulting composite flour, this is particularly beneficial in pharmaceutical industry. The range (4.23-19.51) for solubility index recorded in this study is relatively higher than (8.27-9.55) and this could be attributed to the additive effect of the Bambara groundnut flour in the flour blends and this is of significance in food industry where protein isolates become critical in food product development. Lower least gelation concentration (LGC) depicts a better gelling capacity. The lower the LGC, the better the gelling ability of such protein ingredient. The least gelation capacity of the flour blends varied significantly (p<0.05) and ranged from 0.17 to 0.30% with sample $HQCF_{15.00}WF_{50.00}BNF_{35.00}$ having the lowest value while sample $F_{28.62}WH_{61.38}BNF_{10.00}$ had the highest. The flour blends ($HQCF_{15.00}WF_{50.00}BNF_{35.00}$, with relatively high Bambara groundnut flour had best LGC. Capability of a food material to entrap oil (oil absorption capacity) is important in most food applications, especially in bakery products, where flavor retention and improvement of palatability becomes a major consideration [29]. The oil absorption capacity of the flour blends varied significantly (p<0.05) and ranged from 0.92 to 2.27% with flour blends $HQCF_{15.10}WF_{63.67}BNF_{21.23}$ and $HQCF_{40.00}WF_{50.00}BNF_{10.00}$ having the lowest value while sample $HQCF_{14.65}WF_{70.00}BNF_{15.35}$ had the highest. It was observed that additive effect of Bambara nut flour improves the oil absorption capacity of the flour blends. It has been noted that increased treatment given to food rich in protein tends to increase the hydrophobicity which result into the unfolding of the protein molecules consequently, the observed increased oil absorption capacity; oil entrapping propensity of food material is correlated with composition of amino acid, conformation of the protein and surface polarity; the rate at which oil is trapped is relatively higher in food material with high protein content [24].

3.4. Pasting properties of the flour blends

The pasting properties of composite flour from high quality cassava flour, wheat and Bambara nut are presented in Table 5. The highest viscosity reached as measured by peak viscosity is attained after substantial fraction of the granules that swells had stopped; Gel strength is measured and described by peak viscosity [9, 10]. The peak viscosity of the flour blends varied significantly (p<0.05) and ranged from 110.67 to 162.84 RVU, with sample $HQCF_{22.08}WF_{67.92}BNF_{10.00}$ having the lowest while the control (wheat) sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ had the highest.

The quantity and quality of starch present in wheat and Bambara groundnut flour tends to influence the peak viscosity of the flour blends. The peak viscosity (110.67-162.84 RVU) of flour blends investigated in this study is higher than (62.75-98.50 RVU) reported for composite cassava-wheat prepared with TMS 419 [10] while it is lower to the peak viscosity reported by Elochukwu [23]. Studies by Iwe et al. [10] and Alimi et al. [22] had established the fact that genetic constituents of each variety of crops used to prepare the different composite flours play a significant role in the resultant peak viscosity of composite flour. Stability of starch granules to heating is referred to as the holding strength or trough. Trough viscosity of the flour blends varied significantly (p<0.05) and ranged from 53.88 to 77.96 RVU, with sample $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ having the lowest while the control (wheat) sample $HQCF_{0.00}$ $WH_{100.00}$ $BNF_{0.00}$ had the highest. Generally, it was observed that blending wheat flour with flours from cassava and Bambara groundnut relatively reduce the ability of the resulting composite flour to maintain gelatinized structure; also, composite flours with high proportion of Bambara groundnut flour tends to have relatively increased capacity to maintain gelatinized structure, this could be attributed to additive effect of its protein content. Worth pointing out is the fact that wheat flour (control) had highest capacity to maintain gelatinized structure due to its visco-elastic property as a result of gluten "protein present in wheat" that forms a network. The trend of relative reduction in capacity to maintain gelatinized structure (trough) observed in this study when wheat flour is replaced or blended by flour(s) from other crops was also noted by Alimi et al. [9] and Iwe et al. [10]. The final viscosity (FV) is a major pasting parameter that determines the final product quality of starch-based food; the higher the FV, the better. The final viscosity of the flour blends varied significantly (p<0.05) and ranged from 51.25 to 84.88 RVU, with sample $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ having the lowest while the control (wheat) sample $HQCF_{0.00}$ $WF_{100.00}$ $BNF_{0.00}$ had the highest. Expectedly, wheat flour (control) sample had significantly higher final viscosity value (84.88 RVU) than the composite flours prepared by blending wheat with flours from cassava and Bambara groundnut indicating that wheat flour 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. Relative reduction in the ability of the flour blends to form firmer gels was due to the reduction in the gluten content that result when wheat flour is partially substituted with other flours.

This phenomenon is referred to as "dilution effect". Considering proper fit of the flours for baking purpose with regards to final product quality, the order is: $HQCF_{0.00}WF_{100.00}BNF_{0.00}$ > $HQCF_{10.00}WF_{61.88}BNF_{28.12}$>$HQCF_{10.00}WF_{61.88}BNF_{28.12}$>$HQCF_{15.00}WF_{50.00}BNF_{35.00}$> $HQCF_{15.00}WF_{50.00}BNF_{35.00}$>$HQCF_{15.10}WF_{63.67}$ $BNF_{21.23}$ >$HQCF_{17.46}WF_{55.18}BNF_{27.36}$. The hot paste stability of starch as measured by breakdown viscosity reveals the degree of starch disintegration [30, 31, 9]. Breakdown viscosity of the flour blends varied significantly (p<0.05) and ranged from 92.34 to 158.92 RVU, with sample $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ having the lowest while the control (wheat) sample $HQCF_{0.00}WF_{100.00}$ $BNF_{0.00}$ had the highest. The hot paste stability of starch as measured by breakdown viscosity reveals the degree of starch disintegration [30, 31, 9]. Breakdown viscosity of the flour blends varied significantly ($p<0.05$) and ranged from 92.34 to 158.92 RVU, with sample $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ having the lowest while the control (wheat) sample $HQCF_{0.00}WF_{100.00}$ $BNF_{0.00}$ had the highest. Noteworthy, the hot paste formed by blending wheat flour with HQCF from cassava and Bambara groundnut flours were more stable than that of wheat flour, revealing the additive effect of HQCF and Bambara groundnut flour on hot paste stability of the resulting composite flour. Also, the order of the hot paste stability is: $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ > $HQCF_{32.87}WF_{50.00}BNF_{17.13}$ > $HQCF_{22.08}WF_{67.92}BNF_{10.00}$ > $HQCF_{40.00}WF_{50.00}BNF_{10.00}$ > $HQCF_{22.90}WF_{60.26}$ $BNF_{16.84}$.

The observed variation in the breakdown viscosity value of the composite flours prepared with flour from cassava roots and Bambara groundnut studied could be attributed to quantity and quality of starch Amylose in particular) and the protein present in the flour blends. This trend of hot paste stability in this study is similar to the trend reported by previous investigators [9, 10, 32, 33].

The retrogradation tendency of starch or starch-based food product as measured by setback viscosity has been used successfully to study the behavior of food materials. The lower the setback viscosity value, the better for flour meant for baking purposes. The setback viscosity of the flour blends varied and ranged from 37.29 to 80.96 RVU, with sample $HQCF_{32.87}WF_{50.00}BNF_{17.13}$ having the lowest while the control (wheat) sample $HQCF_{0.00}$ $WF_{100.00}$ $BNF_{0.00}$ had the highest. Replacing wheat flour with flours from cassava and Bambara groundnut reduced the tendency of the resulting composite flour's starch towards retrogradation, the significantly ($p<0.05$) higher setback viscosity attested to this fact. Generally, all the flour blends had setback viscosities lower than that of wheat flour; flour blends $HQCF_{32.87}WF_{50.00}BNF_{17.13}$ and $HQCF_{28.62}WF_{61.38}BNF_{10.00}$ had exceptionally lower setback viscosity value indicating the stability of their starch against retrogradation when used for baking purpose. Reduction in retrogradation tendency when wheat flour is replaced with flour from other crops such as HQCF, wheat flour etc. as observed in this present study is similar to what was observed by other investigators [9, 32, 33].

Time to attain 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 requisite time for the starch portion of the flour blends varied significantly ($p<0.05$) and ranged from 5.34 to 5.93 min, with sample $HQCF_{17.46}WF_{55.18}BNF_{27.36}$ having the lowest while the control (wheat) sample $HQCF_{0.00}WF_{100.00}BNF_{0.00}$ had the highest. It was observed that the flour blends with higher proportion of wheat flour cooked at relatively high time. Also, flour blends with higher proportion of Bambara groundnut flour tends to have relatively reduced cooking time.

The range of cooking time (5.34 to 5.93 min) for the composite flour in this study is relatively reduced when compared to the range (5.45 to 6.20 min), (5.90-6.17 min) and (5.18-6.88 min) reported by Arise et al. [34], Alimi et al. [9] and Iwe et al. [10] for composite wheat-plantain-bambara flour and composite wheat-cassava flour, respectively. Bambara groundnut is relatively low in carbohydrate when compared with wheat and HQCF, and its additive effect regarding formation of paste would be reduced coupled with the fact that amylose content of the resulting starch content could be adduced for the observed

Table 3.

Chemical properties of flour blends from cassava, wheat and Bambara groundnut flour

Sample blends	Moisture (%)	Ash (%)	Color (%)	Wet Gluten (%)	Zeleny (mL)	Protein (dry) (%)	Protein (wet) (%)
HQCF$_{14.65}$WF$_{70.00}$BNF$_{15.35}$	13.00±0.05^{de}	0.52±0.01^{a}	89.05±0.05^{de}	25.35±0.05^{j}	40.55±0. 05^{k}	11.73±0.01^{g}	10.20±0.01^{g}
HQCF$_{10.00}$WF$_{61.88}$BNF$_{28.12}$	12.65±0. 05^{b}	0.48±0.01^{b}	91.35±0.05^{i}	31.10±0.00^{m}	56.35±0. 05^{p}	13.94±0.01^{m}	12.02±0.02^{m}
HQCF$_{28.62}$WF$_{61.38}$BNF$_{10.00}$	13.05±0.05^{ef}	0.52±0.01^{d}	88.85±0.05^{cd}	23.15±0. 05^{f}	45.95±0. 05^{m}	10.66±0. 01^{d}	9.25±0.01^{c}
HQCF$_{15.00}$WF$_{50.00}$BNF$_{35.00}$	12.65±0.05^{b}	0.72±0.01^{k}	88.25±0.15^{b}	24.15±0. 05^{h}	26.95±0. 05^{e}	12.80±0. 01^{k}	11.18±0.01^{k}
HQCF$_{24.97}$WF$_{53.16}$BNF$_{21.87}$	12.75±0.05^{bc}	0.56±0.01^{e}	88.70±0.10^{c}	21.35±0. 05^{c}	30.55±0. 05^{g}	10.41±0. 01^{c}	9.07±0.02^{b}
HQCF$_{14.65}$WF$_{70.00}$BNF$_{15.35}$	12.95±0.05^{de}	0.44±0.00^{a}	88.65±0.05^{c}	26.45±0. 05^{k}	27.95±0. 05^{f}	12.26±0. 01^{h}	10.67±0.01^{h}
HQCF$_{24.97}$WF$_{53.16}$BNF$_{21.87}$	12.95±0.05^{de}	0.70±0.01^{j}	88.85±0.05^{cd}	22.15±0. 05^{d}	23.55±0. 05^{c}	11.07±0. 00^{e}	9.65±0. 01^{e}
HQCF$_{28.62}$WF$_{61.38}$BNF$_{10.00}$	12.95±0.05^{de}	0.50±0.01^{c}	89.95±0.05^{h}	22.55±0. 05^{e}	42.05±0. 05^{l}	10.42±0. 01^{c}	9.05±0. 01^{b}
HQCF$_{32.87}$WF$_{50.00}$BNF$_{17.13}$	13.15±0.05^{fg}	0.77±0.01^{l}	90.15±0.05^{h}	20.75±0. 05^{b}	20.15±0. 05^{b}	10.44±0. 01^{i}	9.07±0. 01^{b}
HQCF$_{15.10}$WF$_{63.67}$BNF$_{21.23}$	12.85±0.05^{cd}	0.60±0.01^{g}	88.65±0.05^{c}	25.35±0. 05^{j}	33.85±0. 05^{i}	12.24±0. 01^{h}	10.67±0. 01^{h}
HQCF$_{40.00}$WF$_{50.00}$BNF$_{10.00}$	13.25±0.05^{g}	0.52±0.01^{d}	90.10±0.10^{h}	17.95±0. 05^{a}	24.25±0. 05^{d}	8.46±0. 01^{a}	7.33±0.00^{a}
HQCF$_{17.46}$WF$_{55.18}$BNF$_{27.36}$	12.75±0.05^{bc}	0.66±0.01^{i}	88.10±0.10^{b}	24.55±0. 05^{i}	36.65±0. 05^{j}	12.41±0. 01^{i}	10.83±0. 01^{i}
HQCF$_{22.90}$WF$_{60.26}$BNF$_{16.84}$	13.15±0.05^{fg}	0.67±0.01^{i}	89.15±0.05^{ef}	28.05±0. 05^{l}	32.15±0. 05^{h}	9.25±0. 01^{b}	9.34±0. 01^{d}
HQCF$_{22.08}$WF$_{67.92}$ BNF$_{10.00}$	13.05±0. 05^{ef}	0.67±0.01^{i}	89.55±0.05^{g}	23.55±0. 05^{g}	49.05±0. 05^{n}	11.65±0. 01^{f}	10.17±0. 01^{f}
HQCF$_{15.00}$WF$_{50.00}$ BNF$_{35.00}$	12.45±0. 05^{a}	0.63±0.01^{h}	89.35±0.05^{fg}	23.65±0. 05^{g}	13.85±0. 05^{a}	12.59±0. 01^{j}	11.01±0. 01^{j}
HQCF$_{10.00}$WF$_{61.88}$BNF$_{28.12}$	12.75±0.05^{bc}	0.66±0.01^{i}	87.85±0.05^{a}	26.55±0. 05^{k}	82.55±0. 05^{q}	13.34±0. 01^{l}	11.63±0. 01^{l}
HQCF$_{0.00}$ WF$_{100.00}$ BNF$_{0.00}$	13.45±0. 05^{h}	0.58±0.01^{a}	89.150±0.05^{ef}	22.45±0. 05^{e}	52.75±0. 05^{o}	14.16±0. 01^{n}	12.24±0. 01^{n}

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level.

HQCF: High Quality Cassava Flour; BNF: Bambara Nut Flour; WF: Wheat Flour

Table 4.

Functional properties of flour blends from cassava, wheat and Bambara groundnut flour

Sample Blends	Swelling index (%)	Water absorption capacity (%)	Solubility index (%)	Least gelation capacity (%)	Oil absorption capacity (%)
$\mathbf{HQCF_{14.65}WF_{70.00}BNF_{15.35}}$	0.83 ± 0.00^{c}	0.58 ± 0.00^{f}	21.67 ± 0.00^{n}	0.20 ± 0.00^{ab}	2.27 ± 0.03^{j}
$\mathbf{HQCF_{10.00}WF_{61.88}BNF_{28.12}}$	0.91 ± 0.00^{e}	0.96 ± 0.00^{j}	4.68 ± 0.00^{a}	0.27 ± 0.03^{bc}	1.30 ± 0.00^{d}
$\mathbf{HQCF_{28.62}WF_{61.38}BNF_{10.00}}$	0.83 ± 0.00^{c}	0.79 ± 0.00^{i}	11.92 ± 0.00^{f}	0.30 ± 0.00^{c}	0.93 ± 0.00^{a}
$\mathbf{HQCF_{15.00}WF_{50.00}BNF_{35.00}}$	0.91 ± 0.00^{e}	0.95 ± 0.00^{j}	4.23 ± 0.00^{a}	0.17 ± 0.03^{a}	2.05 ± 0.00^{i}
$\mathbf{HQCF_{24.97}WF_{53.16}BNF_{21.87}}$	0.77 ± 0.00^{b}	0.76 ± 0.00^{h}	12.53 ± 0.00^{g}	0.27 ± 0.03^{bc}	1.49 ± 0.00^{f}
$\mathbf{HQCF_{14.65}WF_{70.00}BNF_{15.35}}$	0.91 ± 0.00^{e}	0.51 ± 0.00^{e}	16.21 ± 0.00^{ijk}	0.27 ± 0.03^{bc}	1.49 ± 0.00^{f}
$\mathbf{HQCF_{24.97}WF_{53.16}BNF_{21.87}}$	0.71 ± 0.00^{a}	0.19 ± 0.00^{a}	15.79 ± 0.80^{i}	0.20 ± 0.03^{ab}	1.96 ± 0.00^{g}
$\mathbf{HQCF_{28.62}WF_{61.38}BNF_{10.00}}$	0.83 ± 0.00^{c}	0.56 ± 0.00^{f}	19.51 ± 0.00^{m}	0.23 ± 0.03^{abc}	1.12 ± 0.00^{b}
$\mathbf{HQCF_{32.87}WF_{50.00}BNF_{17.13}}$	0.77 ± 0.00^{b}	0.59 ± 0.00^{f}	15.89 ± 0.00^{ij}	0.23 ± 0.03^{abc}	1.19 ± 0.00^{c}
$\mathbf{HQCF_{15.10}WF_{63.67}BNF_{21.23}}$	0.83 ± 0.00^{c}	1.24 ± 0.03^{l}	17.28 ± 0.01^{l}	0.27 ± 0.03^{bc}	0.92 ± 0.00^{a}
$\mathbf{HQCF_{40.00}WF_{50.00}BNF_{10.00}}$	0.83 ± 0.00^{c}	0.37 ± 0.00^{c}	16.46 ± 0.00^{jk}	0.23 ± 0.03^{abc}	0.92 ± 0.00^{a}
$\mathbf{HQCF_{17.46}WF_{55.18}BNF_{27.36}}$	0.71 ± 0.00^{a}	0.63 ± 0.00^{g}	10.60 ± 0.00^{d}	0.23 ± 0.03^{abc}	1.98 ± 0.00^{h}
$\mathbf{HQCF_{22.90}WF_{60.26}BNF_{16.84}}$	0.83 ± 0.00^{c}	0.58 ± 0.00^{f}	14.62 ± 0.00^{h}	0.27 ± 0.03^{bc}	1.67 ± 0.00^{g}
$\mathbf{HQCF_{22.08}WF_{67.92}BNF_{10.00}}$	0.83 ± 0.00^{c}	0.39 ± 0.00^{cd}	16.78 ± 0.00^{kl}	0.23 ± 0.03^{abc}	1.39 ± 0.00^{e}
$\mathbf{HQCF_{15.00}WF_{50.00}BNF_{35.00}}$	0.87 ± 0.00^{d}	1.04 ± 0.00^{k}	11.26 ± 0.00^{e}	0.20 ± 0.00^{ab}	1.39 ± 0.00^{e}
$\mathbf{HQCF_{10.00}WF_{61.88}BNF_{28.12}}$	0.83 ± 0.00^{c}	0.39 ± 0.00^{d}	6.70 ± 0.00^{b}	0.23 ± 0.03^{abc}	1.99 ± 0.00^{h}
$\mathbf{HQCF_{0.00}\ WF_{100.00}\ BNF_{0.00}}$	0.83 ± 0.00^{c}	0.29 ± 0.00^{b}	7.35 ± 0.00^{c}	0.20 ± 0.00^{ab}	1.39 ± 0.00^{e}

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly differentt 5% level.

HQCF: High Quality cassava Flour; BNF: Bambara Nut Flour; WF: Wheat Flour

Table 5.

Pasting properties of flour blends from cassava, wheat and Bambara groundnut

Sample blends	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Final Viscosity Viscosity (RVU)	Breakdown Viscosity (RVU)	Setback Viscosity (RVU)	Peak Time (Min.)	Pasting Temperature (ºC)
HQCF$_{14.65}$WF$_{70.00}$BNF$_{15.35}$	128.88±1.24^{bcde}	62.71±1.59^{abcde}	66.17±0.82^{cdef}	121.75±0.24^{defgh}	59.04±0.37^{gh}	5.70±0.04^{e}	94.05±0.57^{c}
HQCF$_{10.00}$WF$_{61.88}$BNF$_{28.12}$	146.88±0.84^{efgh}	73.54±0.71^{efg}	73.34±1.12^{fg}	136.17±1.72^{gh}	62.63±0.01^{h}	5.50±0.04^{abcd}	92.85±0.00^{c}
HQCF$_{28.62}$WF$_{61.38}$BNF$_{10.00}$	125.63±2.54^{bcd}	65.46±0.76^{bcdef}	60.17±1.76^{abc}	111.09±1.29^{bcde}	45.63±0.53^{bcd}	5.70±0.04^{e}	75.88±0.11^{a}
HQCF$_{15.00}$WF$_{50.00}$BNF$_{35.00}$	149.38±0.06^{fgh}	77.46±0.06^{g}	71.92±0.00^{defg}	132.63±0.06^{fgh}	55.17±0.12^{efgh}	5.37±0.05^{ab}	93.63±1.17^{c}
HQCF$_{24.97}$WF$_{53.16}$BNF$_{21.87}$	132.58±8.13^{cdef}	68.63±0.41^{cdefg}	63.96±0.71^{cde}	115.13±1.24^{cdef}	46.50±0.82^{cd}	5.60±0.00^{de}	76.28±0.53^{a}
HQCF$_{14.65}$WF$_{70.00}$BNF$_{15.35}$	125.88±6.19^{bcd}	62.92±0.41^{abcde}	62.96±0.77^{cd}	118.92±0.88^{cdefg}	56.00±0.47^{fgh}	5.60±0.10^{de}	94.03±0.67^{c}
HQCF$_{24.97}$WF$_{53.16}$BNF$_{21.87}$	135.54±1.12^{cdefg}	67.63±0.77^{bcdefg}	67.92±0.35^{cdefg}	116.71±0.18^{cdef}	49.09±0.94^{cdef}	5.47±0.19^{abcd}	93.98±1.66^{c}
HQCF$_{28.62}$WF$_{61.38}$BNF$_{10.00}$	105.13±0.96^{a}	53.88±1.24^{a}	51.25±1.71^{a}	92.34±1.25^{a}	38.46±0.01^{ab}	5.53±0.00^{bcde}	75.83±0.11^{a}
HQCF$_{32.87}$WF$_{50.00}$ BNF$_{17.13}$	110.88±0.25^{ab}	57.71±1.35^{abc}	53.17±0.88^{ab}	95.00±0.72^{ab}	37.29±0.36^{a}	5.57±0.05^{cde}	76.28±0.53^{a}
HQCF$_{15.10}$WF$_{63.67}$ BNF$_{21.23}$	140.59±0.07^{cdefg}	70.88±1.30^{defg}	69.71±0.77^{defg}	127.54±1.83^{efgh}	56.67±0.54^{fgh}	5.50±0.04^{abcd}	93.98±0.60^{c}
HQCF$_{40.00}$WF$_{50.00}$ BNF$_{10.00}$	124.46±0.48^{bcd}	64.92±0.89^{abcdef}	59.54±1.59^{abc}	106.55±1.02^{abcd}	41.63±0.12^{abc}	5.40±0.00^{abc}	74.35±0.07^{a}
HQCF$_{17.46}$WF$_{55.18}$BNF$_{27.36}$	143.04±1.73^{defg}	73.25±1.54^{efg}	69.79±0.18^{defg}	125.42±1.79^{defgh}	52.17±0.24^{defg}	5.34±0.09^{a}	85.18±1.00^{b}
HQCF$_{22.90}$WF$_{60.26}$ BNF$_{16.84}$	122.00±0.95^{abc}	61.55±0.53^{abcd}	60.46±1.47^{bc}	109.08±0.00^{abcde}	47.545±0.53^{cde}	5.64±0.05^{de}	95.13±0.04^{c}
HQCF$_{22.08}$WF$_{67.92}$ BNF$_{10.00}$	110.67±1.88^{ab}	57.09±0.94^{ab}	53.59±0.94^{ab}	101.17±0.24^{abc}	44.09±0.29^{abc}	5.70±0.14^{e}	76.63±0.11^{a}
HQCF$_{15.00}$WF$_{50.00}$ BNF$_{35.00}$	148.54±0.19^{fgh}	75.96±0.13^{fg}	72.59±1.06^{efg}	130.59±1.03^{fgh}	54.63±0.89^{efgh}	5.40±0.10^{abc}	93.98±0.60^{c}
HQCF$_{10.00}$WF$_{61.88}$BNF$_{28.12}$	153.63±0.12^{gh}	76.88±0.07^{g}	76.75±1.06^{g}	138.92±0.49^{h}	62.05±0.42^{h}	5.50±0.04^{abcd}	93.28±0.53^{c}
HQCF$_{0.00}$ WF$_{100.00}$ BNF$_{0.00}$	162.84±0.94^{h}	77.96±0.83^{g}	84.88±0.88^{h}	158.92±1.13^{i}	80.96±0.30^{i}	5.93±0.00^{f}	94.78±0.53^{c}

Values are mean of duplicates ± standard deviation; Mean values with different superscripts within the same column are significantly different at 5% level.

HQCF: High Quality cassava Flour; BNF: Bambara Nut Flour; WF: Wheat Flour

reduced time to reach maximum viscosity as observed in the flour blends. This is beneficial in relation to energy consumption for the production process. A point at which a notable increase in viscosity of starch with observable simultaneous swelling occurs is referred to as the "pasting temperature". It gives a clear picture of energy cost involved in such a production process. The pasting temperature of the flour blends were significantly ($p<0.05$) different and have a range of value 74.35-95.13 ºC, with sample $HQCF_{40.00}WF_{50.00}BNF_{10.00}$ having the lowest while sample $HQCF_{22.90}WF_{60.26}BNF_{16.84}$ had the highest. The range (74.35 to 95.13 ºC) of pasting temperature for this study is relatively higher than (59.78 to 84.08 ºC) and (70.10-79.95 ºC) reported by Arise et al. [34] and Alimi et al. [24], respectively. Flour blends with relatively high wheat proportion and Bambara groundnut flour had high pasting temperature; this could be attributed to the fact that legume starch had shown restricted swelling pattern [22]. High pasting temperature of starches connotes a higher resistance to swelling and rupture of the starch granules [35]; high crystallinity of wheat starch granules could also be responsible for the observed relatively high pasting temperature in the flour blends.

4. Conclusion

Blending wheat flour with flours from cassava and Bambara groundnut improves the physical (color and bulk density), functional (swelling, water absorption, solubility index and oil absorption capacity) and the pasting profile of the resulting composite flour. Considering proper fit of the flour blends for baking purposes with regards to final product quality, the order is: $HQCF_{0.00}WF_{100.00}BNF_{0.00}$>$HQCF_{10.00}WF_{61.88}BNF_{28.12}$>$HQCF_{10.00}WF_{61.88}BNF_{28.12}$> $HQCF_{15.00}WF_{50.00}BNF_{35.00}$>$HQCF_{15.00}WF_{50.00}BNF_{35.00}$>$HQCF_{15.10}WF_{63.67}BNF_{21.23}$> $HQCF_{17.46}WF_{55.18}BNF_{27.36}$. Based on oil absorption capacity, swelling power and nutritional properties, flour blends $HQCF_{14.65}WF_{70.00}BNF_{15.35}$, $HQCF_{15.00}WF_{50.00}BNF_{35.00}$, $HQCF_{17.46}WF_{55.18}BNF_{27.36}$, $HQCF_{15.00}WF_{50.00}BNF_{35.00}$ and $HQCF_{10.00}WF_{61.88}BNF_{28.12}$ could find application in baking industry, especially in the production of pastry products.

5. Acknowledgement

The authors sincerely acknowledge and appreciate the management of Nigerian Stored Products Research Institute (NSPRI) headed by Prof. Lateef Oladimeji Sanni for funding this research project. The authors appreciate cassava unit of the International Institute of Tropical Agriculture (IITA), for technical support and provision of low postharvest physiologically deteriorated (PPD) cassava roots used for the research.

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