Agrotechnology
ISSN: 2168-9881

Research Article Open Access

Physicochemical and Pasting Properties High Quality Cassava Flour (HQCF) and Wheat Flour Blends

Iwe MO[1]*, Michael N[2], Madu NE[1], Obasi NE[1], Onwuka GI[1], Nwabueze TU[1] and Onuh JO[3]

[1]*Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, P. M. B. 7267 Umuahia, Abia State, Nigeria*
[2]*Department of Bioresource Engineering, Macdonald Campus of McGill University, Ste-Anne-de-Bellevue, Quebec H9X 3V9, Canada*
[3]*Department of Food, Nutrition and Home Sciences, Kogi State University, P. M. B. 1008 Anyigba, Kogi State, Nigeria*

Abstract

High quality cassava flour (HQCF) processed from five different improved cassava varieties (TMS87164, NR8082, TME419, TMS0581 and TMS98/1632) were evaluated for their physicochemical, functional and pasting properties to determine their suitability for baked goods. The HQCFs were then blended with wheat flour (WF) at various ratios (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50% HQCF:WF respectively) and analyzed for the various parameters. The results showed significantly (p<00.05) low contents of moisture, ash, fat, fibre and protein between the HQCF samples which increased significantly (p<0.05) with addition of wheat flour in the blends. However, the carbohydrates content of the HQCF did not vary significantly (p<0.05) between the cassava varieties ranging from 85.58–92.84% and decreasing significantly with increasing levels of WF in the blends. The cyanide content for HQCFs (2.04 to 48.13 ppm) was very low and within safe level for human consumption. The HQCFs exhibited low foaming and emulsion capacities but high bulk densities, water and oil absorption capacities as well as high degree of gelatinization, probably owing to the low protein and high carbohydrates. Gelatinization temperature of all the flour samples investigated (29.00 to 74.000C) fell within the recommended range. The HQCFs also exhibited high pasting properties which were observed to decrease with WF addition into the mix. Overall, HQCFs displayed desirable properties for its incorporation into baked goods as a replacement for wheat flour.

Keywords: Cassava flour; Gelatinization; Cyanide; Fheat flour; Pasting properties

Introduction

Cassava (*Manihot esculenta* Crantz) is perhaps one of the most widely grown important food and cash crops [1]. Its importance is increasing in Africa because of its diverse uses, low cost and its tolerance to environmental stresses such as drought, fire, low soil fertility and its high productivity where other crops fail [2]. It is rich in carbohydrates especially starch and consequently has a multiplicity of end uses [3]. Due to its economic advantage as both a cash and subsistent crop, a lot of researches have been done in developing various high yielding varieties [4,5]. These varieties could be early or late maturing and have varying physico-chemical and rheological properties, which confer diversity to its application in food systems. Nutritionally, cassava is a major source of dietary energy for low income consumers in many parts of tropical Africa including the major urban areas [6]. One hundred grams of cassava roots contain approximately 62.5 g of water, 34.7 g of starch, 1.2 g of protein, 0.3 g of fat, 33 mg of calcium and 36 mg of vitamin C while 100 g of the leaves on the other hand contains 80.5 g of water, 9.6 g of starch, 6.8 g of protein, 1.3 g of fat, 20.6 mg of calcium and 265 mg of vitamin C [7].

Cassava is cultivated widely in most parts of Africa and contributes to improve food and livelihood security in many developing countries [8]. In Nigeria, cassava is one of the most important crops in terms of production, energy intake, and contribution to Gross Domestic Product (GDP). It is considered a food security crop with a great potential for industrial applications [9]. Processing cassava into flour is a value addition for expanding the range of uses of the root crop. The flour has been applied as a raw material for ethanol and other fermented foods [9,10] and has partially replaced wheat flour for food and plywood industries [5,11-12].

There is increasing interest in the utilization of cassava flour in contemporary baked goods especially for bread making, variety of pastries and convenience foods at household level and for the manufacture of industrial products [1,5]. This has consequently increased the demand for the production of high quality cassava flour (HQCF), a flour produced from wholesome freshly harvested and rapidly processed cassava roots. High quality cassava flour is simply unferemented cassava flour, usually characterized as whitish or creamy in colour, odourless, bland or sweet in taste and free from adulterants, insect infestation, sand, peel fragments, dust, and any other impurities. It has been identified as a local alternative for use as a partial replacement of wheat flour in composite flours for bread making [5,8,13,14].

Previously, some composite flours have been applied without any foreknowledge of their performance in food systems and had resulted in products with varying consumer acceptability. Composite flours are known to influence and alter the functional properties of the finished products [15]. The possibility of using starchy tubers instead of wheat flour in foods is a function of their chemical and physical properties. Amylose/amylopectin ratio for example influences the flours' behavior in food systems such as viscosity, gelatinization and setback which affect the texture of the end product [16]. In other to be widely accepted by the food industry, cassava flour needs to meet the high-quality requirements in terms of physicochemical characteristics, microbial safety and cyanogenic glucoside content. Also, the success of completely

***Corresponding author:** Iwe MO, Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, P. M. B. 7267 Umuahia, Abia State, Nigeria, Tel: +2348035487198; E-mail: maduoiwe@yahoo.com

Received March 01, 2017; **Accepted** September 28, 2017; **Published** October 05, 2017

Citation: Iwe MO, Michael N, Madu NE, Obasi NE, Onwuka GI, et al. (2017) Physicochemical and Pasting Properties High Quality Cassava Flour (HQCF) and Wheat Flour Blends. Agrotechnology 6: 167. doi: 10.4172/2168-9881.1000167

or partially replacing wheat flour with cassava flour for bakery and other applications could be better achieved if the cassava flour is adequately characterized in terms of its physicochemical and functional behavior. The objective of this study therefore, was to determine effects of cassava varieties on the physicochemical, functional and pasting properties of high quality cassava flour (HQCF) and wheat flour for utilization in baked goods.

Materials and Methods

Materials

Cassava roots TME 419, TMS 98/1632, TMS 98/87164, TMS 98/8082, and TMS 98/0581 used were obtained from National Root Crops Research Institute, Umudike, Abia State, Nigeria. All-purpose wheat flour (Dangote Groups, Nig. Ltd, Lagos, Nigeria) used was obtained from Umuahia main market at Ubani Ibeku in Abia state, Nigeria.

Methods

Production of high quality unfermented cassava flour: The roots were processed into High Quality cassava flour using the method described by IITA [17] as shown in Figure 1. The fresh root cassava was weighed with Avery Birmingham weighing balance and then peeled manually using stainless knife. The peeled cassava samples were then washed with portable water and weighed to determine percentage yield after peeling. The cleaned tubers were later transferred to a grating machine which grated the cassava tubers to slurry/mash. The mash was dewatered using a hydraulic press to about 40% moisture. The cake was pulverized and subjected to drying in an oven (Uniscope SM9023) set at temperature of 1000°C and dried to 8-10% moisture level. After drying, the cake was milled using hammer mills (power crusher F-23ZS111). The fine High Quality Cassava Flour (HQCF) thus obtained was packed in high-density polyethylene bags.

Formulation of HQCF-wheat flour blends: Composite flours of high quality cassava flour (HQCF) and wheat flour were formulated in the following ratios; 0% and 100, 10% and 90%, 20% and 80%, 30% and 70%, 40% and 60% and 50% and 50% respectively and analyzed for the various parameters.

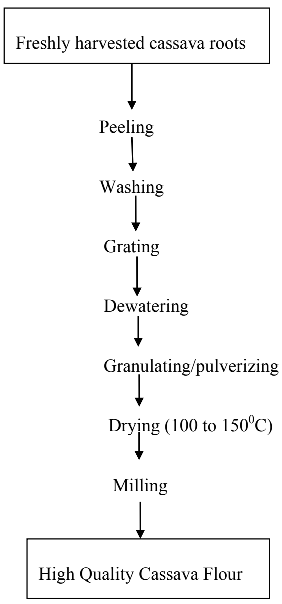

Figure 1: Flow chart for HQCF Production.

Analyses of samples:

Proximate analyses: The moisture contents of the HQCF and wheat flour blends were determined by drying the samples in a forced Genlab (Widnes, England) air oven at 105°C according to the guidelines of AOAC [18] methods. Crude protein (N x 6.25) was estimated through Kjeltec apparatus according to the protocol of AOAC [18]. Crude fat content of the flour samples was estimated using hexane as solvent in a soxtec system as described in AACC [19] methods. Total ash content was estimated by direct incineration of dried samples in a muffle furnace at 550°C after charring till greyish white residue according to the method of AACC [19]. Crude fibre content was determined by digesting the fat free samples in 1.25% H_2SO_4 followed by 1.25% NaOH using Labconco fibretech according to AACC (2000) methods. Total carbohydrate was calculated by difference (total carbohydrate=100 - (moisture + crude protein + crude fat + crude fibre + ash) according to Ihekoronye and Ngoddy [20].

Determination of Hydrogen Cyanide Content: This determination was strictly done on the cassava flour alone. The method of Onwuka [21] was used for this determination. Five grams (5 g) of the cassava flour were weighed into a 250 ml conical flask using an analytical balance followed by the addition of 50 ml of distilled water into the flask and allowed to stand overnight. The solution was filtered and 2 ml of the filterate was poured inside a conical flask (200 ml) and 4 ml of alkaline picrate solution was added. This was then incubated in a water-bath for 5 minutes for colour development (reddish brown) and its absorbance was taken at 490 nm wavelength using a spectrophotometer. Also, a blank was prepared using 2 ml of distilled water and treated the same way as the sample. The hydrogen cyanide content was calculated by the equation:

Hydrogen Cyanide Content = Vf x 1 x 100 x 103(Mg/Kg)/Va x 106

Where Va = Total volume of the extract used and

Vf = Total volume of the extract

W = Weight of sample used.

Analyses of functional properties

Gelatinization temperature: One gram (1 g) of sample was placed in a beaker and 10 ml of distilled water was added and stirred to obtain a homogenized mixture. The beaker containing the sample was heated in a boiling water bath with continuous stirring until it gelled. The temperature was read 30 sec after gelation using a thermometer according to the method of Onwuka [21].

Water absorption capacity: Water absorption capacity was determined as described by Onwuka [21]. 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.

Bulk density: A 10 ml capacity graduated measuring cylinder was weighed and sample was gently filled into the cylinder. The bottom of the cylinder was gently tapped on the laboratory bench severally until there was no diminution of the sample level after filling to the 10 ml mark. Bulk density (g/ml) was then calculated as weight of sample (g)/ volume of sample (ml) according to Onwuka [21].

Determination of Emulsification Capacity (EC): Two grams (2 g) of flour sample was blended with 12.5 ml distilled water at room temperature for 30 sec in a blender at 200 rpm. After complete dispersion, 12.5 ml vegetable oil was gradually added and continued blending for another 30 seconds. The blended sample was transferred into a centrifuge tube and centrifuged at 1600 rpm for 5 min. The volume of oil separated from the sample after centrifuge was read directly from the tube. Emulsion capacity was expressed as the amount of oil emulsified and held per gram of sample [21].

Determination of wettability: Wettability of the flour samples was determined according the method described by Onwuka [21]. One (1) gram of each of the flour samples was weighed using an analytical balance and were each added into a 25 ml graduated measuring cylinder with a diameter of 1 cm. The finger was then placed over the open end of the cylinder in each case, inverted and was clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was then removed and the test sample was allowed to dump. The wettability was recorded as the time required for the sample to become completely wet.

Determination of gelation capacity: The method described by Onwuka [21] was used for the determination of the gelation capacity. Suspensions of the samples in 5 ml of distilled water in test tubes were prepared using 2 –20% (W/V) of the samples in 5 ml of distilled water in test tubes. 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°C. Then, the gelation capacity was determined for each sample as the least gelation concentration. That is, the concentration when the sample from the inverted test tube will not slip.

Pasting properties: Rapid Visco-Analyzer (RVA) (Newport Scientific, Warriewood, Australia) was used to analyze the pasting properties of cassava flours upon heating and subsequent cooling. The RVA General Pasting Method (STD1) was applied. Total running time was 13 min and the viscosity values were recorded every 4 sec by Thermocline Software as the temperature increased from 50°C to 95°C before cooling to 50°C again. Rotation speed was set to 960 rpm for the first 10 sec and to 160 rpm until the end. Three grams of flour and 25.0 ml of distilled water were placed in a canister. A paddle was inserted and shaken through the sample before the canister was inserted into the RVA (Newport Scientific, 1998).

Statistical analysis

Results of all determinations were expressed as means of triplicate values. Data were subjected to one-way Analysis of Variance (ANOVA) and significant differences detected using Tukey's test. An IBM SPSS Statistical package (version 20.0) was used for all statistical analyses.

Results and Discussion

Effects of cassava varieties and level of substitution on the physicochemical properties of high quality cassava flour (HQCF) -wheat composite flour

The results of effects of cassava varieties and level of substitution on the physicochemical properties of cassava-wheat flour blends are presented in Table 1. Moisture contents of the flour samples ranged from 4.15 to 11.90% with sample TMS98/1632 (100%) having the lowest moisture while sample TME419 (90:10%) had the highest. The moisture content of the flour blends increased with increasing HQCF addition. The results also showed that all the cassava-wheat flour blends at given ratios had comparable moisture values. This moisture results however, are lower than the reported values of 10 – 12% moisture content for HQCF [13,22,23]. This result is also an indication that the flour samples will keep well if properly stored under good conditions in other to discourage moisture absorption from the atmosphere which may eventually lead to caking [24]. The moisture content of flour determines its storage stability, as the lower the flour moisture, the higher the storage stability.

The ash content of the flour samples significantly ranged from 0.33 to 2.04% with sample TMS87164 100% having the lowest ash content value while sample TMS0581 100% had the highest. The ash content of the samples increased with increasing level of substitution of HQCF in the blends. This results also shows comparable ash values among the samples at same levels of substitution. The results of the ash values for the HQCF are in agreement with reported specifications of <0.9% [22] and 0.6% [23]. Ash content is a reflection of the mineral matter in a food sample.

Fibre content of the blends ranged from 0.01 to 1.58%. Among 100% cassava flours, 100% TME 419 sample had the highest fibre content (1.58), followed by 100% TMS0581 (1.38), NR8082 (1.09) and TMS98/87164 with 0.96, while 100% TMS 1632 had the least fibre content of 0.01%. The fibre content of the cassava samples is slightly lower than 1.88% reported by Nwosu et al. [25]. However, slight increase in fibre contents were observed for the different compositions though the values did not show any definite pattern.

Results obtained for ether extract (fat) showed that fat content ranged from 0.01 to 1.86% for the flour blends. The results also show significantly low fat content of cassava flours, confirming that cassava tuber is not an oil rich crop [3]. Protein content of the flour blends ranged from 0.18 to 11.38% with 100% cassava flour having lowest protein content values as was expected. The high protein content of flours containing wheat is an indication that wheat is a better source of protein compared to cassava. It is also evident from the result, that increasing level of wheat flour increased protein content of cassava-wheat flour composites. This is in agreement with the report of Akobundu et al. [26] that in selecting the components to be used in composite flour blends, the materials should preferably be readily available, culturally acceptable and provide increased nutritional potentials. It has long been established that the bread-making performance of flours depends on the quantity and quality of their proteins. The variation in protein content of wheat flour significantly affects the mixing characteristics of dough and loaf volume of bread. On the other hand, cassava flour samples recorded higher carbohydrate scores compared to flours containing wheat. This is an indication that cassava tubers are good sources of carbohydrate compared to wheat and the compositions produced blends with higher carbohydrate contents than the parent samples.

Cyanogenic glycosides (HCN) range of 2.04 to 48.13 ppm was obtained for different flour blends with 100% cassava flour varieties containing lower (2.043 to 10.42 ppm) HCN compared with the composite flours. The values are however within the reported safe ranges for human consumption [22]. Hydrogen cyanide (HCN) is the predominant antinutrient in cassava tubers and cassava products. The knowledge of cyanogenic glycoside content of food is vital because cyanide being an effective cytochrome oxidase inhibitor interferes with aerobic respiratory system [21].

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Sample/Treatment	Moisture Content (%)	Ash (%)	Protein (%)	Fibre (%)	Fat (%)	Carbohydrate (%)	Cyanide (ppm)
TMS 87164: Wheat flour							
0:100%	6.9^{c} ± 0.57	0.33^{d} ± 0.00	2.69^{d} ± 0.23	0.96e ± 0.02	0.41^{c} ± 0.01	88.72^{a} ± 0.76	7.12^{c} ± 0.42
0.479166667	9.2^{b} ± 0.28	0.72^{bc} ± 0.18	10.82^{a} ± 0.18	0.16^{d} ± 0.08	1.06^{b} ± 0.08	78.09^{b} ± 0.34	32.48^{ab} ± 0.06
0.888888889	11.30^{a} ± 0.14	0.80^{b} ± 0.01	9.85^{ab} ± 0.93	0.21^{d} ± 0.11	1.20^{b} ± 0.00	76.63^{b} ± 1.16	31.58^{ab} ± 6.40
30:70	10.52^{ab} ± 0.65	0.83^{b} ± 0.00	9.20^{ab} ± 0.62	0.15^{d} ± 0.06	1.42^{ab} ± 0.01	77.63^{b} ± 1.75	30.79^{ab} ± 8.73
40:60	9.10^{b} ± 0.14	0.83^{b} ± 0.03	8.11^{b} ± 0.30	0.32^{d} ± 0.17	1.62^{a} ± 0.02	80.03^{ab} ± 0.33	33.16^{ab} ± 4.38
50:50:00	9.17^{b} ± 0.30	0.88^{b} ± 0.17	7.21^{bc} ± 0.95	0.46^{d} ± 0.04	1.86^{a} ± 0.08	80.42^{ab} ± 0.57	19.95^{c} ± 4.90
NR 8082: Wheat flour							
0.479166667	11.60^{a} ± 0.00	0.83^{b} ± 0.24	10.29^{a} ± 0.93	0.03^{e} ± 0.02	1.15^{a} ± 0.07	76.10^{b} ± 0.74	22.24^{b} ± 0.03
0.888888889	11.10a ± 0.14	0.83^{b} ± 0.03	7.22^{bc} ± 2.79	0.11^{c} ± 0.10	1.05^{b} ± 0.07	79.78^{b} ± 2.99	48.13^{a} ± 9.08
30:70	9.38^{b} ± 0.17	0.88^{b} ± 0.23	8.60^{b} ± 0.40	0.69^{d} ± 0.11	0.68^{c} ± 0.16	80.22^{ab} ± 0.27	11.34^{c} ± 0.55
40:60	9.36^{b} ± 0.39	0.79^{bc} ± 0.13	8.53^{b} ± 0.31	0.04^{e} ± 0.06	0.84^{bc} ± 0.24	80.23^{ab} ± 0.27	8.97^{c} ± 0.48
50:50:00	8.89^{b} ± 0.11	0.85^{b} ± 0.23	0.92^{c} ± 0.23	0.06^{e} ± 0.60	0.60^{c} ± 0.00	88.60^{ab} ± 0.62	5.12^{ef} ± 2.09
TME 419: wheat flour							
0:100%	5.60^{d} ± 0.28	1.33^{a} ± 0.47	3.06^{d} ± 0.62	1.58^{a} ± 0.53	0.21^{d} ± 0.14	88.22^{a} ± 0.95	10.42^{cd} ± 1.74
0.479166667	11.90^{a} ± 0.71	0.83^{b} ± 0.24	11.38^{a} ± 0.62	0.02^{e} ± 0.10	1.55^{a} ± 0.70	74.31^{b} ± 1.15	22.94^{b} ± 2.15
0.888888889	10.90^{ab} ± 0.42	0.50^{d} ± 0.24	10.29^{a} ± 0.31	0.65^{c} ± 0.20	1.30^{a} ± 0.14	76.95^{b} ± 1.09	23.20^{b} ± 1.23
30:70	10.20^{ab} ± 0.28	0.83^{b} ± 0.24	8.76^{b} ± 0.62	0.11^{de} ± 0.01	0.55^{c} ± 0.11	79.56^{b} ± 0.64	19.69^{c} ± 4.11
40:60	9.20^{b} ± 1.41	0.67^{c} ± 0.47	7.00^{bc} ± 0.62	0.12^{de} ± 0.03	0.61^{c} ± 0.00	83.82^{ab} ± 0.54	14.86^{c} ± 0.07
50:50:00	8.60^{bc} ± 0.28	1.17^{a} ± 0.71	6.35^{c} ± 2.79	0.17^{de} ± 0.04	0.35^{d} ± 0.07	84.22^{ab} ± 4.54	14.05^{c} ± 1.85
TMS 0581: wheat flour							
0:100%	7.85^{c} ± 0.04	2.04^{a} ± 0.45	3.60^{d} ± 0.62	1.36^{a} ± 0.10	0.13^{d} ± 0.05	85.58^{a} ± 0.29	3.30^{c} ± 0.33
0.479166667	11.15^{a} ± 0.07	0.64^{c} ± 0.08	10.28^{a} ± 0.31	1.04^{ab} ± 0.18	1.60^{a} ± 0.18	76.71^{b} ± 0.21	25.30^{d} ± 0.88
0.888888889	10.77^{ab} ± 0.13	0.80^{b} ± 0.10	9.41^{ab} ± 0.31	0.91^{b} ± 0.13	1.41^{ab} ± 0.13	78.53^{b} ± 1.18	20.40^{b} ± 0.59
30:70	9.74^{b} ± 0.15	0.98^{b} ± 0.10	9.19^{ab} ± 0.00	0.88b ± 0.13	1.00^{c} ± 0.18	78.35^{b} ± 0.18	18.60^{b} ± 1.64
40:60	8.95^{b} ± 0.19	1.16^{a} ± 0.18	8.85^{b} ± 0.31	0.74^{bc} ± 0.10	1.80^{ab} ± 0.18	79.86^{b} ± 0.61	18.69^{b} ± 1.86
50:50:00	8.56^{bc} ± 0.10	1.36^{a} ± 0.21	8.10^{b} ± 0.30	0.69^{bc} ± 0.18	0.50^{cd} ± 0.12	80.79^{ab} ± 0.92	13.67^{c} ± 1.70
TMS 98/1632: wheat flour							
0:100%	4.15^{e} ± 0.002	1.31^{a} ± 0.170	0.18^{e} ± 0.185	0.70^{c} ± 0.141	0.83^{b} ± 0.105	92.84^{a} ± 0.604	2.043^{f} ± 0.12
0.479166667	10.31^{ab} ± 0.597	0.65^{c} ± 0.119	0.89^{e} ± 0.103	1.30^{a} ± 0.141	0.01^{c} ± 0.000	86.85^{b} ± 0.517	9.722^{d} ± 0.21
0.888888889	8.04^{bc} ± 0.779	0.75^{c} ± 0.118	0.28^{ef} ± 0.000	1.35^{a} ± 0.071	0.12^{c} ± 0.025	89.15^{a} ± 1.393	5.324^{ef} ± 1.09
30:70	8.45^{bc} ± 1.096	0.85^{b} ± 0.118	0.53^{ef} ± 0.371	0.90^{ab} ± 0.141	0.09^{e} ± 0.060	89.19^{a} ± 1.044	8.060^{d} ± 1.10
40:60	7.977^{c} ± 0.43	0.962^{bc} ± 0.19	0.547^{e} ± 0.10	0.1249^{d} ± 0.21	1.100^{b} ± 0.025	89.289^{a} ± 0.10	2.662^{f} ± 0.82
50:50:00	7.147^{c} ± 0.23	1.314^{a} ± 0.112	0.857^{de} ± 0.12	0.2544^{d} ± 0.01	1.100^{b} ± 0.12	89.528^{a} ± 0.42	2.989^{f} ± 0.15
LSD	0.98	0.06	0.98	0.02	0.01	0.21	1

Table 1: Physicochemical properties of cassava-wheat flour (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50% HQCF:WF respectively).

Effects of cassava varieties and level of substitution on the functional composition of high quality cassava flour (HQCF) - wheat composite flour

The results of functional composition of cassava-wheat flour blends are shown in Table 2. Bulk density of the flour blends significantly ranged from 0.550 to 3.69 g/ml with the 40% NR 8082 sample flour having the highest bulk density value while the 100% TMS 0581 and TMS 1632 had the lowest bulk density. Cassava blends compared favorably in bulk density, therefore bulk density of the flours could be used to determine their handling requirement, because it is a function of mass to volume as well as the closeness of packaging [27].

The samples recorded wettability range of 17.07 to 173.01 sec., with flour from 10% TMS 1632 recording the highest wettability value, while flours from TME419 had the least wettability values. However, 100% High quality cassava flours recorded lower values in wettability compared to the composite flours. Wettability is a function of ease of dispersing flour samples in water and the sample with the lowest wettability dissolves fastest in water [28]. This result reveals that 100% cassava flour wets faster compared to its composite flour.

Gelatinization temperature of all the flour samples investigated (29.00 to 74.000°C) fell within the range (<750°C) reported by ARSO [29]. There is a significant variation between the cassava varieties in their gelatinization temperatures with 100%TME419 having the lowest value of 33°C while 100%TMS1632 had the highest value of 69°C. Gelatinization temperature range of was recorded in this study. Gelatinization temperature is the temperature at which starch molecules in a food substance lose their structure and leach out from the granules as swollen amylose and it affects the time required for the cooking of food substances [30].

A range of 0.70 to 2.98 g/ml and 0.91 to 2.85 g/ml were recorded for water and oil absorption capacities respectively. Water absorption capacity (WAC) measures the ability of flour to absorb water and swell for improved consistency in food [31]. Oil absorption capacity (OAC), on the other hand, is important because it acts as flavor retainer and increases the mouth feel of foods. The major chemical compositions that enhance the water absorption capacities of flours are proteins and carbohydrates since these constituents contain hydrophilic parts such as polar or charged side chains. Higher water absorption capacities were observed for the cassava varieties used compared to composite

Sample/ Treatment	Bulk density (g/ml)	Water absorption capacity (%)	Foam capacity (%)	Emulsification capacity (%)	Wettability (sec)	Gelatinization temperature (^{0}C)	Oil absorption capacity (%)
TMS 0581: wheat flour							
100%	0.58^{c} ± 0.58	2.1^{ab} ± 0.89	2.00^{e} ± 0.00	41.52^{f} ± 0.40	21.00^{gh} ± 1.14	42.00^{cd} ± 0.01	1.82^{b} ± 0.00
90:10:00	0.69^{b} ± 0.69	0.70^{d} ± 0.00	14.00^{bc} ± 2.83	48.99^{ab} ± 0.04	120.36^{b} ± 0.02	47.00^{c} ± 1.41	1.45^{bc} ± 0.01
80:20:00	0.70^{b} ± 3.71	1.20^{c} ± 0.01	12.00^{cd} ± 2.83	48.27^{ab} ± 0.16	60.23^{d} ± 0.10	40.50^{c} ± 0.71	1.55^{bc} ± 0.00
70:30:00	0.68^{b} ± 0.68	1.10^{cd} ± 0.02	12.00^{cd} ± 0.00	46.51^{ab} ± 0.18	60.15^{d} ± 0.03	45.00^{bc} ± 0.00	1.36^{c} ± 0.01
60:40:00	0.66^{b} ± 0.66	1.4^{bc} ± 0.10	10.00c^{d} ± 2.83	47.30^{ab} ± 0.14	50.00^{de} ± 2.83	43.50^{c} ± 0.71	1.36^{c} ± 0.00
50:50:00	0.64^{b} ± 0.64	1.6^{b} ± 0.60	8.00^{d} ± 2.83	44.78^{e} ± 0.03	42.00^{c} ± 5.66	44.00^{c} ± 0.00	0.91^{d} ± 0.01
TMS 871641: wheat flour							
0:100%	0.67^{b} ± 0.02	2.65^{a} ± 0.21	2.51^{e} ± 0.26	39.75^{bc} ± 1.03	33.94^{d} ± 1.41	68.38^{ab} ± 0.54	1.27^{c} ± 0.26
0.47916667	0.66^{b} ± 0.12	0.70d ± 0.14	31.13^{a} ± 0.99	42.47^{ab} ± 0.11	104.22^{b} ± 0.55	73.37^{a} ± 0.40	1.17^{c} ± 0.15
0.88888889	0.72^{b} ± 0.01	1.00^{cd} ± 0.28	35.55^{a} ± 0.31	37.55^{cd} ± 0.78	92.30^{c} ± 3.24	72.56^{a} ± 0.16	1.18^{c} ± 0.51
30:70	0.70^{b} ± 0.00	1.00^{cd} ± 0.28	29.91^{a} ± 1.90	36.28^{d} ± 0.78	103.84^{b} ± 2.71	72.05^{a} ± 0.06	1.68^{b} ± 0.06
460:00:00	0.73^{b} ± 0.16	1.15^{cd} ± 0.49	31.63^{a} ± 1.44	43.23^{a} ± 1.66	60.63^{d} ± 0.16	71.44^{a} ± 0.17	1.73^{ab} ± 0.13
50:50:00	0.69^{b} ± 0.05	1.40^{bc} ± 0.00	36.37^{a} ± 0.52	39.99^{bc} ± 02.38	40.97^{d} ± 3.06	70.73^{a} ± 0.23	1.73^{ab} ± 0.14
NR 8082: wheat flour							
0:100%	0.67^{b} ± 0.00	2.98^{a} ± 0.04	4.7^{e} ± 0.25	39.83^{bc} ± 0.69	17.07^{h} ± 0.28	63.27^{b} ± 0.00	1.50^{bc} ± 0.19
0.47916667	0.78^{b} ± 0.00	0.85^{d} ± 0.07	16.25^{b} ± 1.06	44.23^{a} ± 0.53	120.35^{b} ± 0.32	29.00^{d} ± 1.41	1.54^{bc} ± 0.00
0.88888889	0.78^{b} ± 0.01	0.80d ± 0.57	14.25c ± 0.35	47.39^{ab} ± 0.56	60.45^{b} ± 0.11	37.00^{d} ± 4.24	1.46^{bc} ± 0.13
30:70	0.72^{b} ± 0.13	1.00^{cd} ± 0.42	11.00^{cd} ± 1.41	45.01^{ab} ± 0.21	60.33^{b} ± 0.78	35.50^{d} ± 0.71	1.09^{d} ± 0.00
40:60	3.69^{a} ± 4.34	1.25^{cd} ± 0.07	10.00^{cd} ± 2.83	46.01^{ab} ± 0.18	56.55^{bc} ± 13.96	36.00^{d} ± 0.00	1.27^{bc} ± 0.10
50:50:00	0.63^{b} ± 0.02	3.05^{a} ± 0.21	13.67^{c} ± 8.39	40.12^{bc} ± 0.16	41.53^{d} ± 12.66	66.9^{ab} ± 1.27	1.53^{bc} ± 0.10
TME 419: wheat flour							
0:100%	0.77^{b} ± 0.01	2.10^{a} ± 0.14	2.20^{e} ± 0.14	44.23^{b} ± 0.53	27.32^{g} ± 0.62	33.00^{d} ± 0.41	1.41^{bc} ± 0.64
0.47916667	0.77^{b} ± 0.01	1.25^{b} ± 0.07	17.55^{b} ± 0.64	43.34^{b} ± 0.74	74.81^{d} ± 5.10	44.00^{c} ± 5.70	1.41^{bc} ± 0.19
0.88888889	0.78^{b} ± 0.00	1.39^{b} ± 0.01	13.50^{c} ± 0.71	46.36^{a} ± 1.42	62.54^{d} ± 2.34	39.50^{cd} ± 0.71	1.32^{c} ± 0.32
30:70	0.78^{b} ± 0.00	1.44^{b} ± 0.03	7.65^{d} ± 0.21	47.78^{a} ± 0.65	64.78^{d} ± 1.74	40.00^{cd} ± 0.00	1.32^{c} ± 0.32
40:60	0.77^{b} ± 0.01	1.53^{b} ± 0.11	6.25^{d} ± 0.21	45.91^{ab} ± 0.73	77.10^{d} ± 5.66	40.00^{cd} ± 0.00	1.31^{c} ± 0.32
50:50:00	0.76^{b} ± 0.00	1.55^{b} ± 0.07	5.90^{d} ± 0.14	44.83^{b} ± 0.88	35.77^{f} ± 1.20	31.50^{d} ± 2.12	1.27^{c} ± 0.13
TMS 1632: wheat flour							
0:100%	0.55^{c} ± 0.008	1.80^{b} ± 0.131	1.96^{ef} ± 0.000	57.91^{a} ± 2.960	27.52^{g} ± 0.976	69.00^{ab} ± 7.071	2.85^{a} ± 0.212
0.47916667	0.63^{b} ± 0.007	1.63b ± 0.187	9.19^{e} ± 0.872	36.23^{c} ± 3.155	173.01^{a} ± 37.024	74.00^{a} ± 0.000	2.38^{a} ± 0.389
0.88888889	0.621^{b} ± 0.015	1.50^{bc} ± 0.124	18.23^{b} ± 0.824	33.33^{c} ± 0.000	77.41^{d} ± 9.496	73.10^{a} ± 1.556	2.45^{a} ± 0.495
30:70	0.601^{b} ± 0.030	1.51^{bc} ± 0.224	16.55^{b} ± 1.224	41.49^{bc} ± 1.504	55.18^{ef} ± 9.892	71.90^{a} ± 0.141	2.50^{a} ± 0.707
40:60	0.622^{b} ± 0.02	1.55^{bc} ± 0.11	15.82^{bc} ± 0.21	38.00^{bc} ± 1.66	43.81^{d} ± 7.00	71.40^{a} ± 1.90	1.60^{bc} ± 0.211
50:50:00	0.628^{b} ± 0.12	1.60^{b} ± 0.20	14.73^{c} ± 0.32	36.70^{bc} ± 1.33	38.23^{ef} ± 4.90	70.10^{a} ± 0.38	1.59^{bc} ± 0.19
LSD	0.93	0.09	0.89	1	1	1	0.24

Table 2: Functional properties of cassava-wheat flour blends (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50% HQCF:WF respectively).

flours as well as in oil absorption capacity. This is an indication that 100% cassava flour could be a good retainer of flavor and could also give a better mouth feel when used in food preparation. The higher WAC of the HQCFs compared to composite flours could also be an indication of higher polar amino acid residues of proteins having an affinity for water molecules. Water absorption capacity is important in bulking and consistency of products as well as in baking applications [32]. 100% TMS 1632 with mean oil absorption capacity (OAC) value of 2.85 g/ml had the highest value, and best in OAC than other cassava flours.

The foam capacity of the flour samples ranged from 1.96 to 36.37% with the cassava flour samples having the lowest values, increasing level of wheat flour addition. Good foam capacity is a desirable attribute for flours intended for the production of variety of baked products such as bread, cakes, muffins, cookies etc. and also act as functional agents in other food formulations [33]. Emulsion capacity simply determines the maximum amount of oil that can be emulsified by protein. The emulsion capacity of the flour samples ranged of 33.33 to 57.91% with 100% TMS 1632 having the highest mean value. All the flour samples had higher emulsion values than wheat flour. However, there was significant difference ($P<0.05$) in emulsion capacities of the flour samples. High emulsion capacities as observed in this research are positive indication that the flour samples could have excellent emulsifying properties in various foods [26].

Effects of cassava varieties and level of substitution on the pasting properties of the high-quality cassava flour (HQCF) and wheat flour blends

Results of the pasting properties of HQCF – wheat flour composite flours are shown in Table 3. Pasting profile of flour from wheat and the

Sample/Treatment Wheat: cassava	Peak Viscosity (RVU)	Trough (RVU)	Break Down (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temperature (ºc)
TMS 98/1632: wheat flour							
0:100%	133.17^{g}	94.83^{f}	38.33^{g}	130.83^{g}	36^{g}	5.73^{a}	95.2^{a}
10:90%	197.37^{e}	158.92^{d}	38.45^{d}	249.25^{d}	98.33^{c}	5.12^{b}	83.35^{d}
20:80%	235.88^{d}	108.58^{f}	127.30^{a}	183.42^{f}	74.84^{e}	5.55^{ab}	79.66^{g}
30:70%	251.83^{c}	220.08^{b}	31.75^{g}	300.25^{c}	80.17^{d}	5.09^{ab}	84.25^{b}
40:60%	278.67^{b}	199.83^{b}	78.83^{b}	391.58^{b}	191.75^{a}	5.35^{ab}	83.65^{c}
50:50%	301.08^{a}	240.33^{a}	60.75^{c}	413.83^{a}	173.50^{b}	5.18^{ab}	82.45^{e}
100:0%	191.17^{f}	156.00^{e}	35.17^{f}	224.33^{e}	68.33^{f}	5.27^{ab}	82.05^{f}
TMS 98/87164: wheat flour							
0:100%	133.17^{g}	94.83^{f}	38.33^{g}	130.83^{g}	36^{g}	5.73^{a}	95.2^{a}
10:90%	119.67^{g}	70.92^{g}	48.75^{a}	126.50^{g}	55.58^{f}	5.33^{f}	81.75^{f}
20:80%	133.50^{e}	85.08^{f}	48.42^{b}	145.25^{e}	60.17^{e}	6.22^{a}	83.36^{b}
30:70%	169.42^{c}	109.08^{d}	-60.34^{g}	230.57^{d}	61.15^{d}	5.22^{g}	82.65^{c}
40:60%	194.25^{b}	148.75^{b}	45.50^{c}	237.58^{c}	88.83^{c}	6.12^{b}	82.35^{e}
50:50%	197.33^{a}	158.92^{a}	38.42^{d}	249.25^{a}	90.33^{b}	5.42^{d}	81.42^{g}
100:0%	161.17^{d}	123.25^{c}	37.92^{f}	247.33^{b}	124.08^{a}	5.33^{e}	82.39^{d}
TME 419: wheat flour							
0:100%	133.17^{g}	94.83^{f}	38.33^{g}	130.83^{g}	36^{g}	5.73^{a}	95.2^{a}
10:90%	66.08^{f}	62.08^{f}	4.00^{d}	235.42^{c}	173.33^{c}	6.62^{b}	91.75^{d}
20:80%	66.67^{e}	62.42^{e}	4.25^{c}	256.75^{a}	194.33^{a}	5.75^{c}	92.25^{c}
30:70%	69.92^{d}	67.25^{d}	2.67^{e}	250.00^{b}	182.75$_{b}$	5.58^{e}	90.24^{e}
40:60%	79.17^{c}	78.58^{c}	0.59^{g}	129.67^{g}	50.5^{e}	5.18^{g}	83.95^{g}
50:50%	98.50^{b}	91.83^{b}	6.67^{b}	131.17^{e}	39.33^{f}	5.22^{f}	84.12^{f}
100:0%	62.75^{g}	60.58^{g}	2.17^{f}	230.83^{d}	170.25^{d}	6.88^{a}	94.45^{b}
NR 98/8082: wheat flour							
0:100%	133.17^{g}	94.83^{f}	38.33^{g}	130.83^{g}	36^{g}	5.73^{a}	95.2^{a}
10:90%	135.08^{f}	98.00^{e}	37.08^{f}	160.17^{e}	62.17^{d}	4.93^{g}	88.95^{b}
20:80%	157.33^{e}	90.08^{g}	67.25^{c}	123.58^{g}	33.50^{g}	5.19^{e}	82.70^{f}
30:70%	213.83^{c}	107.08^{d}	106.75^{a}	196.67^{d}	89.58^{b}	5.27^{f}	82.49^{g}
40:60%	221.42^{b}	157.00^{b}	64.42^{d}	237.08^{a}	80.08^{c}	6.35^{b}	84.45^{d}
50:50%	222.08^{a}	140.42^{c}	81.67^{b}	233.00^{c}	92.58^{a}	6.75^{a}	85.05^{c}
100:0%	199.00^{d}	194.00^{a}	5.00^{g}	235.58^{b}	41.58^{e}	5.93^{c}	84.00^{e}
TMS 98/0581: wheat flour							
0:100%	133.17^{g}	94.83^{f}	38.33^{g}	130.83^{g}	36^{g}	5.73^{a}	95.2^{a}
10:90%	240.25^{e}	104.17^{e}	136.08^{d}	144.67^{f}	40.52^{f}	4.33^{f}	75.25^{f}
20:80%	302.58^{d}	216.00^{a}	86.58^{e}	390.67^{a}	174.67^{a}	4.80^{c}	80.80d
30:70%	304.08^{c}	132.92^{c}	171.17^{b}	177.83^{e}	44.92^{e}	4.13^{g}	74.35^{g}
40:60%	345.83^{b}	18.67^{g}	164.17^{c}	230.75^{b}	49.08^{d}	4.73^{d}	79.9^{c}
50:50%	358.08^{a}	168.67^{b}	189.42^{a}	228.42^{c}	59.75^{c}	4.53^{e}	81.65^{e}
100:0%	168.92^{f}	128.75^{d}	40.17^{f}	207.17^{d}	78.42^{b}	5.13^{b}	84.80^{b}

Table 3: Pasting properties of cassava-wheat flour.

five varieties of cassava Peak viscosity is indicative of ease of cooking of a particular sample. Values for peak viscosity for the five cassava varieties ranged from 66.08 to 358.08 RVU with 50% TMS98/0581 while the lowest peak viscosity was observed for TME419. Peak viscosity increased with increase in the ratio of cassava flour and this could be attributed to the high degree of swelling of cassava starch granules. The rapid drop in viscosity at 95ºC corresponding to almost half of the peak viscosity suggests a large extent of breakdown of the paste and hence low stability. Cassava flours are reported to be high in amylose (≈ 90%) and consequently, they exhibit a high retrogradation tendency (high final viscosity upon cooling compared to peak viscosity) [16]. The final viscosity, a parameter commonly used to determine a sample's ability to form a gel after cooking and cooling ranged from 123.58 RUV to 413.83 RUV. 100% cassava flour from the five varieties showed an increase in final viscosity and lower peak viscosity compared to wheat flours. A higher setback viscosity was also observed for cassava flour as the final viscosity was relatively higher. These findings confirmed earlier reports that cereal starches have a lower peak viscosity compared to tubers and root starches [34,35].

Pasting temperature, which is also related to paste stability, gives an indication of the strength of associative forces within the granules [16,36]. Flour samples from the five cassava varieties characterized by early gelatinization showed similar pasting temperature of 74.350ºC to 94.45ºC, which was lower compared to pasting temperature of wheat flour (Table 3). This reveals lower gelatinization temperature of cassava starch granules, which translates into shorter cooking time and lower paste stability of cassava flour as opposed to the wheat flour [36].

The pasting profiles of flour from TME419 and its wheat composite flours were verifiably different from flour samples from TMS98/87164, TMS98/0581, TMS98/87164 and TMS98/1632 and their wheat flour composites. The addition of cassava flour to wheat affected some pasting properties of the composite flour. The onset of gelatinization occurred faster for flours with a high inclusion level of cassava and retrogradation decreased as proportion of cassava flour increased. Increasing substitution level would be felt very much in the eating quality of foods prepared from this composite flour as the paste stability is consistently reduced. Nonetheless, 20% replacement of wheat flour with cassava flour showed paste stability which was akin to 30% substitution level. The behaviour in pasting characteristics among starches is attributable to differences in amylose content, crystallinity and the presence or absence of amylose-lipid interaction [37,38]. This effect of cassava flour on the composite flour can therefore be explained by the increase in amylose-gluten or amylose-lipid complexes.

Conclusion

This study has established that differences in cassava varieties have implications on the physicochemical, functional and pasting properties of flours prepared from them. Variety TMS 98/0581 was observed to contain more crude fibre than other cassava varieties and can be regarded as a good source of fibre. TMS98/1632 is lowest in protein but highest in carbohydrates. Substitution of wheat flour with high quality cassava flour (HQCF) increased the carbohydrates content but decreased the protein content considerably. This also had effects on the functional and pasting properties as they depend to a large extent on chemical properties, especially, the starch and protein content of the flours. Overall, the flour blends displayed good characteristics that are desired in baked products.

Acknowledgment

We acknowledge the provision of funds, support and supervision through The Royal Institution for the Advancement of Learning/McGill University, 845 Sherbrooke Street West, Montréal, QC, H3A 0G4, and role of facilitation by the International Institute for Tropical Agriculture, Ibadan (IITA) Nigeria.

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