Physicochemical and Sensory Properties of Gluten-Free Semolina Produced from Blends of Cassava, Maize and Rice

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Abstract**—**The proximate, functional, pasting, and sensory properties of semolina from blends of cassava, maize, and rice were investigated. Cassava, maize, and rice were milled and sieved to pass through a 1000 µm sieve, then blended in the following ratios to produce five samples; FS_1 (40:30:30), FS_2 (20:50:30), FS_3 (25:25:50), FS_4 (34:33:33) and FS_5 (60:20:20) for cassava, maize, and rice, respectively. A market sample of wheat semolina labeled as FSc served as the control. The proximate composition, functional properties, pasting profile, and sensory characteristics of the blends were determined using standard analytical methods. The protein content of the samples ranged from 5.66% to 6.15%, with sample FS_2 having the highest value and being significantly different ($p \leq 0.05$). The bulk density of the formulated samples ranged from 0.60 and 0.62 g/ml. The control (FSc) had a higher bulk density of 0.71 g/ml. The water absorption capacity of both the formulated and control samples ranged from 0.67% to 2.02%, with FS_3 having the highest value and FSc having the lowest value (0.67%). The peak viscosity of the samples ranged from 60.83-169.42 RVU, and the final viscosity of semolina samples ranged from 131.17 to 235.42 RVU. FS_5 had the highest overall acceptability score (7.46), but there was no significant difference ($p \leq 0.05$) from other samples except for FS_2 (6.54) and FS_3 (6.29). This study establishes that high-quality and consumer-acceptable semolina that is comparable to the market sample could be produced from blends of cassava, maize, and rice.

Keywords**—**Semolina, gluten, celiac disease, wheat allergies.

I. Introduction

THE awareness of gluten related disorder is in increasing by the day. The term “gluten-related disorders” is the umbrella-term to be used for describing all conditions related to ingestion of gluten-containing food [1]. Similarly, celiac diseases (CD) are a chronic small intestinal, immune-mediated, enteropathy condition developed upon consumption of dietary gluten and related prolamines in genetically predisposed individuals, characterized by specific autoantibodies against tissue transglutaminase 2 (anti-TG2) and endomysium (EMA). While, wheat allergy (WA) is an adverse immunologic reaction to wheat proteins [2]. Until after year 2000, gluten intolerance has been believed to be typical of CD and WA. Published study result has proved that gluten intolerance can also affect persons who do not suffer from any of the aforementioned diseases [3].

Semolina is used to designate coarse middling from durum and other wheat varieties, and sometimes other grains (such as rice and corn) as well. Semolina does not come from corn; it is traditionally a product of the endosperm of durum wheat. Therefore, it is not gluten-free. In fact, semolina is particularly high in gluten [4]. Semolina from durum wheat is a preferred substrate for the manufacture of pasta products [5]. The term semolina is also used to refer to coarse middlings from other varieties of wheat, and from other grains such as rice and corn [6].

However, wheat pasta is not recommended for people with celiac disease because their immune system has a disorder in which the sentinel lesion is on enteropathy triggered by the ingestion of gluten proteins [7]. It is known that the only possible therapy is a lifetime gluten-free diet, during which the damage to the intestinal mucosa regresses and the patient’s well-being improves considerably. To ensure the manufacture of proper quality gluten-free foodstuffs, such formula must be of such quality characteristics that resemble conventional pasta [7].

The degree of difficulty in producing gluten free products is closely associated with the technological role of gluten in the food-system [5], [8]. Although, the demand for better-tasting, better-textured, and healthier gluten free products offers great market opportunities for food manufacturers, the replacement of gluten functionality still presents a major technological challenge [9]-[11].

Cassava (*Manihot esculenta*, Crantz), is one of the most important food crops in the humid tropics, it provides calories for over 160 million people of Africa [12], [13]. Maize (*Zea mays*) is now a staple food in many parts on the globe, with the total production of Maize surpassing that of wheat or rice [14]. Both the embryo and endosperm of maize contain proteins but the germ proteins are superior in quality as well as quantity [15].

Recently, the fear of health risk (like Diarrhea, constipation, fatigue), gluten intolerance and allergies associated with gluten consumption has been on a high rate. This has led to global quest for gluten-free foods. Semolina is produced from wheat that is known to have high gluten content amongst other plants. Cassava, maize and rice are local staples food with great potentials to be developed. The nutritional composition and functional properties of cassava, maize and rice is comparable to that of wheat except for the gluten and so can be used to formulate gluten-free semolina hence, this study geared towards the development and physicochemical evaluation of gluten-free semolina using cassava, maize and rice blends.

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II. Materials and Methods

A. Materials

White maize (ART/98/SW) was obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Nigeria. High quality cassava roots (058/CMS) were obtained from Cross River Agricultural Development Programme (CRADP), center in Calabar, Nigeria. High quality polished rice and wheat semolina (used as control) was purchased from watt market, Calabar, Nigeria. All analyses and experiments were carried out at the Department of Food Science and Technology Laboratories, University of Calabar, Calabar, Nigeria with analytical grades chemicals and reagents.

B. Preparation and Formulation of Semolina Samples

Freshly harvested cassava root, maize and rice grains were processed into coarse flour separately due to the difference in their preparation processes and peculiarities, before they were formulated into different blends. Wholesome cassava roots for production were peeled manually with a stainless steel knife, washed with portable water and sliced thinly. Sliced cassava were dried in a hot air oven at a temperature of 60 ºC for six hours, then dried milled using a mini-Laboratory mill into coarse flour and then sieved manually with a 1000 µm sieve size and packed in an air tight container. The maize grains were cleaned and milled into *to pass through* sieve size of 1000 µm. Rice semolina was prepared just like maize semolina and packaged in air tight container prior formulation and other analysis. Cassava, maize and rice semolina were mixed in different ratio to get five samples as shown in Table I.

TABLE I
SEMOLINA SAMPLES FORMULATION

Sample Codes	Cassava	Maize	Rice	Wheat
FS_1	40%	30%	30%	-
FS_2	20%	50%	30%	-
FS_3	25%	25%	50%	-
FS_4	60%	20%	20%	-
FS_5	34%	33%	33%	-
FSc	-	-	-	100%

C. Functional Properties Determination of the Semolina Samples

Functional properties of the various blends were evaluated. These include pH, bulk density and water absorption capacity. The pH was measured by making a 10% w/v suspension of the semolina sample in distilled water. The suspension was mixed thoroughly in a Sorex blender and the pH was measured with a Hanna checker pH meter (Model HI 1270) after calibrating the pH meter with buffer 4 and 7. Bulk density was determined according to the method of Onwuka [16]. A 100 ml graduated cylinder, previously tarred, was gently filled with the semolina samples. The bottom of the cylinder was gently tapped on a laboratory bench ten times. Bulk density was calculated as weight of sample per unit volume of sample (g/ml). Water absorption capacity was determined using the method of Sathe and Salunkhe [17] as modified by Gbadamosi and Oladeji [18], distilled water and sample was added in the ratio of 10:1 in a beaker, the suspension was stirred on a magnetic stirrer for five minutes. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 min before the supernatant was measured in a 10 ml graduated cylinder. The density of water was taken as 1.0 $g.cm^3$. Water absorbed was calculated as the difference between the sample and the volume of the supernatant and the initial volume of water added.

D. Proximate Composition Determination

The flour was analyzed for moisture content, crude fat, crude protein, total ash content and crude fiber according to the method of analysis of the Association of Official Analytical Chemists. Carbohydrate content of the samples was determined by difference AOAC [19].

E. Pasting Profile Determination of the Semolina Samples

The pasting properties were measured with a Rapid Visco Analyzer (New Scientific Australia) using the method of Akanbi et al. [20]. Samples (2.5 g) each of the flour samples were weighed into already dried empty canister, distilled water 25 ml was dispensed into the canister with each sample. The solution was thoroughly mixed then the canister was well fitted into the RVA, following recommendation. The slurry was heated from 50 to 95 ºC with a holding time of 2 minutes followed by cooling to 50 ºC with two minutes holding time. The rate of heating and cooling remained constant at 11.25 ºC/min. Peak viscosity, trough, final viscosity, breakdown set back, pasting temperature and peak time were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer

F. Sensory Evaluation of the Semolina Samples

Consumer acceptability of the product was carried out as described by Larmond [21]. A twenty-four member semi-trained panelists consisting of students, lecturers and technologists who were familiar with the product were engaged to assess the products. The products were prepared (3:10 w/v flour and water) under the same condition of temperature, using the same volume of water, coded and rated for color, taste, aroma, texture, and overall acceptability. Samples were evaluated for all sensory attributes on a 9-point Hedonic scale which was quantified from one for dislike extremely to nine for like extremely.

G. Statistical Analysis

The data were generated in three replicates and the result expressed as mean ± standard deviation. Where applicable data were analyzed statistically using analysis of variance (ANOVA) with $\alpha = 0.05$ (SPSS version 17) to statistically determine the significant difference between the samples. Means difference was calculated using Duncan's new multiple range tests of the same package.

III. Results and Discussion

A. Functional Properties of the Semolina

The functional properties of the semolina samples are shown in Table II. The pH of both formulated samples and the market sample were within the slightly acidic range of 5.50-6.20 with

FS_1 significantly different ($p \leq 0.05$) from other samples. The slightest acid range of the samples is an indication that the samples will have a longer shelf life as most microorganisms will rarely in acidic medium [22]. The bulk density of the formulated samples ranges from 0.60 and 0.62 g/ml, the market sample (FSc) had the highest bulk density (0.71 g/ml) compared to other formulated samples at $P < 0.05$ no significant difference existed in samples FS_1, FS_2 and FS_3. The results of bulk density agree with that of Fasasi et al. [23] who reported a bulk density ranged from 0.5-0.6 g/ml for *ogi* fortified with tilapia fish powder. It is also a little lower to 0.56 -0.74 g/ml reported for poundomix by Oladeji and Akanbi [24]. The reduction in bulk density FS_4 might be an indication that bulk density of cassava semolina is lower than that of rice and maize as FS_4 had the highest cassava level. The water absorption capacity of the semolina samples was significantly ($p \leq 0.05$) different. Sample FS_3 with 50% rice blends had the highest water absorption capacity (2.02 g/g). This means that rice semolina absorbed higher water content than cassava and maize.

TABLE II
FUNCTIONAL PROPERTIES OF SEMOLINA SAMPLES

Samples	pH	Bulk density (g/ml)	Water Absorption Capacity (g/g)
FS_1	6.20 ± 0.11^{a}	0.61 ± 0.10^{bc}	1.93 ± 0.13^{b}
FS_2	6.10 ± 0.01^{bc}	0.61 ± 0.01^{bc}	1.71 ± 0.11^{e}
FS_3	6.10 ± 0.11^{c}	0.61 ± 0.11^{bc}	2.02 ± 0.13^{a}
FS_4	6.20 ± 0.13^{ab}	0.60 ± 0.11^{c}	1.76 ± 0.10^{c}
FS_5	6.10 ± 0.11^{c}	0.62 ± 0.11^{b}	1.74 ± 0.01^{d}
FSc	5.50 ± 0.01^{d}	0.71 ± 0.12^{a}	0.67 ± 0.01^{f}

Values are means of three replicates ± standard deviation; same superscripts are not significantly different along the column ($p \leq 0.05$).

Key: FS_1 (40:30:30), FS_2 (20:50:30), FS_3 (25:25:50), FS_4 (34:33:33) and FS_5 (60:20:20) for cassava, maize and rice, respectively.

B. Proximate Composition of the Semolina

The proximate composition of the semolina samples (Table III) showed that the moisture content ranged from 6.40 and 10.40% for the formulated samples. While, the moisture content of the market sample (FSc) was 5.33% and was significantly lower ($p \leq 0.05$) than all the formulated samples. The protein content of the formulated samples ranged from 6.66 and 7.15% with sample FS_2 having the highest value of 7.15%, the protein content of FS_1 shows that the sample was comparable to the market sample as (FSc) with no significant different (Table III). The protein result is expected as lower cassava fraction favor increase protein content and protein content of maize and rice are higher than that of cassava. Carbohydrate level ranges from 63.36 and 71.01%, the range is similar to the reports of earlier studies for maize flour [21], [25]. It was relatively higher in sample FS_1 (71.01%) compared to the market sample (FSc) having 68.89% as the carbohydrate value. The crude ash level of the formulated samples ranges from 0.83 and 1.83% with sample FS_5 having 1.83% as the highest value. The market sample (FSc) had the lowest ash value of 0.83% and significantly different ($p \leq 0.05$) from formulated samples.

C. Pasting Profile of the Semolina

The pasting properties of the samples are presented in Table IV. The peak viscosity of the samples ranges from 60.83-169.42 RVU. The peak viscosity is indicative of the vicious load likely to be encountered during mixing [26]. Increased in peak viscosity lead to increased swelling index, while low paste viscosity is reflection of higher solubility as a result starch dextrinization or degradation [27]. Among the formulated samples, peak viscosity was higher in sample FS_5 (169.42 RVU) and lowest in sample FS_2 (60.83 RVU). The value obtained for FS_4 (66.08) is the closest to the market value (FSc) (79.17) RVU. It was observed that FS_5 with almost equal ratio of cassava, maize and rice had the highest peak viscosity showing synergic activities of their starches. The trough of semolina in this study is between 58.25 and 109.08 RVU. The trough was highest in FS_5 (109.08) RVU and lowest in FBS_2 (58.25 RVU) compared to the control sample (78.58 RVU). The holding strength or trough of the blend is the minimum viscosity after the peak, making the starch granules of the flour to remain undisrupted when the flour paste is subjected to a holding period of constant temperature, time and shear stress [28].

Breakdown viscosity ranged from 2.58-60.34 RVU with highest value obtained in the FS_5 (60.34 RVU) and breakdown viscosity was lowest in FS_2 (2.58 RVU) compared to other formulated samples but the control was lower than the formulated samples. Breakdown viscosity is the measure of the tendency of swollen starch granules to rupture when held at high temperature and continuous shearing breakdown viscosity is indicative of paste stability. Setback value of the blend ranged from 39.33 - 173.33 RVU compared to the control (50.50 RVU). It is the phase of the pasting curve after cooling of the starch and this phase involves re-association, retrogradation or ne-ordering of starch molecules. Setback value is the tendency of starch to associate and retrogradate on cooling. Peroni et al. [29] indicated that flour with low setback may have low values of amylose which have high molecular weight, the lower the retrogradation, the higher the setback value, during cooling of the products made from the flour [30]. High setback is associated with syneresis. The sample FS_4 (173.33 RVU) and FBS_2 (163.92 RVU) had significantly higher setback value compared to the control (50.50 RVU) and FS_5 (61.15 RVU) the setback value of the control and FS_5 had no significant difference. Thus, the starch strength of the formulated semolina is better than the control and sample (FS_5), but could form a better flour paste that could find applications in the confectionary industries.

The peak time of the blends and the control in this study ranged from 6.02-6.66 min. The peak time was highest in the control (6.66 min) and lowest in FS_2 (6.02 min), sample FS_4 (6.33 min) and FS_5 (6.33 min) had no significant ($p \leq 0.05$) difference.

D. Sensory Quality of the Semolina

The sensory scores of both the formulated and control samples are shown on Table V. The results indicate that no significant difference existed in the color of FS_4 and FS_5 at $P \leq 0.05$, samples FS_1, FS_2 and FS_3 equally had no significant difference in their color. However, significant difference existed between the control (FSc) and the formulated samples at $p \leq 0.05$. The aroma of the formulated samples had no significant difference except for FS_3 which was significantly different with (6.21) at $p \leq 0.05$ than others, but the control was significantly different from others. Sample FS_5 (9.46) had the highest overall acceptability but with no significant difference except for sample FS_2 (6.54) and FS_3 (6.29) which are not significantly different at $P \leq 0.05$. Sensory is considered a key factor in food acceptance, since consumers look out for food with specific sensory characteristics.

TABLE III
PROXIMATE COMPOSITION OF THE SEMOLINA SAMPLES

Samples	Moisture (%)	Protein (%)	Fiber (%)	Fat (%)	Ash (%)	CHO (%)
FS_1	6.40 ± 0.02^c	6.93 ± 0.01^{ab}	1.00 ± 0.01^b	1.32 ± 0.01^d	1.50 ± 0.01^c	71.01 ± 0.0
FS_2	8.63 ± 0.01^b	7.15 ± 0.01^a	0.67 ± 0.01^c	0.29 ± 0.01^e	1.07 ± 0.03^e	68.05 ± 0.0
FS_3	9.93 ± 0.02^{ab}	7.04 ± 0.04^a	1.50 ± 0.02^a	1.65 ± 0.02^{ab}	1.67 ± 0.03^b	63.36 ± 0.01
FS_4	9.27 ± 0.01^{ab}	6.66 ± 0.01^b	1.50 ± 0.01^a	1.42 ± 0.01^c	1.17 ± 0.01^d	67.24 ± 0.01
FS_5	10.04 ± 0.0^a	6.73 ± 0.03^{ab}	1.00 ± 0.01^b	1.61 ± 0.02^b	2.83 ± 0.03^a	63.36 ± 0.01
FSc	5.33 ± 0.01^d	6.78 ± 0.01^{ab}	1.07 ± 0.01^{ab}	1.70 ± 0.02^a	0.83 ± 0.01^f	68.89 ± 0.01

Values are means of three replicates ± Standard deviation; same superscripts are not significantly different along the column ($p \leq 0.05$).
Key: FS_1 (40:30:30), FS_2 (20:50:30), FS_3 (25:25:50), FS_4 (34:33:33) and FS_5 (60:20:20) for cassava, maize and rice respectively

TABLE IV
PASTING PROFILE OF SEMOLINA SAMPLES

Samples	FS_1	FS_2	FS_3	FS_4	FS_5	FSc
Peak 1 (RVU)	108.58	60.83	98.5	66.08	169.42	79.17
Trough 1 (RVU)	67.67	58.25	91.83	62.08	109.08	78.58
Breakdown (RVU)	40.91	2.58	6.67	4	60.34	0.58
Final Viscosity (RVU)	170.08	222.17	131.17	235.42	230.57	129.67
Setback (RVU)	102.41	163.92	39.33	173.33	61.15	50.5
Peak time (mns)	6.18	6.02	6.09	6.33	6.33	6.66
Pasting Temperature (°C)	92.42	92.56	93.28	93.22	92.45	92.45

Values are means of three replicates.
Key: FS_1 (40:30:30), FS_2 (20:50:30), FS_3 (25:25:50), FS_4 (34:33:33) and FS_5 (60:20:20) for cassava, maize and rice respectively

TABLE V
SENSORY CHARACTERISTICS OF SEMOLINA SAMPLES

Sample codes	Color	Taste	Aroma	Texture	Overall Acceptability
FS_1	$7.46^{ab} \pm 1.41$	$7.25^a \pm 1.98$	$6.96^{ab} \pm 1.09$	$5.83^c \pm 1.33$	$7.34^a \pm 1.64$
FS_2	$7.67^{ab} \pm 1.20$	$6.58^a \pm 1.64$	$6.54^{ab} \pm 1.19$	$6.00^c \pm 1.79$	$6.54^b \pm 1.38$
FS_3	$7.29^{ab} \pm 1.43$	$6.42^a \pm 1.77$	$6.21^b \pm 1.13$	$6.20^c \pm 1.38$	$6.29^b \pm 1.55$
FS_4	$7.88^a \pm 0.89$	$6.79^a \pm 1.06$	$6.79^{ab} \pm 1.06$	$7.75^a \pm 1.11$	$7.33^a \pm 0.82$
FS_5	$7.92^a \pm 0.97$	$6.79^a \pm 0.93$	$6.70^{ab} \pm 1.29$	$7.08^{ab} \pm 1.38$	$7.46^a \pm 0.98$
FSc	$6.88^b \pm 1.92$	$6.88^a \pm 1.03$	$7.46^a \pm 1.84$	$7.42^a \pm 1.10$	$7.33^a \pm 1.17$

Values are means of replicates ± Standard deviation; same superscripts are not significantly different along the column ($p \leq 0.05$).
Key: FS_1 (40:30:30), FS_2 (20:50:30), FS_3 (25:25:50), FS_4 (34:33:33) and FS_5 (60:20:20) for cassava, maize and rice respectively.

IV. CONCLUSION

The use of cassava, maize and rice blends to substitute wheat semolina improves nutritional content, functional and pasting properties of semolina. So, nutritious and consumer acceptable semolina could be produced from blends of cassava, rice and maize blends. Sample FS_5 with almost equal ratio of cassava, maize and rice resulted to a high quality semolina product that is comparable with 100% wheat semolina. Thus, individuals who are faced with daily challenges imposed by a strict gluten-free diet treatment could find this semolina a good alternative to wheat based counterparts (wheat semolina).

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