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Functional Characterization of Blended Starch

Bitrus Wokhe Tukura*, Florence Nkiruka Obelle

Department of Chemistry, Faculty of Natural and Applied Sciences, Nasarawa State University, Keffi, Nigeria

Email address:
bittytukura@yahoo.com (B. W. Tukura)
*Corresponding author

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Abstract: Native starches, irrespective of their sources, are undesirable for many industrial applications because of their inability to withstand processing conditions. Functional properties of blended finger millet starch using maize modifiers at different ratios for specific applications in food processing industry were determined using standard methods. Functional properties varied according the type of modifier used and blending ratios of the native finger millet starch to that of the modifier. Higher bulk density of the blended starch makes the flour more suitable for packaging, transportation and use in some food preparations. GG starch is a better emulsifier compared to the native MS and FM starch. The blended starches have less tendency of absorbing and retaining water than its native form. Low Carr's index and porosity indicated poor flow for the blended starch, due to cohesiveness of the blended flour. The functional properties of the blended starch did not vary significantly ($P \leq 0.05$) according to mixture ratios; however, show some significant changes according to the type modifier used. Higher charring and browning temperatures of the blended starch make the starch useful in food processes that require heating at high temperatures. Depending on the desirability for use in various food products, functional properties of finger millet flour may be improved by preparing their blends with maize modifiers in suitable proportions.

Keywords: Starch, Blend, Functional Properties, Finger Millet, Food Quality

1. Introduction

Food crops, including cereals, have occupied an important place in human nutrition as they remain the major sources of starch and proteins for a large proportion of the world population, particularly in the developing countries [1, 2]. Starch is an important ingredient in various food systems as thickening, gelling and binding agents. It imparts texture to a great diversity of foodstuffs such as soups, potages, sauces processed foods. The versatility of starch in industrial applications is clearly defined by its physicochemical properties [3].

Native starches, irrespective of their sources, are undesirable for many industrial applications because of their inability to withstand processing conditions such as extreme temperature diverse pH and high shear rate [4, 5]. In order to improve on the desirable functional properties and overcome its limitations, native starches are often modified. Formation of blends of different flours in an appropriate ratio may improve the functional properties and nutritional and product quality of food materials [2, 6, 7].

The application of flour or starch in food production industry depends on various functional properties, which include dispersibility, water absorption capacity, pasting, retrogradation, viscosity, swelling power, and solubility index; which varies considerably based on the type of crop as well as ecological and agronomic influence [8] (Peroni *et al.,* 2006). These functional properties depend on the composition and molecular structures of the starch, which include amylose/amylopectin ratio, phosphorus content, starch molecular weight, granule size and the chain length distribution [1, 9]. Functional properties also determine the application and end use of food materials for various food products [9 – 11].

Functional properties of food materials play a significant role in manufacturing, transportation, storage, stability, texture, taste and flavor of food products; and are also required to evaluate and possibly help to predict how new proteins, fat, fiber and carbohydrates may behave in specific systems as well as demonstrate whether or not such protein can be used to stimulate or replace conventional protein [1, 12].

The variation in functional properties is attributed to the relative proportion of carbohydrates, lipids and protein in different flours. Functional properties of flours are usually affected by any change in the processing conditions such as extraction, isolation, drying, milling, blending, baking, cooking and fermentation [2, 13].

Due to the current market trends, producers are moving towards more natural food components, thus, the need for finding new ways to improve the properties of native starch becomes inevitable. The research, therefore, evaluates the functional properties of blended finger millet starch using maize modifiers at different ratios for specific applications in food processing industry.

2. Materials and Methods

2.1. Sample Collection and Preparation

Five kilograms of finger millet grain which was identified by the botany department and 1 kg each of the food modifiers used for the modification were bought from a supermarket in Keffi, Nigeria manufactured by Bigman, UK.

The method of Sira and Amaiz [14] was adopted in the preparation of the samples. The finger millet grains (5kg) were properly washed with water and steeped for 24 hours in 0.25% sodium hydroxide solution in 10 liters of water. The steeped grains were washed and ground using a Philips blender. Water (5 liters) was added to the paste and screened using 80 µm mesh sieve and a 270 µm consecutively before it was centrifuged. The top brown layer was decanted and excess sodium hydroxide was removed by washing the sediment (5 liters × 4) with distilled water until the pH of starch slurry was close to neutrality using a litmus paper. The starch was dried overnight in an oven at 45°C, cooled and stored in an airtight plastic container.

2.2. Finger Millet Starch Blending

The maize modifiers (CS, GG, XG) were blended with native finger millet starch at the ratios of 5:95%, 10:90%, 20:80%, and 25:75% of the modifier to that of the native starch, using a Hobart mixer, and stored separately in air tight plastic bags.

2.3. Determination of Functional Properties

The functional properties of the blended starches were determined in triplicates using the methods reported by AOAC [15]. Carr's index (CI) and Hausner's ratios (HRs) were obtained using the methods reported by Carr [16] and Hausner's [17] respectively.

2.4. Statistical Analysis

The data were subjected to simple statistical techniques such as mean, standard deviation and correlation coefficient (CV). Analysis of variance (ANOVA) was also carried out to determine any significant differences ($P \leq 0.05$) in levels of the functional properties of the blended flour using SSPS statistical package.

3. Results

The results of the functional properties of native finger millet starch blended with CS grade of maize modifiers at different ratios are presented in Table 1. True density varied between 0.45 ± 0.01 mg/L in CSA_1 to 0.56 ± 0.05 mg/L in CSA_4. The highest (0.66 ± 0.01 mg/L) and the lowest (0.61 ± 0.05 mg/L) levels of Tap density were recorded in CSA_2 and CSA_2 respectively. Variation in BD was directly proportional to the modifier contents. FC, HC, and EC increased from CSA_1 to CSA_3, and then decreased at CSA_4. CI, HR and porosity decreased as modifier level increased from 5% to 25%. CSA_4 and CSA_2 recorded the highest CT (271 ± 0.02°C) and BT (135.4 ± 0.03°C) respectively.

Results in Table 2 for native finger millet starch blended with GG maize modifier indicated that True and Tap densities did not vary much with varying ratios of the blended starch. The highest BD (0.368 ± 0.01 mg/L) was obtained in GGA_2. FC increased with increasing modifier contents. EC was highest for GGA_1 (44.10 0.04%). The highest CI (43.55), HR (1.77) and porosity (98.70) were also recorded in GGA_1. BT increased with an increase in modifier contents, while CT decreased from GGA_1 to GGA_3.

Functional properties for XG modified starch (Table 3) show that XGA_1 recorded the highest values for True density (0.69 ± 0.01 mg/L) and Tap density (0.62 ± 0.02 mg/L). BD increased from XGA_1 to XGA_4, except for XGA_2 where the level was lowest (0.32 ± 0.03 mg/L). FC increased with an increase in the level of the modifiers. The highest and the lowest ECs were obtained in XGA_1 (33.50 ± 0.02%) and XGA_4 (29.40 ± 0.06%) respectively. CI decreased with a decrease in FM level, except for XGA_2. Porosity and HR were highest in XGA_1 (113.26) and XGA_2 (1.96) respectively. BT decreased as the amount of modifier was increased, while CT was highest for XGA_1 (244.9 ± 0.02°C) and lowest for XGA_1 (231.6 ± 0.02°C).

Variations among blended starch (Tables 1 – 3) for each of the functional properties according to mixture ratios show the following trends: True density: $XGA_2 > GGA_3 > CSA_4$; Tap density: $CSA_4 > XGA_4 > GGA_2$; BD: $CSA_2 > XGA_4 > GGA_2$; FC: $XGA_4 > GGA_4 > CSA_3$; HC: $GGA_1 > CSA_3 > XGA_1$; CI: $XGA_2 > GGA_1 > CSA_1$; Porosity: $CSA_1 > XGA_1 > GGA_1$; BT: $CSA_2 > XGA_1 > GGA_4$; CT: $CSA_4 > XGA_3 > GGA_1$. A comparison of the variations in the mean values of the functional properties of the blended starch with the native FM and MS starches are presented in Figures 1 - 4.

Table 1. *Functional property of CS blended finger millet (FM) starch at different ratios.*

Parameters	Blended starch						
	CSA_1	**CSA_2**	**CSA_3**	**CSA_4**	**Mean**	**SD**	**CV (%)**
True D (mg/L)	0.45±0.01	0.55±0.02	0.51±0.03	056±0.05	0.52	0.05	9.62
Tap D (mg/L)	0.61±0.05	0.66±0.01	0.62±0.02	0.63±0.01	0.63	0.02	3.17
BD (mg/L	0.35±0.01	0.43±0.03	0.45±0.01	0.47±0.02	0.42	0.05	11.9
FC (%)	3.01±0.02	3.24±0.04	3.33±0.02	3.09±0.07	3.17	0.14	4.42
HC (%)	66.30±0.06	65.90±0.02	68.90±0.01	64.20±0.03	66.3	1.9	2.87
EC (%)	33.10±0.01	35.90±0.03	37.80±0.02	33.60±0.03	35.1	2.17	6.18
CI (%)	42.97	35.99	27.15	26.11	33.01	7.95	24.02
Porosity	145.31	104	107	95.7	113	8.74	7.73
HR	1.75	1.56	1.37	1.35	1.51	0.19	12.58
CT (°C)	235±0.02	255±0.01	246±0.05	271±0.02	252	15.22	6.04
BT (°C)	125.6±0.01	135.4±0.03	125.0±0.02	122.5±0.04	127	8.14	6.62

Ratios of FM: CS – $A_1$95:5%, A_2 90:10%, A_3 80:20%, $A_4$75:25%; D- Density; BD- Bulk density, FC – Foaming capacity, HC- Hydration capacity, EC-Emulsion capacity, CI- Carr's index, HR- Hausner's ratio, CT- Charring temperature, BT- Browning temperature

Table 2. *Functional properties of GG blended finger millet (FM) starch at different ratios.*

Parameters	Blended starch						
	GGA_1	**GGA_2**	**GGA_3**	**GGA_4**	**Mean**	**SD**	**CV (%)**
True D (mg/L)	0.69±0.01	0.70±0.03	0.70±0.02	0.70±0.01	0.7	0.03	4.29
Tap D (mg/L)	0.558±0.02	0.568±0.05	0.571±0.01	0.574±0.04	0.57	7.42	1.22
BD (mg/L)	0.32±0.02	0.37±0.01	0.33±0.03	0.33±0.04	0.33	0.02	6.06
FC (%)	3.99±0.04	3.68±0.01	4.16±0.02	4.34±0.01	4.03	0.28	6.95
HC (%)	69.40±0.03	67.20±0.01	66.30±0.03	61.00±0.02	66.10	3.33	5.03
EC (%)	44.10±0.04	39.8±0.06	39.3±0.04	41.70±0.03	41.20	1.39	3.37
CI (%)	43.55	35.04	42.91	43.38	41.22	4.13	10.02
Porosity	98.7	90.4	96.42	97.26	95.70	3.65	3.81
HR	1.77	1.54	1.75	1.15	1.55	0.29	18.79
CT (°C)	223.5±0.03	216.8±0.02	216.7±0.01	221.1±0.05	219.52	3.35	1.53
BT (°C)	123.5±0.01	125.1±0.04	125.9±0.03	126.1±0.02	125.15	1.18	0.94

Ratios of FM: GG– $A_1$95:5%, A_2 90:10%, A_3 80:20%, $A_4$75:25%; D- Density; BD- Bulk density, FC – Foaming capacity, HC- Hydration capacity, EC-Emulsion capacity, CI- Carr's index, HR- Hausner's ratio, CT- Charring temperature, BT- Browning temperature

Table 3. *Functional properties of XG blended finger millet (FM) at different ratios.*

Parameters	Blended starch						
	XGA_1	**XGA_2**	**XGA_3**	**XGA_4**	**Mean**	**SD**	**CV (%)**
True D (mg/L)	0.59±0.01	0.69±0.01	0.67±0.03	0.60±0.03	0.64	0.05	7.81
Tap D (mg/L)	0.55±0.03	0.62±0.02	0.59±0.01	0.55±0.01	0.58	0.03	5.17
BD (mg/L	0.33±0.02	0.32±0.03	0.37±0.01	0.42±0.02	0.36	0.04	11.11
FC (%)	3.61±0.01	4.49±0.04	4.51±0.03	4.83±0.02	4.36	0.52	11.93
HC (%)	66.30±0.02	61.20±0.05	58.10±0.04	58.20±0.01	60.95	3.85	6.32
EC (%)	33.50±0.02	31.40±0.02	32.80±0.01	29.40±0.06	31.78	1.81	5.7
CI (%)	39.71	49.11	37.54	24.91	37.82	9.92	26.2
Porosity	113.26	98.7	94.9	97.99	10.1.21	8.2	8.1
HR	1.66	1.96	1.6	1.33	1.64	0.26	15.85
CT (°C)	126.30±0.04	124.10±0.03	120.90±0.05	119.50±0.02	122.7	3.08	2.51
BT (°C)	231.6±0.02	234.5±0.01	244.9±0.02	238.9±0.01	237.5	5.79	2.44

Ratios FM: XG – $A_1$95: 5%, A_2 90:10%, A_3 80: 20%, $A_4$75:25%, D- Density; BD- Bulk density, FC – Foaming capacity, HC- Hydration capacity, EC-Emulsion capacity, CI- Carr's index, HR- Hausner's ratio, CT- Charring temperature, BT- Browning temperature

4. Discussion

True density (True D) values for the blended XG and GG starch (Fig. 1) were higher than in the native starch. Tap density (Tap D) were lower compared to MS but higher than in FM. Bulk density levels were generally higher than the values for the controls. Bulk density is a function of mass and volume of flour, which depends on the size of particles and initial moisture content of the flour. Relatively high bulk density makes the flour more suitable for packaging, transportation and use in the preparations. However, low bulk density is considered favorable for formulation of complementary foods [5]. The BD values reported for the blended starch were lower compared to the values reported by Kaur et al. [18] for blended wheat and chickpea flour (0. 41 ± 0.02 mg/L) and maize flour with chickpea flour (0.42 ± 0.006 mg/L). FC for the blended GG and XG (Fig. 2) were similar to FM starch, but higher than the values for MS. EC for GG was higher than in the native starch. Blended starch had lower HC compared to FM. FC is related to the amount of solubilized proteins, polar and non-polar lipids in a sample; and is used to improve the texture, consistency and appearance of foods [19]. FC is also a function of the type of protein, pH, processing methods, viscosity and surface tension. Protein in dispersion may cause a lowering of the surface tension at the water air interface, thus, forms a continuous cohesive film around the air bubbles in the foam [1, 20]. GG and XG blended starch may be better substitutes for native FM to be used in improving food quality. Differences in the EC may be related to their solubility.

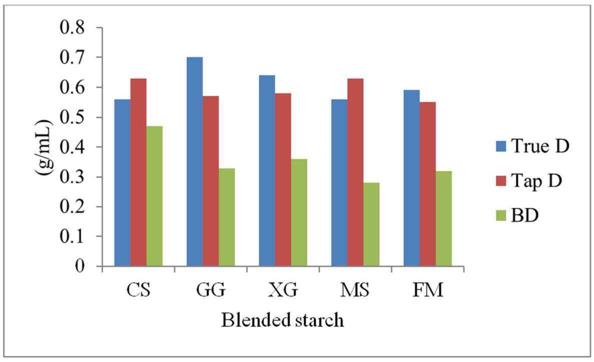

Figure 1. *Mean variations in true density (True D), Tap density (Tap D) and bulk density (BD) of the blended starch.*

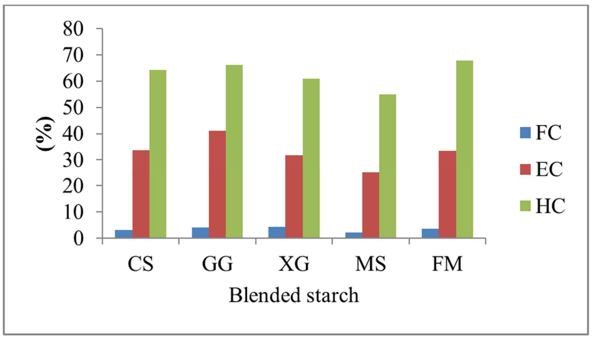

Figure 2. *Mean variations in foam capacity (FC), emulsion capacity (EC) and hydration capacity (HC) of blended starch.*

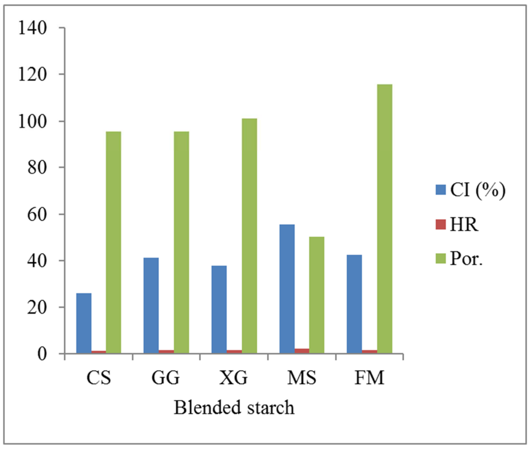

Figure 3. *Mean variations in Carr's index (CI), Hausner's ratio (HR) and porosity (Por.) of the blended starc.*

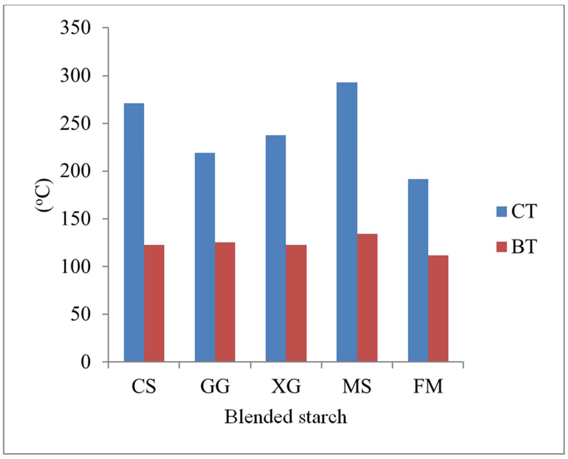

Figure 4. *Mean variations in charring temperature (CT) and browning temperature (BT) of the blended starch.*

Hydrophobicity of protein has been reported to influence their emulsifying properties [20], which depends on solubility, pH and concentration. The presence of non-polar side chains which might bind the hydrocarbon side chains of oil among the flours, possibly explains difference in oil binding capacity of the flours [21]. The relatively high EC values for the GG starch make the starch a better emulsifier.

HC is a measure of association of hydrophilic functional groups of protein with water in a water stressed environment [4], and is an important function of protein in various food products like soups, dough and baked products [9, 22]. The HC values obtained indicate that the blended starch have less tendency of absorbing and retaining water than its native form [5]. The difference in protein structure and the presence of different hydrophilic carbohydrates might be responsible for variation in the HC of the flours. Flours with high HC have more hydrophilic constituents such as polysaccharides [23, 24]. HC values for the blended starch were higher than the result (57.68 ± 2.04) reported by Due et al. [19].

FC and EC values reported by Kolawole et al. [3] for maize and ginger starch were higher and lower respectively than the results obtained in this study. The FC values were also higher than the values reported by Chandra and Smash [1] for rice (0.90 ± 0.00) and Potato (2.488 ± 0.93) flours, but lower than the values for wheat flour (12.922 ± 05.027). The EC values for the blended starch were lower than the value (125.25 ± 30.05%) reported by Due et al. [19] for wild edible *Termotomyces heimii* Nataragan harvested in Cote d'Ivoire.

Flow properties of powders are of significance in determining whether a material is suitable as a direct compression excipient. HR and CI percent compressibility are considered as indirect measurements of powder flow property. HR is an indicative of inter-particle friction, while the CI shows the aptitude of a material to diminish in volume. As the values of these indices increase, the flow of the powder decreases. In general, HR greater than 2.5 indicates poor flow; CI below 16% indicates good flowability while values above 35% indicate cohesiveness [5, 24]. CI and porosity (Fig. 3) of the blended starch were lower compared to the native FM starch. HRs for the blended starch, though similar to FM and MS, were < 2.0, an indication of good flow. Low CI and porosity indicated poor flow for the blended starch, due to cohesiveness of the blended flour. Porosity determines the swelling capacity of starch. The higher the porosity, the more the inter-particulate spaces where water could be absorbed. Lower porosity values for other blended starch as compared to the native FM and MS starch might be attributed to low inter-particulate spaces resulting from particle size and shape. HRs for all the blended starch were higher than the value (1.20) reported by Achor et al. [5] for native cassava starch flour.

Variations in CT and BT (Fig. 4) show that the values were higher for the blended starch compared to the native FM starch, but lower than in MS. CB and CT indicate the temperature to which starch can be heated without changing color or charring. This implies that the blended starch can be heated to higher temperature without changing color easily. This quality may make the blended starch more preferable in industries that use starch at higher temperature [3]. The BTs and CTs for the blended starch in this study were lower than the values reported by Kolawole et al. [3] for maize and Ginger flours.

5. Conclusion

Functional properties varied according the type of modifier used and blending ratios of the native finger millet starch to the modifier. Higher bulk density of the blended starch makes the flour more suitable for packaging, transportation and use in some food preparations GG starch is a better emulsifier compared to the native MS and FM starch. The blended starches have less tendency of absorbing and retaining water than its native form. Low Carr's index and porosity indicated poor flow for the blended starch, due to cohesiveness of the blended flour. The high charring and browning temperatures of the blended starch make the starch useful in processes that involve high temperature. The physical properties of the blended starch did not vary significantly ($P \leq 0.05$) according to mixture ratios. The blended starch may be better alternative to the native finger millet starch in food processing industries for specific applications because of improved functional properties.

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