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Evaluation of Functional Properties of Spontaneous and Starter Culture Fermented Sweet Potato Flour

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Sweet potato tubers obtained from a local market were sorted, washed processed into fermented and unfermented sweet potato flour. The samples obtained were analysed for their functional properties (swelling power, solubility index, water absorption capacity, dispersibility and bulk density) using standard laboratory procedures. A significant difference (p > 0.05) was observed in the loose and packed bulk density with values ranging from 0.488 to 0.607 g/mL and 0.701 to 0.801 g/mL respectively but there was no significant difference (p > 0.05) in the water absorption capacity, oil absorption capacity and dispersibility. There was no significant difference (p > 0.05) in the swelling power but numerically the swelling power increased with increase in temperature. A significant difference in the solubility index above 75°C and increase in solubility with increase in temperature was observed. The result of this study showed that fermentation had no significant effect on the functional properties of the sweet potato flour except its effect on the porosity of the granules as shown in the result of the bulk density. The functional properties of these flours showed their uniqueness which can be useful for food application processes.

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1. INTRODUCTION

Functional properties are properties that are used to predict the application of a food material as well as the end use for various food products. The behavior of the functional properties depend on the source of raw material, presence of various ingredients, and processing conditions [1].They interact with other food components directly or indirectly affecting processing applications, food quality and ultimate acceptance.

Sweet potato [*Ipomoea batatas* (L.) Lam.] is one of the major staple crops and the most important food security promoting root crops in the world, especially in sub Saharan Africa [2]. Well adapted to the tropical and subtropical regions, sweet potato has nutritional advantage for the rural and urban dwellers [3]. Sweet potato (*Ipomoea batatas* [L.] Lam.) is a dicotyledonous plant from the family *Convolvulaceae* that grows in tropical and subtropical areas and even in some temperate zones of the developing world [4]. In developing countries, sweet potato ranks fifth economically after rice, wheat, maize, and cassava, sixth in dry matter production, seventh in digestible energy production, and ninth in protein production [5,6].World production is about 131 million tonnes per year, on approximately 9 million ha with mean estimated yields of 13.7 tonnes ha-1 [7]. China is the world's leading producer of sweet potato, accounting for about 80% of the total production worldwide. Nigeria is the most abundant sweet potato producer in Africa and second to China in world production [8].

Sweet potato is an excellent source of energy (438 kJ/100 g edible portion) and can produce more edible energy per hectare per day than cereals, such as wheat and rice (Abu *et al.,* 2000) and has other advantages, such as versatility, high yield, hardiness, and wide ecological adaptability [9].

Sweet potato roots are rich in starch, sugar, vitamin C, β-carotene, iron, and several other minerals [9,10].Sweet potato has a low glycemic index due to low digestibility of the starch making it suitable for diabetic or overweighed people [11,12,13,14]. In addition, some varieties of sweet potatoes contain colored pigments, such as β-carotene, anthocyanin, and phenolic compounds. However, the potential benefits of crop such as sweet potato are marginalized and are underutilized despite their technological potential which is well recognized and exploited elsewhere.

Fermentation is the conversion of carbohydrates to alcohol and carbon dioxide or organic acids using yeasts, bacteria or a combination under anaerobic conditions. The primary benefit of fermentation is the conversion of sugars and other carbohydrates to usable end products. Fermentation helps to eliminate anti nutritive factors (Tamang et al. [15]) make the nutrients present more bioavailable (Bourdichon et al. [16]) improve the organoleptic properties [17]. Moreover, fermentation of foods also help to extend shelf-life, enhance food quality with protein, essential amino acids, essential fatty acids and vitamins, improve digestibility. Starter cultures are living microorganisms of defined combination used for fermentation purposes. They help to ellicit specific changes in the chemical composition, nutritional value and sensorial properties of the substrate (Opere et al. [18]) and they are generally recognised as safe (Augirre and Collins, 1993).

Moreover, their properties are as follows: They are harmless, initiate and control the fermentation process, typical for product, help in rapid acid formation, and help protect against spoilage organisms. Starter cultures are cheaply reproducible in large amount, they also help provide desirable sensory properties and also assists in reducing fermentation period. Lactic acid bacteria (LAB) are Gram positive acid tolerant, generally non-sporulating, either rod or cocci shaped bacteria that produce lactic acid as the major metabolic end product of carbohydrate fermentation. LAB is the dominant microorganisms, and therefore, lactic acid fermentation is considered as the major contributor to the beneficial characteristics observed in fermented foods [17]. Lactic acid bacteria have been reported to be predominant microorganisms in most of the African indigenous fermented foods [19,20,21].

Yeasts are eukaryotic, single-celled microorganisms classified as members of the fungus kingdom. The first yeast originated hundreds of millions of years ago, and 1,500 species are currently identified [22,23]. By fermentation, the yeast species Saccharomyces cerevisiae converts carbohydrates to carbon dioxide and alcohols. For thousands of years the carbon dioxide has been used in baking and the

alcohol in alcoholic beverages [24]. The objectives of this study were to determine the application and use of fermented sweet potato flour for various food products.

2. MATERIALS AND METHODS

2.1 Sample Collection

Fresh raw sweet potato samples used for this work were purchased from Arena market, Bolade, Oshodi, Lagos state Nigeria. The samples were brought to Biotechnology Department of Federal Institute of Industrial Research, Oshodi, (FIIRO) Lagos State.

2.2 Preparation of Samples

The sweet potato tubers were thoroughly sorted to remove bad ones from the lot. The sorted tubers were washed to remove adhering soil particles, weighed accordingly into four different portions. The tubers after weighing were thereafter peeled and sliced into small pieces, transferred into sterile fermentation bowls, appropriate volume of clean water was added to the sweet potato samples.

2.3 Preparation of Inoculum

Starter cultures (*Lactobacillus brevis* and *Debaromyces polymorphous*) used for this study were isolated from fermenting sweet potato broth, after isolation the organisms were subcultured by streaking on MRS agar (Oxoid) for Lactic acid bacteria and incubated anaerobically at 37°C for 24 hours. Pure culture of yeast isolates was cultivated by streaking on potato dextrose agar PDA (Oxoid) and incubated at 25°C for 3 days. A colony was picked from each pure culture plates of MRS and PDA plates and inoculated aseptically into MRS broth and YEPD (Yeast Extract Potato Dextrose) respectively then incubated. After incubation, the organisms were harvested from the broth media by centrifuging at 5000 rpm for 15 minutes. The supernatants were decanted and the cell biomass dislodged using sterile distilled water.

2.3.1 Preparation of starter culture fermented sweet potato flour

The sweet potatoes were washed to remove adhering soil particles and peeled. The peeled tubers were chipped into slices (4 to 5 mm) and soaked in potable water and inoculated with the starter cultures (Appropriate volume of sterile distilled water was used to wash the organisms into the various fermentation bowls containing the sweet potato samples)s for a period of 48 h and 72 h. After this period has elapsed, the fermented chips were drained and dried in a cabinet drier (Mitchel, Model SM220H) at 55°C for 9 h and milled into flour (≤250 µm) [21].

2.3.2 Preparation of spontaneous fermented sweet potato flour

The sweet potatoes were washed to remove adhering soil particle, the sweet potato was peeled and the peeled tubers were chipped into slices (4 to 5 mm) and soaked in potable water for a period of two days (48 h). After this period has elapsed, the fermented chips were drained and dried in a cabinet drier (Mitchel, Model SM220H) at 55°C for 9 h and milled into flour (≤250 µm) (Oluwole et al., 2012).

2.3.3 Preparation of unfermented sweet potato flour

The sweet potatoes were washed to remove adhering soil particles. Sweet potato was peeled the peeled tubers were chipped into slices (4 to 5 mm). After this period has elapsed, the fermented chips were drained and dried in a cabinet drier (Mitchel, Model SM220H) at 55°C for 9 h and milled into flour (≤250 µm) (Oluwole et al., 2012).

2.4 Functional Properties Determination

2.4.1 Bulk density determination

Bulk density was determined using standard methods [25]. Sample of 10g was measured into a 50 ml graduated measuring cylinder and gently tapped on the bench 10 times to attain a constant height. The volume of sample was recorded and expressed as grams per milliliter. Hausner ratio was determined as a ratio of the packed bulk density to the loose bulk density of the flour [26].

2.4.2 Water absorption capacity determination

The method described by Adebowale et al. [27] was used for determining the water absorption capacity (WAC). Sample of 1 g was weighed into clean pre-weighed dried centrifuge tube and mixed with 10 ml distilled water with occasional stirring for 1 h. The dispersion was centrifuged at 3000 rpm for 15 min. After centrifuging, the supernatant was decanted and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as WAC.

2.4.3 Dispersibility determination

Standard method was used for determining dispersibility [28]. Sample of 10 g was dispersed in distilled water in a 100 ml measuring cylinder and distilled water was added up to 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted and percentage dispersibility was calculated as follows;

Dispersibility (%) = {(50- volume of settled particle)/ 50} × 100

2.5 Oil Absorption Capacity (OAC)

One gram of sample was mixed with vegetable oil (1:10). The mixture was stirred for 30 min at room temperature. After samples were centrifuged (2500 g, 30 min), the supernatant was transferred to a graduated cylinder of 10 mL, where the volume was measured. The OAC was expressed as milliliters of vegetable oil held per gram of sample [29].

2.6 Swelling Power and Solubility Index Determination

The method described by Hirsch [30] was used for swelling power and solubility index determination. One gram of sample was poured into pre-weighed graduated centrifuge tube appropriately labeled. Then, 10 ml of distilled water was added to the weighed sample in the centrifuge tube and the solution was stirred and placed in a water bath heated at different temperature range (55, 65, 75, 85, 95°C) for 1 h while shaking the sample gently to ensure that the starch granules remained in suspension until gelatinization occurred. The samples were cooled to room temperature under running water and centrifuged for 15 min at 3000 rpm. After centrifuging, the supernatant was decanted from the sediment into a pre-weighed petri-dish; the supernatant in the petri-dish was weighed and dried at 105°C for 1 h. The sediment in the tube was weighed and the reading recorded. The starch swelling power and solubility was determined according to the equations below;

Swelling power = (weight of swollen sediment/ Weight of dry starch) × 100

Solubility = (weight of dry supernatant/ weight of starch sample) × 100

2.7 Statistical Analysis

All experimental data obtained were subjected to analysis of variance (ANOVA) procedure of SPSS version 15.0 (SPSS Inc., 2006) at 5% significant level.

3. RESULTS

Table 1. Functional properties of various sweet potato flour

Sample	LBD (g/ml)	PBD (g/ml)	Hausner ratio	WAC (g/g)	(OAC) (g/ml)	Dispersibility (%)
A	0.500 [b]	0.660 [b]	1.32	1.515 [a]	9.100 [a]	0.355 [a]
B	0.607 [a]	0.801 [a]	1.32	1.480 [a]	9.050 [a]	0.385 [a]
C	0.488 [b]	0.702 [b]	1.44	1.540 [a]	9.100 [a]	0.410 [a]
D	0.519 [b]	0.701 [b]	1.35	1.610 [a]	8.550 [a]	0.355 [a]

Values are mean. Mean values (n = 2) having different superscript alphabets in the same column are significantly different (p < 0.05) A: Spontaneously fermented sweet potato flour; B: Unfermented sweet potato flour; C: 48 hours starter culture fermented sweet potato flour; D: 72 hours starter culture fermented sweet potato flour; LBD: Loose bulk density; PBD: Packed bulk density; WAC: water absorption capacity; OAC: Oil absorption capacity

Table 2. Solubility index of various sweet potato flour

s/n	Solubility index (%) 55°C	Solubility index (%) 65°C	Solubility index (%) 75°C	Solubility index (%) 85°C	Solubility index (%) 95°C
A.	349.50 [a]	335.00 [b]	2.50 [b]	6.50 [b]	5.00 [a]
B.	441.00 [a]	212.00 [b]	3.00 [ab]	4.50 [ab]	6.50 [a]
C.	333.50 [a]	259.50 [a]	4.00 [ab]	4.50 [ab]	7.00 [a]
D.	347.00 [a]	338.00 [a]	6.50 [a]	2.00 [a]	4.50 [a]

Sample A: Spontaneously fermented sweet potato flour, Sample B: Unfermented sweet potato flour; Sample C: 48 hours starter culture fermented sweet potato flour; Sample D: 72 hours starter culture fermented sweet potato flour. Values Are Average Of Two Determinations. Values in the same column not followed by the Same Superscript are significantly different (P < 0.05)

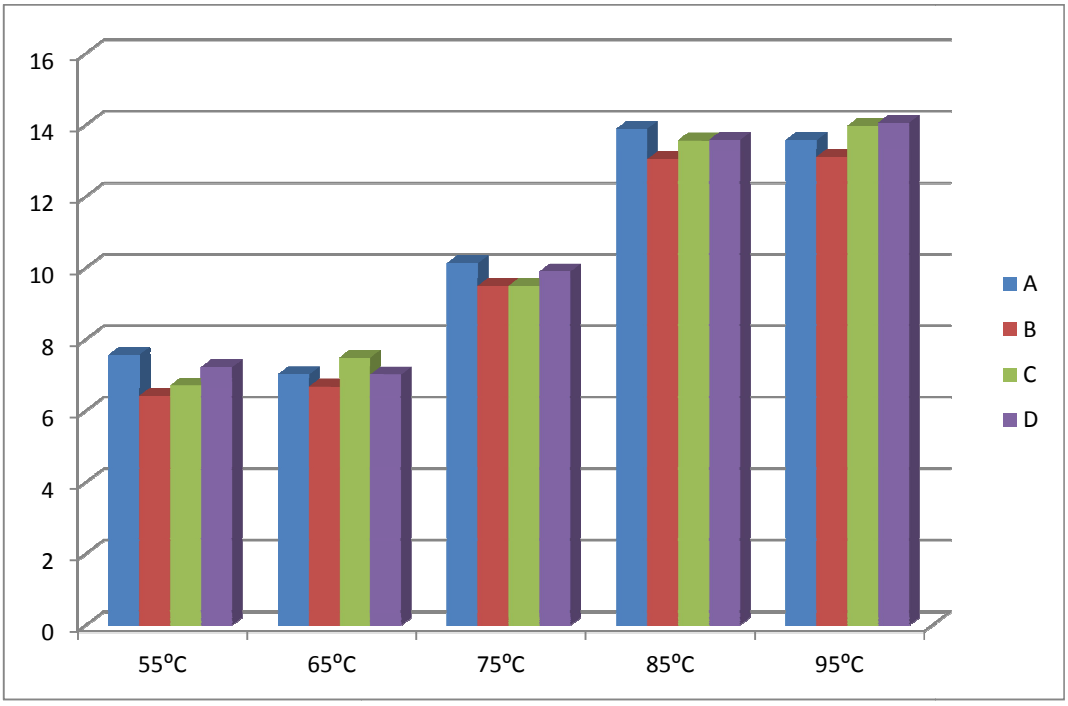

Fig. 1. Swelling power of different sweet potato flour samples at different temperatures. Sample A: Spontaneously fermented sweet potato flour, Sample B: Unfermented sweet potato flour; Sample C: 48 hours starter culture fermented sweet potato flour; Sample D: 72 hours starter culture fermented sweet potato flour

4. DISCUSSION

The functional property of sweet potato flour at different fermentation time is depicted in Table 1. A significant difference ($p<0.05$) was observed in the loose bulk density (LBD), packed bulk density (PBD) but there was no significant difference ($p>0.05$) in the water absorption capacity (WAC), dispersibility and oil absorption capacity (OAC).

Loose bulk density of the flour samples ranged between 0.488 and 0.607 g/ml with sample C having the lowest value while sample B had the highest value. Loose bulk density reveals the ability of a flour sample to occupy larger storage space per weight [26]. This implies that sample C will occupy larger storage space while sample B will occupy less storage space.

Packed bulk density of the samples ranged between 0.701 and 0.801 g/ml, sample D had the least value while B had the highest value. Packed bulk density is a functional property that predicts the ease of transportation and packaging of powdery products [1]. Increase in fermentation time caused a decrease in the packed bulk density although there was no significant difference in the 48 and 72 hours fermentation period, this is in agreement with the findings of Oloyede et al. [31] who also reported a decrease in bulk density of the sample as fermentation increased. This could be due to the effect of fermenting organisms on the porosity of the flours and this probably implies that fermented flours up to 48 hours will occupy less space during packaging and more flour can be transported.

Hausner ratio of the flour samples ranged between 1.32 and 1.44. Hausner ratio is the ratio of packed bulk density to loose bulk density and this predicts the flow properties of food flour or powders and it has been reported that hausner ratio less than 1.4 will facilitate conveying, blending and packaging of the flour/powder which encourages its use in industrial food manufacture [32,33]. Thus, due to the low hausner ratio of sample B and D, this suggests that these samples may be the best applicable flour with the best conveying and blending ability suitable for industrial use. There was no significant difference ($p>0.05$) in the water absorption capacity of the fermented flours. Water absorption capacity is a measure of the

amount of water held by the protein matrix at room temperature. The values ranged from 1.48 to 1.61 g/ml, B had the least while D had the highest value. This finding deviates from the findings of Oloyede et al. [31] who reported significant increase in water absorption capacity of defatted *Moringa oleifera* seed flour as fermentation increased. This probably implies that there was almost equal modification of the macromolecules during fermentation exposing the hydrophilic bond of the sweet potato flours causing each sample to have almost the same water affinity rate. There was no significant difference ($p>0.05$) in the oil absorption capacity of the fermented sweet potato flour. The oil absorption capacity ranged from 8.55 to 9.10 g/ml. All the samples absorbed oil almost equally. This corroborates with the work of Fagbemi, [34] which reported that good absorption of oil suggest its usefulness in preparation of food products such as baked foods.

Significant difference was not observed ($p>0.05$) in the dispersibility of the samples. Dispersibility is a property that indicates the rate of reconstitution of flour sample in water. [35].This probably indicates that the samples will disperse similarly in water.

The swelling power is depicted in Table 2. There was no significant difference ($p>0.05$) between the samples but numerically, slight increase in swelling power was observed with increased period of fermentation. This is in support with the findings of Oloyede et al. [31] who reported increase in swelling power of moringa seed flour with increase in fermentation time. Yuliana et al. [36] also reported increase in swelling power of sweet potato flour with increase in fermentation time. The increase in swelling power as the length of fermentation increased could be due to the modification of the sample's starch granules which disengaged the bonds allowing more water uptake and swelling effect to occur but this effect was not significant enough to indicate this modification.

The solubility index of fermented sweet potato flour is as shown in Table 2. There was no significant difference in the fermented sweet potato flour at 55 and 65°C but significant difference was observed above 65°C. All the samples at temperature range of 55 and 65°C had very high solubility values; this could be due to the gelatinization temperature of sweet potato that has not been attained. The gelatinization temperature of sweet potato has been reported to be between 64.6 to 84.6°C [37].
The solubility above 65°C increased with increase in fermentation time and it also increased as the temperature increased. The increase in the solubility observed above 65°C may be due to the impact of fermentation period on the granular structure of the sweet potato as reported by Sobowale et al. [38] that when starch is heated in excess water above its gelatinization temperature, disruption of granular structure occurs causing molecules to disperse in solution.

Relating the swelling power and solubility values above 65°C, the swelling power were high while the solubility index were low and it has been reported that high swelling power and low solubility are required for formation of highly viscous and elastic gels or dough [39]. This probably suggest that the fermented sweet potato flours will be beneficiary for viscous and elastic food products such as dough in bread baking.

5. CONCLUSION

The starter culture fermented sweet potato flour would be beneficiary for viscous and elastic food products such as dough and it can also be used in the preparation of food products such as baked foods since it can absorb oil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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