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Research Article

Effect of Fermentation on Physicochemical Properties and Oxalate Content of Cocoyam (*Colocasia esculenta*) Flour

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The effect of fermentation on physicochemical properties and oxalate content of cocoyam (*Colocasia esculenta*) flour was evaluated. The cocoyam, white flesh was cleaned, washed, peeled, sliced into chips of 2–2.5 cm thickness, soaked in tap water and left to ferment for 24 h and 48 h. The fermented cocoyam was then drained, dried in cabinet dryer at 60°C for 24 h and milled. The flour samples were passed through a 45 μm mesh size sieve. Unfermented cocoyam flour was also produced and served as a control. Calcium oxalate and some physicochemical properties of flours from the fermented cocoyam were compared with the unfermented flour. Results showed that fermentation effected a significant reduction in oxalate level (58 to 65%) depending on the fermentation period. The amylose content was higher in 48 h fermented flour (55.52%) than in 24 h (54.55%). Pasting (gelatinization) temperature decreased, and water absorption capacity increased markedly due to fermentation.

1. Introduction

Cocoyams are the third most important root crop (after yam and cassava) cultivated in West Africa. More than three quarters of the world cocoyam production come from Africa with Ghana and Nigeria being the world's leading producers [1]. They are also important crops in Hawaii, Japan, and Egypt [2]. In general, they are stem tubers that are widely cultivated in both the tropical and subtropical regions of regions of the world [3]. Among seven species of *Colocasia* (taro) which originated from Asia and about forty species of *Xanthosoma* (tannia) from America, the two species mostly grown in West Africa are *Colocasia esculenta and Xanthosoma sagittifolium* [3, 4].

The *Xanthosoma sagittifolium* variety in Nigeria is hard and highly starchy which makes it easy for fufu preparation while *Colocasia esculenta*, with a softer tuber is usually prepared and eaten like yam. It produces a more floury starch suitable for use in composite mixture for food preparations. In some Nigerian diets, the cormels and young leaves of the taro variety serve as leafy vegetables [5]. Cocoyams can also be processed in several ways to produce food and feed products similar to that of potatoes in the Western world. Among the processes cocoyam can be subjected to, are boiling, roasting, frying, milling, and conversion to "fufu", soup thickeners, flour for baking, chips, beverage powder, porridge, and speciality food for gastrointestinal disorders [5–8].

Several studies have shown that cocoyams contain digestible starch, protein of good quality, vitamin C, thiamin, riboflavin, niacin, and high scores of amino acids [9]. However, one major limiting factor in the utilization of cocoyam is the presence of oxalates, which impart acrid taste or cause irritation when foods prepared from them are eaten. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning. Oxalates are also known to interfere with the bioavailability of calcium [10].

Cocoyam has been processed in many ways to reduce its oxalate content and produce good-quality flour; however, application of flour from different plant or animal sources in food systems depends greatly on information about the physicochemical properties of such food materials [11]. The

levels of oxalate in locally grown cocoyams are important in the assessment of their nutritional status. Hence, the objectives of this research were to determine the effect of fermentation on functional, pasting properties, and oxalate content of cocoyam flour.

2. Materials and Methods

2.1. Sample Preparation. Cocoyams (*Colocasia esculenta*) were purchased from a local market in Ogbomoso, Oyo state, Nigeria. The cocoyams were cleaned, washed, peeled, sliced into chips of 2–2.5 cm thickness, soaked in tap water, and left to ferment for 24 h, and 48 h. The fermented cocoyams were drained, dried in cabinet dryer at 60°C for 24 h and milled. The flour samples were then passed through a 45 μm mesh size sieve. Unfermented cocoyam flour was also produced.

2.2. Pasting Properties Studies. The pasting profiles of the flour samples were studied using a Rapid Visco-Analyzer (RVA) (Newport Scientific Pty. Ltd.) with the aid of a thermocline for windows version 1.1 software (1996) as described by Adeyemi et al. [12]. The following parameters were obtained from the pasting profile: peak viscosity, pasting temperature, setback viscosity, breakdown viscosity, final viscosity, and time to reach the peak viscosity.

2.3. Determination of Functional Properties. The swelling power and solubility index were determined by the methods of Konik et al. [13] and Gudmundsson and Alliasson [14], in a thermostatic Clifton water bath over a temperatures range of 50–95°C. Amylose content of the cocoyam flours were determined by iodine potentiometric titration (IPT). Before evaluation of iodine affinity, the starch was thoroughly defatted for 48 h with 85% methanol by Soxhlet extraction and the samples were dried and pulverized to pass through a 45 μm mesh size sieve [15, 16]. Water absorption capacity (WAC) was determined using the method of Mbofung et al. [17].

2.4. Oxalate Determination. The oxalate content of the cocoyam flours were determined by titrating an aliquot of extracts from the homogenized samples with 0.01 M $KMnO_4$ solution [18]. Prior to determination, the heavy metals in the acidified extracts were precipitated with 5 mL tungstosphophoric acid reagent and centrifuged at 1700 rpm for 15 min, as described by Sefa-Dedeh and Agyir-Sackey [10].

2.5. Statistical Analysis. The data obtained from the studies were analyzed using one factor analysis of variance (ANOVA) and Turkey mean separation for multiple comparisons with the Statistical Analysis System (SAS) program [19]. Significance was accepted at $P \leq 0.05$.

3. Results and Discussion

3.1. Pasting Properties. The effect of fermentation on the pasting properties of cocoyam flour is presented in Table 1.

Table 1: Pasting properties of fermented cocoyam flours obtained from RVA Viscoamylograph.

Attributes	Control 0 h fermentation	24 hours fermentation	48 hours fermentation
Pasting temperature (°C)	64.08 ± 0.7^{a}	63.58 ± 0.5^{a}	63.30 ± 0.5^{a}
Peak viscosity (RVU)	178.75 ± 10.8^{a}	133.08 ± 5.4^{b}	124.46 ± 6^{b}
Trough (RVU)	115.92 ± 5.8^{ab}	104.25 ± 3.5^{b}	117.50 ± 0.2^{a}
Breakdown (RVU)	62.84 ± 5.1^{a}	58.83 ± 1.9^{b}	66.96 ± 5.3^{a}
Final viscosity (RVU)	167.46 ± 8.2^{a}	159.25 ± 7.5^{a}	157.58 ± 0.8^{a}
Setback (RVU)	51.54 ± 2.4^{a}	53.00 ± 4.0^{a}	42.08 ± 1.1^{b}
Peak time (min.)	5.68 ± 0.1^{a}	5.56 ± 0.1^{a}	4.46 ± 0.2^{b}

Means followed by different superscript within the same row are significantly different ($P \leq 0.05$).

The pasting temperature of the 24 h and 48 h fermented cocoyam flours were 63.58 and 63.30°C, respectively. The pasting temperatures of the fermented flours were not significantly different from the unfermented flour (64.08°C). Nwokocha et al. [20] reported that lower pasting temperature (68°C) and rapid rise in viscosity to peak (845 BU at 78°C) of cassava starch relative to cocoyam starch (78°C, pasting temperature and peak viscosity, 630 BU at 91°C) indicate a weak granular structure of cassava compared to cocoyam.

The peak viscosity of 24 h and 48 h fermented cocoyam flour was 133.08 and 124.46 RVU, respectively. Flour with a lower peak viscosity has a lower thickening power than flour with a higher peak viscosity; therefore, 48 h fermented cocoyam flour has a lower thickening power than 24 h fermented cocoyam flour. The final viscosity of the 24 h and 48 h fermented flour (159.25 and 157.58 RVU) was not significantly different from the unfermented flour (167.46). The final viscosity of cocoyam starch paste is related to the amylose content. Flour with higher amylose content gives a higher final viscosity.

The setback from trough is also related to the amylose content and reflects retrogradation of starch. The setback values of the flours were 53 and 42.08 RVU for 24 h and 48 h fermented flours, respectively. There were no significant differences ($P \leq 0.05$) in the setback values of the fermented and the unfermented flour (51.54 RVU). The setback values obtained in this study indicates a higher retrogradation tendency of cocoyam flour. This property of cocoyam starch makes it suitable for use in jelly foods. Earlier work also reported a higher setback ratio for cocoyam starch paste (2.50) when compared with (2.0) cassava starch paste [20].

Trough value ranged from 104.25 to 117.50 RVU for 24 h and 48 h fermented flour, respectively. Flour from 48 h fermentation had higher trough than flour from 24 h fermentation. Trough increased with increase in fermentation period. However, there were no significant differences ($P \leq 0.05$) in trough among fermented flour samples and the unfermented flour. Trough value is the maximum viscosity value in the

Table 2: Functional properties of fermented cocoyam flour.

% composition	Control 0 h fermentation	24 hours fermentation	48 hours fermentation
Sugar	2.40 ± 0.1^a	2.11 ± 0.1^a	1.74 ± 0.1^b
Starch	55.08 ± 1.5^a	54.55 ± 0.1^a	55.26 ± 0.5^a
Amylose	14.79 ± 0.0^b	15.44 ± 0.1^a	15.52 ± 00^a
Amylopectin	97.59 ± 0.1^b	97.89 ± 0.1^b	98.26 ± 0.1^a
Water absorption capacity	231.29 ± 1.4^b	271.11 ± 1.0^a	287.59 ± 2.1^a
Swelling power	17.50 ± 0.6^a	18.31 ± 0.0^a	18.45 ± 0.0^a
Solubility index	16.21 ± 0.4^b	17.33 ± 0.2^a	18.53 ± 0.3^a

Means followed by different superscript within the same row are significantly different ($P \leq 0.05$).

constant temperature phase of the RVA profile and measures the ability to withstand breakdown during cooling [11].

Breakdown value was between 58.83 and 66.96 RVU. The 48 h fermented flour had the highest breakdown value (66.96 RVU) while the 24 h fermented flour had the lowest value (58.83 RVU). Breakdown increased with increase in fermentation period of the flour samples. The breakdown value reported in this study was, however, different from the results of a study on the properties of starches from cocoyam (*Xanthosoma sagittifolium*) tubers planted from different seasons, which reported the breakdown values of 126–186 and 232–840 cP for cocoyam starches [15]. The discrepancy indicated that breakdown value of cocoyam flour and starch varied with plant species. Breakdown viscosity value is a measure of the ease with which the swollen granules can be disintegrated [21] and, hence, an index of the stability of starch [22].

Peak time of the 24 h and 48 h fermented flour was 5.56 and 4.46 min, respectively. Peak time decreased with increase in fermentation period. There were significant differences ($P \geq 0.05$) in the peak time of the two flour samples. Peak time is an indication of the minimum temperature required to cook flour [11]. The peak time reported in this study is close to that of instant yam-bread fruit (5.13 to 5.80 min) composite flour [23].

3.2. Functional Properties. The functional properties of the fermented cocoyam flours are presented in Table 2. The sugar content ranged from 1.74 to 2.40%, with the unfermented flour having the highest value while the 48 h fermented flour had the least value. The sugar content of the flour decreased with increase in fermentation period. This indicates that, the longer the fermentation period, the higher the microbial population and, hence, the higher the consumption of soluble sugars. This is in agreement with earlier studies [24–26].

Total starch contents of fermented cocoyam flours ranged from 54.55 to 55.26% for 24 h and 48 h fermented flour, respectively. There were no significant differences ($P \leq 0.05$) between the starch content of fermented and unfermented flours. Total starch content obtained in this study was close to the range (81.1–87.7%) reported by Lu et al. [15] for cocoyam (*Xanthosoma sagittifolium*) starches.

Table 3: Calcium oxalate content of fermented cocoyam flour.

Sample	Oxalate content (%)
0 h fermented	5.71 ± 0.0^a
24 h fermentation	2.38 ± 0.0^b
48 h fermentation	1.99 ± 0.0^c

Means followed by different superscript within a column are significantly different ($P \leq 0.05$).

The amylose and amylopectin content of the 24 h and 48 h fermented flour were (15.44 and 15.52%) and (97.89 and 98.26%), respectively. The amylose content of the fermented flours was higher than the unfermented flour (14.79%). This observation could be explained by the likely formation of amylose-like materials resulting from enzyme/acid hydrolysis of amylopectin at the amorphous regions of the starch granule during fermentation [26]. The amylose content of the fermented cocoyam flour in this study, was close to the amylose content of fermented cassava starches (18.23–20.35%) reported by Numfor [26]. The percentage of amylopectin in cocoyam flour in this study was higher than the range reported by Lu et al. [15] for cocoyam (*Xanthosoma sagittifolium*) starches (2.47–2.89%). This may be as a result of the different species of cocoyam used for the studies.

The water absorption capacity of the flour increased from 231.29 to 287.59% with the unfermented flour having the lowest value. The water absorption capacity increased with increasing fermentation period. The result of this study agreed with the water absorption capacity of cocoyam flour (296–344%) produced from boiled cocoyam at different time interval [2].

The swelling power and solubility index of the fermented flour range from 18.31 to 18.45% and 17.33 to 18.53%, respectively. Differences in swelling and solubility are indication of difference in the bonding forces within the starch granules. During increased thermal agitation, the bond relax, thereby causing starch granules to imbibe water in swell and a low molecular weight amylase solubilize and leach out into the aqueous medium [27]. The swelling and solubility index of the fermented flours were not significantly different ($P \leq 0.05$). The swelling and solubility profiles indicate that cocoyam flour had greater intragranular organization in which most of the bonding forces required energy supplied in the temperature range of 75–80°C to cause relaxation [20].

3.3. Calcium Oxalate Content. The results (Table 3) show that the oxalate content of the flour decreased from 5.71% (unfermented flour) to 1.99% (48 h fermented flour). Oxalate content decreased with increase in fermentation period. There was a 65% reduction in oxalate content of the 48 h fermented flour when compared with the unfermented flour. The oxalate content of the 24 h fermented flour was also reduced by 58%. The observed marked reduction caused by fermentation may be due to the effect of leaching and enzyme/acid hydrolysis of the starch granule during

fermentation. Iwuoha and Kalu [2] also reported 82.1% and 61.9% oxalate reduction in cocoyam flour produced from boiled and roasted cocoyam, respectively.

4. Conclusion and Recommendation

Fermentation affected the calcium oxalate and some physicochemical properties of cocoyam flour. Calcium oxalate was reduced significantly; the greatest reduction was observed in the 48 h fermentation, which reduced the oxalate level by approximately 65%. Water absorption capacity of the fermented cocoyam increased markedly, and viscosity was reduced. The high setback value of fermented cocoyam flour makes it suitable for jelly foods. Further work needs to be carried out on the effect of longer fermentation period (72–96 h), as well as the microorganism associated with the fermentation, and, if possible, the development of starter culture to ferment cocoyam, to see changes on the oxalate content and other physicochemical properties of cocoyam flour.

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