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Full Length Research Paper

Effect of fermentation on the proximate composition, antinutritional factors and functional properties of cocoyam (*Colocasia esculenta)* flour

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ABSTRACT

Cocoyam tubers were harvested, peeled washed and processed by fermentation for 0, 24, 48 and 72 hours and oven dried at 65^{0}C followed by milling with the unfermented sample as control. The flour samples were designated as A,B,C, and D with increasing fermentation time. Proximate composition, anti nutritional factors and functional properties of the fermented and unfermented flours were evaluated. Result showed significant difference ($p < 0.05$) in proximate composition. Fat increased from 1.83- 2.61%, protein 15.61-18.75% and carbohydrate 66.53-71.57% with corresponding increase in fermentation time. While ash decreased from 4.82-1.92%, moisture 10.45-5.15% and fibre 0.73- 0.19% with corresponding increase in fermentation time. Fermentation also reduced significantly all the anti nutritional factors studied. The result indicated alkaloid (0.11-0.03%), phytate (132.0-97.07mg/g), Oxalate (0.95-0.50mg/g), Saponin (0.63-0.13%) and HCN (0.74- 0.01 mg/m) with increase in fermentation time. The results of the functional properties showed increase in viscosity (159.3-380cp) and water absorption capacity (0.21-0.90 g/g) while a decrease was observed in bulk density (0.63-0.58 g/ml), Gelatinization temperature (84. 35– 83.03 ^{0}C) and oil absorption capacity (3. 77- 1.14 g/g). The result has shown that fermentation processing of cocoyam is adequate to increase nutrients, reduced antinutritional factors, improve functional properties and enhance utilization of cocoyam flour in different food systems.

Keywords: Cocoyam, fermentation, antinutritional factors, functional properties, proximate composition.

INTRODUCTION

Cocoyam (*Colocasia esculenta) is* an edible, highly nutritious and an underutilized crop that belongs to the family, *Araceae*. About 30 – 40 species of cocoyam have been identified but only 5 – 6 species produce edible parts (Nwanekezi *et al,* 2010). *Colocasia esculenta* (L.) Schott commonly known as *Taro* and *Xanthosoma sagittifolium* (L.) Schott, which is generally referred to as *Tannia* are the most important species of the family *Araceae* (Anthony and Eka, 1998). They are simply referred to as cocoyam in many parts of the world, especially in Africa.

Nutritionally, the tubers contain easily digestible starch and are known to contain substantial amounts of protein, fibre, vitamin C, thiamine, riboflavin, potassium, sodium, phosphorus, magnesium, calcium and niacin. The leaves are rich in iron, folic acid and beta carotene (FAO, 1990, Eka, 1990, Niba, 2003).

Cocoyams are grown primarily for their edible starch storage corms and cormels called tubers, and secondarily as a leafy vegetable (Aregheore and Perera, 2003). It is a staple food for millions of people living in the tropics and subtropics (Nwanekezi *et al*., 2010, Ojinnaka *et. al.,* 2009).

Cocoyam is still regarded as less important than other tropical root crops such as yam, cassava and sweet potato and as food for low income people (Ojinnata *et al*.,

2009).

In Nigeria cocoyam is one of the under exploited tropical root plant that is very nutritious but its utilization is still at the subsistence level and highly neglected crop (Chwuku *et al.,* 2009). Some researchers have decried the extinction of cocoyam in Nigeria (Nwosu, 2007, Chwuku *et al*., 2009) despite its numerous nutritious and health benefits. Some ethnic groups in Nigeria reward women that cultivate cocoyam crop (Chukwu, 2011) as part of encouragement. In phytomedicine, (Ilonzo, 1995) reported that consumption of roasted cocoyam with palm oil for a period of three months can cure diabetes. Diabetic patients in Nigeria eat cocoyam to manage the disease. Three songs were composed by (Chukwu, 2011) to extol cocoyam, as a pragmatic, novel and effective approach to re-awaken peoples' interest in cocoyam to embark on commercial farming of the crop.

Among the reasons advanced for its under utilization are poor knowledge of nutritional, biochemical, molecular and functional properties of available varieties (Chwuku, 2011) presence of toxicants like calcium oxalate, phytate, trypsin inhibitors, cyanide, alkaloid and Saponin [Amanze, 1993] and its susceptibility to pre and post harvest diseases, which reduce storage stability and quality of the products. Phytates in the form of phytic acid form insoluble salts with metals such as calcium, zinc, iron, and magnesium. Formation of these salts renders the metals unavailable for absorption in the body. The high content of calcium oxalate crystals, about 780mg per 100g in some species of cocoyam has been implicated in the acridity or irritation caused by cocoyam. Oxalates turns to precipitate calcium and makes it unavailable for use by the body. Oxalates have also been suspected to cause kidney stones (Emmanuel– Ikpeme, *et al*., 2007).

Thus fermentation and other elaborate processing can be carried out to enhance consumption, improve nutritional safety, storability, palatability, and convenience both in handling and utilization (Iwuoha, *et al*., 1995)

Natural fermentation processes are increasingly attracting the attention of scientists and policy makers as a vital part of food security strategies (Abegaz *et al*., 2002). Food fermentation is capable of improving nutrients in cocoyam, preserving it by generating acidic condition, detoxify and reduce cooking time of the food (Fagbemi *et al*., 2005). All over the world, fermented foods are known to provide an important part of human diet. Fermented foods and beverages provide about 20-40% of human food supply (Fagbemi *et al*., 2005). Lactic acid bacteria are found to be useful in flavouring foods, in inhibiting spoilage bacteria and pathogens, in intestinal health and other health benefits related to blood cholesterol levels, immune competence and antibiotics production (Sobowale, 2007). Lactic acid fermentation is inexpensive and often little or no heat is required during the process thus making it fuel efficient (Shimelis and Rakshit, 2008). Fermentation could therefore, be a useful tool that can be used to improve the nutritional quality and safety profile of cocoyam flour as a raw material for food products development. This would enhance production of variety of food products, increase utilization and may possibly encourage farmers to venture into commercial farming. Thus food security would be assured on the African continent and other continents where these foods would be exported to.

This work therefore makes use of natural fermentation to eradicate antinutritional factors and improve the bioavailability of nutrients in cocoyam. The effect of fermentation on the proximate composition and functional properties of cocoyam flour is also investigated.

MATERIALS AND METHODS

Source of raw materials

Wholesome cocoyam Cormels (*colocasia esculenta*) used in the work were harvested from a local farm in Makurdi Local Government Area of Benue state, Nigeria. They were put in jute bags and taken to the Food Processing Laboratory of the University of Agriculture for further processing. Other materials are: stainless kitchen knife, basins, a cutting board. All other chemicals and reagents were of analytical grade.

Preparation of Raw materials

About 5kg of Cocoyam tubers were washed to remove soil particles and other debris and then peeled. The peeled tubers were washed using clean water, sliced into smaller pieces of 2.0 mm thickness using stainless kitchen knife and divided into four portions. Three portions of the sliced pieces were subjected to natural fermentation using deionized water in the ratio of 1:3(w/v) at 30± 2^{o}C for 24hr, 48hr and 72hr respectively using rubber containers, the fourth portion was not fermented and acted as the control. Each portion was arranged randomly on drying tray in single layers and was dried at 65^{0}C in an air draught oven (Gallenkamp, BS Model 250 size 2 UK), until they were dry enough to break sharply between the hands.

The unfermented slices were also dried at the same temperature. Each of the dried portion was then milled separately using Attrition mill and sieved with a 500 micrometer sieve to obtain cocoyam flour. The flour was then stored in the air tight polyethylene bags prior to analysis

Proximate composition Analysis

Protein Content: The protein content was determined using a micro-Kjedhal method (AOAC, 2005) which involves wet digestion, distillation, and titration. The protein content was determined by weighing 3 g of sample into a boiling tube that contained 25 ml

concentrated sulfuric acid and one catalyst tablet containing 5 g K_2SO_4, 0.15 g $CuSO_4$ and 0.15 g TiO_2. Tubes were heated at low temperature for digestion to occur. The digest was diluted with 100 ml distilled water, 10 ml of 40% NaOH, and 5 ml $Na_2S_2O_3$, anti-bumping agent was added, and then the sample was diluted with 10 ml of boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 N standard HCl using a 25 ml burette. A blank was prepared without the sample. The protein value obtained was multiplied by a conversion factor, and the result was expressed as the amount of crude protein.

% crude protein = Actual titre value – Titre of the blank x 0.1N HCl x 0.014 x conversion factor x 100/ weight of the sample.

Fat Content: Fat content was determined using the method of (AOAC,2005). About 10 g of sample wrapped in a filter paper was weighed using a chemical balance. It was then placed in an extraction thimble that was previously cleaned, dried in an oven, and cooled in the desiccator before weighing. Then, about 25 ml of petroleum ether solvent was measured into the flask and the fat content was extracted. After extraction, the solvent was evaporated by drying in the oven. The flask and its contents were cooled in a desiccator and weighed.

The percentage fat content was calculated as follows:

Percentage of Total fat content = $\frac{weight\ of\ fat\ extracted}{weight\ of\ food\ sample} \times 100$

Crude Fibre: Crude fibre was determined using the method of (AOAC, 2005). About 5 g of each sample was weighed into a 500 ml Erlenmeyer flask and 100 ml of TCA digestion reagent was added. It was then brought to boiling and refluxed for exactly 40 minutes counting from the start of boiling. The flask was removed from the heater, cooled a little then filtered through a 15.0 cm no. 4 Whatman paper. The residue was washed with hot water stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105°C. After drying, it was transferred to a desiccator and weighed as W_1 . It was then burnt in a muffle furnace at 500°C for 6 hours, allowed to cool, and reweighed as W_2.

Percentage crude fibre = $\frac{W_1 - W_2}{W_0} \times 100$

W_1=weight of crucible+fiber+ash

W_2=weight of crucible+ash

W_0=Dry weight of food sample

Ash Content: Ash content was determined using the method of(AOAC,2005) . About 5 g of each sample was weighed into crucibles in duplicate, and then the sample was incinerated in a muffle furnace at 550°C until a light grey ash was observed and a constant weight obtained. The sample was cooled in the desiccators to avoid absorption of moisture and weighed to obtain ash content.

Moisture Content: Moisture content was determined using Association of Official Analytical Chemist (AOAC, 2005). About 5 g of sample was weighed into petri dish of known weight. It was then dried in the oven at 105 ± 1°C for 4 hours. The samples were cooled in a desiccator and weighed. The moisture content was calculated as follows:

Percentage moisture content = $\frac{Change\ in\ weight}{Initial\ weight\ of\ food\ before\ drying} \times 100$

Total Carbohydrate Content: Carbohydrate content was determined by difference using the method of Egounlety and Awoh (1990), by subtracting the total sum of the percentage of fat, moisture, ash, crude fibre, and protein content from hundred (100).

Analysis of Antinutritional Factors

Oxalate: The calcium oxalate content was determined using the method of Ukpabi and Ejidoh (1989).This involves the digestion of the sample, precipitation of the oxalate contained in the sample to remove ferrous ions on addition of ammonium hydroxide solution and then titration against permanganate solution (0.05M $KMnO_4$) to a faint pink colour, which persisted for 30 seconds.

Phytate: This was determined using Nkama and Gbenyi (2001) method. 4g sample was soaked in 100 ml of 2% hydrochloric acid for 3 h and then filtered. 5 ml of 0.3% ammonium thiocyanate solution was added to 25 ml of the filtrate. 53.5 ml of distilled water was also added to the mixture. This was then titrated against a standard iron (III) chloride solution until a brownish yellow colour persisted for 5 min. The phytate content was calculated from the iron determinations, using a 4:1 iron-to-phytate molecular ratio.

Hydrocyanic acid: This was determined using the procedure of AOAC (2005).

About 20 grams of ground sample was transferred to 1 litre distillation flask, then 200 ml water was added and allowed to stand for 2 hrs.It was Steam distilled and 150-160 ml distillate was collected in NaOH solution (0.5 gm in 20 ml water) and diluted to 250 ml. Then 100 ml was taken, 8 ml 6 M NH_4OH and 2 ml of Potassium iodide solution was added and titrated with 0.02 M AgNO3 until permanent turbidity appeared.

Calculation: 1 ml 0.02 M Silver Nitrate = 1.08 mg of HCN

Alkaloid: The gravimetric method of Harborne (1980) as described by Onwuka (2005) was used for the determination of alkaloid content. About 5g of the sample was weighed into a 250ml beaker and 200ml of 10ml acetic acid in ethanol was added, covered and allowed to stand for 4hrs. This was filtered and the filtrate was concentrated on a water bath to one –quarter of the original volume. Concentrated ammonium hydroxide was

added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid which was dried and weighed.

Saponin: The method described by Obadoni and Ochuko (2001) was used to determine the saponin content. Twenty grams of each sample was put into a conical flask and 100cm of 20% aqueous ethanol was added. This was heated over a hot water bath for 4hrs with continuous stirring at about 55^{0}C. The mixture was filtered and the residue re-extracted with another 200ml 20% aqueous ethanol. The combined extracts were reduced to 40ml over water bath at about 90^{o}C. The concentrate was transferred into a 250ml separatory funnel and 20ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded, the purification process was repeated. 60ml of n- butanol was added, the combined n-butanol extract was washed twice with 10ml of 5% aqueous sodium chloride. The remaining solution was heated in a water bath, after evaporation the samples were dried in the oven to a constant weight; the saponin content was calculated as a percentage.

Functional Properties Analysis

Water and oil Absorption capacities: Water and oil absorption capacities were determined according to the method of Onwuka (2005). One gram of sample was weighed into a clean conical graduated centrifuge tube and was mixed thoroughly with 10 ml distilled water/oil in a warring mixer for 30 secs. The sample was then allowed to stand for 30 mins at room temperature, after which it was centrifuged at 5000 rpm for 30 mins. After centrifugation, the volume of the supernatant, water or oil was read directly from the graduated centrifuge tube. The absorbed water was converted to weight (in grams) by multiplying by the density of oil (0.894 g/ml) and water (1 g/ml). The oil and water absorption capacities were expressed as grams of oil/water retained per gram of sample used.

Bulk density: This was determined using the method described by Onwuka (2005) About 2.5 g of sample was filled in a 10 ml graduated cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample. The volume was recorded.

$$\text{Bulk density} = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ (mL)}$$

Viscosity: Viscosity was determined by the method described by Mosha and Senberg(1983) Ten grams of sample was weighed and emptied into a beaker after which 100ml of water was added. The mixture was then stirred properly and heated in a boiling water bath at 90^{o}C for a period of 20 minutes. This followed further heating for 15minutes with occasional stirring. The beaker containing the sample was then transferred to another water bath maintained at 45^{o}C and the viscosity was determined at this temperature. A spindle number 2 from a Brookfield viscometer (model LV8) was used. The effect of stirring speed was determined by comparing the speed of 3,6, and 12 rpm respectively. Measurements were in duplicates.

Gelatinization temperature: This was determined using the procedure described by Onwuka (2005). Ten grams of cocoyam flour was suspended in distilled water in a 250 ml beaker and made up to 100 ml flour suspension. The aqueous suspension was heated in a boiling water bath, with continuous stirring using a magnetic stirrer. A thermometer was then clamped on a retort stand with its bulb submerged in the suspension. The heating and stirring continued until the suspension began to gel and the corresponding temperature was recorded.

Statistical analysis: All the data were subjected to analysis of variance (ANOVA) as described by (SAS, 1999). The means were then separated with the use of Duncan's multiple range test using the statistical package for the social sciences, SPSS 19.0 software.

RESULT AND DISCUSSION

Proximate Composition

Table 1 shows the effect of fermentation on the proximate composition of cocoyam flour samples. The moisture content decreased significantly ($p < 0.05$) as fermentation time increased. The values ranged from 10.45% for the control sample to 5.15% after fermentation for72hrs. The decrease in moisture content with increase in fermentation time may probably be due to the soft and porous texture of the corms after fermentation resulting in maximum moisture loss. The microorganisms must have utilized some moisture for metabolic activities.

The ash content of the flour samples ranged from 4.82- 1.92% with corresponding increase in fermentation time and differed significantly ($p<0.05$). The decrease in ash content of the flour can be ascribed to possible leaching of soluble mineral elements into fermenting medium or due to general activities of the fermenting microorganisms whose enzymatic activity resulted in breakdown of the food components into their absorbable forms. It therefore means that prolonging fermentation time would drastically result to loss of important minerals. The result agrees with the report by Atti (2000) on a decrease in ash content (2.70- 2.68%) in fermented millet. It is also consistent with the report of Michodjehoun *et al.* (2005) on the decrease in ash

Table 1. Effect of fermentation on proximate composition of cocoyam flour

Parameters	A	B	C	D	LSD
Moisture (%)	10. 45^{a} ± 0.50	9. 47^{b} ± 0.42	8. 21^{c} ± 0.15	5.15^{d} ± 0.50	0.14
Ash (%)	4.82^{a} ± 0.01	3.18^{b} ± 0.20	2.51^{c} ±0.01	1.91^{d} ±0.12	0.27
Crude protein (%)	15.61^{d} ± 0.02	17.20^{c} ±0.01	17.81^{b} ± 0.02	18.75^{a} ± 0.01	0.36
Crude fat (%)	1.83^{b}± 0.03	2.00^{b} ± 0.01	2. 41^{a} ± 0.01	2. 61^{a} ± 0.01	0.21
Crude fibre (%)	0.73^{a} ± 0.02	0.65^{ab}± 0.01	0. 50^{b}± 0.00	0. 19^{c}± 0.25	0.15
Carbohydrate %	66.53^{d} ± 0.03	68. 69^{b} ± 0.01	68.56^{c} ± 0.01	71.57^{a} ± 0,01	0.07

*Values are means ± SD triplicate determinations
*Values with common superscript letters in each row are not significantly different (p> 0.05)
LSD = Least significance difference
A= unfermented cocoyam flour (0hr)
B= Fermented cocoyam flour (24hr)
C= fermented cocoyam flour (48hr)
D= fermented cocoyam flour (72hr)

content during fermentation of "Gowe" a traditional food made from sorghum, millet or maize. In contrast to this observation, Sefa-Dedeh and Kluvitse (1995) observed an increase in ash content of fermented maize cowpea blends. The higher ash content for the control appears to suggest that minerals in the unfermented samples would be much more available than in the fermented samples.

The protein content was found to increase from 15.61-18.75%. The increase could be attributed to the increase in microbial mass during fermentation, causing extensive hydrolysis of protein molecules to amino acid and other simple peptides. The increase could also be as a result of the enzymatic hydrolysis of some protein inhibitors during fermentation. It may also be due to the structural proteins that are an integral part of the microbial cell Tortora *et al*., (2002). The increase corresponds to the observation of Michodjehoun *et al*. (2005) on increase in protein content from 7.9 to 10% during fermentation of millet and the findings of Egounlety, (1994) in his work on soybean, cowpea and ground bean. The values (15.61-18.75%) reported in this work are much higher than (7.4-8.9%) and (4.93-5.17%) reported for cocoyam by Amandikwe (2012) and Ogunlakin *et al* (2012) respectively. These variations may be attributed to differences in species, climatic and other environmental factors where the cocoyam were grown, Ihekoronye and Ngoddy (1985) and Asaoka *et al* (1991).

Crude fat showed a significant increase (p< 0.05) with an increase in fermentation time. The values ranged from 1.83- 2.61%. This observation agrees with that of Onoja and Obizoba (2009). The increase could be as a result of extensive break down of large fat molecule to simpler fatty acid units due to the high activity of the lipolytic enzymes which could have resulted in fat increase. The increase in fat might be fat from dead microflora or the fermenting microflora did not use fat from these foods as source of energy (Reebe *et al.,* 2000).

Crude fibre content decreased from 0.73- 0.19% which is an indication of softening of the fibrous tissues during fermentation. The low crude fibre values obtained in this study could be due to the activities of microorganisms which are known for the bio-conversion of carbohydrates and lignocelluloses into protein. This agrees with the findings of Hwei-Ming *et al*. (1994) and Balagopalan (1996).

Carbohydrate content showed significant difference (p < 0.05) with increase in fermentation time. The values obtained increased from 66. 53% for unfermented to 71.57% for fermentation after 72hrs. This increase may be attributed to the decrease in moisture content of the cocoyam flour as fermentation time increased.

Antinutrients

The effect of fermentation on the antinutritional factors of cocoyam flour is presented in table 2. All the antinutritional factors analyzed; alkaloids, phytate, oxalate, saponin and hydrocyanic acid decreased with increase in fermentation time and there was significant difference between the samples.

Phytate content of the flour samples reduced significantly (p < 0.05) from 131.96mg/g to 97.07mg/g. The result agrees with the earlier report of Marfo and Oke (1988), Marfo *et al* (1990) on a decrease in phytate content of cocoyam tubers from 855mg/g to 13mg/g with increase in fermentation time. This finding is also consistent with the results of Fardiaz and Markakis (1981),Sutardi and Buckle (1985) who reported 96.3-54.77% reduction in phytic acid content of peanut and soyabean respectively. The reduction may be attributed to the activity of the endogenous phytase enzyme from the raw ingredient and inherent microorganisms which are capable of hydrolyzing the phytic acid in the fermented food preparations into inositol and orthophosphate (Reddy and Peirson, 1994; Sandberg

Table 2. Effect of fermentation on some antinutritional factors of cocoyam flour

Parameters	A	B	C	D	LSD
Alkaloids(%)	$0.11^{a} \pm 0.01$	$0.09^{b} \pm 0.01$	$0.05^{c} \pm 0.00$	$0.03^{d} \pm 0.01$	0.01
Phytate (mg/g)	$131.96^{a} \pm 0.05$	$105^{b}.50 \pm 0.01$	$101.70^{c} \pm 0.06$	$97^{d}.07 \pm 0.01$	0.67
Oxalate (mg/g)	$0.95^{a} \pm 0.01$	$0.70^{b} \pm 0.01$	$0.55^{c} \pm 0.01$	$0.50^{d} \pm 0.00$	0.01
Saponin(%)	$0.63^{a} \pm 0.01$	$0.28^{b} \pm 0.01$	$0.25^{c} \pm 0.01$	$0.13^{d} \pm 0.01$	0.02
HCN (mg/g)	$0.74^{a} \pm 0.01$	$0.50^{b} \pm 0.01$	$0.10^{c} \pm 0.00$	$0.01^{d} \pm 0.00$	0.15

*Values are mean ± SD of triplicate determinations
*Values with common superscript letters in each row are not significantly different (p >0.05)
LSD = Least significance difference
A= unfermented cocoyam flour(0hr)
B= Fermented cocoyam flour (24hrs)
C= fermented cocoyam flour (48hrs)
D= fermented cocoyam flour(72hrs)

Table 3. Effect of fermentation on the functional properties of cocoyam flour

Parameters	A	B	C	D	LSD
Bulk density (g/ml)	$0.63^{ab} \pm 0.01$	$0.65^{a} \pm 0.04$	$0.65^{a} \pm 0.01$	$0.58^{b} \pm 0.01$	0.05
Gelation temperature (^{0}C)	$84.35^{a} \pm 0.05$	$83.88^{b} \pm 0.02$	$83.41^{c} \pm 0.01$	$83.03^{d} \pm 0.06$	0.07
Viscosity (CP)	$159.3^{c} \pm 1.16$	$200.3^{b} \pm 0.58$	$200.0^{b} \pm 0.00$	$380.0^{a} \pm 0.00$	1.05
Water absorption capacity (g/g)	$0.21^{d} \pm 0.01$	$0.51^{c} \pm 0.02$	$0.60^{b} \pm 0.00$	$0.90^{a} \pm 0.00$	0.10
Oil absorption capacity (g/g)	$3.77^{a} \pm 0.01$	$3.58^{b} \pm 0.01$	$3.14^{c} \pm 0.01$	$1.14^{d} \pm 0.06$	0.05

*Values are meant ± SD of duplicate determinations
*Values with common superscript letters in each row are not significantly different (p >0.05)
LSD = Least significance difference
A= unfermented cocoyam flour(0hr)
B= fermented cocoyam flour (24hr)
C= fermented cocoyam flour (48hr)
D= fermented cocoyam flour (72hr)

and Andlid, 2002). The residual phytate content of the fermented cocoyam flour falls within the FAO recommended safe level making the cocoyam flour safe for human and animal consumption.

Oxalate content of the cocoyam flour samples also showed a significant difference ($P<0.05$) with increase in fermentation time. The values ranged from 0.95mg/g - 0.50mg/g. It is known that oxalate forms insoluble complex with calcium ions, and it is often anticipated that oxalate containing foods when consumed may interfere with calcium metabolism. However, studies by Liener (1998) and Lees (1979) have shown that the risk for calcium deficiency due to oxalate rich plants is very minimal.

Table 2 also shows a significant decrease ($p<0.05$) in saponin content (0.63-0.13%) with increase in fermentation time.

Hydrocyanic acid content of the cocoyam flour samples also decreased significantly from 0.743mg/g to 0.01mg/g with increase in fermentation time. The decrease in cyanide content may be due to its hydrolysis by fermenting microorganisms. The residual cyanide in the fermented flour is much below the recommended safe level of 10mg set by regulatory bodies. This reduction in residual cyanide agrees with similar report of Kobawilla *et al*., (2005) of 70 – 75% reduction in cyanogenic glycosides content of fermented roots and leaves of cassava. This observation is also in line with that of Agbor-Egbe *et al*. (1995) confirming fermentation to be a very effective process for eradication of endogenous cyanic compounds in cassava roots.

Alkaloids content of the flour sample differed significantly at $p<0.05$ with increase in fermentation time. The values of the alkaloid of the cocoyam flour samples decreased from 0.11- 0.03%.

Table 3 shows the effect of fermentation on some functional properties of cocoyam flour.

Fermentation was found to have no much significant difference after 48hrs, after 72hrs of fermentation, there was significance decrease in the bulk density of cocoyam flour. The higher the bulk density the greater the quantity of material that can be packaged within a specified packaging space (Fagbemi, 1999). According to Peleg and Bagley (1983) bulk density depends on the combined

effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and number of contact points.

Fermentation significantly ($P<0.05$) decreased the gelation temperature of cocoyam flour. This may be due to the rapid change in the consistency of the starch matrix in the fermented flour samples.

The data presented in table 3 also showed a significant difference ($p<0.05$) in viscosity with increase in fermentation time. This increase could be as a result of an increase in the effective volume of the protein which generally results from increased molecular asymmetry brought about by a change from highly compact to an elongated random coil (Onimawo and Akubor, 2005).

Water absorption capacity of the flour showed a significant difference ($p<0.05$) increasing from 0.21 to 0.90ml/g with increase in fermentation time. This increase in water absorption capacity could be attributed to the maximum loss of moisture during drying occasioned by rapid softening of cocoyam corms during fermentation.

Oil absorption capacity was found to decreased significantly ($p<0.05$) with increase in fermentation time. The values ranged from 3.770mlg^{-1} to 1.37mlg^{-1}. This trend is similar to the observation of Abulude, (2004) who observed a significant decrease in oil absorption capacity of rice (*Oryza Sativa*) in his work on "effect of processing on nutritional composition; phytate and functional properties of rice". The decrease observed could be as a result of the increase in fat content during fermentation process, which probably decreased the hydrophilicity of the system.

CONCLUSION

Processing of cocoyam by fermentation enhanced the proximate composition and functional properties of the flour. It also significantly reduced all the antinutrients that were analyzed in this study. They were all decreased with increase in fermentation period. The result of proximate composition shows increment in fat, protein and carbohydrate while ash, moisture and fibre were found to decrease after fermentation. Fermentation also increased the viscosity and water absorption capacity of the flour while a decrease was observed in bulk density, Gelation temperature and oil absorption capacity. Fermentation is therefore adequate for processing cocoyam into flour that can be utilized in many food systems at the household and industrial level for achieving food security and combating global hunger.

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