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Evaluation of the Physico-Chemical, Functional, Pasting and Anti-Nutritional Properties of Fermented and Unfermented Cocoyam (*Colocasia* and *Xanthosoma* Species) Flours

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Abstract: ***Flours of fermented and unfermented Colocasia (Nce varieties) and Xanthosoma (Nxs varieies) were evaluated for Physico-chemical, pasting, functional and anti-nutritional properties. Results revealed that fermentation significantly (P>0.05) reduced the ash content, swelling power, solubility values and also the oxalate content of the flours. In addition, water absorption capacities of unfermented flours of the Nce varieties were significantly higher (P<0.05) than the fermented flours; an indication that Nce varieties would take up more water and would be required for development of ready-to eat foods. Pasting properties revealed that Nxs varieties with higher final viscosities than the Nce varieties is an indication that the Nxs varieties will form better viscous paste or gel after cooking and cooling. This finding has given insight into the use of fermented and unfermented cocoyam flour in the processing of different foods for which each variety may be suited.***

Keywords: Cocoyam, Fermented, Flours, Pasting, Unfermented

1. Introduction

Cocoyam is a generic term for *Colocasia* and *Xanthosoma* which belong to the *Araceae* family. It is a traditional staple root crop widely cultivated in both the tropical and sub-tropical regions of the world [1]. Nigeria is the largest producer of cocoyam in the world and accounts for about 40 % of the total world output [2]. *Colocasia esculenta* and *Xanthosoma sagittifolium* are the two species of cocoyam mostly grown in Nigeria. Cocoyam is a starchy staple food crop in Nigeria that can be boiled, fried or pounded into *fufu*, it can also be made into pottage, as well as chips and flour. In the eastern part of Nigeria, cocoyam is used as soup thickener.

Unlike other root and tuber crops such as cassava and yam, the level of utilization of cocoyam and its products both domestically and industrially is quite low and as a result could be categorized as one of the neglected crops which over the years have received minimal attention from researchers and other stakeholders [3]. Cocoyam could be of invaluable importance for food security and the knowledge of the physico-chemical, pasting, and anti-nutritional properties of cocoyam would go a long way to tapping the potential of cocoyam as a food and cash crop and unravel opportunities for its expanded utilization.

2. Materials and Methods

Material Collection and Identification

Five freshly harvested cocoyam varieties (*Colocasia and Xanthosoma* spp.) were procured from the Cocoyam Programme of National Root Crops Research Institute, Umudike. The *Colocasia* species were (Nce 001, Nce 002, and Nce 006) while the *Xanthosoma* species were (Nxs 001 and Nxs 002).

Preparation of Flour

The cocoyams were processed into flour (fermented and unfermented) using the method of [4] with a slight modification. The cocoyams were peeled, washed, sliced into chips with a manually operated chipping machine to produce chips of approximately 4 mm thickness. The chips were washed with potable water and divided into two equal parts. One part was sun-dried to constant moisture content. The other part was soaked in tap water for 24 hours. The soaked chips were drained and sun-dried to constant moisture content. The dried samples were subsequently milled into flour in laboratory hammer mill. The flour products were sieved and packaged in sealed polyethylene bags until required for analysis.

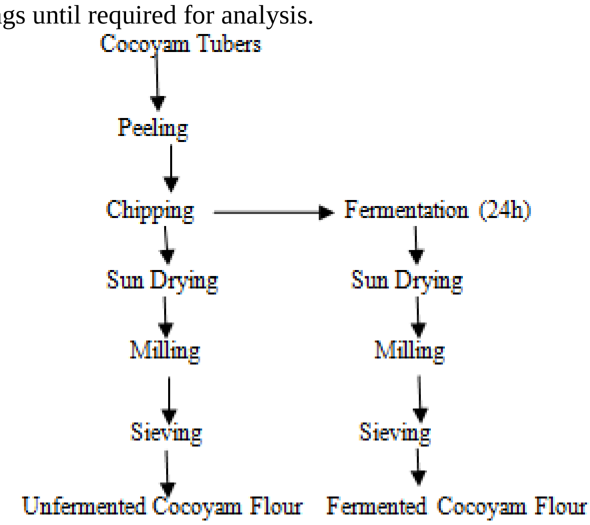

Figure 1: Flow chart for fermented and unfermented cocoyam flour production.

Determination of Moisture Content
The moisture content of the samples was determined using [5].

Determination of Ash Content
Ash content was determined using [6].

Determination of fat content
The fat content of samples was determined using [7].

Determination of Protein Content
The method of [8] was used to determine the protein content.

Determination of Amylose content
Amylose content of the cocoyam flour samples were determined by the method of [9].

Determination of pasting properties
The pasting profile of the flour samples was studied using a Rapid Visco-Analyzer (RVA). 3.0 g of the flour sample was weighed and dispensed into the test canister. 25.0 ml of distilled water was dispensed into the canister. The Visco Analyser was switched on and the pasting performance of the flour was automatically recorded on the graduated sheet of the instrument.

Determination of water and oil absorption capacity
Water and oil absorption capacities (WAC and OAC) were determined using the method of [10]. The swelling power and solubility index was determined by the methods of [11] and [12].

Determination of Bulk Density
Bulk density of samples was determined by the method of [13].

Oxalate Content Determination
This was determined using the method of [14].

Phytic Acid Content Determination
The method of [15] was used to determine the phytate content. The tannin content of the cocoyam samples was determined by the method of [16].

Statistical Analysis
Statistical analysis of data generated was performed by subjecting the data to analysis of variance (ANOVA) to calculate significant difference in treatment means and Duncan was used to separate the means. [17] was used and significance was accepted at $p \leq 0.05$.

3. Results and Discussion

Table 1: Chemical Composition of Fermented and Unfermented Cocoyam Flours

Variety	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Amylose (%)	Amylopectin (%)
Nce 001(U)	6.43^{de}	8.84^{b}	0.52^{a}	4.69^{b}	33.13^{a}	66.88^{e}
Nce 001(F)	6.25^{e}	8.69^{b}	0.47^{a}	4.41^{c}	32.10^{ab}	67.91^{de}
Nce 002(U)	6.22^{e}	12.85^{a}	0.43^{ab}	5.15^{a}	26.57^{e}	73.43^{a}
Nce 002(F)	6.22^{e}	12.80^{a}	0.34^{bc}	4.13^{d}	28.64^{d}	71.36^{b}
Nce 006(U)	6.78^{bc}	6.92^{c}	0.50^{a}	3.42^{f}	31.70^{b}	68.30^{d}
Nce 006(F)	6.60^{cd}	6.10^{de}	0.42^{ab}	2.76^{h}	30.10^{c}	69.93^{c}
Nxs 001(U)	7.04^{b}	1.03^{g}	0.51^{a}	3.84^{e}	32.61^{ab}	67.39^{de}
Nxs 001(F)	7.40^{a}	1.13^{g}	0.30^{c}	2.72^{h}	32.61^{ab}	67.39^{de}
Nxs 002(U)	6.78^{bc}	6.23^{d}	0.32^{bc}	2.92^{g}	33.15^{a}	66.85^{e}
Nxs 002(F)	6.84^{bc}	5.66^{e}	0.30^{c}	2.48^{c}	31.80^{b}	68.21^{d}
LSD	**0.27**	**0.46**	**0.11**	**0.09**	**1.31**	**1.31**

Means with the same superscripts in the same column are not significantly different (p>0.05)
F=Fermented; U= Unfermented

The moisture content of the flours ranged from 6.22 % to 7.40 %. [18] reported moisture content value of 6.3 % for cocoyam flour. Moisture content is an indicator of flour storability. Low moisture contents are required for safe and prolonged storage as higher moisture contents can lead to microbial damage and subsequent deterioration in quality. The moisture levels obtained in this study indicates that the cocoyam to flours would store for relatively a long time under good packaging.

Fermentation significantly ($p<0.05$) reduced the ash contents of the flours. Unfermented Nce 002 had the highest ash content of 5.15% while fermented Nxs 001 had the least ash content value of 2.72 %. [19] and [20] reported ash content values of 5.5 % and 4.1 % respectively for cocoyam flour. The higher ash content value of 5.15 % (table1) obtained for unfermented Nce 002 is an indication that this variety is rich in mineral elements.

The fat content values of the fermented and unfermented flours were between 0.3 and 0.52 %. [20] reported fat content value of 0.42 % for raw cocoyam. Root and tuber crops generally contain very low levels of fats [21], [22]. The results obtained in this study are in agreement with this, table 1.

Amylose contents of the fermented and unfermented flours were between 26.57 and 33.13 %. [21], [23] reported the range of 3 to 43 % for cocoyam starches and that range is dependent on variety. The amylose content of starch is one important characteristic that affects its functionality. [24], [25] reported that increase in amylose content of starch has been found to lower swelling power and solubility of cocoyam and wheat starches This statement agrees with the results obtained in this work The higher the amylose content, the lower the swelling power and solubility (Tables 1 and 2).

Table 2: Functional Properties of fermented and unfermented cocoyam flours

Variety	WAC (%)	OAC (%)	BD (g/ml)	SP (%)	SI (%)
Nce 001(U)	3.31^{a}	2.01^{a}	0.91^{b}	10.32^{bc}	10.47^{b}
Nce 001(F)	2.82^{b}	1.69^{bcd}	0.90^{c}	8.87^{cd}	9.18^{bcd}
Nce 002(U)	3.21^{a}	1.99^{a}	0.89^{c}	11.94^{a}	8.79^{cd}
Nce 002(F)	2.58^{cd}	1.86^{ab}	0.89^{c}	10.70^{ab}	7.90^{de}
Nce 006(U)	2.78^{bc}	1.76^{bc}	0.91^{b}	8.95^{cd}	17.98^{a}
Nce 006(F)	2.28^{e}	1.69^{bcd}	0.86^{e}	8.81^{d}	10.13^{bc}
Nxs 001(U)	2.45^{de}	1.55^{d}	0.95^{a}	10.50^{ab}	6.85^{e}
Nxs 001(F)	2.41^{de}	1.74^{bcd}	0.88^{d}	5.25^{e}	3.24^{f}
Nxs 002(U)	2.38^{de}	1.61^{dc}	0.89^{c}	7.71^{d}	9.06^{bcd}
Nxs 002(F)	2.47^{de}	1.81^{ab}	0.89^{c}	7.49^{d}	7.10^{e}
LSD	**0.24**	**0.21**	**0.004**	**1.50**	**1.53**

Means with the same superscripts in the same column are not significantly different (p>0.05)
F=Fermented; U= Unfermented
WAC=Water absorption capacity; OAC=Oil absorption capacity ; BD= Bulk density; SP=Swelling Power; SI= Solubility Index.

Water absorption capacity (WAC) of fermented and unfermented flours was between 2.28 and 3.31 %. Water absorption capacity is important in the development of ready-to-eat foods, and a high absorption capacity may assure product cohesiveness [26]. Results showed that unfermented flours of Nce varieties (Nce 001; Nce 002 and Nce 006) had significantly (p<0.05) higher water absorption capacities than the fermented flours of the same varieties. This implies that unfermented flours of Nce 001; Nce 002 and Nce 006 varieties would take up more water and would be required for development of ready-to eat foods.

The swelling power of flours is an indication of the water absorption index of the granules during heating. It is also regarded as quality criterion in some food formulation such as bakery products [27]. The flours of Nce varieties had higher swelling power (8.81 to 11.94%) than flours of Nxs varieties (5.25 to 10.50 %).The suggests that, flours produced from Nce varieties will absorb more water than those produced from Nxs varieties.

Bulk density is influenced by particle size. The density of flour is important in determining the packaging requirement and material handling [28]. The bulk densities of the fermented and unfermented flours obtained in this study was between 0.86 and 0.95 g/ml. This result is higher than bulk density value of 0.71 g/ml for *colocasia* flour reported by [18]. The high bulk densities obtained from fermented and unfermented flours of cocoyam in this study suggests that the particle size of the flours is very small, and can be used in formulation of infant formulas.

Table 3: Pasting properties of fermented and unfermented cocoyam flours

Variety	Peak (RVU)	Trough (RVU)	BDV (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temp. (^oC)
Nce 001(U)	223.75^c	146.34^d	77.42^{ab}	198.59^{def}	52.25^e	5.17^c	49.03^a
Nce 001(F)	205.75^{cd}	143.24^d	62.50^{bcd}	211.75^{de}	68.50^d	5.20^c	49.20^a
Nce 002(U)	190.54^d	140.50^{de}	50.04^d	187.09^{fg}	46.58^e	5.72^b	49.18^a
Nce 002(F)	152.38^e	136.29^{de}	16.08^e	213.59^d	77.30^c	6.28^a	49.30^a
Nce 006(U)	185.17^d	129.42^e	55.75^{cd}	182.30^g	52.88^e	5.07^c	49.40^a
Nce 006(F)	222.96^c	136.63^{de}	86.34^a	197.96^{ef}	61.34^d	4.90^c	49.25^a
Nxs 001(U)	313.42^{ab}	243.38^b	70.05^{abc}	363.92^b	120.54^b	5.10^c	49.28^a
Nxs 001(F)	333.96^a	257.29^a	79.67^a	392.08^a	134.80^a	4.97^c	49.40^a
Nxs 002(U)	259.21^b	223.75^c	71.50^{abc}	343.63^c	119.88^b	5.15^c	49.18^a
Nxs 002(F)	319.98^{ab}	233.38^{bc}	86.00^a	362.08^b	128.71^a	4.91^c	49.30^a
LSD	**28.67**	**13.04**	**17.14**	**15.40**	**7.19**	**0.34**	**0.91**

Means with the same superscripts in the same column are not significantly different (p>0.05)
F=Fermented; U= Unfermented; BDV= Breakdown viscosity

Peak viscosity values of the fermented and unfermented flours ranged from 152.38 to 333.96 RVU. Fermented Nxs 001 had the highest peak viscosity of 333.96 RVU and thus will have a higher thickening power than fermented Nce 002 with the least peak viscosity of 152.38 RVU. Peak viscosity indicates water binding capacity of the starch mixture; it is the ability of the starch to swell before it physically breaks down [29]. It also provides an indication of the viscous load likely to be encountered during mixing [30].

Furthermore, fermented and unfermented Nxs 001 and Nxs 002 with very high peak viscosities will form thicker viscous gels on cooking and may be more suitable for products which require high gel strength [29].

Final viscosity is the most commonly used parameter to define the quality of a particular starch-based sample quality, it also gives an idea of the ability of a material to form a viscous paste or gel after cooking and cooling[27];[29]. Nxs varieties had higher final viscosities (343.63 to 392.08 RVU) than the Nce varieties (182.30 to 213.59 RVU) and this implies that the Nxs varieties with higher final viscosities will form better viscous paste or gel after cooking and cooling than the Nce varieties. The trough measures the ability of paste to withstand breakdown during cooling [30], [31]. Nxs 001 and Nxs 002 flours with higher holding strength (trough) will remain undisrupted when subjected to long period of high temperature during cooking than Nce 001; Nce 002 and Nce 006 flours. Setback values of all the flour samples were significantly (p<0.05) increased after fermentation. Flours of the Nxs varieties had higher setback values (119.88-134.80 RVU) than flours of the Nce varieties (46.58-77.30 RVU). High setback is associated with syneresis, or weeping, during freeze and thaw cycles. When used in food formulations requiring freeze and thaw cycles, the Nce varieties will be less associated with syneresis, or weeping than the Nxs varieties.

Table 4: Anti- nutritional factors of fermented and unfermented cocoyam flours

Variety	PhyticAcid mg/100g	Tannin mg/100g	Oxalate mg/100g
Nce 001(U)	1.59^a	2.17^b	21.49^c
Nce 001(F)	1.28^{ab}	1.70^{bcd}	16.12^e
Nce 002(U)	0.94^{bcd}	4.72^a	35.82^a
Nce 002(F)	1.23^{ab}	1.97^{bc}	23.88^b
Nce 006(U)	1.39^{bc}	2.32^b	18.00^d
Nce 006(F)	0.62^{cde}	0.93^{def}	11.94^g
Nxs 001(U)	0.57^{de}	1.45^{bcde}	13.50^f
Nxs 001(F)	0.32^e	0.53^f	5.37^i
Nxs 002(U)	0.77^{cd}	1.12^{cdef}	10.74^g
Nxs 002(F)	0.56^{de}	0.93^{def}	8.06^d
LSD	0.44	0.89	1.24

Means with the same superscripts in the same column are not significantly different (p>0.05)
F=Fermented; U= Unfermented

There was a marked reduction in the oxalate content of the flours on fermentation. The observed marked reduction caused by fermentation may be due to the effect of leaching of enzyme and acid hydrolysis of the starch granule during fermentation. This result agrees with result obtained by [32]. In their findings, there was a 65 % reduction in oxalate content of the 48 hour fermented flour when compared with the unfermented flour. They also reported that the oxalate content of the 24 hour fermented flour was also reduced by 58 %.

4. Conclusion

The results obtained from this study offer an indication of the application of fermented and unfermented cocoyam flour in the processing of different foods for which each variety may be suited. The high viscosities obtained for the Nxs varieties will make them very useful in food applications where high thickening power is desired such as sauces, soups and dairy desserts. Flours of Nce 001; Nce 006; Nxs 001 and Nxs 002 will withstand heating and shear stress during processing. Flours of Nce 001; Nce 002 and Nce 006 when used in the preparation of *fufu* and used for baked products will not be associated with syneresis.

This finding has given insight into the use of fermented and unfermented cocoyam flour in the processing of different foods for which each variety may be suited.

5. Future Scope

This research could be further extended by characterizing other local varieties of cocoyam so as to add value and improve the utilization of this crop which is almost going extinct.

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