Sorption Isotherm, Particle Size, Chemical And Physical Properties Of Cocoyam Corm Flours

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ABSTRACT: The sorption isotherm, particle size chemical and physical properties cocoyam corm flours were studied in order to enhance the storage and their applications in food formulation. Cocoyam corms: *Colocasia exculenta cv ede cocoindia*, *Colocasia exculenta cv ede ofe*, *Xanthosoma sagittifolium cv ede uhie* and *Xanthosoma sagittifolium cv ede ocha* were processed into flour. The flours were subjected to analysis to determine their equilibrium moisture content at different relative humidity, particle size distribution, chemical and physical properties. The equilibrium moisture content at 30^{o}C determined over varied relative humidity showed differences in the amounts of moisture absorbed while the sorption isotherm curves obtained revealed typical type II isotherm. Moreover the monolayer values obtained differed among the cultivars. Chemical properties determined were moisture content, crude proteins, fibre, fat, and ash as well as the carbohydrate content. Also, the physical properties investigated were the particle size, water absorption capacity, viscosity, bulk density, porosity, gelatinization temperature, blue value index, pH and solid density. Mean water absorption capacity: 2.195g/g, 2.410g/g. 2.178g/g and 2.0082g/g were recorded for *ede cocoindia*, *ede ofe*, *edeuhie* and *ede ocha* respectively. Also gelling temperature: 63.8^{o}C, 96.8^{o}C, 65^{o}C and 73.8^{o}C for *ede coconidia*, *ede ofe*, *ede uhie* and *ede ocha* respectively. The results show that the physicochemical properties of cocoyam corm flours are comparable to other root crops and could be used in various food formulations. [Researcher. 2010;2(8):11-19]. (ISSN: 1553-9865).

Key words: Cocoyam corms; equilibrium moisture; Water activity; Sorption isotherm; Chemical and Physical properties.

1. INTRODUCTION

Taro (*Colocasia esculenta*) and Tannia (*Xanthosoma sagittifolium*) are the important species of edible aroids grown in tropical and sub tropical countries (FAO, 2006). They contribute significantly to the carbohydrate diet, even though ranked less important after yam, cassava and potato (Obomeghei. et al. 1998; FAO, 2006). Cocoyam is produced in abundance in eastern part of Nigeria, but less valued in this area as it is regarded as staple food for rural dwellers, the poor and the less privileged in society (IITA, 1992). Enwere (1998) reported that the corms and cormels are cooked and pounded with cassava or yam into fufu and eaten with stew or soup, and that the cormels are exclusively used as a thickener in preparation of soup. The nutritional and chemical compositions as reported by FAO (2006) shows that cocoyam if fully exploited would enhance the food security of people living in the Tropics. A major problem of cocoyam is that the corms are susceptible to physical damage during harvesting and thus leading to high post harvest losses (Onwueme and Simha, 1991; FAO, 2006). To overcome these losses, Onyeike et al. (1995) reported that the corms and cormels may be processed into flour. Kwarteng and Towler (1994) reported that the flours stores much longer than the unprocessed tubers of cocoyam. The need to widen the scope of information on the physical, chemical and engineering characteristics has been stressed by FAO (2006). This will improve cocoyam competitiveness along side other roots and tuber crops, enhance its application in other food systems and improve marketing potential. Cocoyam flour can be used in making biscuits or as composites in bread making (Idowu et al., 1996). The corm's flour is a good source of carbohydrate for diabetics and production of weaning food for infants and for those with gastrointestinal disorders (Onwueme, 1978). The taro and tannia flours in precooked forms may find good uses in pie filling, binder in sausage and as emulsifier in food systems (Fagbemi and Olaofe, 1998). In the current study, sorption isotherm, physical and chemical properties of cocoyam flour are reported. This is expected to provide information for those involved in processing of flour and its application in food formulation.

2. Materials and Methods

2.1 Sample preparation:

Wholesome cocoyam cormels (*Colocasia esculenta cv ede ofe, Colocasia esculenta cv ede cocoindia, Xanthosoma sagitifo litium cv ede ocha* and *Xanthosoma sagittifolium cv edeuhuie)* used in this study were harvested on the month of

November, 2008 from an experimental farm at Imo State University Owerri, Nigeria. The cornels were cleaned, peeled and sliced with stainless kitchen knife and washed with tap water. The slices were treated with 20ppm solution of sodium metabisulphate in water for 20min. The slices were subsequently treated with hot water for 5min and then oven dried at 70°C. The dried samples were milled into flour and stored in air-tight containers.

2.2 Chemical Composition:

Moisture content crude protein, fibre, fat, ash and carbohydrate were determined according to AOAC (1990).

2.2.1 Moisture Content Determination

The moisture cans were washed and dried in the oven and weighed using analytical weighing balance. Five (5 g) grams of the sample were put into previously weighed moisture can. The sample in the moisture can was put into the oven (Gallenkamp Hot box size 1, air- dried type) at 105°C for 3.0 h. The sample was removed and placed in the desiccators to cool and weighing was carried out afterwards. The sample was reheated and cooled intermittently until constant mass was obtained. The difference in mass as percent moisture was calculated as the % moisture content.

2.2.2 Crude Protein Determination

The Kjeldahl apparatus was used for the determination of crude protein. One half (0.5 g) grams of each dry sample was weighed and put into a Kjeldahl digestion flask. One tablet of Selenium catalyst was added into each of the flask moistened with distilled water and mixed with 10 ml of concentrated H_2SO_4. The mixture was heated to red-hot temperature under a fume cupboard for 2 h to obtain a clear solution. The digest was transferred quantitatively to 100 ml volume flask and diluted to mark with distilled water. An aliquot of the digest (10 ml) was mixed with equal volume of 45% NaOH solution in a semi-micro kjeldahl distillation apparatus. The mixture was distilled and the distillate collected into 10 ml of 4% boric solution containing 3 drops of mixed indicator (methyl red and bromocressol green). A total of 50 ml distillate was collected and titrated against 0.02N H_2SO_4 solution. A blank experiment was also set involving digestion of all the materials except the sample. The distillation was also carried out on the blank. The titre value of the blank was subtracted from that of the sample and the difference obtained was used to calculate the crude protein.

The percent nitrogen content was calculated a

% crude protein = % N x 16.25.

2.2.3 Crude Fibre Determination

Two (2 g) grams of each sample were digested with 200 ml of 1.25% H_2SO_4 solution under reflux for 30 min boiling. The digest was allowed to cool and then filtered with Buckner funnel equipped with muslin cloth. The residue was washed thrice with hot water, scooped into a conical flask and digested with 200 ml of 1.25% NaOH solution under reflux for 30 min boiling. The digest was cooled, filtered and washed thrice with distilled water. The residue was drained and scooped into a previously dried and weighed crucible and then put into the oven to dry at 105 °C to a constant mass. The dish with its content was reweighed after drying and then placed in the muffle furnace to ash at temperature of 550°C for 3 h. The ash was withdrawn at the end and put in a bell jar and reweighed. The difference in mass of the sample was calculated as crude fibre and expressed as a percent of the initial mass.

2.2.4 Ash Determination

Two (2 g) grams of the sample was weighed into previously cleaned, dried crucible of known mass. The crucible with the content was weighed and the mass recorded. The crucible with the content was placed into a muffle furnace at 550°C for 3 h until the sample turned white and free from carbon. At the end of incineration, the ash substance was withdrawn and cooled in a bell jar and reweighed. The mass of the residual incinerate was calculated as % ash content.

$$\% \text{ ash} = \frac{\text{Mass of Ash} \times 100}{\text{Mass of Sample}}$$

2.2.5 Carbohydrate Determination

The carbohydrate content was determined by deference that is by deducting the mean values of other parameters that were determined from 100.

Therefore %carbohydrate =100-
(%mc+%CP+%fat+crude fibre+%Ash).
Where mc= moisture content; cP = crude protein.

2.3 Physical Properties

2.3.1 Particle Size:

The method of Idowu et al. (1996) was used. Test sieves of various apertures (90µm, 75µm and 50 µm) were arranged in ascending order and mounted on the test sieve shaker. 30g of the flour was put in the top sieve and covered with the lid. The shaker was switched on and operated for 30min after which the sieves were removed and the retained amount was determined by weighing. The percent retention of

each sieve was calculated. Means values were calculated after four determinations.

2.3.2 Viscosity:

The brook field synchrolectric viscometer was used to determine the viscosity of slurry made from the flour. Twenty (20) g of the flour was put in 250ml beaker and 200ml of tap water added to form slurry. The slurry was heated at 100^{o}C for 15 min to gelatinize. The brook field synchrolectric viscometer was set at zero and 60 rev per minute. The viscosity of the pap was determined when the spindle revolves 60 time/minute.

2.3.3 Blue Value Index (BVI):

The method of Atkins (1982) was followed. Three (3) g of the flour was weighed into 50ml beaker and 30ml dispersion made and allowed to stand for 30min 30C, which was filtered afterward with whatman (No 42) filter paper. 10ml of the filtrate was measured into 25ml conical flask and titrated with O.I.N iodine solution using phenophtalein as indicator. The titre value was recorded at the blue colour end point. Percent blue value index was calculated as:

$$\%BVI = \frac{VD \times Vt \times N \times 100}{VA \quad Mf \quad 100 \quad I}$$

Where : VD = Total volume of dispersion; VA=Volume of aliquot used for filtration; Vt =Titre value;

Mf =Mass of flour used; N=Normality of iodine.

2.3.4 Water Absorption Capacity:

The method of Abbey and Ibeh (1988) was followed to determine water absorption capacity. One (1) gram of the flour was mixed with tap water in a centrifuge tube and made up to 10ml dispersion and allowed to rest at room temperature for 30mins. The sample was centrifuge at 3000rpm with Heltich model centrifuge. The volume of the supernatant was measured using 10ml graduated cylinder. The density value 1000kg/m3 was assumed and mean water absorption capacity obtained after four determinations in (g/g).

2.3.5 Gelatinization Temperature:

The method of Narayana and Narasinta – Rao (1982) was adopted with slight modification. Twenty five (25) grams of the flour was dissolved in tap water in a beaker and made up to 100ml dispersion. The dispersion was placed on heating mantle and stirred as heating progresses. The gelling temperature was recorded at the gelling point of the flour in ^{0}C.

2.3.6 Bulk Density:

The method of Milson and Kirk (1980) was followed to determine the bulk density. Fifty (50) grams of the sample was weighed into 100ml graduated cylinder and the initial volume recorded. The cylinder was tapped repeatedly for 100 times to a constant volume and the final volume recorded. The bulk density was calculated as the mass of the sample divided by the volume at the end of tapping.

2.3.7 Porosity: The porosity was calculated using the values obtained for the case of bulk density: thus

$$\text{Porosity} = \frac{\text{Initial volume} - \text{Final volume}}{\text{Initial volume}}$$

3.4 Data Analysis

The data obtained from the study were subjected to analysis of variance (ANOVA) procedure of Steel and Torrie (1980) and the Fisher's least significant difference (LSD) used to separate significantly differing means as described by Roessler (1984).

3. Results and Discussion

3.1 Sorption Isotherm:

The sorption isotherm curves are presented in Figure 1. The cocoyam corm flours exhibited sigmoid shape which is typical of type II isotherm going by Brunauer et al. (1938) classification and is also in agreement with the works of Aguerre et al. (1996). The various flours adsorbed minimal amount of water at a region of water activity ($a_{w)}$ 0.0 - 0.25, which the moisture is unavailable for reactions (monolayer adsorption). At $a_{w,}$ 0.65 the equilibrium moisture content was within the amount suitable to maintain shelf stability for dehydrated food as stated by Lewis (1990). The colocasia cultivar, *ede* cocoindia adsorbed the highest amount 0.13 at 65% humidity while *ede ofe* had the least 0.10 (Table 2). At a_w range from 0.00 - 0.7, the uptake of moisture was gradual but raised sharply at a_w range 0.70- 0.97. The sudden rise in moisture uptake in the range 0.70 - 0.97 corroborates previous works by Nanjundaswany et al. (1976); Mir and Nath (1995) and Ariahu et al. (1999). The high sugar content of these flours might be responsible for the high moisture uptake at a_w range 0.70 and above. Pezzutti and Crapiste (1997) attributed the moisture uptake to physical adsorption of water on polymeric molecules. Moreover the rate of moisture uptake or sorption kinetics might be associated with the large surface areas of the flours. Sorption isotherm gives the relationship between water activity and water content of the food material at particular temperature and at certain humidity. According to Nwanekezi (2007) sorption isotherm enables processors to evaluate a drying process.

The monolayer moisture content ranged from 0.0353- 0.0471 gH20/g solid with *ede uhie* having the highest value, 0.0471gH2O/g solid as presented in Table 1. Onwuka (2003) listed monolayer range, 0.0320- 0.160g H2O/g solid for some dry starchy flours. Monolayer moisture content is a measure of sorption possibility of starchy food (Kiranoudis et al., 1993). It is the minimum amount of water bound to active sites and guaranties the stability of flour during storage (Iglesias et al., 1975). The higher the monolayer values the more the stability of the flour. Thus suggesting that *ede uhie* provides more binding sites for water molecules and would be least stable in storage, while *ede ocha* with the lowest monolayer value might store for longer time than the rest.

3.2 Chemicial Properties:

The result of proximate composition is shown in Table 2. The percent crude protein differed significantly (P< 0.05) with ede ofe scoring the highest, 11.36% while cocoindia had the least value of 7.88%. Also the crude fibre differed significantly (P< 0.05). Okpokiri (1981) obtained 9.2% protein for ede ocha while FAO (2006) reported crude protein (wet weight basis), 1.8% for Colocasia esculanta and 2.0% for Xanthosoma sagittifolium corms. Protein content plays important role in water absorption capacity of flour in food systems. The carbohydrate contents of all the cultivars were high when compared to other parameters, thus signifying that cocoyam is a rich source of energy for human nutrition. However among the cultivar ede uheie contributed the highest amount of carbohydrate than the rest (Table 2). Onwueme (1978) reported that cocoyam corm is a source of carbohydrate for diabetics and for those with gastrointestinal disorders. These may suggest that cocoyam corms contain slowly digestible starches and dietary fibre which are of nutritional importance (Srilakshmi, 2008).

3.3 Particle Size:

The results of particle size distribution of the samples were as shown in Table 3. Major portions of the flours were retained in the 90µm mesh and the percent retention differed significantly (P<0.05) among the cultivars. The 50µm had intermediate retention while 75µm scored the least amount. *Ede ofe* with the largest particle size had the highest retention (97.42%) on 90µm mesh, which is followed by *ede cocoindia,* (96.29%) while *ede ocha* had the least 95.44%. Particle size plays important role in the dispersion of flour in both cold and hot water. Iwuoha and kalu (1990) showed that there are linear relationship among particle size, water absorption and viscosity of flour. The distribution of the particle sizes of these flours might necessitate their application in production of face powder, body cream and for the manufacture of biodegradable plastics as suggested by (Onwueme, 1987).

3.4 Water Absorption Capacity:

The water absorption capacity of the flours differed significantly P<0.05 with *ede ofe* having the highest, (2.41g/g) while *ede ocha* had the least, 2.082g/g. *Ede ocha* which had the least water absorption also had the smallest particle size when subjected to 90µm aperture (Table 4). The high water absorption *ede ofe* corroborates high equilibrium moisture content at 0.97 water activity. Water absorption capacity of flours is influenced by the degree of disintegration of native starch granules (Greer and Stewart, 1959). Suggesting that undamaged starches have low potential absorption capacities. The water absorption capacity of flour enables the processor to add more water during food preparation which enhances profitability; and also improves handling characteristics. It maintains the freshness of bread, cakes and sausage (Akobundu et al., 1982). The high water absorption of colocasia species favours their use as a soup thickener.

3.5 Viscosity:

The highest viscosity was recorded for *ede uhie* (0.24cp) while *ede*cocoindia had the least (0.089cp) as presented in Table 4. The high viscosity of *ede uhie* might be associated with the degree of damage starch as there is a correspondingly high value of blue value index for *ede uhie* than the rest. High viscosity is a desirable quality attribute of flour for baking purpose. Thus suggesting that ede uhie might be suitable as a baking material (Adeyemi and Omolayo, 1984). Generally, xanthosoma spp would be possess better baking ability than the Colocasia spp going by the high viscosity scores. The high viscosity of xanthosoma spp makes their cultivars better suitable for the production of cocoyam flour for use in fufu preparation. Obomeghei et al. (1998) however reported that cocoyam corm when pounded into fufu gave inferior hand feel than pounded yam.

3.6 pH:

The pH of the cultivars as presented in Table 4 shows that the colocasia spp. had low pH as compared to their xanthosoma spp counterparts; *cocoindia* had pH, 4.2; *ede ofe*, 4.48; *ede uhie*, 5.03 and *ede ocha*, 5.78 respectively. pH is important in determining the acid factor which is an indicator for the rate of conversion of starch to dextrin (Hollamann and Alten, 1956). The pH values of all the cultivars are within the low acid range that might support

spoilage by all sorts of microorganisms. Therefore the extension of storage life may necessitate the use of chemical anti microbial agents and anti oxidants.

3.7 Solid Density (SD):

The xanthosoma spp had high score of SD than the colocasia counterpart. Among xanthossoma, *ede uhie* had the highest SD value of 0.344g/cm^3 while *ede ofe* of colocasia had the least SD value of 0.297g/$cm^{3.}$ SD is important in food separation process such as sedimentation, centrifugation, and in pneumatic and hydraulic transportation of powders particulate foods Lewis (1987). SD is desirable quality factor for assessment of flours.

3.7Bulk Density and Porosity:

The bulk density of the cultivars as presented in Table 6 indicates that the xanthosoma spp scored high than the colocasia spp. *ede ocha* and *ede uhie* did not differ significantly($p<0.05$). *ede ofe* score the least bulk density, 0.714g/ cm^3 . On the other hand, the cultivars from Colocasia spp recorded high porosity than the Xanthosoma spp Bulk density and porosity are affected by the particle size of flour and play important roles during mixing (as in dough formation), sorting, packaging as well as transportation of particulate foods (Sakai, 1979). Lewis (1987) stated that bulk density and porosity are influenced by the geometry, size and surface properties of a given material. Ede ocha which recorded the highest bulk density might be associated with small particle size at 90 µm while ede ofe with the largest particle scored the least (Table 4).

3.8 Gelatinization Temperature:

Cocindia had the least gelling temperature of 63.8^{0}C, followed by *ede uhie*, 65^{0}C, while *ede ofe* and ede ocha had 69.75^{o}C and 73.8^{o}c respectively as presented in Table 4. There is no clear line of difference in gelling temperature between the two species of cocoyam as determined at $P<0.05$. According to Ayenor (1985), gelling temperature might be associated with the relative ratio of amylase and amylopection in flour. The implication of the result is that lesser amount of energy will be spent on cooking cocoindia than the other cultivars.

4. CONCLUSION

The sorption isotherm study has shown that cocoyam flours from the various cultivars respond to moisture equilibration at varying storage condition like any other flour from cereal or root crops. A relative humidity not exceeding 65% might be suitable environment for flours from cocoyam corms at 30^{o}C. Thus processing cocoyam into flour immediately after harvest is a sure means of extending shelf life and overcoming post harvest losses.

Cocoyam is a good source of carbohydrate going by the chemical score and therefore should be appreciated as a food security crop those people living in the area where cocoyam is produced in abundance. The crude protein score for all the cultivars studied has shown that cocoyam contains more protein than the amount present in other root crops such as yam or cassava.

However when it is necessary to disperse the flour as it is a common practice during food formulation the corms flour from xanthosoma spp would be of advantage than the colocasia spp, considering their relative small particle size distribution. Also, within the xanthosoma spp, ede ocha would be highly preferred. Moreover, the high viscosity of the cultivars from the xanthosoma spp makes them the preferred choice for preparation of thick paste fufu. On the other hand, the high water absorption of the colocasia spp might be the reason behind their use in thickening soup. The pH of all the cultivars which were found to be in the low acid range is an indication that outside drying to low water activity, antimicrobial additive and antioxidant might be of help in an attempt to extend the storage life of the corm's flours. The low gelling temperature of cocoindia means that the starch in it would require lesser energy to cook than the other cultivars. This study has highlighted the importance of processing cocoyam into flour immediately after harvest. Thus cocoyam can be processed, packaged and stored like cereal flour. The physical and chemical properties have shown that they will play better role in food emulsion system beyond their current use in fufu preparation and soup thickening.

It is recommended that cocoyam flour be used as composite in bread making, biscuits, pasta, binder in sausage etc. This can be enforced through legislation which will have dual effects on increasing crop production for rural farmers to earn revenue and provision food security for people living in the area where cocoyam is produced in large quantity but is neglected.

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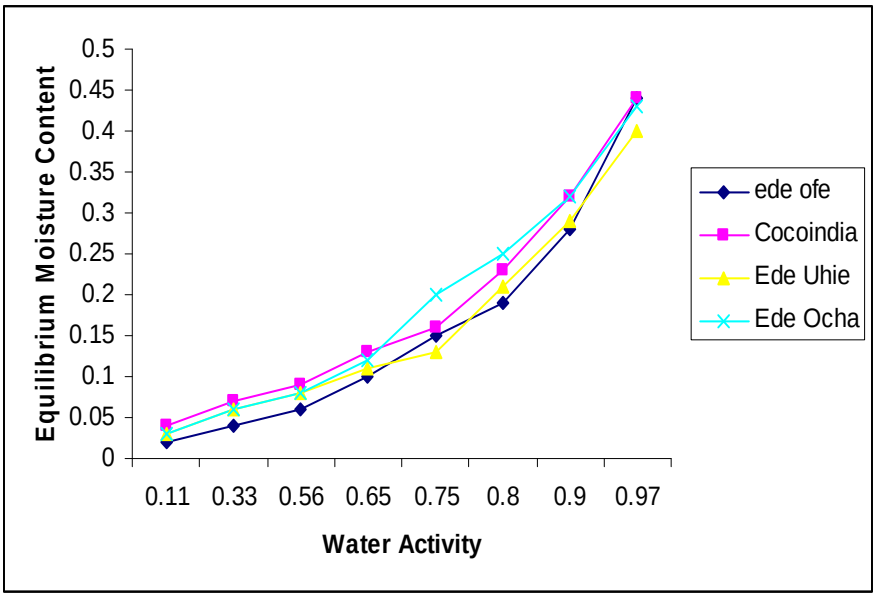

Figure 1: Sorption Isotherm of flours from cocoyam corms at 30°C

Table 1. Monolayer moisture content of Cocoyam Corms' Flour

Cultiver	Monolayer (Mo)gH2O/g solid
Ede uhie	0.0471
Ede ocha	0.0353
Cocoindia	0.0438
Ede ofe	0.0409

Table 2. Chemical Properties Cocoyam Corm Flour

	Colocasia esculenta		Xanthosoma Sagittifolium		
Chemical properties (%)	Cocoindia	Ede ofe	Ede Uhie	Ede ocha	LSD
Ash	$3.50^{a} \pm 1.6x\ 10^{-2}$	$3.15^{b} \pm 5.2x10^{-3}$	$3.00^{a} \pm 0.00$	2.45± 6x10-4	2.7x10-4
Fat	$0.82^{a} \pm 6x10^{-3}$	$0.78^{a} \pm 0.0$	0.8[a]± 9.6x10-3	0.74[a]± 1.89x10-2	Nil
Crude Protain	$7.88^{d} \pm 1.4x10^{-2}$	$11.36^{a} \pm 1.3x10^{-2}$	$8.08^{c} \pm 1.2x10-2$	$8.74^{b} \pm 2.0$	0.0179
Moisture content	$8.55^{a} \pm 1.6x10^{-2}$	$10.68^{a} \pm 8.1x10^{-2}$	$8.73^{a} \pm 1.2x10-2$	$8.60^{a} \pm 2.4x10-2$	Nil
Fibre	$0.46^{c} \pm 8.2x10^{-4}$	$0.48^{b} \pm 8.1x10^{-3}$	$0.20^{d} \pm 8.2x10^{-3}$	$0.99^{a} \pm 8.2x10^{-3}$	0.0319
Carbohydrate	$78.79^{b} \pm 4.2x10^{-2}$	$73.55^{d} \pm 3.7x10^{-2}$	$78.82^{a} \pm 0.1$	$78.5^{c} \pm 7.5x10^{-2}$	0.0949

.Mean + standard deviation of quadruplet determination on dry weight basis. Means with similar alphabets across the row are not significant different at P<0.05

Table 3. Particle Size Distribution of Cocoyam Corm Flours

Mesh Size	Cocoindia	ede ofe	ede uhie	ede ocha	LSD
90µm (%)	$96.29^{b} \pm 0.06$	$97.42^{a} \pm 0.25$	$95.57^{c} \pm 0.03$	$95.44^{c} \pm 0.09$	0.375
75µm (%)	$1.44^{b} \pm 0.01$	$0.50^{c} \pm 0.02$	$1.45^{b} \pm 0.03$	$2.30^{a} \pm 0.02$	0.034
50µm (%)	$2.27^{c} \pm 0.4$	$2.11^{d} \pm 0.09$	$4.08^{a} \pm 0.02$	$2.88^{b} \pm 0.03$	0.102

Mean quadruplet samples of Cocoyam corn flours. Means of samples with similar alphabets across the row are not significant at $P<0.05$

Table 4. Physical properties of cocoyam corm flours

Physical properties	Colocasia esculanta		Xanthosoma sagittifolium		LSD
	Cocoindia	Ede ofe	Ede uhie	Ede ocha	
pH	$4.20^{d} \pm 5x10^{-2}$	$4.48^{c} \pm 5x10\text{-}2$	$5.03^{b} \pm 5x10^{-2}$	$5.78^{a} \pm 5x10^{-2}$	0.0019
Blue value index	$6.05^{a}x10^{-4}$	$7.8^{a}x10^{-4}$	$6.7^{a}x10^{-4}$	$7.5^{a}x10^{-4}$	Nil
Viscosity (cp)	$0.089^{d} \pm 2x10^{-3}$	$0.153^{c} \pm 1.0x10^{-3}$	$0.24^{a} \pm 2x10^{-3}$	$0.213^{b} \pm 6x10^{-3}$	0.01
Bulk density (g/cm3)	$0.734^{d} \pm 1.5x10^{-3}$	$0.714^{c} \pm 0,73$	$0.780^{a} \pm 9,6x10^{-4}$	$0.781^{a} \pm 5.8x10^{-4}$	0.00102
Porosity (g/cm3)	0.332^{a}	0.326^{a}	0.236^{b}	0.318^{a}	0.052
Solid density (kg/m3)	$0.327^{c} \pm 9.6 x10^{-4}$	$0.297^{d} \pm 9.5x10^{-4}$	$0.344^{a} \pm 9.6x10^{-4}$	$0.338^{b} \pm 9.6x1$	0.00114
Water absorption (g/g)	$2.195^{b} \pm 9.6x10^{-4}$	$2.410^{a} \pm 9.6x10^{-4}$	$2.178^{c} \pm 9.6x10^{-4}$	$2.082^{d} \pm 9.6x10^{-4}$	0.00143
Gelling temperature (^{o}C)	$63.75^{c} \pm 0.43$	$69.75^{b} \pm 0.50$	$65^{c} \pm 0.0$	$73.8^{b} \pm 1.3$	1.28

Mean quadruplet samples of Cocoyam corn flours. Means of samples with similar alphabets across the row are not significant at $P<0.05$

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