PROXIMATE AND FUNCTIONAL PROPERTIES OF OPEN AIR, SOLAR AND OVEN DRIED COCOYAM FLOUR.

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ABSTRACT

This study was carried out to determine the functional and proximate characteristics of cocoyam flour produced using different drying methods namely; sun (open air), solar and oven drying methods. Flours were obtained from two cultivars of cocoyam (*Colocasia* spp : coco India and *Xanthosoma* spp : red cocoyam) by peeling, slicing, washing, blanching, drying, milling and sieving. The flours obtained were evaluated for functional properties and proximate composition. The flour samples had proximate composition ranging from 6.55% to 13,2% moisture, 1.2% to 2.5% ash, 1.5% to 2.4% crude fiber, 1.7% to 2.6% fat, 7.4% to 8.9% protein and 72.1% to 79.3% carbohydrate. The flour samples have functional properties ranging from 1.50 ml/g to 3.70 ml/g water absorption capacity, 0.54 ml/g to 1.34 ml/g oil absorption capacity, 0.69 g/ml to 0.81 g/ml bulk density, 82°C to 90°C gelatinization point, 13 ml to 22 ml swelling index, 7secs to 16secs wettability and 21 cp to 34 cp viscosity measurement. The result of this study showed that the drying methods have effect both on the proximate and functional properties of flour from the two cocoyam varieties.

Keywords: proximate, functional, drying method, cocoyam, flour

INTRODUCTION

The cocoyams-*Colocasia*(taro) and *Xanthosoma*(tannia) are the two most important genera of the family *Aracea* (Ihekoronye and Ngoddy, 1985) and constitute one of the six most important root and tuber crops worldwide (Ekanem and Osuji, 2006). Although, they are less important than other tropical root crops such as yam, cassava and sweet potato, they are still a major staple in some parts of the tropics and sub-tropics (Opara, 2002). Cocoyam is an under-exploited tuber crop although the literature is replete with its potential nutritional applications. Annual production of cocoyam in Nigeria is estimated at 26.587 million tonnes (FAO, 2006). Nigeria is the world's largest producer of cocoyam, accounting for about 37% of total world output (FAO, 2006). In the Eastern part of Nigeria, it serves as staple food and is used as a thickener in food preparations especially the varieties *Colocasia esculenta* and *Xanthosoma cultivar*. This is because the starch grain of cocoyam is small and has improved digestibility as this is an important factor when selecting a starchy food that will not be cumbersome on the digestive system (Ihekoronye and Ngoddy, 1985). Cocoyam is rich in digestive starch, good quality protein, vitamin C, thiamine, riboflavin, niacin and high scores of protein and essential amino acids (Onayemi and Nwigwe, 1987; Lewu *et al.,* 2009). Cocoyam like other root crops deteriorate few weeks after harvest due to inadequate post harvest technologies and this makes the crop scarce and expensive outside the harvesting period. Processing of cocoyam into flour will automatically extend the shelf life of the commodity thereby making it available for use all year round. Processing of food commodities into flour involves drying of the food commodity in order to reduce the moisture content to a minimal level where the food material will be shelf stable

Drying is the oldest method of preserving food. Maxwell and Zantoph (2002) define drying as a mass transfer process consisting of the removal of moisture from a solid, semi-solid or a liquid. It is also a method of food preservation that works by removing water from the food, which inhibits deterioration (Zantoph and Schuster, 2004). Food can be dried in several ways for example by the sun if the air is hot and dry enough, in an oven if the climate is humid and in solar system if the climate is hot to about 30-40°C (Zantoph and Schuster,2004). Sun (open air) drying uses heat from the sun and natural movement of the air and expose the food material to environmental factors such as dust, bacterial growth and excessive respiration. Oven drying involves use of equipment (dryer) and can be used only on a small scale. Solar drying involves the use of the sun's energy for drying but excludes an open air ''sun drying''. Research on the use of these drying methods for cocoyam flour production has been minimal. There is therefore the need to investigate the effect of these drying methods on the characteristic properties of cocoyam flour. The specific objectives of this research are to investigate the effect of sun drying, solar drying and oven drying on the proximate and functional properties of flour from two main cultivars of cocoyam (*Xanthosoma* and *Colocasia* spp).

MATERIALS AND METHOD

Material collection

Two cultivars of cocoyam used in this research were purchased from Owerri main market and were identified as follows: *Colocasia* species (cultivar 1 being 'coco-India') and *Xanthosoma* species (cultivar 2 being red cocoyam or 'ede uhie'). The chemicals and reagents used for this research were sourced from the Food Science and Technology Laboratory of the Federal University of Technology, Owerri and were of analytical grade.

Production of cocoyam flour sample

The cocoyam corms were withdrawn from the stock in storage and sorted to remove unwholesome ones. The corms were then peeled, washed and sliced into chips of 1.5 mm thickness. The yam slices were blanched in boiling water (100 °C) for two minutes. The blanched slices from each cultivar were divided into three portions. Each of the portion was subjected to different drying method i.e oven drying (85 °C), sun drying and solar drying (65 °C) until they were dry enough to break sharply between hands. The moisture content of the samples ranged between 6.5 to 13.2%. Each of the dried samples was milled separately using an attrition mill and sieved using a 500-micrometer sieve to obtain the flour. The flour obtained was stored in air-tight container for further analysis. At the end of the drying process, there were a total of six (6) samples.

CHEMICAL ANALYSIS

The chemical composition was determined using the method of AOAC (1990)

Protein content was determined on 0.5g sample by the Kjeldahl method. The percentage nitrogen obtained was used to calculate the crude protein by multiplying with a conversion factor of 6.25. Moisture was determined on 5g sample using the gravimetric method of AOAC (1990) at 105°C for 3hours. Ash content of the samples was determined on 5g sample by incinerating in a muffle furnace at 550 °C for 4 hours. The ash was cooled in a desiccator and weighed. This was determined on 5g sample by dilute acid and alkali hydrolysis. Fat content was determined on 5g sample using the soxhlet solvent extraction method. The carbohydrate content was calculated by difference.

Determination of functional properties

The method of Onwuka (2005) was used for the determination of functional properties. The functional properties determined include water and oil absorption capacities (1g sample); bulk density (5g sample); swelling index (3g sample) and wettability capacity(1g sample). Gelatinization temperature was determined using the method described by Onwuka (2005).

Water / Oil absorption capacity

One gram of sample was weighed into a clean conical graduated centrifuge tube and was mixed thoroughly with 10 ml distilled water/oil using 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 free water (supernatant) 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 express in grams of oil/water absorbed per gram of flour sample.

Absorbed water = total water - free water.

Bulk density

The gravimetric method was used. A weighed sample (10 g) was put in a calibrated 10 ml measuring cylinder. Then the bottom of the cylinder was tapped repeatedly onto a firm pad on a laboratory bench until a constant volume was observed. The packed volume was recorded. The bulk density is calculated as the ratio of the sample weight to the volume occupied by the sample after tapping.

Bulk density (g/ml) = weight of sample (g) / volume of sample (ml)

Gelatinization point

10 g of flour sample 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 corresponding temperature was recorded 30 secs after gelatinization was visually noticed.

Swelling index

This was determined as the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. The method of Abbey and Ibeh (1988) was used. One gram of the sample was weighed into a clean dry measuring cylinder. The volume occupied by the sample was recorded before 5ml of distilled water was added to the sample. This was left to stand undisturbed for an hour, after which the volume was observed and recorded again. The index of swelling ability of the sample was given by the formula below:

$$\text{Swelling index} = \frac{\text{volume occupied by sample after swelling}}{\text{volume occupied by sample before swelling}}$$

Wettability

The method described by Onwuka (2005) was used. A graduated cylinder (25 ml) was washed and dried in the oven and one gram of sample was weighed out and filled into the cylinder. A 600 ml beaker was filled with distilled water up to the 500 ml mark. A finger was placed over the open end of the 25 ml cylinder containing the sample. The cylinder was inverted and clamped at a height of 10cm from the surface of a 600 ml beaker containing distilled water. The finger was then removed to allow the test flour sample to be dumped into distilled water. The wettability was recorded as the time required for the sample to be completely wet.

Viscosity measurement

The rotating spindle method described in the Encyclopaedia of Industrial Chemical Analysis (E.I.C.A.,1979) was employed in the viscosity determination. The viscosities of each of the sample were determined with a Brookfield dial viscometer. A 5-gram portion of cocoyam flour sample was dissolved in 100 mls of water in a disposable plastic cup. The cup with its content was placed in a water bath and heated up to boiling. Each sample was in a separate cup. The cups were then removed and cooled to room temperature of about 25 °C. Each sample in the disposable cup was placed under the equipment. Using spindle number 2 and speed of 30 rpm, dial readings were taken and recorded. The actual viscosity reading in centipoises (cp) were calculated with the formula

Actual viscosity reading (AVR) = M multiply by 10

Where M= Dial reading

Statistical analysis

All analysis was carried out in triplicates. The experiment was laid out in a completely randomized design comprising of two factors. Factor A is cocoyam variety while factor B is drying method. The values obtained were analyzed statistically using analysis of variance (ANOVA) at 5% level of significance while Fisher's Least Significant Difference (LSD) was used to separate the factor means.

RESULTS AND DISCUSSION

Proximate composition of flour samples

Table 1 shows the result of the proximate composition of the cocoyam flour samples.

The result of proximate composition showed that there were significant differences in all the parameters evaluated at $P \leq 0.05$. The moisture content of the flour samples ranged from $6.5 \pm 0.082\%$ to $13.2 \pm 0.490\%$ with oven dried red cocoyam having the least (6.5%) and solar dried coco India having the highest (13.2%). Comparing the cocoyam cultivars, the coco-India (taro) had slightly higher moisture content than the red cocoyam (tannia). On the other hand, oven dried samples had the lowest moisture content. This may be as a result of the high temperature used for the drying. The ash content of the flour samples ranged from $1.2 \pm 0.374\%$ to $2.5 \pm 0.356\%$ with oven dried coco-India having the highest (2.5%) and solar dried red cocoyam having the lowest (1.2%). Coco-India has higher ash content that red cocoyam. The ash content of 1.56 to 2.98% reported by Sefa-Dede and Agyr-Sackey (2004) for cocoyam is similar to that reported in this present research. Oven dried samples had the highest ash content. This may be attributed to the temperature used for the drying. The higher the drying temperature, the lower the moisture content and this has a direct effect on the concentration of the food components.

The fiber content of oven dried red cocoyam (2.4%) was significantly higher at $P<0.05$ than all the other flour samples. Oven dried red cocoyam had the highest (2.4%) while solar dried coco-India has the lowest (1.5%). The result of this research indicate that red cocoyam have higher fiber content than coco-India.

The fat content of the cocoyam flour samples ranged from $1.7 \pm 0.163\%$ to $2.6 \pm 0.374\%$ with solar dried red cocoyam having the highest and oven dried coco-India having the lowest. Red cocoyam has higher fat content than coco-India while solar dried samples had the highest fat content for each of the cultivars used for the research. The crude protein content of the flour samples ranged from $7.4 \pm 0.4083\%$ to $8.9 \pm 0.374\%$ with solar dried red cocoyam flour having the lowest (7.4%) and oven dried coco-India flour having the highest (8.9%) the oven dried samples have the highest protein content. The protein content of 7.4 to 8.9% for cocoyam flour reported in this present research is slightly higher than 4.93 to 5.17% reported by Ogunlakin *et al*. (2012). The observed variations in the result could be attributed to the differences of the species, cultural, climatic and other environmental factors under which the cocoyams were grown. Asaoka *et al*. (1991) reported that age, variety, growth season and cultivar's type of tubers affect their physio-chemical properties. Maturity at harvest and the length of storage time and elapsed time between harvesting and processing period may also contribute to these variations (Ihekoronye and Ngoddy, 1985).

The carbohydrate content of the flour samples ranged from 72.9± 0.829% to 79 ± 0.086% with solar dried coco-India flour having the lowest and oven dried red cocoyam flour having the highest. The result of this research showed that red cocoyam contains more carbohydrate than coco- India. Oven dried flour samples also contains more carbohydrate than flour samples produced using the other drying methods. Enwere (1998) reported that in all the solid nutrients in roots and tubers, carbohydrates predominate. The high carbohydrate content indicates that cocoyam is an excellent source of energy.

Table 1: Mean Values of the proximate Composition of Cocoyam flour subjected under different drying methods.

SAMPLE	COMPOSITION (%)					
	MOISTURE	ASH	FIBER	FAT	PROTEIN	CARBOHYDRATE
SNDRC	11±0.817^{b}	1.7±0.163^{b}	2.1±0.163^{ab}	2.4±0.245^{ab}	7.7±0.163^{b}	75.1±0.735^{c}
SLDRC	11±0.082^{ab}	1.2±0.374^{c}	1.9±0.245^{ab}	2.6±0.374^{a}	7.4±0.4083^{b}	75.1±0.616^{c}
ODRC	6.5±0.082^{c}	1.9±0.245^{b}	2.4±0.245^{a}	2.3±0.327^{ab}	7.9±0.327^{b}	79±0.0860^{a}
SNDCI	12.4±0.163^{ab}	2.1±0.125^{ab}	1.6±0.327^{b}	1.8±1.143^{b}	8.8±0.327^{b}	73.3±0.408^{d}
SNDCI	13.2±0.490^{a}	1.7±0.245^{b}	1.5±0.490^{b}	2.0±0.327^{ab}	8.7±0.374^{a}	72.9±0.829^{d}
ODCI	7.7±0.653^{c}	2.5±0.356^{a}	2.0±0.330^{ab}	1.7±0.163^{b}	8.9±0.374^{a}	77.2±0.898^{b}
LSD	1.8876	0.4791	0.6891	0.7212	0.7372	1.6209

Values are means of triplicate determination. Means with different superscripts in the same column are significantly different from each other at (P<0.5)

RC = Red cocoyam, CI = cocoa India, SND = sun drying,
SLD = Solar drying, OD = Over drying

FUNCTIONAL PROPERTIES

Water absorption capacity

The water absorption capacity of the flour samples ranged between 1.5±0.033 ml/g and 3.7±0.022 ml/g (Table 2) with oven dried red cocoyam flour having the highest and solar dried coco-India flour having the lowest. There was a significant difference in the water absorption capacity of flour samples at P<0.05. Oven dried samples showed higher absorption capacity than all the other flour samples.

The high value of the oven dried flour samples could be as a result of the higher temperature used for the drying which might have led to low moisture content thereby causing the flour samples to absorb more water. Drying increases the absorption capacity of flour (Hayata, *et al*., 2006). According to Circle and Smith (1972), water absorption capacity is a useful indication of whether flours can be incorporated into aqueous food formulations especially those involving dough handling. Niba *et* ***al.,*** (2001) also stated that water absorption capacity is important in bulking and consistency of products as well as baking applications.

Oil absorption capacity

Oven dried coco-India flour sample had significantly (P<0.05) higher oil absorption capacity (1.34 ml/g) than all the other samples (Table 2). Coco-India flour sample have higher oil absorption capacity than red cocoyam.

For red cocoyam, solar dried flour sample had the lowest (0.54 ml/g) while oven dried flour sample had the highest (0.89 ml/g). For coco-India, solar dried flour sample have the least (0.89ml/g) while oven dried flour sample have the highest (1.34ml/g). The high value of the oven dried samples could be attributed to the drying temperature used which could have led to low moisture content observed in oven dried samples. Oil gives soft texture and good flavour to food. Therefore, the absorption of oil by food products improves mouth feel and flavour retention.

A high oil absorption capacity is valuable in ground meat formulations, meat replacers and extenders, doughnuts, pancakes and soups (Onimawo and Egbekun, 1998).

Bulk density

The bulk density of the flour samples varied from 0.69± 0.022 g/ml to 0.81± 0.025 g/ml with solar dried red cocoyam flour having the highest and oven dried coco-India having the lowest. There was a significant difference in the bulk density of the flour samples at P>0.05.

Among the red cocoyam flour samples, oven dried flour sample had the lowest bulk density (0.75g/ml) while solar dried flour sample have the highest (0.81 g/ml).

For the coco-India flour samples, the oven dried flour sample had the lowest (0.69 g/ml) while solar dried flour sample have the highest (0.74 g/ml).

Table.2: Mean values of the functional properties of Cocoyam flour Subjected under different Drying Methods.

SAMPLE	PARAMETER						
	WAC(ml/g)	**OAC(ml/g)**	**BD(g/ml)**	**GP(°C)**	**SI(ml/ml)**	**WC(secs)**	**VM(cp)**
SNDRC	2.7 ± 0.054^{b}	0.79 ± 0.029^{d}	0.76 ± 0.025^{a}	83 ± 2.450^{b}	15 ± 2.450^{c}	15 ± 0.817^{a}	30 ± 2.450^{ab}
SLDRC	2.5 ± 0.041^{c}	0.54 ± 0.037^{e}	0.81 ± 0.025^{a}	82 ± 1.700^{b}	13 ± 0.817^{b}	16 ± 1.247^{a}	28 ± 2.450^{b}
ODRC	3.7 ± 0.022^{a}	0.89 ± 0.22^{c}	0.75 ± 0.037^{a}	84 ± 1.633^{b}	15 ± 1.633^{b}	15 ± 1.633^{c}	34 ± 0.817^{a}
SNDCI	1.6 ± 0.054^{d}	1.07 ± 0.016^{b}	0.72 ± 0.025^{b}	90 ± 0.817a	16 ± 0.817^{b}	9 ± 0.817d^{e}	24 ± 2.160b^{c}
SLDCI	1.5 ± 0.033^{e}	0.89 ± 0.033^{c}	074 ± 0.029^{a}	88 ± 1.633a	16 ± 1.414^{b}	10 ± 1.414c^{d}	21 ± 2.450^{c}
ODCI	2.5 ± 0.025^{c}	1.34 ± 0.037^{a}	0.69 ± 0.022^{b}	90 ± 2.160a	22 ± 1.633^{a}	7 ± 0.817^{e}	26 ± 1.414^{b}
LSD 0.05	0.0945	0.0659	0.0823	3.9338	3.4083	2.5512	4.4762

Values are means of triplicate determination
Means with different superscript in the same column are significantly different from each other at (P>0.05)

WAC	=	**Water Absorption Capacity (g/ml)**	**RC**	=	**Red Cocoyam**
OAC	=	**Oil Absorption Capacity (g/ml)**	**CI**	=	**Coco-India**
BD	=	**Bulk Density**	**SND**	=	**Sun Drying**
GP	=	**Gelatinization Point**	**SLD**	=	**Solar Drying**
SI	=	**Swelling Index**	**OD**	=	**Over Drying**
WC	=	**Wettability Capacity**			
VM	=	**Viscosity Measurement**			

The low bulk density exhibited by the oven dried flour samples could be as a result of the low moisture they contain. According to Hayata *et al.,* (2006), drying decreases the bulk density of flour. Bulk density gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness (Padmashree *et al.*, 1987, Udensi and Eke, 2000). Low bulk density of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Agunbiade and Sanni, 2003).

Low bulk density is advantageous for the infants as both calorie and nutrient density is enhanced per feed of the child (Onimawo and Egbekun, 1998). High bulk density is a good physical attribute when determining mixing quality of particulate matter (Lewis, 1990).

Gelatinization point

The gelatinization point of flour samples varied from 82$\pm$ 1.7°C to 90$\pm$ 2.16°C with solar dried cocoyam flour having the lowest while sun dried and oven dried coco-India flour sample have the highest. There was a significant difference in the gelling point of the flour samples. For red cocoyam, solar dried sample have the least (82°C) while the oven dried flour sample have the highest (84°C). For coco-India, solar dried flour sample have the least (88°C) while sundried and oven dried have the highest (90°C). The low gelatinization point of red cocoyam flour sample might be attributed to the high starch content of red cocoyam compared to coco-India which has a higher gelatinization point and low starch content. High gelling point indicates low starch content.

Swelling index

The swelling index of the flour samples varied from 13$\pm$0.817 ml/ml to 22$\pm$1.633 ml/ml (Table 2) with solar dried red cocoyam flour sample having the lowest and oven dried coco-India flour having the highest. There was a significant difference among the flour samples at P>0.05. For red cocoyam, sun dried and oven dried flour samples had the highest value (15 ml/ml) while solar dried sample has the lowest (13 ml/ml). For coco-India, oven dried flour have the highest (22 ml/ml) while the other samples have the same value (16 ml/ml). The result showed that coco-India flour have higher swelling index than red cocoyam. This could be as a result of loose particles of coco-India and packed particles of red cocoyam. Generally cocoyam samples shows good swelling index when compared to other root crops like cassava (Ojinaka *et al*., 2009). This is because of the type of granules cocoyam starch has and its highly digestible nature. The starch grain of cocoyam is about one tenth of potato starch grain (Akomas *et al*., 1987).

Wettability capacity

The flour samples have wettability capacity of 7$\pm$0.817 secs to 16$\pm$1.247 secs with oven dried coco-India flour sample having the lowest while solar dried red cocoyam sample has the highest. There was a significant difference in the wettability capacity of the flour samples. The red cocoyam flour showed higher wettability than the coco-India flour.

Also, oven dried samples for each of the cultivars exhibited the lowest wetting capacity. This could be attributed to the high temperature treatment which made them to absorb moisture fast thereby making them to have a low wetting time.

Viscosity

The viscosity (34 cp) of the oven dried red cocoyam sample (ODRC) differed significantly from all the other samples. For the two cultivars of cocoyam, oven dried samples had the highest viscosity measurement (34 cp for red cocoyam and 26 cp for coco-India) while solar dried samples had the lowest (28 cp for red cocoyam and 21 cp for coco-India). The result of this research showed that red cocoyam flour is more viscous than coco-India flour. This result implies that in order to obtain a more viscous cocoyam flour, oven drying method should be adopted.

Conclusion

The results of this research showed that different drying methods have effect on the functional and proximate composition of cocoyam flour. Depending on the end use of the flour sample, different drying methods should be adopted. For easy transportation and storability, oven dried samples are recommended since they showed low bulk density. High absorption capacities exhibited by oven dried samples indicate that they can easily be incorporated into various food formulations such as in thickening of soups. In view of the result obtained, oven drying is recommended because it favoured most of the functional properties determined. Oven dried samples showed higher absorption capacity, low bulk density, high gelatinization point, high swelling index, low wettability and high viscosity.

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