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Evaluation of Drying Temperature on Proximate, Thermal and Physical Properties of Cocoyam Flour

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Abstract

Flours were produced from cocoyam Colocasia esculentum schott (taro) using tunnel dryer with different drying temperature of 50, 55, 60, 65, 70, 75, 80 and 85^{0}C. The proximate, thermal and physical composition of the samples was determined. It was observed that all parameters examined were affected by drying temperatures. The result of the experiment showed that increase in drying temperature resulted in decreasing the values of proximate except carbohydrate and fibre. Thermal properties decreased with increase in temperatures while physical properties increased with increase in drying temperature of the samples.

Keyword: drying, temperature, cocoyam and flour.

1. INTRODUCTION

Cocoyams are monocotyledonous herbs that belong to the family Araceae and are grown primarily for their roots which are edible (Onwueme, 1982). The name cocoyam is generally applied to a variety of useful and edible species belonging to different genera including Colocasia, Xanthosoma, Alocasia, Crytospema and Amorphophallus. They are the third most important root crop (after yam and cassava) cultivated in Nigeria (Shiyam *et al., 2007*; Onwueme, 1999). By far, more important and more extensive cultivation in Nigeria are *Colocasia* and *Xanthosoma* (Ekpo, 2001 and Nwauzor, 2001). Nigeria has the largest population of cocoyam consumers, followed by Ghana (Sagoe *et al.*, 2001). The bulk of the production of cocoyam is in Southern Nigeria (Enyinnia, 2001).

2. LITERATURE REVIEW

Various researches have been carried out on cocoyam, for instance, Shiyam *et al.* (2007) studied growth and corm yield response of upland cocoyam. Azeez and Madukwe, (2010) studied cocoyam production and economic status of farming households in Abia State. Oke, and Bolarinwa, (2012) studied the effect of fermentation on physicochemical properties and oxalate content of cocoyam. Ogunniyi, (2008) examined profit efficiency among cocoyam producers in Osun State, Nigeria. Agwunobi *et al.* (2002) studied on the use of Colocasia esculenta (taro cocoyam) in the diets of weaned pigs. However, studies on how drying at higher temperatures affect the nutritional composition of cocoyam has rarely been given attention as far as literature is concerned. Therefore, the objective of this study is to investigate effect of temperature on the physical and chemical properties of cocoyam flour

3. MATERIALS AND METHODS

A. Materials

Fresh corm of cocoyam (*Colocasia esculenta)* was purchased from a local market in Osun State. Other reagent and solvent that was used was of analytical grade.

B. Methods

The cocoyam corms were weighed washed, peeled with stainless steel knife. It was then sliced into 2mm thickness and the pieces were dried in the tunnel dryer at 50, 55, 60, 65, 70, 75, 80, and 85^{0}C. The dried samples were grinded into fine flour using a milling machine. The samples were sieved and packaged in properly labeled air–tight polythene sachets for further analysis.

(i) Determination of proximate composition of the flour

Moisture, ash, fiber, fat, protein and carbohydrate were carried out using (AOAC 2000) method

(ii) Determination of thermal properties of the flour

(a) Specific heat capacity

The specific heat of cocoyam flour was determined by the method of mixtures applied by Sopa *et al.,* (2008). The calorimeter employed was well insulated with fiber glass, the water was heated to a constant temperature and selected sample of known mass of the cocoyam flour was dropped and covered immediately, the mixture was stirred at intervals and temperature monitored every 10 minutes till the calorimeter temperature began to return slowly to room temperature. Specific heat capacity cocoyam was calculated using Equation 1

$$H_1 = H_2 + H_3 \qquad 1$$

Where H_1= heat given up by water (kJ), H_2= heat taken up by the cocoyam, H_3 = heat taken up by the calorimeter 1.

(b)Thermal conductivity

Thermal conductivity may be defined as the rate of heat flow through unit thickness of materials per unit area normal to the direction of heat flow and per unit time for unit temperature. The thermal conductivity could be expressed from the following equation 2:

$$Q = \frac{KA(\theta 2 - \theta 1)}{L} \qquad 2.$$

Where: A = Specific surface area (m^2), K = Thermal conductivity ($w/m^{2o}C$), $\theta 1$ = Initial temperature of the cold sample (^oC), $\theta 2$ = Final temperature of the hot sample (^oC), Q = is the heat energy (J), L = Length (m)

(c)Thermal diffusivity

The experiment was conducted using the equation reported by Sopa *et al.*, (2008) as shown in Equation 3. To determine the thermal diffusivity of cocoyam flour, a copper calorimeter was loaded with the sample of which a thermocouple was inserted in to the center of the material to monitor the temperature. The loaded calorimeter was placed in a water bath with heated water at a constant temperature; another thermocouple was inserted in the water- bath to monitor its temperature, the third thermocouple was placed at the exterior of the food material and the readings were recorded.

$$\alpha = \frac{K}{\rho C} \qquad 3$$

Where: α = thermal diffusivity (m^2/s), K = thermal conductivity ($W/m^{2o}C$), C = specific heat capacity (J/kg^oC) ρ = bulk density (g/cm^3)

(iii)Determination of physical and functional properties of the flour

Water absorption capacities, bulk density and swelling capacity was carried out using the AOAC (2000) method

4. RESULTS AND DISCUSSION

(a) Proximate Composition

The result of protein, lipids, ash, fibre, carbohydrate and moisture content of cocoyam flours that were produced at different temperatures in their percentage composition are as shown in Table 1. The protein content ranged between 4.340 and 6.960 % and sample A was found to have the highest value at 50^0C, while sample H was found to have lowest value at 85^0C. Sample B and C were not significantly different, Sample G was not significantly different from sample H, and sample D, E and F were not significantly different**.** The value of protein in this study is greater than those reported by Oladebeye *et al. (2008a)* with values of 1.41% and 1.63% for red cocoyam and sweet potato respectively. Generally wheat, cassava and cocoyam are poor sources of protein as reported by Oyenuga, (1992); Okaka and Isieh, (2002). The value obtained for cocoyam in this study is higher than that reported by Ajewole, (2004) for *Zanthosoma* variety. Hence, the variations in the results may be as a result of species. It was observed that as temperature increased the protein content decreased; this is due to denaturation of the protein as reported by Sefa – Dedeh and Kofi-Agyir, (2002), who work on some properties of cocoyam flour.

It has been observed that the lipid (fat) content ranged between 0.645 and 0.483% as shown in Table 1. Sample A has the highest value at 50^0C and sample H the lowest value at 85^0C. This means at lower temperature the lipid content was high, while at higher temperature the lipid content was low, this indicates that temperature affected the lipid content of cocoyam flour produced; this observation has been earlier reported by Enonfom and Umoh (2004) on cocoyam. From Table 1, Samples A and B were not significantly different, sample C and D also were not significantly different while samples D, E, F, G and H were not significantly different. The decrease in lipid (fat) content could be associated with the oxidation of fat during the period of drying (McGill *et al.,* 1974). The low content of fat would enhance the storage life of the flour due to the lowered chance of rancid flavor development. Hence samples dried at higher temperatures of 85^0C would tend to have longer shelf life than samples dried at 50^oC. Fat serves as energy store in the body. It can be broken down in the body to release glycerol and free fatty acids. The glycerol can be converted to glucose by the liver and used as a source of energy. It has been reported by [32] that flours of rice, millet and wheat have fat content 0.75%, 0.79% and 3.03% respectively. This indicates that fat content of the cocoyam flour in this work is lesser than rice millet and wheat flour. It has been reported that 1g of fat provides 37 kcal of energy Gaman, and Sherington (1990).

The ash content which is the total mineral content, present in the samples ranged between 2.467 and 2.967% with sample A having the lowest value and sample H having the highest value. The result indicates an indication of the presence of inorganic nutrients in the flour samples, therefore the samples could be a source of mineral elements having nutritional importance. However, the results indicate that temperature affects the ash content of the cocoyam flour produced in such a way that as the temperature increased, the ash content decreased; this was in accordance with the report of Blanco *et al.*(2004) which was on roots and tubers.

Crude fibre measures the cellulose, hemicelluloses and lignin content of food. The crude fiber composition ranged between 1.923 and 3.22% with sample H having the highest value and sample C with the lowest value. Statistical analysis shows that samples A, E and H were not significantly different; samples B and F were not also significantly different and sample C, D and G were not significantly different. The values of fibre content in this work was greater than those report by Oladebeye *et al.* (2008a) with value of 0.5%. Fibre has useful role in providing roughage that aids digestion (Marer and Martin 2003). Dietary fibre reduces the risk of cardiovascular diseases. Report have shown that increase in fibre consumption might have contributed to the reduction in the incidence of certain diseases such as diabetes, coronary heart disease, colon cancer and various digestive disorder. Fibre consumption also soften stools and lowers plasma cholesterol level in the body (Norman and Joseph, 1995).

The moisture content ranged between 9.383 and 10.570% with sample A having the highest value at 50^{0}C while sample H had the lowest value at 85^{0}C. Sample A, B and C was not significantly different from each other. Samples D and E were not significantly different while samples G and H were not significantly different. The values obtained for moisture content of cocoyam in this study were comparable with the value (12.94%) as reported by (Gbadamosi and Oladeji, 2013) for cassava but were higher than the value (3.07%) obtained for Phaseolus vulgaris starch by Sathe and Saluunkhe, (1981) but agree with the 11.08% reported for taro by Amandikwa, (2012). The result showed that at lower temperature the moisture content was high, at higher temperature the moisture content was low; this indicates that temperature has an effect on the moisture content of cocoyam flour produced.

The carbohydrate content ranged between 76.29 and 80.533% with sample H having the highest value at 85^{0}C while sample A had the lowest value at 50^{0}C. Drying temperatures affected the percentage composition of the samples in such a way that as drying temperature increased from 50 to 85^{o}C, the values of carbohydrate increased from 76.293 to 80.293%. This same temperature effect on carbohydrate was earlier reported by Amandikwa, (2012) on comparison of carbohydrate content of cocoyam dried in both oven at 85^{o}C and solar dryer at 65^{o}C**.** This observation of high carbohydrate content values is in line with the report of Amandikwa, (2012), which may be attributed to the high content of carbohydrate in cocoyam. According to Enwere, (1998) , of all the solid nutrients in roots and tubers, carbohydrate predominates. Carbohydrate supplies quick source of metabolizable energy and assist in fat metabolism.

Table 1 Proximate Composition of Cocoyam Flour (%)

Sample	Protein%	Lipid%	Ash%	Fibre%	Carbohydrate%	Moisture
A	6.960±0.160^e	0.650±0.30^d	2.967±0.057^c	2.51±0.121^c	76.293±0.078^a	10.620±0.173^d
B	5.413±0.163^d	0.643±0.035^d	2.867±0.025^c	2.360±0.080^a	78.143±0.231^b	10.570±0.101^d
C	5.267±0.106^d	0.590±0.020^c	2.850±0.040^c	1.920±0.066^b	78.810±0.066^c	10.560±0.101^d
D	4.943±0.136^c	0.570±0.046^{bc}	2.610±0.070^b	1.931±0.055^b	79.713±0.311^d	10.230±0.101^c
E	4.867±0.074^{bc}	0.540±0.030^{abc}	2.593±0.106^b	2.673±0.050^c	79.713±0.311^d	10.020±0.140^c
F	4.673±0.148^b	0.520±0.020^{ab}	2.553±0.081^{ab}	2.770±0.020^a	79.713±0.311^d	9.770±0.108^b
G	4.397±0.095^a	0.510±0.30^a	2.470±0.040^a	2.89±0.061^b	80.290±0.166^e	9.443±0.111^a
H	4.340±0.120^a	0.483±0.025^a	2.467±0.055^b	3.22±0.065^c	80.713±0.211^e	9.383±0.045^a

Means in the same column followed by the same alphabet are not significantly different from each other ($p\leq 0.05$)
Sample code: A- 50^{0}C B- 55^{0}C C- 60^{0}C D- 65^{0}C E- 70^0 C F- 75^{0}C G- 80^{0}C H- 85^{0}C

(b) Thermal Properties of Cocoyam Flour

The result of thermal conductivity, specific heat capacity and thermal diffusivity of cocoyam flour samples produced at various drying temperatures are as shown in Table 2. The thermal conductivity ranged between 0.271 and 0.266 W/m^{2o}C with sample A having the highest value at 50^{0}C and sample H had the lowest value at 85^{0}C. Samples C, D, E and F were not significantly different; also samples G and H were not significantly different from each other but samples A and B were significantly different from each other. Thermal conductivity (k) has an inverse relationship with temperature as demonstrated in Equation 2, therefore as temperature increased, thermal conductivity of cocoyam decreased during drying. The same observation was reported by Tansakul and Chaisawang, (2006) on the study of the effect of temperature on thermal conductivity of coconut milk; similar observation was reported by Zainal iet al. (2001) on a study of temperature effect on guava juice. Therefore, an increase in temperature might have also influenced the results of thermal conductivity as shown; more so, thermo – physical properties are significantly dependent on changes in moisture and temperature as reported by Barbosa-Cánovas *et al.* (2005b). Thermal conductivity is important to predict or control heat flux and processing time. This ensures the efficiency of equipment which in turn improves economy of the process and enhances quality product.

The specific heat capacity ranged between 1.744 and 1.785 kJ/kg^{o}C with sample A having the highest value at 50^{0}C and sample H had the lowest value at 85^{0}C. Samples C, D, E, and F were not significantly different from one another; samples G and H were not significantly different from each other also. However, samples A and B were significantly different. The value of the specific heat capacity of cocoyam in this study is less than the value of cassava starch solution reported by Sopa *et al.* (2008)**.** The values of the specific heat capacity decreased with increase in temperature of drying. The same observation was reported by Sopa *et al.* (2008). Siebel, (1892) also proposed direct relationship between moisture content and specific heat capacity, however, since the earlier report of Ajala *et al.* (2012) showed that temperature of drying has inverse relationship with moisture content of the samples, hence it could be deduced that as the temperature of drying increased, the value of specific heat capacity decreased because moisture content decreased. Therefore, Sopa *et al.* (2008) suggested that decrease in specific heat capacity affected by higher temperature might possibly be due to the increase in volume occupied by cassava starch granules, thereby reducing free moisture transfer within the starch granules**.** Specific heat is an essential parameter in design of heat exchanger. The information is useful in choice of heat transfer medium and processing conditions.

Thermal diffusivity ranged between 2.84 E-04 and 4.22 E-04 m^2/s with sample H having the highest value at 85^{0}C and sample E had the lowest value at 50^{0}C. The value of thermal diffusivity in this work is comparable with thermal diffusivity of cassava chips reported by Nwabanne, (2009). The results of thermal diffusivity shows that as temperature increased, thermal diffusivity increased; this was a similar observation reported by Oluwo et al. (2014). Moreso, Nwabanne, (2009) submitted that thermal diffusivity of food materials is related to moisture content in such a way that thermal diffusivity decreased as moisture content increased. Thermal diffusivity relates to the ability to store heat. Therefore speed of heat diffusion through a material is also relevant information in processing time prediction models. An increase in specific heat and thermal conductivity leads to increase in thermal diffusivity of cocoyam flour; so also it is for the thermal properties of rough rice as submitted by Bamgboye and Adejumo, (2010).

Table 2 Thermal properties of cocoyam flour

Sample	Thermal Conductivity ($W/m^{2o}C$)	Specific Heat Capacity (kJ/kg^oC)	Thermal diffusivity (m^2/s)
A	0.271 ± 0.001^d	1.785 ± 0.005^e	$2.84E\text{-}04\pm0.00^b$
B	0.269 ± 0.000^c	1.778 ± 0.004^d	$2.88\ E\text{-}04\pm0.00^e$
C	0.268 ± 0.000^b	1.772 ± 0.001^c	$2.94\ E\text{-}04\pm0.00^c$
D	0.268 ± 0.000^b	1.765 ± 0.003^b	$3.07\ E\text{-}04\pm0.00^g$
E	0.268 ± 0.001^b	1.762 ± 0.004^b	$3.11\ E\text{-}04\pm0.00^a$
F	0.268 ± 0.000^b	1.759 ± 0.003^b	$3.14\ E\text{-}04\pm0.00^d$
G	0.267 ± 0.000^a	1.745 ± 0.000^a	$3.29\ E\text{-}04\pm0.00^f$
H	0.266 ± 0.001^a	1.744 ± 0.003^a	$4.22\ E\text{-}04\pm0.00^h$

Means in the same column followed by the same alphabet are not significantly different from each other ($p\leq0.05$)
Sample code: A- 50^0C B- 55^0C C- 60^0C D- 65^0C E- 70^0 C F- 75^0C G- 80^0C H- 85^0C

(c) Functional properties of cocoyam flour

The result of swelling capacity, water absorption and bulk density of cocoyam flour samples produced using different drying temperatures are as shown in Table 3. The swelling capacity ranged between 4.745 and 10.00% with sample A having the lowest value and sample H had the highest value. The values of swelling capacity of the sample were less than value of cocoyam reported by Oke and Bolarinwa, (2012), but were in the range of value of cocoyam reported by Amandikwa, (2012) as well as value of sorghum starch reported by Aviara *et al.* (2010). These values of the swelling capacity indicate strength and character of the starch granules. 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 cocoyam starch granules and it is highly digestible nature. The starch grain of cocoyam is about one tenth of potato starch grain (Akomas *et al.*, 1987).

The water absorption capacity (WAC), ranged between 89.140 and 86.145% with sample A having the lowest value at 50^0C while sample H has the highest value at 85^0C. There was no significant difference among the samples. The values of WAC in this work is in close range with the value of sorghum starch reported by Amandikwa, (2012) but less than the value of cocoyam reported by [30], the value also agrees with the value of cocoyam reported by Famurewa *et al.* (2014). From Table 3, it is observed that at lower temperature, WAC was low while at higher temperature, WAC was high. This same observation has been reported by Aviara *et al.* (2010) and the reason for this according to the work was that the hydrophilic tendency of the starch increased with increase in its drying temperature. Adebowale *et al.* (2005) gave further reason that at higher temperature, starch expands rapidly especially in the amorphous region. The WAC is important in the development of ready to eat foods and a high absorption capacity may assure product cohesiveness as reported by Houson and Ayenor, (2002) and the difference in WAC of a flour depends on the amount and nature of hydrophilic constituents (Ayele and Nip, 1994).

The bulk density ranged between 0.363 and 0.532 g/cm^3 with sample A having the highest value while sample H had the lowest value. Sample H was significantly different from sample A, B, C, D, E, F and G. The effect of drying temperatures on the samples show that bulk density decreased with increase in temperature, this observation has been earlier reported by Amandikwa, (2012) on the study of cocoyam dried at 65^oC and 85^oC**.** Also, Ajala *et al.* (2012) noted that bulk density of a food sample is related with its moisture content**.**

Table 3: Physical Properties of Cocoyam Flour

Sample	Swelling Capacity (g/g)	Water Absorption (%)	Bulk Density (g/cm^3)
A	4.745 ± 6.965^a	86.145 ± 0.813^a	0.532 ± 0.030^b
B	5.794 ± 0.078^b	86.580 ± 0.693^a	0.525 ± 0.018^b
C	7.319 ± 0.028^c	86.985 ± 0.318^a	0.513 ± 0.002^b
D	8.100 ± 1.414^d	87.605 ± 2.765^a	0.494 ± 0.002^b
E	8.782 ± 0.078^c	88.000 ± 0.141^a	0.488 ± 0.032^b
F	9.067 ± 0.64^e	88.270 ± 0.580^a	0.485 ± 0.071^b
G	9.088 ± 0.042^e	88.605 ± 0.318^a	0.460 ± 0.000^b
H	89.140 ± 0.000^a	0.363 ± 0.001^a	0.363 ± 0.001^a

Means in the same column followed by the same alphabet are not significantly different from each other ($p\leq0.05$)
Sample code: A- 50^0C B- 55^0C C- 60^0C D- 65^0C E- 70^0 C F- 75^0C G- 80^0C H- 85^0C

5. CONCLUSION

In conclusion, acceptable cocoyam flour can be produced through different drying temperature depending on the intended utilization. The result of the experiment carried out on the cocoyam flour indicates that drying temperature tends to affect proximate composition, thermal properties and physical properties of flour.

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