# Physicochemical, Functional Properties and Drying Characteristics of Three Varieties of Cocoyam Flour

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***Abstract- Physicochemical, functional properties and drying characteristics of three varieties of cocoyam (Ede Ugwuta, Ede Alo and Ede Ofe) were studied. The samples were washed, one part peeled and the other unpeeled. Both parts were sliced, dried at 70°C oven temperature, milled and sieved into flour using 45µm sieve mesh and packaged in polythene bags into six (6) samples for analysis. Result shows that; peeled cocoyam has moisture content range of 7.954-8.605% higher than that of unpeeled cocoyam with moisture content range of 7.756-8.069%. Ash content of the samples ranged from 3.235% – 6.073% with unpeeled Ede Ugwuta having the highest value of 6.073%. Unpeeled Ede Alo with 6.106% crude fibre has the highest value while Unpeeled Ede Ofe with 6.913% protein has the highest value. For proximate properties, unpeeled cocoyam has higher values than the peeled cocoyam samples though there was no significant difference p > 0.05 in the sample values. The bulk density of the samples ranges from 0.363– 0.452g/cm$^3$ with peeled Ede Ugwuta having the highest value of 0.452g/cm$^3$. Water absorption capacity of the samples ranged from 2.457–3.934g/g while oil absorption capacity value ranged from 2.336- 2.513g/g with peeled Ede Ugwuta having the highest value of 2.513g/g. The drying of cocoyam could be considered to be solely in the falling rate order, since the moisture content and drying rate steadily decreased with increase in drying time. Peeled Ede Ofe had the highest drying rate of 0.53%/min, while unpeeld Ede Ugwuta had the least drying rate of 0.28%/min.***

***Index Terms- Cocoyam flour; physicochemical; functional properties; drying characteristics; industrial application***

## I. INTRODUCTION

The increasing world population and the need for food have left the world with a quest to develop new food source from any existing food crop. Accordingly, the pursuit to widen the scope of information on food processing and preservation has been established by (FAO, 2006). Cocoyam is not left out, being a root crop with great nutritional potentials, yet its utilization/ consumption is not economically feasible without first processing it. Cocoyam, a tuber crop known as “ede” in the Eastern part of Nigeria is grown widely in Nigeria for its nutritive, medicinal and economic values. Cocoyam is a root and tuber crop belonging to Araceae family and also an herbaceous perennial, monocotyledonous plant mainly grown for its edible corms and cormels. Cocoyam has two main species *Colocaisa Exculanta* (taro) and *Xanthosoma Sagittiffolum* (tannia) with several varieties of each. Colocaisa exculanta could be traced to have originated from Asia while Xanthosoma sagittiffolum traced to have originated from America (Oke and Bolarinwa, 2012). Cocoyam is widely cultivated in tropical and subtropical region of the world (FAO, 2003). However, the cultivation of cocoyam is mainly by rural dwellers; mostly by poor women farmers in small scale. This makes use of large expanse of land to increase yield which is contrary to the projections of FAO that the 70% growth in global agricultural production needed to feed an additional 2.3 billion people by 2050 must be achieved by increasing yields and cropping intensity on existing farmlands, rather than by increasing the amount of land brought under agricultural production (FAO, 2009). (Ekanem and Osuji, 2006) said that cocoyam was the sixth most important root and tuber crop in the world and the third most important root crop (after yam and cassava) cultivated in West Africa. Africa produces more than three quarter of World cocoyam production with Ghana and Nigeria being the world's leading producers (Oke and Bolarinwa, 2012; Okafor et al, 2022). According to FAOSTAT 2012, Nigeria was the largest producer of cocoyam in the world with an annual production of 3.450 million metric tonnes in 2012. This represents 45.9% of total production in the world, 57.7% in Africa, and 72.2% in West Africa. In Nigeria, Ebonyi State (producing approximately 12%) was the highest producer of cocoyam followed by Ondo State while Cross River State ranked third (Ikegwu et al., 2022). Nonetheless, cocoyam cultivation in Nigeria is receding due to the notion that the root crop is meant for the poor, therefore there is urgent need to step up research in cocoyam production and utilization.

Nutritionally, cocoyam is rich in carbohydrates, protein, essential minerals and vitamins and can compete favourably with other root & tuber crops such as cassava, yam, potato, etc. However, the consumption / utilization of cocoyam is greatly affected by the presence of oxalates in cocoyam which imparts acrid taste, cause sharp irritation, and burning sensation in the throat and mouth when foods prepared from it are eaten (Akpan and Umoh, 2004; Sefa-Dedeh and Agyir-Sackey, 2004). Despite the great nutritional potential of cocoyam, its utilization is not economically feasible unless it is first processed to possibly remove or reduces its high calcium oxalate levels. This compound adversely affects the corm palatability, conferring acridity and a bitter-astringent taste (Owusu-Darko et al., 2014; Sefa-Dedeh & Agyir-Sackey, 2004).

The role of cocoyam in the economies of nation and its importance to the livelihoods of millions of people has been under-estimated, under-reported, and therefore poorly appreciated. In an International Workshop on Cocoyam organised at Cameroon, the International Institute of Tropical Agriculture (IITA) noted that marginalized or under-researched crops such as cocoyam, will continue to worsen due to neglect and limited competitiveness unless necessary actions are taken to raise their profile (IITA, 2008). The flowers and stems of 2 cocoyam varieties Xanthosoma sagittifolium and Colocasia esculenta were revealed to be unsuitable to be marketed as a standard spice (Ogukwe et al, 2017). Heat treatment was shown to affect pasting characteristics of the resultant cocoyam flour (Mbanali et al, 2019). At harvest, cocoyam has high moisture content which makes it difficult for long term storage due to its high rate of deterioration upon microbial attack. This however, brings about immediate processing into flour for easy packaging, transportation, storability and industrial use. Application of flours in the food industry is primarily governed by their functional and physicochemical properties. Investigation of these properties is necessary to know the requisite characteristics of cocoyam if its utilisation would be enhanced and widened. Drying is one of the Unit Operations in processing of agro produce. It is a critical operation since it can destroy or improve the produce, depending on the process/method deployed. Cocoyam therefore requires drying for conversion to flour for long term storage and industrial use, but there is dearth of information on the drying behaviour of the root crop. Hence the need for information on engineering properties/ data on cocoyam for the design of suitable processing machines. such as dryers. This research work therefore compares the physicochemical and functional properties and drying characteristics of three varieties of cocoyam flour. The aim of this research work is to compare the physicochemical and functional properties, and the drying characteristics of three varieties of cocoyam flour. The Objectives of the study are:

1. To determine the physicochemical properties of the three varieties of cocoyam flour. 2. To determine the functional properties of the three varieties of cocoyam flour.
3. To determine the drying characteristics of the three varieties of cocoyam flour.

## II. MATERIALS AND METHODS

Fresh cormels of three species of cocoyam (Ede Ugwuta, Ede Alo, & Ede Ofe) were purchased from a local market (New Market, Enugu). All the fresh cormels were thoroughly washed with clean water to remove clogged soil particles or any debris and shared into two batches A & B of equal halves, giving rise to a total of six samples. Batch A (containing three samples) was peeled using a stainless-steel knife and Batch B (containing three samples) was not peeled, then both batches were cut into 10mm thick slices.

Each sample of the batches was weighed with a weighing balance and the weight recorded.

2.1 Sample processing

Drying of the samples were done using a laboratory oven (Model N0: MCQTR54) at the Department of Agricultural and Bioresources Engineering laboratory, ESUT, Enugu State, Nigeria. The drying characteristics such as variations in moisture content, drying rate and moisture ratio during drying were investigated at $70^0$C temperature level and at an interval of 60minutes (1hr). The samples were weighed, the temperature and moisture content were taken with a moisture analyzer (i.e. moisture analyzing machine), then spread in a mesh and put in the oven for drying. After 60mins. (1hr.), the samples were brought out, readings taken and put back again into the oven. This was repeated until the samples weight remained constant. The samples after drying were milled into flour using a disc attrition mill (Asiko AII, Addis Nigeria). The flour was then sieved with 0.42mm sieve mesh and packaged in polyethylene bags for further analysis.

2.2 Experimental Methods.

2.2.1 Proximate Composition of Cocoyam Flour

Proximate analysis of bio-materials describe the basic nutrient composition of the bio-material in terms of crude protein, moisture content, fat, ash, fiber and carbohydrate. The flour samples were analyzed for moisture content, dries matter, crude protein, crude fiber, fat, ash and carbohydrate using Approved Methods of The American Association of Cereal Chemist (Ide *et al.*, 2022). All the chemicals were of analytical concentration.

2.2.2 Moisture Content of the Samples.

The moisture content (MC) of the samples were determined using the procedure described by Ide *et al.*, (2019). $MC$

$$= \frac{W_w - W_D}{W_D} X \ 100\%$$

Where; MC = moisture content (%); $W_w$ = weight of wet sample (g); $W_D$ = weight of dry sample (g)

2.2.3. Crude Fiber

The crude fiber was determined using Ide *et al.*, (2019) method. This involves pouring 2g of the sample into 1litre of conical flask. Then heating 100ml of water until it boils and pouring it into the conical flask that contains the samples, the mixture were then boiled together for about 30 minutes. After boiling for 30 minutes, the mixture was filtered using a Muslin cloth held in a funnel. The residue was thoroughly rinsed until it was no longer alkali. The residue was then poured into an already dried crucible and ached at 600ºC ± 200ºC. The crude fiber was evaluated using the equation below.

$$Crude\ fiber = \frac{weight\ of\ crucible}{weight\ of\ the\ sample}\ X\ 100\%$$

$$Crude\ fat(\%) = \frac{weight\ of\ fat}{weigth\ of\ sample}\ X\ 100\%$$

2.2.4 Ash Content

The ash content represents the mineral or organic residue of a bio-material. It gives an idea of the amount of total mineral content of the food material. The ash content was determined using (Malowo *et al.*, 2012).

$$Ash\ content(\%) = \frac{weight\ of\ Ash}{weight\ of\ sample}\ X100\%$$

2.2.5 Crude Fat Content

The Crude Fat content was evaluated using procedure proposed by (Malowo *et al.*, 2012) by using Soxhiet extractor with Hexane. 1g of the samples was measured into a thimble extractor placed into extraction chamber with some Hexane added to extract the fat. The fat was evaluated using equation below

2.2.6 Crude Protein

Protein is amino acids joined together by peptide linkage. They contain essential elements such as Carbon, Hydrogen, Oxygen and Nitrogen etc. The Crude Protein was evaluated using Foss Desiccators, Protein Digester and KJECTEC2200 Distillation apparatus using (Malowo *et al.*, 2012) procedure.

2.3 Determination of functional properties of cocoyam flour

Functional properties are the essential physicochemical properties of foods that reflect the complex interactions between the structures, molecular conformation, compositions, and physicochemical properties of food components with the nature of the environment and conditions in which these are measured and associated (Awuchi *et al*., 2019, Suresh and Samsher, 2013; Kaur and Singh, 2006; Ojinnaka *et al.,* 2016). Functional characteristics are required to possibly help to predict and precisely evaluate how new proteins, fat, carbohydrates (starch and sugars), and fibre may behave in specific food systems as well as demonstrate whether or not such can be used to stimulate or replace conventional protein, (Suresh and Samsher, 2013; Kaur and Singh, 2006; Ojinnaka *et al*., 2016) fat, carbohydrates (starch and sugars), and fibre.

Functional properties also describe the behaviour of ingredients during preparation and cooking, as well as how they affect the finished food products in terms of how it looks, feels and tastes. Functional properties include Swelling capacity, water absorption capacity, oil absorption capacity, Emulsion activity, Emulsion stability, Foam capacity, Foam stability, Gelatinization, Bulk density, Dextrinisation, Preserving, Denaturation, Coagulation, Gluten formation, Jelling, Shortening, Plasticity, Flakiness, Retention of moisture, Aeration, Sensory attributes, among others (Awuchi *et al*., 2019).

2.3.1 Oil Absorption Capacity (OAC)

The mixture of 1g of flour with 10 ml refined corn oil in a centrifuge tube allowed to stand at room temperature of 30 ± 2°Cfor 60mins It was centrifuged at 1600g for 20min. The volume of free oil was noted and poured. Fat absorption capacity was measured as ml of oil bound by 100g dried flour (Onwuka, 2005).

2.3.2 Water Absorption Capacity (%)

The mixture of 1g of flour with 10 ml refined corn oil in a centrifuge tube allowed to stand at room temperature of 30 ± 2°Cfor 60mins. It was shaken on a platform tube rocker for 1 minute at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200g for 30 min. The volume of free water was read directly from the centrifuge tube (Onwuka, 2005).

2.3.3 Swelling Power (SP)

According to Obadina *et al*, (2016), 3g of the flour sample was partitioned and each part of the dried flour was transferred into clean, dry, calibrated 50ml cylinders. Flour samples were slightly levelled and their volumes were recorded. 30ml distilled water was added to each sample then the cylinder was allowed to be swirled and stand for 60 minutes while the swelling power (change in volume) was recorded at 15 minutes interval. The swelling power of each flour sample was calculated at interval of 15 minutes at each volume raised.

3.9 Determination of Thermal Property of Cocoyam Flour

Ide *et al.*, (2019) method was used. This was done with bomb calorimeter of model XRY-1A made from Shanghai Changji, China. It involves in igniting the sample in oxygen bomb calorimeter under a high pressure of oxygen gas. The heat energy that was released was absorbed by the surrounding water and this was used to estimate the energy value of the sample. 1g of the sample was pelleted and turned in the oxygen bomb calorimeter. The heat of combustion was calculated as the gross energy using

$$Energy\ Content\ = \frac{E\Delta T - 2.3B - V}{g}\left(\frac{KJ}{KG}\right)$$

Where; E = Energy equivalent of the calorimeter = 13039.308; ΔT = Temperature rise;

B = Length of burnt wire; V = Titration volume; G = Weight of the sample.

3.9.1 Thermal conductivity (k): Thermal conductivity of a material is a measure of its ability to transmit heat. Thermal conductivity of cocoyam flour was determined using Mohammed (2013);

$$K = \frac{Q\Delta ln\ (t)}{4\pi\Delta T}$$

Where; K = Thermal conductivity (w/m); Q = Power rating of the calorimeter (J); t = Change in temperature (k).

3.9.2 Specific heat capacity (cp): This is the amount of heat needed to increase the temperature of a unit of mass by one degree. It is measured in KJ/KgK in S.I. unit. It can be mathematically illustrated using equation reported by Aviara (2000).

$$Cs = Qt/(Ms(\Delta T) - MwCw\Delta T$$

Where; Q = quantity of heat (J); t = time (s); Ms = mass of the sample (kg); Cs = specific heat capacity (KJ/KgK); Mw = mass of water (kg); Cw = specific heat capacity of water; ΔT = change in temperature (k).

3.9.3 Thermal diffusivity (α): this qualifies a material's ability to conduct heat relative to its ability to store heat. Thermal diffusivity was determined using the following equation reported by (Ide *et al.*, 2013). $\propto$

$$= \frac{K}{\rho cp} \qquad (3.8)$$

Where; ; $\propto = thermal\ diffusivity\ m2/s$; $\rho = bulkdensity$; Cp = specific heat capacity KJ/KgK.

3.10 Determination of Pasting Properties of Cocoyam Fluor

Pasting characteristics were determined using a Rapid Visco Analyzer (Model RVA 4500 Newport Scientific Australia). 3.0g of this research work, tends to investigate the behaviour of cocoyam properties at different moisture contents in order to verify the moisture content level at which the thermal parameters will be efficient. The value that was obtained during the research were used to enhance thermal processing of Mucuna sloanei to reduce lost and damages during such for windows software connected to a computer.

## III. RESULTS AND DISCUSSION

The data collected were analysed using tables, graphs and statistical method. These data were gotten from the measuring cocoyam weights, moisture content, drying time, drying rate, estimation of the proximate properties, functional properties, pasting properties, mineral contents and anti-nutritional properties. The results are presented in tables and figures below:

### 4.1 PROXIMATE COMPOSITION

Table 1. Proximate Composition

| | EDE ALO | | EDE OFE | | EDE UGWUTA | |
|---|---|---|---|---|---|---|
| Parameters | PEA | UPEA | PEO | UPEO | PEU | UPEU |
| Moisture Content (%) | 8.483 | 7.756 | 7.954 | 8.069 | 8.605 | 7.921 |
| Ash Content (%) | 3.235 | 5.822 | 5.248 | 5.902 | 5.654 | 6.073 |
| Crude fiber (%) | 1.640 | 6.106 | 1.801 | 1.953 | 2.212 | 3.728 |
| Crude fat (%) | 1.086 | 1.994 | 1.566 | 0.193 | 0.146 | 6.393 |
| Protein (%) | 0.088 | 0.600 | 4.994 | 6.913 | 0.606 | 3.969 |
| Carbohydrate (%) | 85.468 | 77.722 | 78.437 | 76.970 | 82.777 | 71.916 |

Note: UPEA = Unpeeled Ede Alo, PEA = Peeled Ede Alo, PEO = Peeled Ede Ofe, UPEO = Unpeeled Ede Ofe, PEO = Peeled Ede Ofe, PEU = Peeled Ede Ugwuta and UPEU = Unpeeled Ede Ugwuta

Table 4.1 shows the result of the proximate composition. The moisture content (MC) ranges from 7.954- 8.605% for peeled while that of unpeeled ranged from 7.756- 8.069%. these values were within the range of values and comparable to the values obtained by (Iwe et al., 2016) & (Offia – Olua, 2014) for proximate, functional & pasting properties of "FARO44 rice, African yam bean & brown Cowpea Seeds composite flour" and "Proximate Composition & functional properties of different grain flour composites for Industrial applications" respectively. Also food material such as flour containing more than 12% moisture have lesser storage stability than those with a lower moisture content (Awuchi, 2019). From the table, it could be seen that the peeled cocoyam flour had higher moisture content than that of unpeeled cocoyam flour. This could be attributed to the unpeeled back having a porous membrane which allows easy removal of water. With the moisture content range of 7.756- 8.605% the cocoyam flour could be stored for a reasonable length of time without change in quality as moisture content of above 14% are not often stable at room temperature, since organisms present in them tends to grow, producing off odours and flavours (Twinowuhwezi et al., 2020).

Ash content of food material is an indication of the total quantity of the mineral element in the food. It is the total inorganic composition of the food material after the moisture and organic materials (fats, carbohydrates, proteins, etc) have been removed by oxidation and/or incineration (Twinowuhwezi et al., 2020). From the results gotten, ash content of the samples ranged from 3.235% – 6.073%. Peeled cocoyam ranges from 3.235% - 5.654% and that of unpeeled ranges from 5.822% – 6.073%. It could be observed that the unpeeled cocoyam has higher ash content than the peeled, which indicates that the unpeeled contains more mineral element than the peeled, as high ash content means that the food material contains more mineral elements (Offia-Olua. 2014). The high ash content of unpeeled cocoyam could be attributed to the non - removal of the cocoyam back indicating that the back also contains mineral elements.

Crude fibre content of the samples ranges from 1.604% - 6.106%. This was comparable with that obtained by (Offia-Olua. 2014) which ranges 3.20% - 11.30% crude fibre. Crude fibre corresponds only to feeds of plant origin considering the constituent compounds, though a small quantity of it is contained in feeds of animal (Twinowuhwezi et al., 2020). Crude fibre of Plant origin is mainly made up of cell wall which comprised of indigestible carbohydrates such as Cellulose, hemicellulos. Pectin, and lignin (Twinowuhwezi et al., 2020) which explains why the crude fibre of unpeeled cocoyam with range 1.953% - 6.106% is higher than that of peeled cocoyam with range 1.640% - 2.212% due to the higher cellulose content of cocoyam back. Again, unpeeled ede Alo had the highest value of 6.106% out of the three cocoyam varieties considered. Crude fibre delays the rate of release of glucose into the blood stream and decreases intercolonic pressure thereby reducing the risk of colon cancer (Iwe et al., 2016). Prevent heart diseases colon cancer, diabetes, etc (Awuchi, 2019). For prevention / treatment of the afore mention diseases using cocoyam, it is better to use unpeeled cocoyam, preferably ede Alo. The crude fat content of the food material is a reflection of the oil content of the food material. The crude fat content in this research ranges from 0.146% - 6.393% which is similar to the result gotten by (Twinowuhwezi et al., 2020 & Awuchi 2019). Peeled cocoyam has lower range of 0.146- 1.566% to that of unpeeled cocoyam which has 0.193% - 6.393% range value. Unpeeled ede Ugwuta has the highest crude fat which makes it good for blends in weaning diet of infants, a good flavor enhancer and also good in improving the lusciousness of food in which it is integrated (Twinowuhwezi et al., 2020). Though it has the problem of poor shelf life because fats and fat containing foods contain unsaturated fatty acids that are potentially susceptible to oxidative rancidity (Iwe et al., 2016). Peeled ede Ugwuta has the lowest value of 0.146% which is good for prolonged shelf life.

Crude protein is the value obtained by quantifying the amount of Nitrogen contained in a food material using kjeldahl method (Twinowuhwezi et al., 2020). The range of values for unpeeled cocoyam flour 0.600% - 6.913% was higher than that of the peeled cocoyam flour with range of values 0.088% - 4.994%. Unpeeled ede Ofe has the highest value of 6.913% while peeled ede Alo has the lowest value of 0.600%.

The carbohydrate content of the samples ranged from 71.916% - 85.468% with the peeled ede Alo having the highest value of 85.468% and the unpeeled ede Ugwuta having the lowest value of 71.916%. So, for one having interest in carbohydrate content of cocoyam should go for ede Alo. Carbohydrate is a good source of energy which makes it suitable for weaning formular and breakfast meals where concentration of carbohydrate is required (Awuchi, 2019). From table 4.2, there was no significant difference between the unpeeled and peeled samples for the following analysis – moisture, ash, crude fiber, protein and carbohydrate ($p > 0.05$). However, there is a significant difference between the unpeeled and peeled crude fat ($p < 0.05$).

4.2 FUNCTIONAL PROPERTIES

Table 2. Functional Properties of the Fluor

| | EDE ALO | | EDE OFE | | EDE UG-WUTA | |
|---|---|---|---|---|---|---|
| Parameters | PEA | UPEA | PEO | UPEO | PEU | UPEU |
| Bulk density ($g/cm^3$) | 0.442 | 0.410 | 0.428 | 0.435 | 0.452 | 0.363 |
| Water absorption (g/g) | 2.114 | 2.457 | 3.466 | 3.453 | 2.401 | 2.934 |
| Oil absorption (g/g) | 2.336 | 2.420 | 2.390 | 2.420 | 2.513 | 2.385 |
| Swelling property (%) | 13.636 | 23.810 | 40.909 | 40.000 | 22.000 | 27.143 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Foaming ability (%) | 3.570 | 6.670 | 3.770 | 3.570 | 1.960 | 11.670 |

*Note: UPEA = Unpeeled Ede Alo, PEA = Peeled Ede Alo, PEO = Peeled Ede Ofe, UPEO = Unpeeled Ede Ofe, PEO = Peeled Ede Ofe, PEU = Peeled Ede Ugwuta and UPEU = Unpeeled Ede Ugwuta*

The bulk density of the samples ranges from 0.363g/cm$^3$ – 0.452g/cm$^3$ with peeled ede Ugwuta having the highest value of 0.452g/cm$^3$ and unpeeled ede Ugwuta having the lowest value of 0.363g/cm$^3$. The variation in bulk density could be as a result of variation in starch content of the samples, since increase in starch content increases the bulk density (Iwe et al., 2016 & Twinowuhwezi et al., 2020). This explains why peeled ede Ugwuta has the highest value and the unpeeled ede Ugwuta the lowest value. The starch content of peeled ede Ugwuta was higher than that of unpeeled ede Ugwuta per unit volume because of the non-removal of the back in the unpeeled ede Ugwuta. This decreased the bulk density of unpeeled ede Ugwuta. The values obtained in this work is similar to ones obtained by (Ubbor and Nwaogu, 2010 & Arukwe et al., 2017) in their work on Cocoyam – Breadfruit – Wheat Flour blends and Pigeon Pea Flour respectively. Bulk density measures the heaviness of solid samples and Its important for determining packaging requirements, material handling and application in food industry (Falade and Okafor, 2014).

Water absorption capacity of the samples ranged from 2.457g/g – 3.934g/g. It was observed from table 4.3, that the unpeeled cocoyam flour had a range of 2.457g/g – 3.934g/g which is higher than that of peeled cocoyam flour with water absorption capacity range of 2.114g/g – 3.466g/g. This may infer that some components of the back may have absorbed water also. High water absorption capacity of flours influences positively their use as soup thickener (Falade and Okafor, 2014). Oil absorption capacity is an important functional property of flours that improves the mouth feel while also retaining the flavour of the food product (Adebowale and Lawal, 2014). From table 4.3, It could be observed that the peeled cocoyam flour with oil absorption capacity value range 2.336- 2.513g/g was higher than that of unpeeled cocoyam flour with value range of 2.385– 2.420g/g. Peeled ede Ugwuta had the highest value of 2.513g/g, this could be because it contains more starch than the unpeeled ede Ugwuta and also its starch may be absorbing oil more than other varieties under investigation in this research work. Swelling capacity is a measure of the starch ability to absorb water and swell. It is also a reflection of the extent of associative forces in the starch granules (Twinowuhwezi et al., 2020). The unpeeled cocoyam has the range of values 23.810% - 57.143% as against that of peeled cocoyam with range of values as 13.636% - 40.909%. This agrees with the result of water absorption capacity where unpeeled cocoyam had higher range of values than that of peeled cocoyam, since it is the ability of the starch granules to absorb water and swell. It shows that there is a relationship between the water absorption capacity and swelling capacity other factors remaining constant. This plays out in all the samples.

Foaming capacity of flours refer to the amount of interfacial area created by whipping the flour. It depends on the interfacial film formed by the proteins that maintains the suspension of our bubbles (Twinowuhwezi et al., 2020). Foaming capacity of unpeeled cocoyam ranged from 3.570- 11.670% which is higher than that of peeled cocoyam with ranged value as 1.960- 3.770%. Unpeeled *ede Ugwuta* had the highest value of 11.670% followed by unpeeled ede Alo with 6.670% while peeled ede Ugwuta has the lowest value of 1.960%. This then shows that the unpeeled ede Ugwuta contains more protein than the peeled ede Ugwuta. From Table 4.4, there was no significant difference between the unpeeled and peeled samples for the following analysis – Bulk density, Water Absorption, Oil Absorption, Swelling and Foaming ($p > 0.05$).

4.3 Drying Characteristics

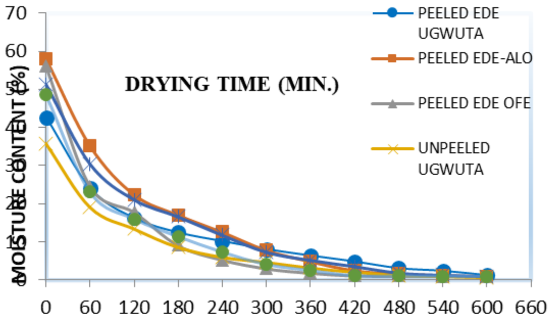


Fig. 1. Drying curve of unpeeled and peeled cocoyam varieties dried at 70°C oven temperature, using Moisture content and Drying time.

| Samples | Best fit Regression Equations | $R^2$ Values |
|---|---|---|
| PEU | MC = $0.0002x^2 - 0.1435x + 36.068$ | $R^2 = 0.9241$ |
| PEA | MC = $0.0002x^2 - 0.22x + 51.327$ | $R^2 = 0.9616$ |
| PEO | MC = $0.0003x^2 - 0.2294x + 45.756$ | $R^2 = 0.9027$ |
| UPEU | MC = $0.0001x^2 - 0.1349x + 30.434$ | $R^2 = 0.9339$ |
| UPEA | MC = $0.0002x^2 - 0.1863x + 45.115$ | $R^2 = 0.9607$ |
| UPEO | MC = $0.0002x^2 - 0.1896x + 40.358$ | $R^2 = 0.9212$ |

Table 3. Best fit equations and relationship between moisture content and drying time of unpeeled and peeled cocoyam varieties

The drying of cocoyam could be considered to be solely in the falling rate order, since the moisture content and drying rate steadily decreased with increase in drying time. This indicates that the entire drying process was controlled by the internal moisture diffusion phenomenon. The results gotten in this work were in agreement with that reported by Oyefeso., et al (2020) & Nwajinka et al., (2014) for cocoyam drying characteristics and Ugwuanyi-Nnadi et al., (2022), & Doymaz (2011) for trifoliate yam and sweet potato drying characteristics respectively. Also from fig.1, & table…, it was observed that the effect of drying time on the moisture content could be described by the regression equations for the samples; PEU - MC = $0.0002x^2 - 0.1435x + 36.068$, PEA - MC = $0.0002x^2 - 0.22x + 51.327$, PEO - MC = $0.0003x^2 - 0.2294x + 45.756$, UPEU - MC = $0.0001x^2 - 0.1349x + 30.434$, UPEA - MC = $0.0002x^2 - 0.1863x + 45.115$, & UPEO - MC = $0.0002x^2 - 0.1896x + 40.358$ of which the best fitting regression equation was the equation for Peeled ede Alo MC = $0.0002x^2 - 0.22x + 51.327$ since its correlation coefficient ($R^2$) value was the closest to 1. Correlation coefficient ($R^2$) of the samples measure the relationship and variation between samples.

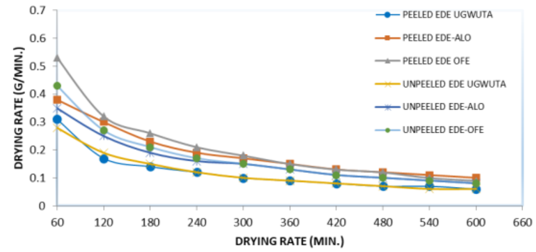


Fig. 2. Drying curve of unpeeled and peeled cocoyam varieties dried at 70°C oven temperature, using Drying rate and Drying time.

| Samples | Best fit Regression Equations | $R^2$ Values |
|---|---|---|
| PEU | DR = $1E\text{-}06x^2 - 0.0011x + 0.3295$ | $R^2 = 0.8977$ |
| PEA | DR = $1E\text{-}06x^2 - 0.0012x + 0.4338$ | $R^2 = 0.9825$ |
| PEO | DR = $2E\text{-}06x^2 - 0.0019x + 0.5777$ | $R^2 = 0.9386$ |
| UPEU | DR = $1E\text{-}06x^2 - 0.001x + 0.314$ | $R^2 = 0.9642$ |
| UPEA | DR = $1E\text{-}06x^2 - 0.0011x + 0.3867$ | $R^2 = 0.959$ |
| UPEO | DR = $2E\text{-}06x^2 - 0.0016x + 0.4718$ | $R^2 = 0.9415$ |

Table 4. Best fit equations and relationship between Drying rate and drying time of unpeeled and peeled cocoyam varieties

For the drying rate, it was seen that the peeled cocoyam samples had higher drying rate than the unpeeled cocoyam samples. Peeled ede Ofe had the highest value range of 0.09/min. – 0.53%/min. followed by Peeled ede Alo with value range of 0.10%/min. – 0.38%/min. while Unpeeled ede Ugwuta with a value range of 0.06%/min – 0.28%/min. was the least. This observation could be attributed to the presence of the back of cocoyam in the unpeeled which may be inhibiting the movement of water molecules. From fig. 2 & table 14, Peeled ede Alo had the best fitting regression equation DR = $1E\text{-}06x^2$ -

0.0012x + 0.4338 and correlation coefficient of $R^2$ = 0.9825 since it was the closest to 1 of all the samples.

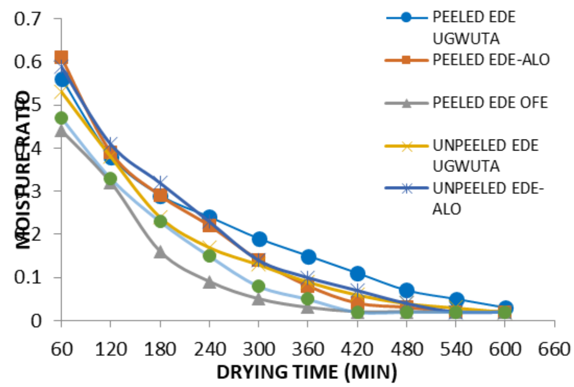


Fig. 3. Drying curve of unpeeled and peeled cocoyam varieties dried at 70oC oven temperature, using Moisture Ration and Drying time

| Samples | Best fit Regression Equations | $R^2$ Values |
|---|---|---|
| PEU | MR = 2E-06$x^2$ - 0.002x + 0.6298 | $R^2$ = 0.9783 |
| PEA | MR = 3E-06$x^2$ - 0.0028x + 0.729 | $R^2$ = 0.9873 |
| PEO | MR = 3E-06$x^2$ - 0.0025x + 0.5615 | $R^2$ = 0.9713 |
| UPEU | MR = 2E-06$x^2$ - 0.0024x + 0.6385 | $R^2$ = 0.9832 |
| UPEA | MR = 2E-06$x^2$ - 0.0026x + 0.7117 | $R^2$ = 0.9936 |
| UPEO | MR = 2E-06$x^2$ - 0.0024x + 0.592 | $R^2$ = 0.9951 |

Table 5. Best fit equations and relationship between Moisture Ratio and drying time of unpeeled and peeled cocoyam varieties

It could be deduced that the peeled cocoyam samples had a better drying characteristic than the unpeeled cocoyam samples. The equations generated in this research work could be used model drying process, design a drying machine or enhance the design of a continuous oven dryer.

## CONCLUSION

1. From the result of the proximate analysis it could be concluded that the peeled cocoyam flour had higher moisture content than that of unpeeled cocoyam flour. Unpeeled back having a porous membrane which allows easy removal of water.
2. Unpeeled cocoyam flour contain more mineral element than the peeled cocoyam flour since it contains more ash content, indicating that cocoyam back contain some mineral element.
3. Unpeeled cocoyam flour contain more crude fibre than the peeled cocoyam flour making it good for use over peeled cocoyam flour in prevention of some diseases such as heart diseases, colon cancer, diabetes, etc
4. Peeled cocoyam flour has more oil absorption capacity than the unpeeled cocoyam flour. Of the varieties of cocoyam flour considered in this work, peeled ede Ugwuta absorb most.
5. Unpeeled cocoyam flour foam better than peeled cocoyam flour indicating that unpeeled cocoyam contain more protein than peeled cocoyam, since foaming ability is linked with quantity of protein present in food material. This suggests that the back of cocoyam contain protein element.
6. Peeled cocoyam flour showed a better pasting properties than unpeeled cocoyam flour. Peeled cocoyam flour had higher peak viscosity, lower trough viscosity, set back viscosity, peak time and pasting temperature than unpeeled cocoyam flour.
7. From the result of drying characteristics, it could be concluded that peeled cocoyam samples had a better drying characteristics than the unpeeled cocoyam samples.
8. The equations generated in this research work could be used model drying process, design a drying machine or enhance the design of a continuous oven dryer.

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