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PHYSICAL, CHEMICAL AND FUNCTIONAL PROPERTIES OF FLOUR AND STARCH FROM TWO TIGERNUT (*Cyperus esculentus*) VARIETIES

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ABSTRACT

This study characterized the physical, chemical, and functional properties of flour and starch from two tigernut varieties (Brown and Yellow). The tigernut was processed into starch and flour following a standard method. Chemical analysis, functional properties, anti-nutrient properties, physical properties and colour properties was examined. Chemical analysis of flours showed moisture (7.70–9.00%), crude protein (4.45–4.99%), crude fat (26.8–30.7%), and carbohydrate (44.77–55.12%). Starches contained 4.30–4.45% protein and 70.63–77.28% carbohydrate; brown starch was significantly higher in moisture and carbohydrate. Anti-nutrients (tannins, phytates, oxalates, alkaloids) were higher in flour than starch in both varieties. Functional properties of the flour and starch are; water absorption capacity (1.15–2.18 g/g and 1.85–2.18 g/g) and gelatinization temperatures (62–63°C and 65–67°C). Swelling power and solubility increased from 60°C to 90°C, with starches consistently have higher values than flours. Physical properties of the brown starch granules were oval/regular (1.75–2.17 mm), while yellow granules were polygonal/irregular (0.96–1.21 mm). Starch samples exhibited higher lightness (L^*) values (57.98–61.50) than flour samples (49.76–51.58). Variations in these properties indicates distinct utilization potential for each variety in food systems.

Keywords: Tigernut, Flour, Starch

INTRODUCTION

The over-reliance on importation of raw materials for the production by food processors, small-scale and medium enterprises, and manufacturing sectors engaged in the food production has contributed to hidden hunger in the developing countries. The surging increase in the price of food commodities witnessed in many underdeveloped nations may raise the mortality rate. The hardship faced by citizens cannot be overemphasized. The call by the federal government of Nigeria to internally source raw materials for day-to- day food production to promote our food manufacturing sector has led to the search for alternatives to major temperate crops used in functional foods. This led to a comprehensive search for local underutilized crops with the potential to maintain equilibrium between agricultural productivity and the growing population in the tropical and subtropical region. Tigernut (*Cyperus esculentus)* is a member of the family Cyperaceae that produces rhizomes. It is one of the underutilized, nutritious, spherical, and versatile tuber crops.

Tigernut, also known as chufa, zulu nut, and earth almond. In Nigeria, tigernut was called different names as each tribe have local name for it. In Yoruba land, it is known as "ofio", Igbo people call it "Akiausa", while Hausa call it "Ayaya". There are three main cultivars of tigernut being cultivated around the tropical and sub-tropical areas, namely: yellow, black and brown. These cultivars vary in their properties (physicochemical and functional properties), Edo (2024). The chemical variations are a result of genetic variability, growing conditions, production location and environment. The commonly available cultivars in the market are brown and yellow. The yellow cultivars are pleasant, having attractive colour, fresher in nature, large in size and more importantly, they have high milk yield, protein and reduced anti-nutritional factors, especially polyphenols, making them most preferred (Adejuyitan *et al.*, 2009).

The research trends on tigernut are enormous. Most studies carried out are mainly centered on the flour properties. There are no spontaneous studies on flour and starch done so far. Thus, the present research aimed to characterize the physical, chemical, and functional attributes of flour and starch from two tigernut varieties. Thereby, providing alternative and substitute raw materials for use in the food industry.

MATERIALS AND METHODS

Materials

Dried tigernut tubers were obtained from Mushin market in Lagos, Nigeria. All Reagents used are of analytical grade.

Methods

Starch Isolation

The starch was isolated by the use of the technique described by Ocloo *et al.* (2014) with slight modification: 1.0 kg of tigernuts were sorted, cleaned to get rid of any foreign material such as stones and other seeds or grains that might have adhered, then dried, using an oven at 50°C for 3 hours. The dried nuts were milled into large, multi-particulate, coarse particles (>1 mm), then, treated with n-hexane to remove oils, the particles were boiled in ethanol for one and half hours to inactivate enzymes and denature proteins, followed by drying for two hours at 50°C in a hot air oven, the defatted granules were soaked for six hours in two liters of 0.075% (w/v) sodium metabisulphite. A homogenizer was used to mill the water – steeped mass of the granules into a uniformly smooth pulp. The smooth pulp was mixed with 12 liters of $Na_2S_2O_5$ solution (0.075%, w/v) and then sieved through a 150µm – pore – size muslin cloth. The suspension was left to stand for 17 hours to allow the starch granules to fully settle before decanting the supernatant. Distilled water was used to continuously rinse the starchy portion, followed by centrifuging at 3,000 rpm for ten minutes. A hot air oven, set at 50 °C (for 4 hours), was used to dry the resultant starch.

The dried starch was milled into a fine powder, sieved through a 250-µm mesh screen, and kept in an airtight, dry container.

Flour Production

The approach described by Oladele *et al.* (2007) was used. Fresh tigernut tubers were sorted and cleaned to exclude dirt and extraneous matters (such as stones, debris), after which they were washed in potable water and drained. Excess water was removed by oven drying at 50 °C for 3 hours. It is then milled, sieved through a 200µm sieve, and the flour is then packaged in a moisture-proof polyethene bag.

Chemical Analysis

The moisture content, the ash, crude fiber, crude protein, and crude fat are determined using (Maliki *et al.,* 2023) methods, while the carbohydrate value was calculated by difference.

A draft air-circulating (*Gelenkamp*) oven was used to determine the moisture content, while the pre-weighed samples were incinerated (550 °C) using *a UK Gallenkamp Hotbox* muffle furnace to constant ash weight. Crude fat content was analyzed using soxhlet extraction method. The Micro-Kjeldahl method was used to determine protein content. A pre-weighed defatted sample was refluxed in 1.25% H_2SO_4 and NaOH with intermittent rinsing, using water to estimate the crude fiber content (Maliki et al. 2023). The summation of the percentages of protein, fat, ash, crude fibre and moisture content was subtracted from 100% to give the total nitrogen – free extract of the samples, known as carbohydrate and the process is termed carbohydrate estimation by difference.

Determination of Anti-nutritional Factors

Determination of Phytate

The method reported by Apea-Bah *et al.* (2014). was adopted for phytate content determination. This process involves soaking 2g of the sample in about 20 ml of *0.2N* hydrochloric acid solution. The dispersed mixture was then filtered, and 0.5ml of the filtrate was measured. The measured portion was then mixed with 1ml of $NH_4Fe(SO_4)_2$ solution in a test tube, followed by boiling in a water bath for 30 minutes and then cooling in ice for 15 minutes. The cold sample mixture was then centrifuged for 15 minutes at 3000 x g. About 1.5 mL of 2, 2 – pyridine solution was mixed with 1ml of the supernatant portion of the centrifuged sample and its absorbance was measured at 519nm, using a spectrophotometer. The reading was extrapolated from the standard curve of standard phytic acid solution to estimate the phytic content of the sample.

Determination of Tannin Content

Tannin content was determined by mixing 0.2g of the sample with 10ml solution of 70% acetone in a bottle, which was properly covered and placed in an ice bath shaker at 30 ^oC for 2 hours. This was followed by centrifuging the mixture and storing the liquid phase in ice. About 0.2 ml of this liquid phase was measured into 0.8 ml of distilled water to which 0.5 ml of Folin reagent and 2.5 ml of 20% sodium trioxocarbonate were added. The mixture was vortexed and incubated for 40 minutes at ambient temperature, after which its absorbance was measured at 725 nm. A control sample was prepared using standard tannic acid solution and the necessary reagents in the same manner as the sample. The tannin content of the sample was then estimated from the standard tannic acid curve (Oladele *et al.,* 2023).

Determination of Oxalate

The oxalate content of the sample was determined by mixing 75 ml of *3N* hydrogen tetraoxosulphate IV acid (H_2SO_4) with 1g of the sample in a conical flask with intermittent stirring for 1 hour, using a magnetic stirrer. The mixture was then filtered, and 25ml of the filtrate was measured and titrated against *0.1N* potassium permanganate solution ($KMnO_4$) while still hot (80 – 90 ^oC) until a faint pink colour persisted for at least 30 seconds (Oluwole *et al.,* 2018).

Determination of Alkaloids

The methodology reported by Onwuka (2006) was used to determine the alkaloid content of the samples. The procedure involves dispersing about 10g of the sample in 100ml of 20% acetic acid solution in ethanol, which was shaken and left to stand for 4 hours. The mixture was then filtered, and the filtrate was concentrated through evaporation to one – fourth of its initial volume, after which the alkaloid was precipitated out through the addition (in drop-wise) of conc. NH_4OH. A pre-weighed Whatman No.1 filter paper was used to filter out the alkaloid precipitate, which was then washed with NH_4OH solution (1%) and oven dried at 60 °C for 30 minutes. The dried content was cooled in a desiccator, reweighed, and expressed as a percentage.

Physicochemical Analysis

About 0.1g of the sample was mixed with 10 mL of distilled water in a test tube. The resulting mix was placed in the water bath, set at 60 °C and heated for 30 minutes with steady shaking. The heated sample contained in a test tube was then centrifuged for about 20 minutes at 1,500 rpm, after which the supernatant water was gently decanted, and the starch paste's weight was taken. Afolayan *et al.* (2012).

The swelling power of the sample was then calculated using the formula below:

$$\text{SP}\ (g/g) = \frac{\text{Weight of starch paste}}{\text{Weight of dry starch sample}}$$

The experiment was conducted at a varied range of temperatures, between 60 ^OC to 90 ^OC.

Determination of Solubility Index (SI)

Solubility Index was determined by weighing 0.5g of the starch and flour with 10 mL of distilled water in a test tube mixed and then heated for 30 minutes in a water bath set at 50 ^oC after which it was centrifuged for 30 minutes at 1,500 *rpm.* After this process, about 5mil of the material was decanted and oven dried to constant weight. The SI was expressed as a percentage (%) by weight of the dissolved starch sample from the solution. This process was repeated over a 60 – 90 ^oC temperature range (Afolayan *et al*., 2012).

Determination of pH

pH meter was used to determine the degree of acidity and alkalinity of the sample by immersing the electrode into the mixture, prepared by dispersing about 20% w/v of the sample in water, which was shaken for 5 minutes.

Determination of Water Absorption Capacity (WAC)

The procedure reported by Omojola *et al.* (2010) was utilized to determine the WAC of the sample. The sample was prepared by dispersing 5% w/v (of the sample in water) into a centrifuge tube of known weight and shaken in a vortex mixer for about 2 minutes. The liquid phase was then decanted, and the underlying solid weight was taken and recorded as the weight of water bound by a 100g dry sample.

Determination of Gelatinization Temperature (GT)

About 1g of the sample was mixed with 10ml of distilled water in a beaker. This was then heated on a laboratory-type

hot plate with a thermometer suspended in the slurry to read the gelatinization temperature (Attama *et al.* 2003).

Determination of Bulk Density (BD)

The method reported by Ocloo *et al.* (2014) was adopted for bulk density determination. A pre-weighed calibrated centrifuge tube was filled to the 20ml mark with the sample while the tube was constantly tapped until no change in volume was observed. Mass difference was noted, which was divided by the volume (10ml) to obtain the BD of the sample.

Physical Analysis

Evaluation of Color

A Hunter's Lab color analyzer was used to determine the color (*L, a* and *b*) parameters of the samples. The initial procedure involves standardization of the instrument. About 10 different points of L, a and b parameters were identified by placing the colorimeter's sensor on the sample. The data obtained were used to calculate; Delta Chroma (ΔC), Color Intensity (ΔE) and hue angle, using appropriate Equations. (Cal *et al.,* 2006).

Evaluation of Granule Morphology and Size

Analysis was performed using an Acuscope (China) microscope with a TSView Software (China) for imaging. The starch Morphometry was performed using Motic 2000 (China), an adaptation of a method originally reported by Sivoli *et al.,* (2005). Microscopes can be used to view starches when a small amount of the starch is placed on the slides with a drop of distilled water and covered with a glass so as to increase the refractive index of the sample and to obtain better images. The granules were studied at three magnifications (x40, x100 and x400).

Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) at p=0.05. The Duncan multiple range test was used to separate means, using XLSTAT 2019 software.

RESULTS AND DISCUSSIONS

Effect of Variety on Proximate Composition and Yields of Tigernut Flour and Starch

Table 1. shows proximate composition and yields of tigernut flour. Moisture content ranged from 7.70-9.00% in the flour sample for the brown and yellow variety, and 8.20-9.70% in the starch sample for the brown and yellow variety, respectively. These were within the recommended standard for 13% (w/w) maximum for edible cassava flour (Sanni *et al*., 2005). The available moisture content in the flour and starch of the brown and yellow varieties depends on the degree of dryness, and the low moisture content is an indication of a good, stable shelf life if properly packaged and stored.

The crude protein content, percentage crude fat composition, ash content, crude fibre content, as well as the carbohydrate composition of flours produced from brown and yellow varieties were 4.45 and 4.99%, 30.7 and 26.8%, 1.95 and 2.14%, 11.06 and 3.92% and 44.77 to 55.12%, respectively. The low protein content indicates that the flours cannot be used as a protein-rich food. The high fat content of *Cypenes esculentus* (26.8 – 30.07) discovered in this work is far higher than that discovered by Zakka *et al.* (2026) (10.07 – 12.03) and lower than that of Ijarotimi et al. (2018) (40.41 – 46.52). This is enough to enable *Cypenes esculentus* as an oil-rich seed. Ash is a reflection of the inorganic mineral elements present in the flour samples. The undigestible component (crude fibre) is an essencial component required in the significant component in the body. It increases the bulk and decreases the time that waste materials spend in the gastrointestinal tracts (Adeola and Ohizua, 2018). Carbohydrates are one of the main types of nutrients. They are the most important source of energy. There was a significant difference in the proximate composition of flour from the two varieties. Flour from the yellow variety was significantly higher in moisture, crude protein, ash and carbohydrate content. The yields of the flour were 66.5 and 71.6% for brown and yellow varieties, respectively. The percentage yield of the yellow variety can be considered as satisfactory since it is comparable to the yield of wheat flour, which ranged from 70-75% as reported by Dari and Abendaw (2021). The crude protein, crude fat, ash, crude fibre and carbohydrate of starches produced from brown and yellow varieties varied from 4.30 and 4.45%, 1.21 and 6.60%, 1.16 and 1.18%, 6.33 and 8.91% and 77.28 to 73.63%, respectively. There was no significant difference in the crude protein and ash content of the starch from brown and yellow samples; however, the brown sample was significantly higher in moisture content and carbohydrate content.

The yields were 26.9% and 18.1% for brown and yellow varieties, respectively, which are within the range reported for cocoyam and sweet potato (Salwa *et al.,* 2010).

Table 1: Proximate Composition and Yield of Flour and Starch from Two Tigernut Varieties

Tigernut variety	Sample	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)	Yield (%)
Brown	Flour	7.70^{d}±0.03	4.45^{b}±0.01	30.07^{a}±0.01	1.95^{b}±0.01	11.06^{a}±0.03	44.77^{d}±0.07	66.5^{b}±0.00
	Starch	9.70^{a}±0.01	4.30^{b}±0.01	1.21^{d}±0.03	1.18^{c}±0.00	6.33^{c}±0.03	77.28^{a}±0.03	26.9^{c}±0.00
Yellow	Flour	9.00^{b}±0.00	4.99^{a}±0.01	26.8^{b}±0.85	2.14^{a}±0.01	3.92^{d}±0.03	55.12^{c}±2.84	71.6^{a}±0.00
	Starch	8.20^{c}±0.14	4.50^{b}±0.11	6.60^{c}±0.14	1.16^{c}±0.01	8.91^{b}±0.00	70.63^{b}±0.73	18.1^{d}±0.00

Mean ± S.D for two determinations.

Means in the same column followed by the same letters are not significantly different from each other ($p<0.05$).

Effect of Variety on Anti-nutritional Factors of Tigernut Flour and Starch

Table 2 shows the anti-nutritional factors of flour and starch from two tigernut varieties. The tannin, phytate, oxalate and alkaloid content in flour samples from brown and yellow varieties were 301.86 and 243.90mg/100g, 1.44 and 1.38mg/100g, 52.40 and 14.86mg/100g, and 6.27 to 14.93mg/100g, respectively while in starch samples from brown and yellow were 104.75 and 112.84mg/100g, 0.83 and 1.22mg/100g, 4.89 and 5.86mg/100g and 2.62 to 4.60mg/100g, respectively. The flour from the yellow variety was significantly lower in tannin, phytate and oxalate contents, while the starch from the brown variety contained significantly lower tannin, phytate, oxalate, and alkaloid contents, respectively.

Tannin, which binds to and precipitates protein (amino acids), is a polyphenolic compound with an astringent and bitter taste. Alkaloids are a group of naturally occurring chemical compounds that basically contain nitrogen atoms (Oluwole *et al.,* 2018). Phytate binds certain dietary minerals, including iron, manganese and to a lesser extent, calcium and slows their absorption (Ojo et al. 2023). Thus, the lower anti-nutritional factors in the flour sample from the yellow variety and the starch sample from the brown variety are indications of good nutritional value since the macro nutrients may be more readily available for utilization in the body.

Table 2: Anti-Nutritional Factors of Flour and Starch from Two Tigernut Varieties

Tigernut variety	Sample	Tannin (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)	Alkaloids (mg/100g)
Brown	Flour	301.86^{a}±10.40	1.44^{b}±0.88	52.40^{a}±4.81	6.27^{b}±0.00
	Starch	104.75^{c}±18.29	0.83^{c}±0.11	4.89^{d}±0.64	2.62^{c}±0.85
Yellow	Flour	243.90^{b}±20.95	1.38^{a}±0.09	14.86^{b}±0.44	14.93^{a}±0.46
	Starch	112.84^{d}±5.23	1.22^{ab}±0.35	5.86^{c}±0.55	4.60^{d}±0.48

Mean ± S.D for two determinations.
Means in the same column followed by the same letters are not significantly different from each other (P<0.05).

Effect of Variety on Functional Properties of Tigernut Flour and Starch

The functional attributes of the flour and starch are contained in Table 3. There were significant differences in water absorption capacity (WAP) loose and packed bulk density, pH and gelatinization temperature of the flour and starch samples at (P<0.05). The WAP for flour from brown and yellow varieties were 1.15 – 2.04 g/g and 1.85 – 2.18 g/g for starch from brown and yellow varieties, respectively. These were higher than the value obtained for chickpea (Jagannadham and Parimalavalli, 2015). WAC describes the manner of association between flour and water under a limited water supply. This result highlights the possibility of tiger-nut flours' applicability in baked products such as cookies. The differences in the proportions of amorphous and crystalline region within the granule of the starch sample may be behind the variation in the WAC of the samples.

Bulk density (loosed and packed), loosed BD ranged from 0.38g/cm^3 – 0.44g/cm^3 while there was no significant difference in the packed density value (0.59 to 0.59g/cm^3) obtained for the brown and yellow flour varieties while the value of brown and yellow starch varieties ranged from 0.26g/cm^3 – 0.38 g/cm^3 (for loosed) and 0.56g/cm^3 – 0.67g/cm^3 (for packed). Bulk density is significant in packaging design, storage and transport of food stuff (Olapade *et al.,* 2011). Therefore, the brown starch can be easily packaged, stored and as well as for transportation.

The gelatinization temperature ranged from 62 – 63 °C for the brown and yellow flour varieties and 65 – 67 °C for brown and yellow starch varieties. These fall within the ranges of gelatinization temperatures commonly observed for starches. The flour and starch samples had pH ranging between 5.10 – 5.90 and 5.40 - 6.50**,** respectively. pH of 4 or less signifies an appreciable degree of fermentation as well as the level of starch breakdown, making it an essential indicator/parameter for identifying flour quality. The values obtained fall within the range of pH values 5.07 – 6.65 obtained for cassava starches (Apea-Bah *et al.,* 2011).

Table 3: Functional Properties of Flour and Starch from Two Tigernut Varieties

Tigernut variety	Sample	Water Absorption Capacity (g/g)	Loosed Bulk Density (g/cm^3)	Packed Bulk Density (g/cm^3)	Gelatinization Temperature (°C)	P^H
Brown	Flour	1.15^{c} ±0.04	0.26^{c} ±0.00	0.59^{b}±0.00	62.00^{c}±1.41	5.10^{c}±0.14
	Starch	1.85^{b} ±0.01	0.38^{b}±0.35	0.56^{b}±0.00	65.00^{ab}±0.00	5.40^{c}±0.14
Yellow	Flour	2.04^{a} ±0.09	0.44^{a}±0.00	0.59^{b}±0.00	63.00^{bc}±0.00	5.90^{b}±0.00
	Starch	2.18^{a} ±0.04	0.38^{ab}±0.28	0.67^{a}±0.00	67.00^{a}±1.41	6.50^{a}±0.14

Mean ± S.D for two determinations.
Means in the same column followed by the same letters are not significantly different from each other (p<0.05).

Effect of Temperature on Swelling and Solubility Profile of Flour and Starch from Two Tigernut Varieties

The swelling profiles of flour and starch over a temperature range of 60 – 90 °C are shown in Figures 1 and Figure 2, respectively. The profile showed a general trend of increase with increase in temperature for flour and starch as reported by (Oladele and Aina, 2007) and (Adama *et al.,* 2014). The brown starch variety showed a higher swelling power than the yellow starch variety. This may be an indication of the water absorption characteristics of the starch granules during heating

Figures 3 and Figure 4 show the solubility profile of flour and starch over a temperature range of 60 – 90 °C. The profile also showed a general trend of increase with an increase in temperature for flour and starch. The yellow flour variety showed more solubility property than the brown flour variety, while the brown starch variety showed more solubility property than the yellow starch variety when heated at 60, 70, 80, and 90 °C, respectively. The starch result follows a similar trend with cocoyam (taro variety) and maize starches as reported by Salwa *et al.,* (2010) and Adama *et al.,* (2014).

However, the swelling and solubility properties depend on the amylase composition and starch granule size. Rapid swelling is observed when the granules are large, and amylase is crystalline. The breaking down of the starch structure causes an increment in the solubility and absorption of the starch as molecules of water are bound through hydrogen bond to the free hydroxyl groups of amylose and amylopectin (Singh *et al.,* 2003).

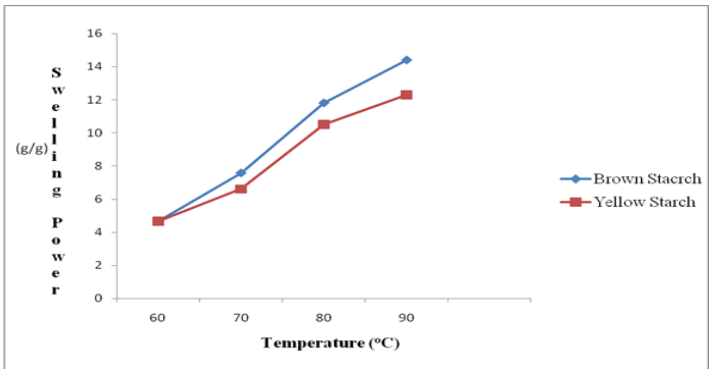

Figure 1: Effect of Temperature on Swelling Power of Brown and Yellow Starch

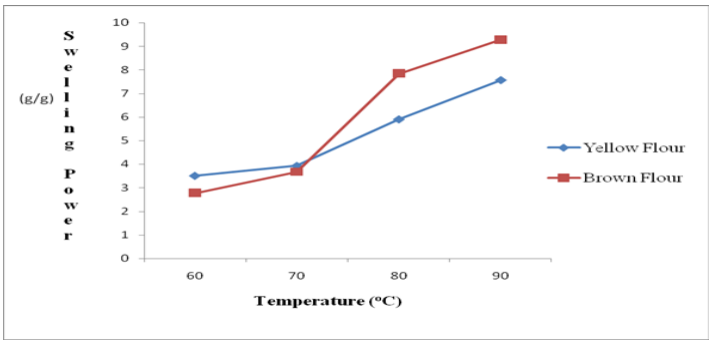

Figure 2: Effect of Temperature on Swelling Power of Yellow and Brown Flour

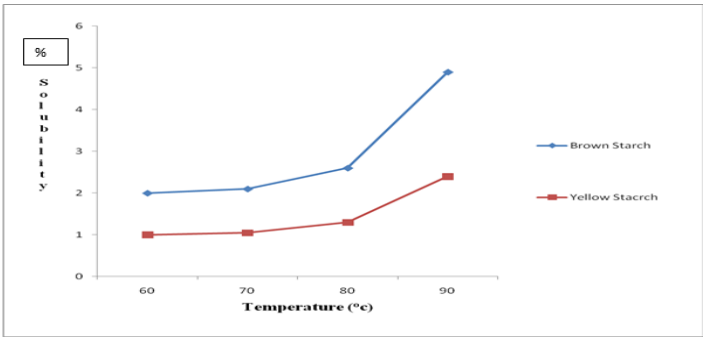

Figure 3: Effect of Temperature on Solubility of Brown and Yellow Starch

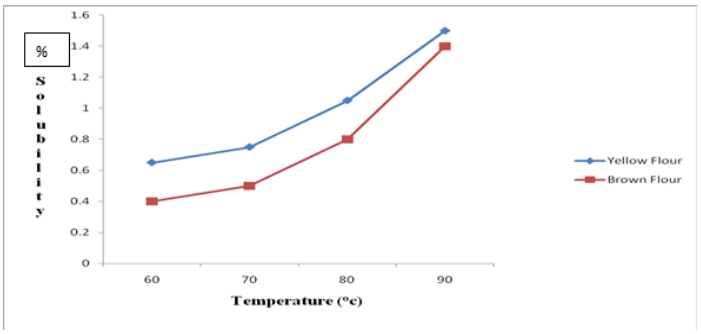

Figure 4: Effect of Temperature on Solubility of Yellow and Brown Flour

Colour Evaluation of Flour and Starch from Two Tigernut Varieties

Table.4 shows the result of colour evaluation of the flour and starch from two tigernut varieties. The lightness of the flour and starch was a significant difference at (P=0.05). The brown flour variety was significantly lighter (51.58) than the yellow flour variety (49.76), as well as the brown starch variety (61.50) than the yellow starch variety (54.98), respectively. The values of *a** (which indicate redness to greenness) ranged from 3.48 to 4.64 in brown and yellow flour variety, while 1.04 to 2.10 in brown and yellow starch, respectively. The dominance of red tone over green in the flour and starch samples is confirmed by the measurements above zero. The *b** values (which indicate yellowness to blueness) ranged

from 13.84 to 13.10 for brown and yellow flour varieties and 7.95 to 8.71 for brown and yellow starch varieties, respectively. Moreso, the dominance of yellow tone over the blue in the starch and flour samples is confirmed by measurements above zero as the yellow tone was far more expressed than the red tone. However, the yellow tone intensity differs for different flours and starch differed when measured. The most expressed yellow tone was observed in the brown flour variety, while the least expressed yellow tone was observed in the brown starch variety. There was no significant difference in the chroma (*C**) of brown and yellow flour varieties, while there were significant differences between brown starch and yellow starch varieties, with the values ranging from 4.53 to 5.69 at (P<0.05). Color differences, including yellowness to blueness (b), redness to greenness (a), as well as visual brightness (L) of the flour and starch produced from two tigernut varieties, were measured by Color Hunter Lab. L* value is a measure of the lightness–darkness fraction (L* =0 yields black and L* =100 indicates white) (Mamat *et al.,* 2010).

Table 4: Hunter Lab Colour Evaluation of Flour and Starch from Two Tigernut Varieties

Tigernut variety	Sample	L	A	B	C	E	Hue angle
Brown	Flour	51.58^{c}±1.33	3.48^{b}±0.11	13.84^{a}±0.43	10.91^{a}±0.44	39.68^{b}±1.15	76.43^{b}±0.02
	Starch	61.50^{a}±0.46	1.04^{d}±0.01	7.95^{d}±0.13	4.53^{c}±0.11	28.58^{d}±0.47	82.57^{a}±0.18
Yellow	Flour	49.76^{d}±0.04	4.64a±0.06	13.10^{b}±0.09	10.77^{a}±0.76	41.38^{a}±0.05	70.48^{d}±0.10
	Starch	54.98^{b}±0.29	2.10^{c}±0.02	8.71^{c}±0.38	5.69b±0.35	35.21^{c}±0.24	75.89^{c}±0.47

Mean ± S.D for two determinations

Means in the same column followed by the same letters are not significantly different from each other (p<0.05).

Granule Shape and Size Distribution of Flour and Starch from Two Tigernut Varieties

The starch granule shapes and size distribution of brown and yellow starch measured by Acuscope Microscope are shown in Plate I and II, respectively. The Acuscope Microscope with a TS view showed that the yellow starch variety had oval and regular shapes, and the size distribution ranged from 1.75 to 2.170mm. The yellow sample had polygonal shapes with irregular shapes, and the diameter ranged from 0.96 to 1.21mm. The morphology of the flour particles is an essential attribute used in identifying and characterizing powdered pharmaceutical excipients. Some functional properties related to powder compaction and flow can also be predicted (Lin et al., 2003). However, the brown starch variety can be compared with corn and potato starches as reported by Salwa *et al.,* 2010, due to its smooth and bigger granule size with rapid swelling and solubility.

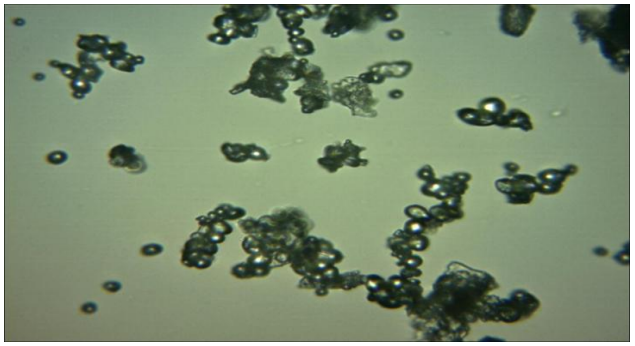

Plate I: Granule Shape of Brown Starch Variety (x400)

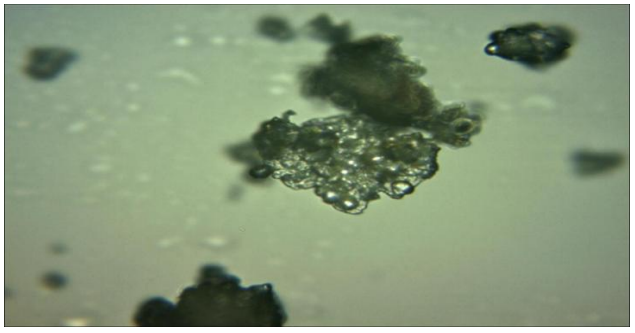

Plate II: Granule Shape of Yellow Starch Variety (x400)

CONCLUSION

Two tigernut varieties (brown and yellow) were evaluated for their physical, chemical and functional characteristics. There were variations due to the variety in the physical, chemical and functional properties of flour and starch produced from brown and yellow tigernut. The proximate composition showed low moisture and protein content with high fiber and carbohydrate content for the flour and starch of the brown and yellow varieties. The study also revealed that the oil content of the brown and yellow varieties ranged from 30.7 to 26.8%, respectively. These qualify them as an oil-rich tuber when compared with soybean, with oil value ranging from 22.8 to 23.5%. The granule size and shape of the brown starch variety showed that it can be compared with maize and sweet potato starches. Water absorption capacity describes flour – water association ability under limited water supply, which suggests

that the flours may find application in baked products such as cookies. Bulk densities of the flour and starch of brown and yellow varieties will guide the processors to determine the packaging requirement as it relates to the load, as well as the storage condition.

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