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PROXIMATE COMPOSITION, PHYSICOCHEMICAL AND PASTING PROPERTIES OF A NOVEL AFRICAN STAR APPLE (*Chrysophyllum albidum*) SEED NUT STARCH AS SUPPLEMENT TO INDUSTRIAL STARCH.

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Abstract

Starch are often being sourced from tuber and grains/cereals of crops. African Star Apple (*Chrysophyllum albidum*) is an unconventional source of starch. Starch isolated from the seed nut after the seeds has been dehulled were analysed for their proximate composition, physicochemical and pasting properties. *Chrysophyllum albidum* kernel starch contained 16.32% moisture, 0.17% ash , 7.01% protein, 0.01% fat and 15.85% amylose. Swelling power and solubility of the starch increased with increase in temperature. The bulk densities (loose and tapped) were 0.484 g/ml and 0.617 g/ml respectively. The least gelation studies revealed that the starch gelled at 6%. The Rapid Viscosity Analysis revealed that the starch has high peak and final viscosities. African star apple kernel starch could be an alternative novel source of starch thereby reducing the over reliance on the normal conventional starch sources for applications in food, paper, pharmaceutical and other industries.

Key words: African Star Apple, *Chrysophyllum albidum*, Proximate composition, physicochemical properties.

1.0 Introduction

Starch, as a renewable and biodegradable natural resource, is an important polysaccharide reserved in higher plants. It is the most important source of carbohydrates and the main component in all well-balanced human diets. It is made up of both amylose (typically 18-33%) and amylopectin (typically 67-82%). Starches are obtained from various botanical sources such as maize, wheat, rice, potato, banana, acha and tapioca. Starches from roots/tubers[1-4] and seeds/grains[5] have been extensively studied and have application in processed food products. Recently, the conventional starches from corn, rice, potato, wheat, and their derivatives have not been sufficient to satisfy demands, with the developments of society and technology [6]. Therefore, identification of an alternatively new starch source with novel properties is of great importance, in order to select the most adequate starch for specific application.

African Star Apple (*Chrysophyllum albidum*), is known by various tribal names in Nigeria as *agbalumo or Osan* (Yoruba), *udara* (Ibo, Efik and Ibibio), *ehya* (Igala) andagwaluma (Hausa). It is an indigenous plant, an edible tropical fruit, which is classified as a wild plant, and belong to the family *sapotaceae* and classified under the genus chrysophyllum [7]. *Chrysophyllum* is agenus of about 70-80 species of tropical trees native totropical regions throughout the world, with the greatest number of species in the Northern South America and some parts of Africa [8]. The fruit is seasonal and glaborous when ripe, ovoid to subglobose, pointed at the apex and up to 6 cm long and 5 cm in diameter. The skin or peel is orange of golden yellow when ripe and pulp within the peel may be orange, pinkish, bricked or

light yellow. African star apple fruit contains five large coffee-coloured seeds or sometimes fewer by abortion [9]. It is a tree with great potentials not only as a plantation species, but also in agro-forestry system [10-11]. In Nigeria, the fruit is gathered for household use or for sale in local markets during the months of December to April. There has not been any report on the properties of starch from African star apple kernel starch (*Chrysophyllum albidum*). In this study we reported the proximate composition, some physicochemical properties and pasting properties of starch isolated from African star apple kernel.

2.0 Materials and methods

2.1 Starch Isolation

The seeds of African star apple (*Chrysophyllum albidum*) were collected at different locations in Ago-Iwoye, Ogun State, Nigeria. The seeds were cracked manually and separated from the hulls. The seed nuts were cut into thin slices of 1.0 cm thickness, washed and ground with a kitchen blender at low speed. The slurry was dispersed in five times its volume of distilled water and the fiber removed by passing through a 2.0 mm mesh muslin cloth. The starch milk was allowed to settle and the supernatant decanted. The starch was re-suspended in water and washed repeatedly with fresh water until the wash water was clear and the resulting starch was spread on a tray and air dried for 48 hrs. The dried starch was blended at low speed and packed in high density polyethylene bags prior to use.

2.2 Proximate composition

Standard Association of Official Analytical Chemistry methods (AOAC) [11-14], were used for estimating moisture content, total ash, crude protein and crude fat, while amylose was determined using the method of Williams et al. [15] .

2.3 Physicochemical properties of starch

2.3.1 pH

The method reported by [16] was used for pH determination. Approximately 5 g of starch sample was added to 20 ml of distilled water in a beaker. The contents were stirred for 5 min. Starch was allowed to settle and the pH of the water phase was measured using a calibrated pH meter.

2.3.2 Loose and tapped bulk densities

2 g of the powdered sample was placed in a 10 ml measuring cylinder and the volume (V_0) occupied by the sample without tapping was noted. After 100 taps on the table, the filled volume (V_{100}) was read. The bulk loose and tapped densities were calculated as the ratio of weight to volume (V_0 and V_{100}, respectively) [17]

Bulk density g/ml = Wt of sample/Vol (1)

2.3.3 Dispersibility

This was determined by the method described by [18]. 10 g of starch was suspended in 100ml measuring cylinder and distilled water was added to reach a volume of 100 ml. The setup was stirred vigorously and allowed to settle for 3 hrs. The volume of settled particles was recorded and subtracted from 100. The difference was reported as % Dispersibility according to equation 2

Dispersibiliy = 100 – V (2)

V= Volume of the settled particles

2.3.4 Oil and water absorption capacity

The method of [19] was used with a little modification to determine oil and water absorption capacity of the starch. 10 ml of distilled water or oil (Power Oil, Raffles Oil LFTZ Enterprise, Lagos, Nigeria) was added to 1 g of sample. The mixture was mixed thoroughly with a glass rod for 5 mins and allowed to stand for 30 mins. Then, the volume of the supernatant was recorded.

2.3.5 Swelling power and solubility

A total of 0.1 g of starch samples were accurately weighed and quantitatively transferred into a clear dried test tube and weighed (W_1). 10 ml of distilled water was added to the test tube and the mixture was mixed thoroughly with a Vari-whirl mixer for 30 secs. The resultant slurries were heated at desired temperatures, varied between 55 and 95 ◦C for 30 min in a water bath (using temperature regulated water bath). The mixture was cooled to room temperature and centrifuged (5000×*g*, 15 min) [20]. The residue obtained from the above experiment (after centrifugation) with the water it retained and the test tube was weighed (W_2).

$$Swelling\ of\ starch = \frac{w_2 - w_1}{weight\ of\ starch} \quad (3)$$

Aliquots (5 ml) of the supernatant obtained after centrifugation were dried to a constant weight at 110°C. The residue obtained after drying the supernatant represented the amount of starch solubilized in water. Solubility was calculated as grams per 100 g of starch on dry weight basis.

2.3.6 Gelation studies

Sample of starch, 2–18% (w/v), were prepared in test tube with distilled water (5 ml). The starch suspensions were mixed with Vari-whirl mixer for 5 min. The test tubes were heated for 30 min at 80 °C in a water bath, followed by rapid cooling under running cold tap water. The test tubes were further cooled at 4 °C for 2hrs. The Least gelation concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

2.3.7 Light transmittance

Paste clarity was studied using the method of [21] with modifications. The native starch (50 mg on dry weight basis) were suspended in 5ml of distilled water and heated in a boiling water bath (with occasional shaking) for 30 min. After cooling to ambient temperature, transmittance (%) was determined at 650 nm against water blank using spectrophotometer. Also, to monitor tendency for retrogradation, samples were stored for 24 h at 4 °C to effect nucleation, after which they were stored at (30±2) °C for 1 to 9 days before determining the absorbance.

2.4 Pasting properties

3.5 g of the starch sample was weighed and 25 ml of distilled water was dispersed in a canister, paddle was placed in the canister and was joggled for few seconds and then inserted into the Rapid Visco Analyser (RVA). The measurement cycle was initiated by pressing the motor tower of the instrument. The profile can be seen as it is running on the monitor of the computer connected to the RVA machine. The 13 min profile was used, time temperature region used was idle temperature 50 °C for 1 min heated from 50 °C to 95 °C in 3 min 45 secs, then held at 95°C for 2 min 30secs, the sample was subsequently cooled to 50 °C over a 3 mins 45 secs period followed by a period of 2 min where the temperature was controlled at 50 °C, after these the pasting characteristics of the starch was shown on a graph

3.0 RESULTS AND DISCUSSION

3.1 Proximate composition

The starch obtained from *Chrysophyllum albidum* kernel starch (CAKS) is off white in colour and amorphous in nature. Table 3.1 shows the proximate composition of CAKS. The moisture content of CAKS is 16.93% which is slightly higher than 14.93% reported for mango starch [22] and 6.4-10.6% reported for mango cultivars [23] but still within the commercially acceptable range.

Table 3.1: Proximate Composition of CAKS

Composition	CAKS
Moisture %	16.32 ± 0.03
Ash %	0.17 ± 0.01
Protein %	7.01 ± 0.01
Fat %	0.01 ± 0.00
Amylose %	15.85 ± 0.21

Moisture content depends on the drying method, extent of drying and humidity in the surrounding atmosphere and it influences the flow and mechanical properties of the starch. Low moisture content is advantageous in terms of good keeping properties and excellent shelf life of the product and also gives stability on dried products. Low moisture content plays a vital role in long storage. The ash content was lower (0.17%) and falls within the range reported for Mango cultivars (0.1-0.4%) by [23] and is consistent with 0.12-0.15% reported in the literature for mango seed kernel cultivars [24].Protein in starch is from the remains of cell wall or residues of enzymes. The protein content of CAKS is 7.01% which is higher than 4.5% reported for *Chrysophyllum albidum* kernel flour [25].High protein content of isolated *Chrysophyllum albidum* kernel starch indicated the low purity of the starch extract [26]. High protein content may affect surface charge, rate of hydration and thus interfere with starch swelling and gelatinization [27]. Lipids can influence starch functionality by forming helical inclusion complexes with amylose and thus inhibit swelling and lower paste clarity [28-29]. The value for the fat content of CAKS is 0.01% which is lower than 9.3% reported for *Chrysophyllum albidum* kernel flour [25]. The amylose content observed for CAKS was found to be 15.85% which is consistent with that reported for mango seed kernel cultivars (9.1-16.3%)[24] but lower than 35.06% reported for mango starch[22]. Amylose content affects the pasting, gelatinization, retrogradation, swelling power and enzymatic vulnerability of starch [30].

3.2 Physicochemical properties

Table 3.2. Physicochemical Properties of CAKS

Parameters	CAKS
pH	7.18±0.02
Bulk density (Loose)g/ml	0.484±0.02
Bulk density(Tapped)g/ml	0.617±0.01
Dispersibility (%)	85.83±0.14
Water absorption capacity (%)	110
Oil absorption capacity (%)	187

3.2.1 pH

pH is an essential property in starch applications and it is generally used to indicate the acidic or alkaline properties of liquid media. The pH of CAKS was found to be slightly basic (7.18) which was higher than (5.27) reported for mango starch [22] and 3.8-4.2 for mango seed kernel cultivars [24].

3.2.2 Loose and tapped bulk density

The bulk density (Loose and tapped) was 0.484g/ml and 0.617g/ml respectively. Bulk density is a measure of the degree of coarseness of the starch sample. This implies that CAKS particles is very smooth and could find application for making face powder in the cosmetic industry. Bulk density is also important in infant feeding where less bulk is desirable. The low bulk density of CAKS would have an advantage in the preparation of complementary foods.

3.2.3 Dispersibility

Dispersibility is defined as a measure of reconstitution of starch flour in water, the greater the dispersibility, the better the starch flour reconstitutes in water [18]. The dispersibility of CAKS was found to be 85.83% which is higher than 72.10-80.02% reported for cereals and legume starches [31]. The value obtained for CAKS were better than those of legume and cereal starches reported by [31] since the greater the dispersibility, the better the starch flour reconstitute in water.

3.2.4 Water (WAC) and oil absorption capacity (OAC)

Water and oil absorption capacity of CAKS was 110% and 187% respectively. WAC value of CAKS was lower than 120% reported for kersting's groundnut starch [32]. Water absorption capacity is the ability of a substance to associate with water under a limited water condition. OAC value of CAKS was higher than 55% reported for Kersting's groundnut starch [32]. OAC is the ability of the dry starch to physically bind fat by capillary attraction and it is of great importance, as fat is used as a flavor retainer and also increases the mouth feel of foods.

3.2.5 Gelation studies

The least gelation concentration (LGC) was used as the index of gelation (Table 3.3). The lower the LGC, the better the gelating property of the starch. The lowest concentration for gelation of CAKS is 6% w/v. Starch gelation is a complex process that involves gelatinization, swelling and absorption of water to build a three-dimensional network that offers structural rigidity in various food applications.

Table 3.3: Gelation capacity of CAKS

Concentration % w/v	CAKS
2	Liquid
4	Viscous
6	Gel
8	Firm gel
10	Very firm gel
12	Very firm gel
14	Very firm gel
16	Very firm gel
LGC	6%

The building of structural network involves as well the bridging of the intergranular binding forces among the starch molecules which largely involves hydrogen bonding.

3.2.6 Light transmittance

Table 3.4: Influence of storage days on paste clarity of CAKS

Starch Sample	**Transmittance (%)**					
	Day 1	Day 2	Day 3	Day 5	Day 7	Day9
CAKS	8.4	8.0	7.32	5.27	3.55	0.91

Starch is employed as a thickener in many foods. Paste clarity is an important starch property when considering starch for use as thickener in food products such as pies, gravies, sauces and soups, which require transparency [35]. A high clarity implies good aesthetic appeal while low clarity starch pastes will give starch-thickened foods a dull colour. The clarity of such starch-thickened food is important if the food product is to retain its appeal to the consumers. Manufacturers of starch-thickened products will want the starch that will provide the desired appeal to consumers. Light transmittance of CAKS reduced as the storage days increased from the first day to the ninth day as shown in Table3.5. Similar time dependent reduction in transmittance (%) has been reported for hybrid maize starch[36] and banana starch [37].

3.2.7 Effect of temperature on swelling and solubility power

Swelling and solubility patterns provide information on the nature of the associative bonding within the starch granule [20, 34]. The starch granules are discrete semi crystalline aggregates consisting of amylose and amylopectin as major components. The ratio of these fractions in the starch granule and the manner in which they are arranged inside the granule affect the swelling and solubility of starch [34]. Swelling power and

solubility of CAKS are temperature dependent as presented in Table 3.5. Increase in temperature weakened the inter-granular binding forces of CAKS, thus facilitating less restricted swelling as the temperature increased. Swelling and Solubility of CAKS increases with increase in temperature. For CAKS the swelling and solubility power has the highest value at 95 °C.

Table 3.5: Effect of temperature on swelling power and solubility of CAKS

Temperature ^{o}C	55	65	75	85	95
Swelling power (g/g)	3.72±0.03	3.90±0.03	6.07±0.02	9.37±0.08	13.29±0.10
Swelling power (g/g)	0.99±0.01	1.95±0.03	1.98±0.01	3.92±0.03	3.97±0.03

3.3 Pasting Properties

The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. Pasting temperature is a measure of the temperature at which a starch thicken, the higher the temperature, the faster the tendency for the paste to be formed [38]. Hence, in the presence of water and heat, starch granules swell and form paste by imbibing water [39]. The pasting temperature of CAKS was found to be 80.65 °C. This agrees with the 81 °C reported for square banana [40] but higher than 68 °C and 61 °C reported for white and yellow plantain starches [41] and 50.20 – 62.10 °C reported for cereal and legume starches [31]. The peak viscosity of CAKS is 2553.00cP (212.75RVU) and it is lower than 220 – 474.83RVU reported for legume and cereal starches [31]. Peak viscosity is a measure of the ability of starch to form paste on cooking. The hold period of CAKS was 1600.00cP (133.33 RVU) and it is higher than 98.33RVU reported for acha native starch [33]. The holding strength is the ability of the granules to remain uninterrupted when the starch was subjected to a hold period of constant high temperature (95 °C for 2mins 30secs) and mechanical shear stress. The hold period is often accompanied by a breakdown in viscosity.

Table 3.6: Pasting Properties of CAKS

Parameters	Values
Peak viscosity (cP)	2553.00
Trough viscosity (cP)	1600.00
Breakdown (cP)	953.00
Final viscosity (cP)	2931.00
Setback (cP)	1331.00
Peak Time (min)	5.20
Pasting temperature °C	80.65

Breakdown value is the difference between peak viscosity and hot paste viscosity [42]. It is a measure of the fragility of the starch. The breakdown of CAKS is 953.00 cP (79.42RVU), which is lower than 202.58RVU reported for acha native starch [33]. It indicated the ability of the paste to breakdown during cooking. The ability of a starch to withstand this shear thinning or breakdown in viscosity (high breakdown value) is of high industrial significance in starches. The final viscosity of CAKS was 2931.00 cP (244.25RVU) similar to acha native starch [33] and it is an important parameter in predicting and defining the final textural quality of foods. The setback of CAKS is 1331.00 cP (110RVU) and it is lower than 145.92RVU reported for acha native starch [33]. This is the phase of the pasting curve after cooling of the starches (cooling to 50 °C) and this stage involve re-association,

retrogradation of starch molecules. It indicated the tendency of the starch to associate and retrograde. A high setback value is useful for domestic products. CAKS can find application in domestic products because of its high setback value.

4.0 Conclusion

Starch was successfully isolated from *Chrysophyllum albidum* kernel. The low fat content is a good property that allows long storage when necessary without loosing its values. This suggests that *Chrysophyllum albidum* kernel starch and other products made from it are not susceptible to quick rancidity due to its low fat content. *Chrysophyllum albidum* kernel starch can be very useful in the formulation of food component parts, as a stabilizer and as tablet binder in pharmaceutical companies because of its high value of viscosity. This study reveals that starch could be isolated from *Chrysophyllum albidum* kernel which is a waste material and an unconventional source.

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