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*Full Length Research Paper*

# Isolation and characterization studies of *Dioscorea dregeana* (Kunth) root starch as a potential pharmaceutical and industrial biomaterial

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**ABSTRACT**: The study focused on the physicochemical characterization of starch extracted from *Dioscorea dregeana* as a way of determining its suitability for use in pharmaceutical and other industries. The starch was isolated using 1% w/v sodium metabisulphite solution and the obtained starch was found to be a brilliant white, crystalline, non-hygroscopic powder with a yield of about 18.5%. The starch had low foam and emulsion capacities of 2 and 5.5% respectively, gelatinization temperature of 66 $^{o}$C and it had appreciably high water absorption capacity of 99.81 mg/100g. The amylose content of the starch was observed to be 7.48 %, while the browning and charring temperatures were 260.4 – 266.9$^{o}$C and 270.1 – 285.5$^{o}$C respectively. The swelling and solubility profiles of the starch were quite high and showed a trend of increase with the increase in temperature. The various results from the physicochemical characterization of starch from *Dioscorea dregeana* indicates that it is a potential biomaterial that may be employed as a pharmaceutical/industrial starch since its properties compare favourably with those of starch being used in the pharmaceutical, cosmetics, textiles, food, and other industries.

**Keywords**: Biomaterial, *Dioscorea dregeana*, pharmaceutical, physicochemical, starch

## INTRODUCTION

*Dioscorea dregeana* (Kunth) commonly called the wild yam, is a perennial creeper that is native to the eastern parts of South Africa and Swaziland. It is locally called 'Elube Uchuabegwu' among the Igala tribe in Nigeria. It is a perennial, twining, pale green herbaceous creeper, which grows up to 15 m long. It has a slightly thorny stem which grows annually from a fleshy, tuberous rootstock. The stems of wild yam are produced in spring; however, the plant tends to die off or become dormant in winter. It is a dioecious climber having large underground hairy and fleshy tubers which grow up to 300 mm in diameter (Zukulu *et al*., 2012]).

*Dioscorea dregeana* can be used in different ways and for different purposes. It is a popular and widely utilized medicinal plant in some regions of South Africa. Tubers of the plant have been discovered to have sedative properties hence they are employed in the treatment and management of some diseases like convulsions, epilepsy and hysteria. The fresh tuber is generally taken orally as a weak decoction, with an adequate dose resulting in sleep within 20-30 minutes (Kulkarni *et al*., 2007). *Dioscorea dregeana* tubers are also used in the treatment of fits, sores and wounds. They also help for easy childbirth. In spite of having medicinal properties, the tubers contain some poisonous ingredients that are highly toxic to humans (Van Wyk *et al*., 2002).

Starch exists as a major carbohydrate storage product in all plants containing the green pigment called chlorophyll. It is synthesized in the plastids and found in the leaves of green plants. It is also synthesized in the amyloplasts of seeds, grains, roots and tubers of most plants where it serves as the chemical storage form of energy (Afolayan *et al*., 2012). Starch is a natural biopolymer which is biodegradable and used widely in various industries [Afolayan *et al*., 2020]. It is the only qualitatively important digestible polysaccharide and has been regarded as nutritionally superior to low molecular weight carbohydrate or sugars (Ogungbenle, 2007). Unmodified starch (in its natural form) has a lot of potential uses in various industries including the mining, paper, building and pharmaceutical industries (Afolayan *et al*., 2014). It can be modified and converted to starch derivatives (Omojola *et al*., 2012). Some industries like the plastic, food, cosmetics, textiles, adhesives, pharmaceutical and paper industry employ starch as one of its most applicable biomaterial. The diverse industrial usage of starch is based on its availability at low cost, high calorific value and inherent excellent physicochemical properties (Omojola *et al*., 2010). The wide industrial application of starch depends on its physicochemical properties; hence the need for a thorough evaluation of some important parameters to determine the specific industrial applicability. Starch from different plant sources will likely differ from each other in its properties, appearance and biochemical composition because the biological source of starch determines its specific physicochemical properties and morphology (Emmanuel *et al*., 2021). Since there is a high demand for starch for use as food and coupled with its use in various industries as well as the necessity to produce more starch to meet the huge demands, there is now a urgent necessity to discover other sources of starch with high yields apart from the already known sources like potato, cassava and maize (Gebre – Mariam and Schmidt, 1996). Starch has been extracted from a lot of locally available fruits, rhizomes and tubers which have also been studied extensively and currently find so much industrial applications (Fagbohun *et al*., 2013); however, little or no work appears to have been done on the isolation and physicochemical characterization of starch from *Dioscorea dregeana.* The purpose of this study is therefore to extract, characterize and provide data on the various physicochemical parameters of starch extracted from *Dioscorea dregeana* as a new starch feedstock with suitable application in some industries which can essentially reduce the burden on other widely known sources of starch like yam, corn, potatoes and cassava.

There is a lack of data on the chemical composition and properties of some lesser known and unconventional crops which could be good sources of starch (Afolayan *et al*., 2012) and even have the potential of broadening the present narrow food base of the human species, this has limited the prospects for the utilization of such plants as viable starch sources (Viano *et al*., 1995). The acquisition of good quality starch containing plants is fundamental to produce acceptable food product as well as industrial raw materials (Atokple *et al*., 2014). It is in tandem with this that the study on starch from *Dioscorea dregeana* was carried out as a new source of starch for pharmaceutical and other industrial applications.

This study is therefore a continuation of our quest for discovery of starches from lesser known, unconventional and non – food sources for appropriate industrial usage. Presently, starch was extracted and isolated from *Dioscorea dregeana* tubers and thereafter analyzed for its physicochemical properties as a way to ascertain its possible use as a biomaterial.

## MATERIALS AND METHODS

*Dioscorea dregeana* tubers were collected from Akpagidigbo village in Ofu Local Government Area of Kogi State, Nigeria by night hunters. The tubers were identified and authenticated at the National Institute for Pharmaceutical Research and Development (NIPRD), Abuja, Nigeria, by Mr. Akeem A. Lateef, with the assigned voucher number NIPRD/H/7184.They were stored in an open space in the laboratory until samples were needed for starch extraction.

All reagent used for the analysis were of analytical grade and were used without further purification.

### Starch isolation

Starch was extracted from the tubers using the method of Adama *et al*. (2014). Basically, the tubers were peeled and washed. The washed tubers were then weighed, cut into smaller pieces and soaked in sodium metabisulphite solution (2 L 1 % w/v) at room temperature (27 °C) overnight. Thereafter, the hydrated tubers were removed and wet milled into slurry using an industrial blender. The paste was dispersed in a large volume of 1 % sodium metabisulphite solution and filtered through muslin cloth. The suspension was centrifuged at 3500 rpm for 10 mins to facilitate the removal of dirty. The supernatant was carefully decanted and the mucilage scraped off. The process was repeated for three times with the mucilage on the starch scraped continuously until a pure starch was obtained. The resulting starch was dried in the sun and further dried at 60°C in a hot air oven, pulverized, weighed and stored in sample bottles for analysis.

### Physicochemical analysis of starch samples

The starch extracted from *Dioscorea dregeana* was analyzed for its physicochemical properties as shown below:

### Swelling profile

The method described by Afolayan *et al* (2012) was used to determine the swelling profile (Afolayan *et al*., 2012).

The starch sample (0.1 g) was weighed into a test tube and 10 ml of distilled water was added. The mixture was heated in a water bath at a temperature of 50 °C for 30 min with continuous shaking. In the end, the test tube was centrifuged at 1500 rpm for 20 min in order to facilitate the removal of the supernatant which was carefully decanted and weight of the starch paste taken. The swelling power was calculated as follows:

$$\text{Swelling power} = \frac{\text{Weight of powder paste}}{\text{Weight of dry powder sample}}$$

This was carried out over a temperature range of 50°C – 95°C.

### Solubility index

The method described by Afolayan *et al* (2012) was also used to determine the solubility index (Afolayan *et al*., 2012). Starch sample (0.5 g) was added to 10 ml distilled water in a test tube. This was subjected to heating in a water bath with a starting temperature of 50°C for 30 min. It was then centrifuged at 1500 rpm for 30 min. 5 ml of the supernatant was decanted and dried to constant weight. The solubility was expressed as the percentage (%) by weight of dissolved starch from heated solution. This was carried out over a temperature range of 50°C – 90°C.

### pH

A 20% w/v dispersion of the sample was shaken in water for 5 min and the pH was determined using a pH meter (Adama *et al*., 2014).

### Browning and charring temperature

The method of Builders *et al* (2001) was used. Some of the starch sample was put into a capillary tube, the browning and charring temperatures was determined using a melting point apparatus with model Electrothermal 9100.

### Foam capacity

The method of Omojola *et al.* (2010) was used with slight modifications (Omojola *et al*., 2010). Starch sample (1 g) was homogenized in 50 ml distilled water using a vortex mixer (vortex 2 Genie set at shake 8) for 5 min. The homogenate was poured into a 100 ml measuring cylinder and the volume recorded after 30 s. The foam capacity was expressed as the percent increase in volume.

### Emulsion capacity

Sample (1 g) was dispersed in 5 ml distilled water using a vortex mixer for 30 s. After complete dispersion, 5 ml vegetable oil (groundnut oil) was added gradually and the mixing continued for another 30 s. The suspension was centrifuged at 1600 rpm for 5 min. The volume of oil separated from the sample was read directly from the tube. Emulsion capacity is the amount of oil emulsified and held per gram of sample (Afolayan *et al*., 2012).

### Gelatinization temperature

This was evaluated using the method of Attama *et al* (2003). The starch sample (1 g) was put in a 20 ml beaker and 10 ml of distilled water was added. The dispersion was heated on a hot plate. The gelatinization temperature was then read with a thermometer suspended in the starch slurry.

### Water holding capacity

The method described by Omojola *et al.* (2010) was used to determine the water absorption capacity (Omojola *et al*., 2013). The starch sample (5% w/v) was dispersed in a pre-weighed centrifuge tube. The tube was agitated in a vortex mixer for 2 min. The supernatant was then discarded and the weight of the tube and hydrated sample taken. The weight was calculated and expressed as the weight of water bound by 100 g dry starch.

### Bulk and tapped density

The bulk density of the starch was determined using the method described by Narayana and Narasinga Rao (1984) with slight modifications (Narayana, 1984). Starch powder (50 g) was poured into a 250 $cm^3$ calibrated measuring cylinder by means of a short – stemmed glass funnel. The volume occupied by the starch was noted to determine the bulk density.

$$\text{Bulk density (g/cm3)} = \frac{\text{Weight of sample}}{\text{Volume occupied}}$$

For the tapped density determination, the cylinder was tapped continuously using a ruler until a constant volume was obtained.

### Paste clarity

This was determined spectrophotometrically. Accurate concentrations of the starch slurry between 0.15 – 2.5% w/v were made in different boiling tubes and heated in a water bath for 30 min. The transmittance was determined at 580 nm using a UV spectrophotometer with corn starch as the reference standard (Builders *et al*., 2001).

### Amylose and amylopectin content

Starch sample (0.1 g) and standard were weighed into separate test tubes. To these test tubes, 1cm$^3$ of 95% ethanol and 9cm$^3$ and 1 mol dm$^{-3}$ NaOH were carefully added. The test tubes were covered with foil paper and mixed thoroughly. The samples were heated for 10 min in a boiling water bath to gelatinize the starch and cooled very well. The suspensions were diluted 10 times. An aliquot of 0.5 cm$^3$ of the extract was used for analysis where 0.1 cm$^3$ of acetic acid solution was added, followed by the addition of 0.2 cm$^3$ of iodine solution. This was made up to 10 cm$^3$ with 9.2 cm$^3$ of distilled water. The solution was left for 20 min for colour development, vortexed and read at 620 nm (Juliano 1971).

$$\text{\% Amylose content} = \frac{\text{\% Amylose of standard} \times \text{Absorbance of sample}}{\text{Absorbance of standard}}$$

## RESULTS

The starch obtained was found to be a brilliant white, crystalline, non- hygroscopic powder with no smell and a yield of about 18.5 %. The yield is considered to be appreciable especially when compared with starches from other previously studied tubers such as *Anchomanes difformis*, *Icacina tricantha* and tiger nut (Afolayan *et al*., 2012; Omojola *et al*., 2012; Adama *et al*., 2014). Table 1 shows the results of the physicochemical properties of *Dioscorea dregeana* starch. The swelling profile, solubility profile and paste clarity are shown in (Figures 1, 2 and 3) respectively.

## DISCUSSION

Gelatinization is the process whereby starches undergo an irreversible change under heat and absorb water with swelling thereby making the granules swell more and become a paste rather than a dispersion which it forms in cold water. The starch sample isolated from *Dioscorea dregeana* was observed to have a gelatinization temperature of 66ºC which falls within the range of gelatinization temperatures commonly observed for starches (Agbo and Odo, 2010). Foam capacity and emulsion capacity of *Dioscorea dregeana* starch as seen in the results were observed to be quite lower than that observed for other starches; this could be indicative of a low fat content and further imply that it may not find good applicability as an emulsifier in the industry (Afolayan *et al*., 2012). This is also in line with earlier results obtained from other tubers like *Anchomanes difformis*, *Icacina tricantha* and tiger nut (Afolayan *et al*., 2012; Omojola *et al*., 2012; Adama *et al*., 2014). The pH measurement shows that *Dioscorea dregeana* starch is very close to that of corn starch (Omojola *et al*., 2010), comparable with the previous pH values reported for tuber starches (Coursey and Rasper,1967) and within the pH range of 3 – 9 obtained for most starches used in the pharmaceutical, cosmetics and food industries. The water holding capacity of 99.81 mg/100g is very much comparable to corn starch which has a water holding capacity of 93 mg/100g (Omojola *et al*., 2010). The bulk and tapped densities are in conformity with the findings of Shiihii *et al*. (2011) as reported and falls within the range indicated for maize starch. This shows that the starch can be compressed well (Shiihii *et al*., 2011). The browning and charring temperatures of the starch were observed to be quite high. This shows that the starch can even be heated to a higher temperature without changing colour or charring. This property will make *Dioscorea dregeana* starch very suitable for use in industries that employ starch at elevated temperatures (Adebiyi *et al*., 2011). The starch was also observed to have quite low amylose content which makes it a good choice food for diabetics and other health conscious individuals (Agbo and Odo, (2010). The starch has very low paste clarity when compared to corn starch.

The swelling and solubility profiles of the starch over a temperature range of 50 – 95$^o$C are illustrated in (Figures 1 and 2) respectively. The profiles show a general trend of increase with increase in temperature for all the starches although a slightly two – stage swelling pattern can be observed. This shows how the starch granules absorb water as it is being heated. The swelling curve for the starch demonstrated temperature relaxation between 50 – 60$^o$C and also at 80$^o$C just like it was reported for several other starches.

This pattern has been attributed to two sets of internal bonding forces that relax at different temperatures (Loss *et al*., 1981). The swelling power of the starch was observed to be quite higher than that of corn starch but slightly lower than that of starch extracted from cassava (Afolayan *et al*., 2014). Increase in swelling power is indicative of suitability of a starch being used as a disintegrant in the pharmaceutical industry (Chowdary and Enturi, 2011) hence *Dioscorea dregeana* starch can find application as a disintegrant in the pharmaceutical industry for tablet formulation.

High swelling power of starch gives rise to high digestibility and also makes the starch easy to use in solution; these gives rise to improve dietary properties and the versatile use of starch in a range of dietary applications Nuwamanya *et al*. (2010) this confirms the applicability of *Dioscorea dregeana* starch in other industries.

The solubility profile for the starch also shows an increase in solubility with temperature rise.

**Table 1:** Physicochemical properties of *Dioscorea dregeana* Starch.

| Parameters | Values |
|---|---|
| Gelatinization temperature | 66°C |
| Foam capacity | 2% |
| Emulsion capacity | 5.5% |
| pH | 6.64 |
| Water holding capacity | 99.81 mg/100g |
| Bulk density | 0.556 g/cm$^3$ |
| Tapped density | 0.658 g/cm$^3$ |
| Browning temperature | 260.4 – 266.9°C |
| Charring temperature | 270.1 – 285.5°C |
| Amylose content | 7.48% |
| Amylopectin content | 92.52% |

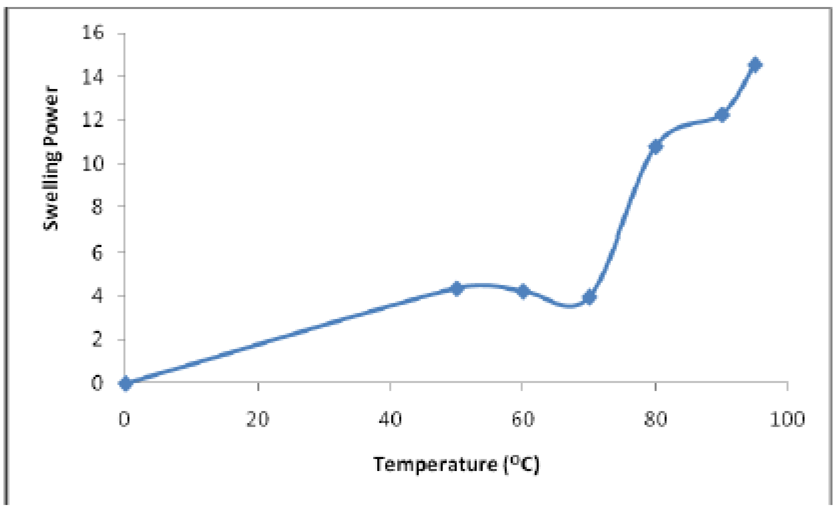


**Figure 1:** Swelling profile for *dioscorea dregeana* starch.

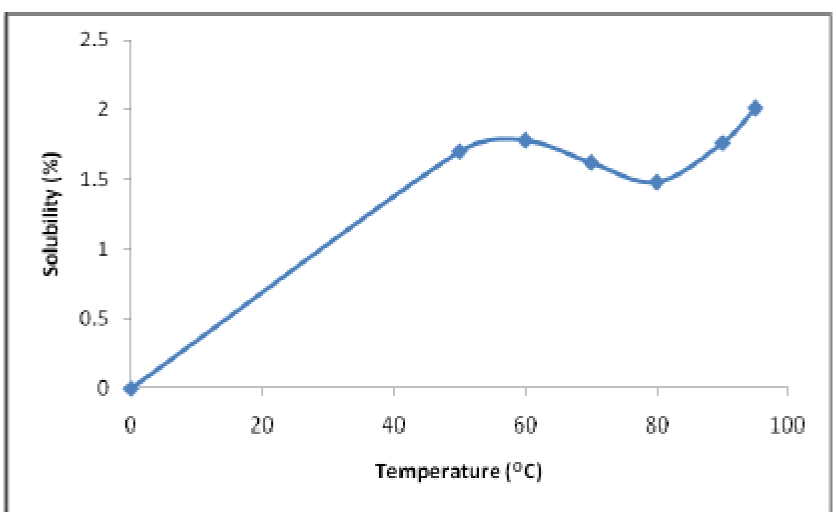


**Figure 2:** Solubility profile for *dioscorea dregeana* starch.

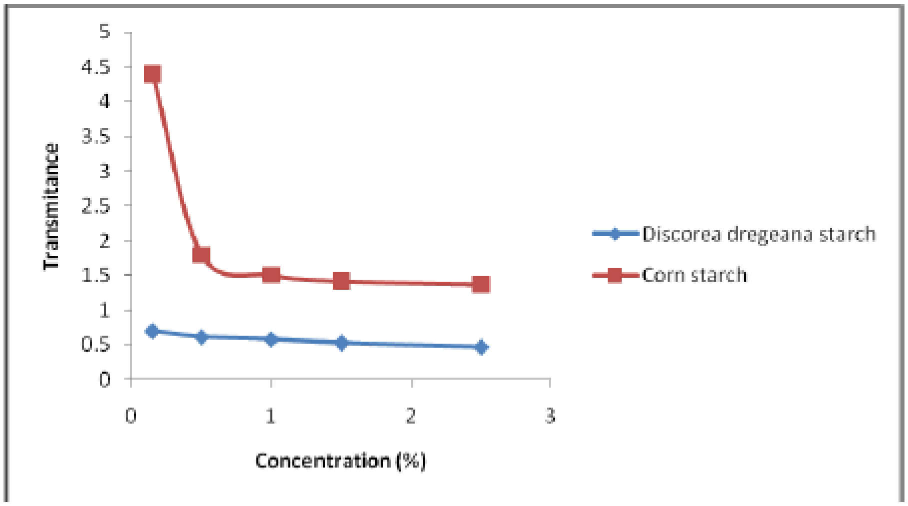


**Figure 3:** Paste clarity for *dioscorea dregeana* and corn starch.

## Conclusion

Some physicochemical properties of *Dioscorea dregeana* starch have been examined and these properties compare favourably with other starches. The study has therefore shown that *Dioscorea dregeana* is a potential source of starch for use as a biomaterial in pharmaceutical, cosmetics, textiles, food and other industries. This will help to reduce the burden on starch from other well known sources such as corn, potato and cassava and make starch available at low cost.

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