Determination of Physicochemical Properties of *Dioscorea bulbifera* Starch.

A. E. Abara¹, M. E. Obi-Abang² and G. O. Obochi³.

¹Department of Chemical Sciences, Cross River University of Technology, Calabar, Nigeria.
²Department of Biochemistry, Benue State University, Makurdi, Nigeria.
³Author for correspondence: e-mail: abaraae@yahoo.co.uk

Abstract

The physico-chemical properties of *Dioscorea bulbifera* starch were determined and the results showed that the granules were irregular and semi-cylindrical in shape and 2-5µm in size. Starch purity was 95.08% with amylose content of 17.28%, 14.00% of moisture, 0.26% of lipid, 3.42% of protein, 1.33% of ash and 0.089% of phosphorous. The results also showed that *Dioscorea bulbifera* starch had a swelling power of 9.21%, water solubility index of 5.31%, water absorption capacity of 103.39%, relative degree of retrogradation of 23.81% and gelatinization temperature range of 58-66°C. The results of this study suggested that *Dioscorea bulbifera* starch was a potential material for culinary applications in sauces, soups and gravies and for industrial production of adhesives, biodegradable plastics, aerosols and powders.

**Keywords:** *Dioscorea bulbifera*, starch, physicochemical properties.

Introduction.

*Dioscorea bulbifera* (aerial yam or air potato) is widely grown in West Africa, the Carribean Islands, South East Asia, South Pacific and the West Indies (Tindall, 1983). However, the greatest production of *Dioscorea bulbifera* is in Africa where over 95% of total world production takes place, and Nigeria alone accounts for over 78% of the total world production, followed by the West Indies (Tindall, 1983). The wild varieties are also abundant in the regions of the world where the edible varieties are extensively cultivated. *Dioscorea bulbifera* is used as food as boiled, roasted or fried yam and eaten along with meat, fish or green vegetable sauce (Tindall, 1983). The aerial yam is rich in starch (Osagie, 1992) and this marks it a potential source of starch for both domestic and industrial purposes.

Starch has wide domestic culinary applications as thickener in gravies and soups, stabilizers in beverages and salad dressings and for dusting bread. Starch also finds wide applications in industries for sizing yarns preparatory to weaving, for finishing cloth and printing fabrics with paste made from mainly starch and dye and for the hydration of fibres during pulping in the paper industry (Ihekoronye and Ngoddy, 1989). The physico-chemical properties responsible for the functional characteristics of starches include particle size, purity, gelatinization temperature, degree of retrogradation, swelling power, solubility index, viscosity, water absorption/binding capacity and moisture.

*Dioscorea bulbifera*, both the edible and the wild varieties, promises a potential source of starch for both domestic and industrial applications in view of its rich starch content. Starch from the edible species could be used mainly for domestic applications while that from the wild varieties could be extensively applied in the industries.

Presently yams are not listed among the most common sources of industrial starch which is primarily provided by corn (*Zea mays*), potato (*Solanum* spp.), wheat (*Triticum* spp.), tapioca (*Manihot* spp.) and rice (*Oryza sativa*) (Alexander, 1996). Starch is a polysaccharide carbohydrate which constitutes about 20-30% of mature tubers of yam, the amount depending principally on the age of the tuber (Martin, 1979). Egbe and co-workers (1984) reported the starch content of 21.0% for *Dioscorea bulbifera*. Generally, there is a dearth of information on the starch of *Dioscorea bulbifera*.

The cultivation of *Dioscorea bulbifera* in Nigeria in recent times appears to be stagnating which is unfortunate in the light of the food shortages and escalating food prices being experienced in the country and which increased production and consumption of this yam variety might have helped to mitigate. The problem of declining interest in the cultivation and use of *Dioscorea bulbifera* as food and other purposes in Nigeria may be attributed to the limited areas of its application currently due to lack of sufficient information on the nutritional and industrial potentials of the yam. Availability of information on the potential application of the starch from *Dioscorea bulbifera* may help to stimulate interest in the cultivation of the yam and arrest the decline in its production.

The objectives of this study, therefore, were twofold.

(i) To isolate starch from *Dioscorea bulbifera* through a suitable method.

(ii) To generate data on the physicochemical properties which would provide information on the potential applications of the starch.

**MATERIALS AND METHODS.**

**Collection of samples**

*Dioscorea bulbifera* tubers were purchased from Watt and Ika-Ika Oqua markets in Calabar. The tubers from the two locations were mixed together
and a representative sample extracted for analysis.

**Isolation of starch from *Dioscorea bulbifera* tubers:**

The sampled tubers were peeled, sliced and kept under distilled water to avoid browning. The pieces were dried in an air-draught oven at 60°C for 24 hours and allowed to cool to room temperature. The dried pieces were crushed to powder, dispersed in water and filtered. The starch was allowed to settle under gravity after filtration, the supernatant decanted and the starch dried in the oven at 40°C for 24 hours, and allowed to cool to room temperature, stored in polythene bags, and subsequently used for analyses.

**Determination of the Purity of Starch**

The purity of starch from *Dioscorea bulbifera* was determined by the method of Osborne and Voogt (1978). Starch (1g) was hydrolyzed in aqueous solution with hydrochloric acid and the resulting glucose quantitated titrimetrically with 0.1N sodium thiosulphate solution. The amount of glucose corresponding to the volume of thiosulphate solution consumed was determined from a conversion table and expressed as percentage starch content.

**Determination of Amylose Content:**

The amylose content was determined by the method of Farhat et al (1999) as modified by Riley et al (2006). Starch (0.5g) was defatted by standard AOAC (2000) method using hexane. The defatted starch (0.1g) was dispersed in 1.0ml of ethanol and 9.0ml of 1M sodium chloride (NaCl). The volume was made up to 100ml with distilled water and 5ml aliquot transferred to a volumetric flask containing 25ml of water. 0.5ml of 1M acetic acid and 1.0ml of iodine solution (0.2% iodine in 2% potassium iodide) were added and the volume made up to 50ml with distilled water and absorbance read at 620nm. The amount of amylose in the starch was read from a calibration curve prepared by using corn starch of known amylose content.

**Determination of Granule Size and Morphology.**

Starch granule morphology was measured by staining 0.01g granule suspension with 0.1% iodine solution and viewed under a microscope. Granule size was measured and photographed with an S26045 zoom stereo microscope (Olympus Optical Co. Japan) fitted with a calibrated eyepiece to calculate the average and range of granules (Umerie and Ezenzo, 2000).

**Determination of Swelling Power and Solubility Index:**

The swelling power and solubility index of *Dioscorea bulbifera* starch were determined by the method of AACC (1983). Swelling power is a measure of the hydration capacity of starch and is expressed as the weight of centrifugal swollen granules, divided by the weight of the original dry starch used to make the paste. *Dioscorea bulbifera* starch (1g) was suspended in 10ml of distilled water and incubated in a thermostatically controlled bath at 95°C in a tarred screw cap tube of 15ml. The suspension was stirred intermittently over 30min periods to keep the starch granules suspended. The tube was then rapidly cooled to 20°C. The cool paste was centrifuged at 2000 x g for 15 min to separate the gel and supernatant. Thereafter, the aqueous supernatant was removed and poured into a dish for subsequent analysis of solubility index. After this, the weight of the swollen sediment was determined. The supernatant liquid (dissolved starch) was poured into a tarred evaporating dish and placed in an air oven at 100°C for 4 hours. Water solubility index was determined from the amount of dried solids recovered by evaporating the supernatant, and was expressed as gramme dried solids per gramme of sample.

\[
\text{Solubility (\%)} = \frac{W_s}{W_w} \times 100 \quad \text{(1)}
\]

\[
\text{Swelling Power} = \frac{W_s}{W_w} \times 100 \quad \text{(2)}
\]

\[
\text{Dry matter Weight} (W_{dm}) = W - (100 - \text{Solubility})
\]

where,

\[
W_s = \text{Weight of supernatant granules}
\]

\[
W_w = \text{Weight of centrifugal swollen granules}
\]

\[
MC = \text{Moisture content of sample on dry basis (decimal)}
\]

**Determination of Degree of Retrogradation:**

The method of Potter (1954) was modified and applied in the determination of the relative degree of retrogradation. Instead of the Blue Value Index (BVI) used by Potter (1954), the solubility index as measured by the method of AACC (1983) was applied. The solubility index of starch measured with the addition of surfactant and without it were determined and used to calculate the percentage degree of retrogradation. The surfactant used was 0.4M CaCl₂.

Relative degree of retrogradation (\%) = \frac{S_2 - S_1 \times 100}{S_2} \quad (3)

where

\[
S_1 = \text{Solubility index of starch with surfactant added}
\]

\[
S_2 = \text{Solubility index of starch without surfactant}
\]

**Determination of Gelatinization Temperature Range**

The gelatinization temperature range was determined by the method of MacMaster (1964). The gelatinization temperature range was determined by measuring the range within which the loss of birefringence of the heated starch sample occurred under a polarizing microscope. *Dioscorea bulbifera* starch (2g) was dispersed in 10ml of distilled water in a beaker immersed in a water bath. A thermometer for monitoring the temperature and stirring the slurry was placed in the beaker and the temperature of the bath raised by 1°C every 5 min. Samples were withdrawn at intervals of 1°C, mounted on the microscope and observed for loss of birefringence under polarized light. The temperature range at which loss of birefringence occurred was read from the thermometer and recorded.
Determination of Water Absorption/Binding Capacity

Water absorption capacity was determined by the method of Linko et al (1980). 1g of sample was mixed with 10ml of distilled water. The sample was allowed to stand for 30min at 21°C, centrifuged at 5000 x g for 30 min, and the volume of the supernatant was noted in a 10ml graduated cylinder. The density of distilled water was assumed to 1g/ml. The result was expressed on a dry weight basis.

Determination of Other components of Starch.

Moisture, ash, crude protein and crude lipid were analysed according to AOAC (2000) methods. A 2g portion of the sample was used in each case. Phosphorous was also determined by the standard titrimetric method of AOAC (2000).

RESULTS

Data on the physicochemical properties of Dioscorea bulbifera starch analysed in this study are as shown in the Tables 1 and 2.

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Lipid (%)</th>
<th>Phosphorous (%)</th>
<th>Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.00±0.35</td>
<td>1.33±0.10</td>
<td>3.42±0.25</td>
<td>0.26±0.03</td>
<td>0.089±0.001</td>
<td>95.06±0.55</td>
</tr>
</tbody>
</table>

Table 1: Proximate Composition of Dioscorea bulbifera Starch

Table 2: Pasting and Functional Properties of Dioscorea bulbifera Starch.

<table>
<thead>
<tr>
<th>Property</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amylose content (%)</td>
<td>17.28±0.13</td>
</tr>
<tr>
<td>Swelling power (%)</td>
<td>9.21±0.05</td>
</tr>
<tr>
<td>Water solubility index (%)</td>
<td>5.31±0.04</td>
</tr>
<tr>
<td>Water absorption/binding capacity (%)</td>
<td>103.39±0.22</td>
</tr>
<tr>
<td>Relative degree of Retrogradation (%)</td>
<td>23.81±0.83</td>
</tr>
<tr>
<td>Gelatinization temperature Range (°C)</td>
<td>98 – 66</td>
</tr>
<tr>
<td>Particle size (µm)</td>
<td>2 – 5</td>
</tr>
</tbody>
</table>

DISCUSSION

Amylose-Amylopectin Content.

The amylose content of Dioscorea bulbifera starch was found to be 17.28%. Hence, the amyllopectin content obtained by difference was 82.72%. There are no available reports in the literature of the amylose content of Dioscorea bulbifera. Some workers have reported that the amylose-amyllopectin ratio of yam starches varies from species to species. Rasper and Coursey (1967) reported a value of 23% for the amylose content of D. rotundata and 21% for D. alata. The same authors found the amylose content of D. esculenta and D. dumetorum starches to be between 14 – 15%. Oke and co-workers (2002) reported a range of 27.5 – 41.90% for many varieties of Dioscorea alata. Thus, the amylose content of D. bulbifera starch of 17.28% found in this study was higher than the values reported for Dioscorea esculenta and Dioscorea dumetorum but lower than those reported for Dioscorea rotundata and Dioscorea alata.

The amylose portion of the starch affects its degree of retrogradation, swelling and hot paste viscosities (Hollo, 1960; Shimelis and Rakshit, 2005).

Low levels of amylose in starches are associated with lower degrees of retrogradation (Hollo, 1960). The result of this study therefore showed that Dioscorea bulbifera starch should retrograde rather slowly in the light of the low level of amylose in it. Retrogradation has grave implications for the stability and acceptability of starchy foods as it causes staling of such foods. The data from this study therefore indicated that products derived from Dioscorea bulbifera should be relatively stable.

Proximate composition of Dioscorea bulbifera Starch.

Ash: The ash content of the starch from Dioscorea bulbifera was 1.33%. Available reports for the ash content of some other yam starches showed that Dioscorea alata, Dioscorea rotundata, Dioscorea esculanta and Dioscorea dumetorum contained ash in the range of 0.16 - 0.46% (Rasper, 1967; Nkala et al, 1994). The result obtained for Dioscorea bulbifera was thus higher than those reported for other yam species. Ash is a source of mineral elements and the result would imply that Dioscorea bulbifera starch was a better source of minerals relative to other yam species so far studied.

Lipid: The value obtained for the crude fat content of Dioscorea bulbifera starch was 0.26% which was low compared to the result of 3.73% obtained by (Nkala et al, 1994) for Dioscorea dumetorum. To the best of our knowledge the lipid content of other yam starches are not available. Lipids have strong effect on the properties of starch. The formation of starch-lipid or starch-surfactant complexes improves the textural properties of various foods (Hoover, 1998). Tuber starches contain much lower quantities of lipids so that the effect is not so pronounced.

Protein. The protein content of Dioscorea bulbifera starch was found to be 3.42% in this study. To the best of our knowledge, there are no available data on the protein content of yam starches in the literature. The ability of food materials to absorb water is attributed to its protein content (Kinsella, 1976) and the data from this study is suggestive of good absorptive capacity of Dioscorea bulbifera starch.

Phosphorous: The phosphorous content of Dioscorea bulbifera starch from this study was 0.089%. The phosphorous content of Dioscorea rotundata varieties (Moorthy and Nair, 1989) ranged from 0.011% - 0.015% and that of Dioscorea dumetorum was 0.003% (Nkala et al, 1994). The phosphorous content from this study was higher than any so far reported for other yam starches. Wide variation occurs in the phosphorous contents of various starches. High phosphorous content imparts high viscosity to starch and also improves the gel strength. High phosphorous starches are used in food applications requiring high gel strength, such as

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jellies (Moorthy, 2002). Thus, Dioscorea bulbifera starch would be useful in this application.

Moisture:

The moisture content found in this study for Dioscorea bulbifera starch was 14% on dry weight basis. The moisture content of dry starches varies from 6-16% depending on the process used to dry the starch (Moorthy, 2002). The level of moisture in Dioscorea bulbifera starch was within the range reported for other starches. The considerable variation in moisture content of tuber starches has been attributed to climatic factors (Rasper, 1967). Low moisture level is compatible with extended half-life of food materials. Higher levels of moisture may lead to microbial damage and subsequent deterioration in quality.

Purity of Starch.

The starch isolated from Dioscorea bulbifera by the method described above had a purity of 95.08%. Starches are normally associated with some impurities such as nitrogen, fatty acids and mineral elements collectively referred to as ash. The difference between hundred percent purity of starch and the value of 95.08% found in study may be due to the presence of these impurities.

Morphology and size of starch granules.

The morphology of Dioscorea bulbifera starch granules observed in this study varied considerably from irregular flat to semi cylindrical shapes while granule size varied from 2 to 5 µm in diameter. There are no available reports on the morphology and granule size of Dioscorea bulbifera starch. However, available data in respect of some other yam species showed that the size and shape of starch granules varied widely among yam starches (Moorthy, 2001; Kay, 1987; Rasper and Coursey, 1967). Dioscorea rotundata and Dioscorea alata have large granules with size of the order of 10 - 70µm while Dioscorea esculenta and Dioscorea dumetorum have granule size of the order of 1 - 5 µm (Rasper and Coursey, 1967).

The granule size of 2 - 5 µm found in this study was lower than the values of 10 - 70 µm reported for Dioscorea alata and Dioscorea rotundata but of the same order (1 - 5 µm) reported for Dioscorea esculenta and Dioscorea dumetorum (Rasper and Coursey, 1967). Granule size affects gelatinization temperature, swelling power and solubility index (Scott, 1996; Lindeboom et al., 2004). Large granule size results in faster swelling but unstable viscosity (Opata et al., 2009). The small granule size observed for Dioscorea bulbifera starch would positively affect the stability, smoothness and mouthfeel of the cooked yam and other products from it.

Gelatinization Temperature Range.

The gelatinization temperature range of Dioscorea bulbifera starch found in this study was 58 - 66°C. this result is similar to that reported for potato starch by Whistler and Paschall (1965). The gelatinization of starch does not occur at one temperature but over a range due to various factors including differences in size among individual granules (Greenwood, 1970). The initial gelatinization of Dioscorea bulbifera starch occurred at 58°C. Among starches, a range of 8°C is not uncommon. The gelatinization temperature of Dioscorea bulbifera starch is moderate and suggests the presence of moderately strong bonding forces in the granules. High gelatinization temperature in starches had been explained to be due to extensive hydrogen bonding caused by the presence of a large number of amylose molecules (Goering and Schuh, 1967). It is unlikely that this explanation is applicable to Dioscorea bulbifera starch as the amylose content is low and only 17.28%. The moderately high gelatinization temperature range observed for Dioscorea bulbifera starch might be due to intra and intermolecular bondings both in the amylose and amylopectin molecules. Starch gelatinization is of culinary importance and it is responsible for the thickening of sauces, soups and gravies. The gelatinization process is also important in making bread to the desired crumb structure and texture of the products (Ihekeronye and Ngoddy, 1985). Wheat flour which is popular for baking bread and corn starch used in the thickening of sauces, soups and gravies show gelatinization temperature ranges of 59.2 - 64°C and 62 - 70°C respectively (Ihekeronye and Ngoddy, 1985). The gelatinization temperature range of Dioscorea bulbifera starch found in this study was 58 - 66°C and similar to those of wheat and corn starches suggesting that Dioscorea bulbifera starch could be used as a substitute for both wheat and corn starches wherever they find applications as in gravies, sauces, soups and in bread making. In Nigeria where wheat is imported, and corn flour finds other compelling uses, the substitution of Dioscorea bulbifera starch (flour) in place of them for the more mundane culinary applications would be a welcome relief.

Degree of Retrogradation:

The degree of retrogradation of Dioscorea bulbifera starch measured in terms of the water solubility index was 23.81%. The result showed that Dioscorea bulbifera starch retrograded rather slowly which might be related to the low amylose content of the starch. Starch is composed of amylose and amylopectin and of these two components, amylose retrograde faster than the amylopectin (Hollo, 1960). Consequently, the low degree of retrogradation found in this study could be attributed to high amylopectin and low amylose content of Dioscorea
bulbifera starch. Low retrogradation is useful in food systems as it enhances stability.

Swelling Power.

The swelling power of yam starches varies widely among species. The result of this study showed that Dioscorea bulbifera had a swelling power of 9.21%. The low swelling power shown by Dioscorea bulbifera starch is indicative of a highly ordered internal arrangement in the granules of the starch. A low swelling power of starches is associated with a highly ordered internal arrangement within the granules (Soni et al., 1985) while a high swelling power is suggestive of weak internal bonding as well as the presence of ionizable groups which promote swelling due to mutual electrical repulsion (Leach et al., 1959). The low swelling power shown by Dioscorea bulbifera might limit its use in bread making in spite of other favourable characteristics. However, it might be useful in the biscuit industry.

Water Absorption Capacity:

The water absorption/binding capacity of Dioscorea bulbifera starch was found to be 103.39% and high. Soni et al. (1985) attributed high water binding capacity to loose association of starch polymers in the native granules while Wooton and Bramunuarachchi (1978) considered the hydroxy groups and the interglucose oxygen atoms as the water binding sites. Proteins may also account for the absorption capacity observed in this study (Kinsella, 1976). High water absorption capacity in food systems enables bakers to manipulate the functional properties of the dough in bakery products (Achinewhu and Orafun, 2000; Iwe and Onadipe, 2001). Thus, Dioscorea bulbifera starch may find application in the formulation of bakery products.

CONCLUSION.

This study has shown that it was easier to produce starch in good yield from the dry rather than the wet matter of Dioscorea bulbifera. A new approach to the determination of the degree of retrogradation of starches through the use of water solubility index (WSI) in place of the blue value index (BVI) used by Potter (1954) was also adopted.

The data obtained for physicochemical properties of Dioscorea bulbifera starch in this study showed that the starch was a potential material for the production of adhesives, syrups, soups and gravies as well as bakery products. The small granular size of Dioscorea bulbifera would also make it an ideal filler in biodegradable plastics and in aerosols and talcum powders.

It was concluded, therefore, that edible species of Dioscorea bulbifera portended good sources of starch for industrial and culinary purposes while the wild forms could be exploited exclusively for industrial applications subject to further investigation.

REFERENCES
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