

Physicochemical Properties of Starch obtained from Tubers of *Anchomanes difformis* and *Tacca involucrata*

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Abstract

Anchomanes difformis and *Tacca involucrata* are wild tuberous plants rich in starch. Starch granules were isolated from the tubers of these plants using wet milling method of extraction and further subjected to physicochemical characterization by different experimental procedures. *A. difformis* afforded starch with a percentage yield of 28.15 % while *T. involucrata* yielded 12.25 % starch. The physicochemical analysis of isolated starch compounds revealed a swelling power of 8.5 and 12.0, gelatinization temperature of 73 and 75 °C, pasting temperature of 79.96 and 77.89 °C, with a pH of 5.8 and 6.5 and bulk density 0.77 and 0.76 g/cm³ for *A. difformis* and *T. involucrata* respectively. The microscopic and X-ray diffraction analysis indicated that the starch granules are generally small in size, with clustered arrangement. This study has revealed that both *A. difformis* and *T. involucrata* are not only rich in starch but that the investigated starch compounds have high potential for industrial applications and could serve as alternative sources to avoid competition with the staple crop, cassava.

Keywords: Starch, *Anchomanes difformis*, *Tacca involucrata*, physicochemical properties

Introduction

Starch is a naturally occurring, biodegradable, and widely available polysaccharide molecule. It is composed of the chains of glucose units $(C_6H_{12}O_6)_n$, with n ranging from 300 to 1000, bound with a glycosidic linkage. Starch occurs widely as reserve for carbohydrate in stems, grains, and fruits of all forms of green plants. Cereal grains such as corn, wheat, sorghum and tubers and some roots such as potato, tapioca, arrowroot, etc. are some of the commercial sources of starch for industrial exploitation. Different starches differ depending on their botanical source, biochemistry and morphological properties (Neelam *et al.*, 2012). Starch is also one of the most widely used biomaterial in the food, textile, cosmetics, plastics, adhesives, paper and pharmaceutical industries. 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).

Tacca involucrata (Sch. and Thonn.) is a rhizome, usually found in the savannah grassland. It belongs to the family *Taccaceae*. It is a perennial herb with a round swollen tuber underneath the ground from which it shoots out a leaf stalk up to 1 m long. The plant had a long history of being a major source of carbohydrate in the savannah belt of Nigeria until the advent of cassava when its importance waned, it is now harvested wild (Nwokocha *et al.*, 2011). The tuber is first boiled to remove the toxic element and then converted to flour and employed in a variety of food preparations. *T. involucrata* is an under-utilized crop with a high potential as a source of industrial starch (Nwokocha *et al.*, 2011).

Anchomanes difformis, a member of Araceae family (Burkill, 1985), is an herbaceous plant with prickly stem having huge divided leaf and spathe that arise from a horizontal rhizome occurring in the forest of West Africa. It is sometimes called forest Anchomanes in English (Oyetayo, 2007), while among the Yoruba speaking populace of the Southwestern Nigeria, it is known as Abirisoko, Ogirisako or Igo (Soladoye *et al.*, 2005).

The quest for cheaper and higher quality starch from biological materials has necessitated this research into lesser known plants which have better physicochemical properties over the present commercial starch sources. Therefore, the purpose of this study is to compare the physicochemical properties of starch granules from tubers of *Tacca involucrata* and *Anchomanes difformis* obtained from South Western Nigeria.

Materials and Methods

Freshly harvested rhizomes of *Anchomanes difformis* and *Tacca involucrata*, grown naturally were collected from Ekiti East local government area of Ekiti State, and authenticated at the Herbarium unit of the Department of Plant Biology, University of Ilorin, Ilorin, Kwara state. Voucher specimens were deposited, the following voucher numbers were thus issued; UILH/001/1850 and UILH/001/1930 for *T. involucrata* and *A. difformis* respectively.

Isolation of Starch

The tubers were weighed, washed, peeled and cut into 2 cm long chips. The chips were homogenized in a Phillips HR1720 blender with 50 ml of water. The slurry obtained was mixed with five times its volume of water and sieved with a muslin cloth. The starch milk was allowed to settle overnight and the supernatant decanted. This was washed several times with fresh water. The resultant white starch was sun dried, pulverized, weighed and stored in a plastic container (Nwokocha *et al.*, 2009).

Determination of physicochemical properties

Swelling power:

The method described by Daramola and Osanyinlusi (2006) was used to determine the swelling power with slight variations. 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. This was carried out over a temperature range of 50 – 100 °C.

The swelling power was calculated using the expression 1.

$$\text{Swelling power: } \frac{\text{Weight of starch paste}}{\text{Weight of dry starch sample}} \cdot 1$$

Solubility Index:

Solubility index was determined over a temperature range of 50 – 100 °C as follows: 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 (Mandala and Bayas, 2004).

Gelatinization Temperature:

This was evaluated using the method of Attama *et al.* (2003). The starch sample (1 g) was placed in a 20 ml beaker and 10 ml of distilled water was added. The dispersion was heated on a hot plate at between 60 – 80 °C. The gelatinization temperature was then read with a thermometer suspended in the starch slurry.

pH:

A 20 % w/v dispersion of the sample was shaken in water for 5 minutes and the pH was determined using a pH meter (ATPH-6 water proof pocket pH tester meter).

Pasting Properties:

Pasting characteristics such as pasting temperature and viscosity of the starch obtained from the tubers were determined with a Rapid Visco – Analyser (RVA), (Model RVA 3D+, Network Scientific, Australia). The starch (2.5 g) sample was weighed into a dried empty canister, 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well filled into the RVA as recommended. The slurry was heated from 50 – 95 °C with a holding time of 2 minutes followed by cooling to 50 °C with 2 minutes holding time. The rate of heating and cooling were at constant rate of 11.25 c/min viscosity and pasting temperatures were read from the pasting profile with the aid of thermocline (Adewumi *et al.*, 2015).

Microscopy:

A scanning electron microscope (SEM) (model EVO/MA 10) was used to determine the particle size at 50 X and 100 X magnifications. The sample was imaged with the secondary electron detector at an accelerating voltage of 5 kV, probe current of 200 pA and variable pressure of 50 Pa (Fanon *et al.*, 1992).

X-ray Diffraction:

The starch samples were pulverized to powder particle size of less than 63 μm mesh sieve and equilibrated in a desiccant of a desiccator overnight. The samples were placed in the cavity of a disc sample holder of the diffractometer. Diffraction diagrams were recorded using Inel X-ray equipment (Inel CSP120, 45410 Artenay, France) operating at 40 kV and a generator current of 30 mA. Cu K-1 radiation ($\lambda = 0.15405 \text{ nm}$) was selected using a quartz monochromator and scanned at $\theta - 2\theta$ degrees. A curved position detector was used to monitor the intensities using 2 h exposure periods. PeakFit software (Systat software Inc., Chicago, USA) was used to quantitatively estimate the degree of crystallinity using the ErfcPk type in peak fitting and analyze the amorphous area ($r^2 > 0.99$), the percentage crystalline area was obtained by difference.

Results and Discussion

Chemical Composition:

The starch compounds obtained were slightly off white in colour with no smell and yields of about 28.15 % and 10.25 %. Both yields were considered to be appreciable especially when compared with starch compounds from other sources such as cassava, 30 % (Fakir *et al.*, 2012) corn, 66.31 % (Khan *et al.*, 2014) and *Mesua ferrea*, 5.85 % (Sayeed *et al.*, 2004). The pH measurement showed that starch *A. difformis* is very close to that of corn starch properties (Omojola *et al.*, 2010), comparable with the previous pH values reported for starch from tubers and within the pH range of 3 – 9 obtained for most used in the pharmaceutical, cosmetics and food industries (Coursey and Rasper, 1967).

Amylose and amylopectin composition varied in both starch compounds with values from 20.68 to 10.30 % and 75.60 to 90.70 %, respectively. While, *Tacca involucrata* shows the highest amylose content this is also higher than 20.68 % compared to that obtained from Cassava starch. High amylose starch compound would be suitable for the coating of fried products, pasta, sweet and bread production (Vignaux *et al.*, 2005). The very low amylose content obtained in *Anchomanes difformis* makes it a good choice food for diabetics and other health conscious individuals (Agbo and Odo, 2010). Table 1 presents physicochemical properties of the starch.

Gelatinization temperature:

The temperature at which starch granules undergo transition from the crystalline state to a gel is referred to as gelatinization temperature. This is an important parameter in starch characterization. The gelatinization temperature of *Tacca* starch (75 °C) obtained is comparable to that of cassava starch (Omojola, 2013) while that of *Anchomanes* starch is 73 °C which falls within the range of gelatinization temperatures commonly observed for starch compounds (Afolayan *et al.*, 2012). It has however been established that high amylose starch sometime have high gelatinization temperature and since *Tacca* starch has higher amylose content which well related to the reduced gelatinization temperature (73 °C) for *Anchomanes* starch.

Bulky Density:

Bulk density is a function of particle size; particle size is inversely proportional to bulk density. Table 1 showed that there is little significant difference in values of the bulk densities for both *Tacca* and *Anchomanes*. Their relatively high value of bulk density supported their suitability as drugs binder and disintegrant in pharmaceuticals (Zaku *et al.*, 2009].

Table 1: Physicochemical properties of starch from *Tacca involucrata* and *Anchomanes difformis*

S/N	Physicochemical Analyses	<i>Tacca involucrata</i>	<i>Anchomanes difformis</i>
1	Starch yield (%)	28.15	12.25
2	pH	6.50	5.80
3	Gelatinizaton Temperature (°C)	75.00	73.00
4	Bulk density (g/cm ³)	0.76	0.77
5	Pasting Temperature (°C)	77.89	79.96
6	Amylose (%)	24.40	10.30
7	Amylopectin (%)	75.60	90.70

Morphology:

The variability in the granular shape of the starch samples are shown in Plate 1. The shapes of *Tacca involucrata* and *Anchomanes difformis* starch granules were heterogeneous, having different shapes of oval and polyhedral for *Tacca* and hexagonal for *Anchomanes*. From particle size distribution analysis of the starch compounds, the results showed that the mean granule size of 6.49 μm for *Tacca involucrata* and a granule size range of 1-5 μm for *Anchomanes difformis*. This clearly showed that both starch compounds are smaller than cassava starch which has a mean granule size of 11.82 μm and average range of 1.05 – 36.08 μm . Granule size and particle size distribution of starch influences the functional properties of starch this includes; swelling power, solubility and digestibility (Moorthy et al., 2002). Generally, small and medium sized starch granules have been reported to have varied utilization in the food and pharmaceutical industries properties (Omojola et al., 2010) which gives credence to the industrial potentials of the starch.

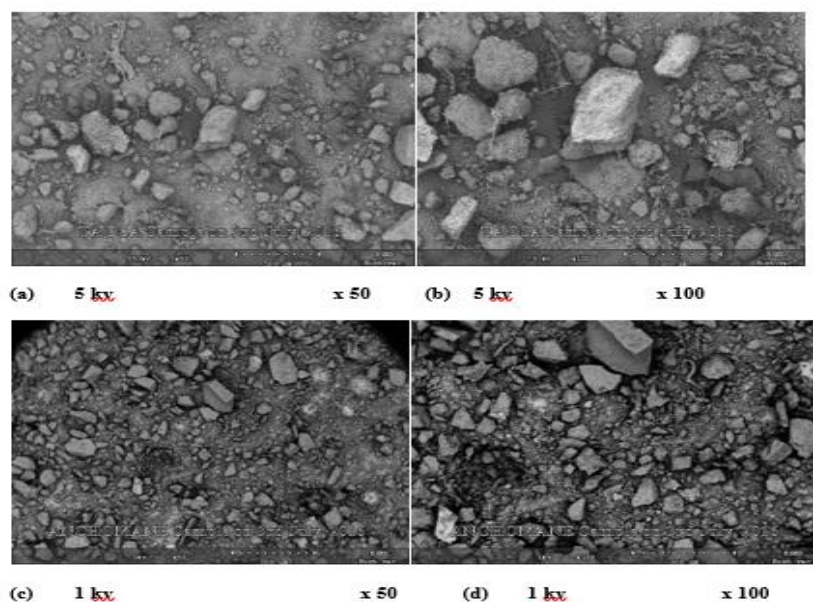


Plate 1: Photomicrograph of (a) *Tacca* Starch and (b) *Anchomanes* Starch sample at 5 KV, and 1 KV respectively

X-ray diffraction:

The x-ray diffractogram of starch compounds presented in Fig. 1 and Fig. 2 showed that *Tacca* gave characteristic peaks at 10.8° , 18.2° , 20.5° , 24.0° , 24.8° 2θ which are diffraction peaks corresponding to A-type diffraction pattern while *Anchomanes* gave characteristic peaks at 18.12° , 18.27° , 23.7° , 24.0° 2θ which are diffraction peaks corresponding to A-type. Cassava starch was also reported by Rocha *et al.*, (Rocha *et al.*, 2010) to exhibit A-type diffraction pattern. It has been shown in previous studies that an A-type X-ray diffraction starch, that has a high proportion of short branch chain amylopectin, has inferior crystallinity and thus is more susceptible to digestion by α -amylase compared to its opposite, B-type starch (Jane *et al.*, 1997).

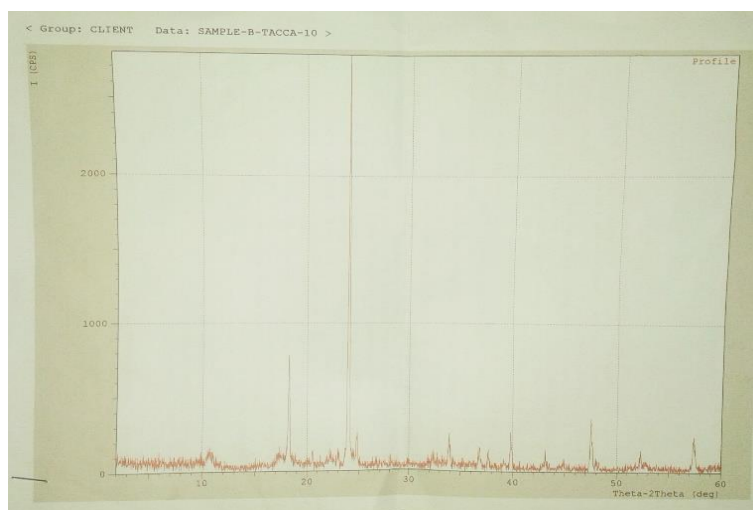


Fig.1: X-ray Diffractogram of *Tacca involucreta* Starch

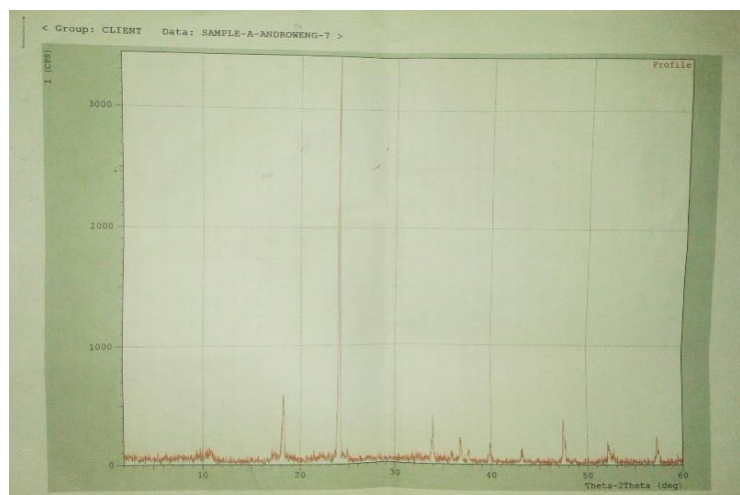


Fig. 2: X-ray diffractogram of *Anchomanes difformis* Starch

Swelling and Solubility properties

Figure 3 and 4 showed the swelling power and solubility properties starch compounds from *Tacca involucrata* and *Anchomanes difformis* as a function of temperature.

Solubility and swelling power provides the evidence of interactions between the water molecules and the starch chains in the crystalline and amorphous regions (Ratnayake *et al.*, 2002). Swelling power increased with increased temperature (60 to 100 °C) in the starch samples with *Tacca* possessing a higher swelling power than *Anchomanes*. The solubility profile also shows an increase in solubility with temperature rise which relaxes at 90 °C before rising again for *Anchomanes*, this was an indication that the starch granules has a greater intra granular organization in which most of the bonding forces required energy supplied in the temperature range 80 to 90 °C to cause a relaxation (Nwokocha *et al.*, 2009). Factors that influence the solubility of starches include: origin, granule size and other component s of the starch. Solubility has been shown to positively correlate with swelling, indicated that solubilization occurred along with granular swelling (Srichuwong *et al.*, 2005). Increased swelling power is an indicative of the suitability of such starch for use as a disintegrant in the pharmaceutical industry.

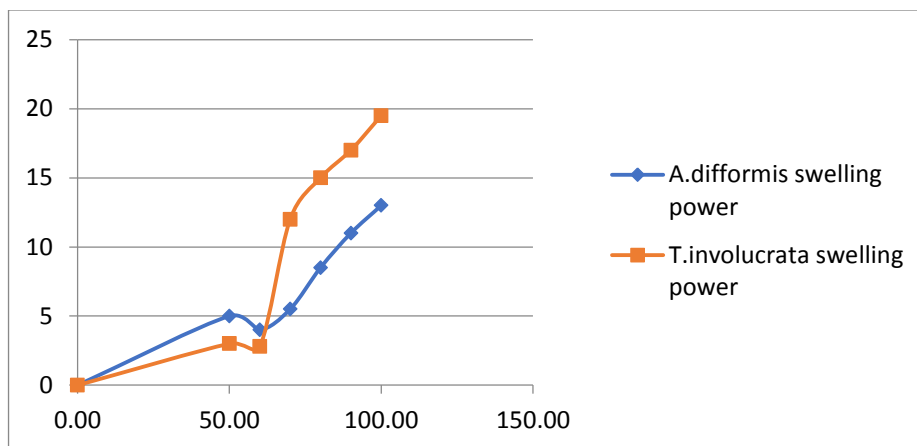


Fig. 3: Swelling Power Profile of *Anchomanes difformis* and *Tacca involucreta* starch

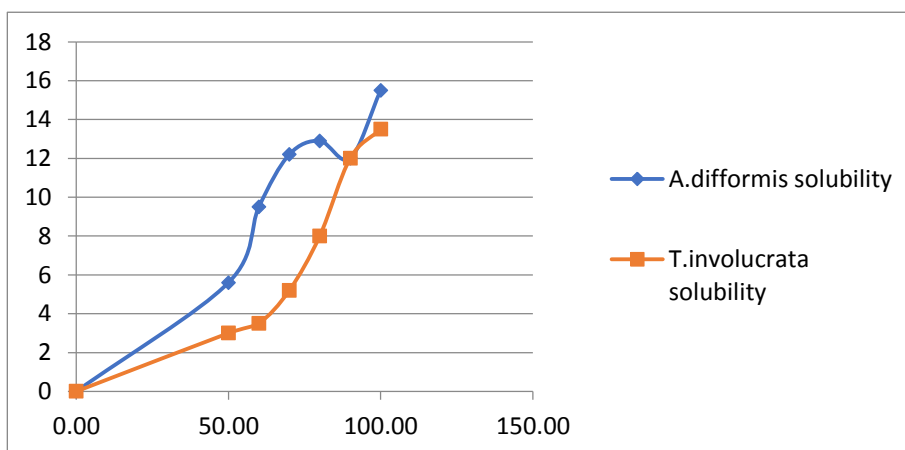


Fig. 4: Solubility Index Profile of *Anchomanes difformis* and *Tacca involucreta* Starch

Conclusion

The results of the physicochemical and functional properties of starch compounds from *Tacca* and *Anchomanes* revealed that the starch granules can compare favourably with starch from cassava plant. This confirms the potential of starch compounds from *Tacca* and *Anchomanes* in both food

and non-food industries. These results may allow variety of choice when sourcing new ingredients or ingredients with properties to enhance production and development of starch. This will help to lessen stress on starch from other well-known sources such as cassava.

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