Physical, Chemical and Functional Characterization of a Novel Starch from *Dioscorea sagittifolia* and its Synergetic Studies with *Terminalia mantalys* Gum

¹O. U. Igwe*, ¹E. H. Oko, ¹J. C. Nnaji and ¹F. Chisom

¹Department of Chemistry, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267
Umuahia, Abia State, Nigeria

*Corresponding author's e-mail: okenwauigwe@gmail.com; +234806-386-2710

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ABSTRACT

A novel starch extracted from *Dioscorea sagittifolia* and its composite blends with gum from *Terminalia mantalys* were studied. The starch/gum blends were prepared in the following ratio: 3.0:0.0, 3.0:0.25, 3.0:0.50, 3.0:0.75 and 3.0:1.0. The proximate and functional properties of the novel starch were determined using standard procedures. The proximate analysis of the starch gave values of 14.37%, 84.63%, 2.30%, 1.92%, 1.34%, 0.56% and 93.88% for moisture, dry matter, crude protein, ash, crude fibre, crude fat and carbohydrate respectively. The energy value was 389.76 Kcal/100 g. The amylose and amylopectin contents of the novel starch were 23.65 and 76.35% respectively. There were significant differences in the solubility index, bulk/particle density, least gelation concentration and foaming capacity of the free starch and its blends while there were no significant differences in their water absorption capacity and swelling power. The peak and trough viscosities ranged from 26.17 (starch/gum ratio of 3.0:0.25) to 246.75 RVU (starch/gum ratio of 3.0:1.0) and 19.00 (starch/gum ratio of 3.0:0.25) to 221.75 RVU (starch/gum ratio of 3.0:1.0) respectively. Final viscosity ranged from 73.25 (starch/gum ratio of 3.0:0.25) to 290.67 RVU (starch/gum ratio of 3.0:1.0) while the pasting temperature and time ranged from 88.05 to 95.00°C and 6.87 to 7.0 min, respectively. The morphology of the starch granules (size and shape) was studied with scanning electron microscope (SEM), which revealed cylindrical, rod-like or oblong and oval shaped granules that are symmetrical with smooth surfaces and with lengths between 134 and 179 µm. There were no appreciable change in shapes and sizes of the starch granules after modification with *T. mantalys* gum. Generally, there were improvements in the functional properties of the starch after modification. The nutritional properties of the novel starch have also been revealed.

Keywords: *Dioscorea sagittifolia*, *Terminalia mantalys*, Starch, Gum, Functional properties

1.0: INTRODUCTION

Dioscorea species are generally called 'yam' and they originated from Africa and Asia but are now found in other parts of the world [1]. Yam belongs to the family *Dioscoreaceae* comprising many species [2]. It is used as a staple food in West Africa and contributes to the diet need and economic life of the people [3]. In Southeast Nigeria, yam is so popular and important that it has ritual and socio-cultural significance before and after its planting and harvesting. Yam is consumed in different forms. It could be boiled, fried, roasted or processed into flours for various products. The boiled yam could be pounded and eaten with soup. A few yam species have been reported to be grown for medicinal purposes [4].

Dioscorea sagittifolia is an unarmed, herbaceous perennial climbing plant with stems growing up to 8 m tall from a tuberous rootstock. The stems twine right-handed around other plants for support, or scramble over the ground. The deeply-rooted tubers are protected by spiny roots [5]. The tuber is gathered from the wild for local use as a food. The plant is occasionally cultivated for its tuber. So many *Dioscorea* species are well known and studied, however, there is paucity of information on *D. sagittifolia* because this plant is not popular and no research work was found on the starch from the tuber of the plant. It is noteworthy that this plant helped to sustain the 'Item People' of Bende Council Area of Abia State, Nigeria, during and shortly after the Nigeria-Biafra civil war that lasted between 1967 and 1970 (Personal

communication with the lead author's mum). The plant is called 'kokonsilo' by the natives of Item.

Nowadays, *D. sagittifolia* tubers are greatly underutilized as a staple food due to the abundance of other *Dioscorea* species and also because of its perceived and unfounded unimpressive food quality properties as well as its size. Also, it is seen as a food meant for the poorest amongst the poor. In order to exploit *D. sagittifolia* starch for diverse uses, the inherent/intrinsic tuber starch properties that presumably influenced its usage should be well investigated. Modification of the starch is also necessary to study the extent to which these intrinsic properties are altered which would suggest how best the modified composite could be applied or utilized in the industry. In view of the foregoing, we herein make the first report on the physical, chemical and functional characterization of *D. sagittifolia* starch and its synergetic studies with *Terminalia mantalys* gum.

2.0: MATERIALS AND METHODS

2.1: Sample Collection and Identification

D. sagittifolia tubers were harvested in the month of March 2019 from a fallowed farmland at Okoko Item in Bende Local Government Area of Abia state, Nigeria. *Terminalia mantalys* gum was harvested from the tree plant located in front of the College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike. For the purpose of proper identification, the plant materials (leaves and stems) were also harvested. They were then identified and authenticated at the Plant Taxonomy Section, Forestry Department, Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria.

2.2: Starch Extraction

Starch extraction was carried out using the wet method as described by Bensi *et al.* [6] with slight modification. One kilogram of fresh tubers were thoroughly washed with water and then

peeled with the aid of a clean kitchen knife and thoroughly washed again before being chopped into small pieces of approximately 1 cm length and then crushed in a blender to produce a pulp. The pulp was suspended in ten times its volume of deionised water and filtered through a clean muslin cloth. The filtrate was allowed to stand for 2 h until the starch settled. Afterwards, the starch was separated from the supernatant and suspended again in water. This washing procedure was repeated five times until a white starch and a translucent supernatant were obtained. The starch was collected and dried at room temperature under forced air circulation for approximately 12 h. The extraction of *D. sagittifolia* starch required the use of sodium sulfite as an antioxidant at a concentration of 0.03% in accordance with established food legislation to avoid enzymatic oxidation. This antioxidant was only employed during the first extraction phase i.e. during tuber milling.

2.3: Preparation of *Terminalia mantalys* Gum

T. mantalys gum was oven dried at 45°C for 3 h for easy milling. It was however milled by means of a hammer mill and passed through a 500 µm sieve and then transferred into an air-tight container where it was stored properly.

2.4: Starch/Gum Blending

D. sagittifolia starch was thoroughly mixed with *T. mantalys* gum powder with the aid of a blender in the following starch/gum ratio: 3.0:0.0, 3.0: 0.25, 3.0:0.5, 3.0:0.75 and 3.0: 1.0. A uniform blending was achieved in 10 min.

2.5: Chemical Analysis

2.5.1: Proximate Analysis

Moisture and total ash contents were determined by the method described by AOAC [7]. Crude protein, fibre and fat contents were determined by the method described by James [8]. Carbohydrate content was calculated by difference as described by James [8]. The difference in value was taken as the percentage of total carbohydrate content of the sample. Calculated thus:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Protein} + \% \text{ Moisture} + \% \text{ Fat} + \% \text{ Ash})$$

2.5.2: Amylose Determination

The starch amylose and amylopectin contents were determined according to the method described by Valcárcel-Yamani *et al.* [9]. A volume of 5.0 mL of dimethyldisulfide and urea (UDMSO) at 6 M, 9:1 was added to 40 mg of isolated starch sample; the suspension was vigorously shaken and incubated in a boiling water bath for 30 min, then placed on a stove at 100 °C for 90 min. A 0.5 mL aliquot of this solution was diluted to 50 mL with distilled water and 1.0 mL I2-KI (2 mg I2, 20 mg

KI/mL). Finally, the absorbance at 635 nm was measured with a UV-Vis B582 spectrophotometer. The amylose content was determined with a standard curve, using stock amylose (from potato starch, SigmaAldrich Co. St. Louis, USA).

2.6: Energy Value

The gross food energy value (E.V) of *D. sagittifolia* starch was estimated in Kcal/100 g energy using the Atwater Factor Method as described by Osborn and Voogt [10], by using the equation below.

$$E.V = [(\%Crude\ Fat \times 9) + (\%Crude\ Protein \times 4) + (\%Carbohydrate \times 4)]$$

2.7: Physical and Functional Properties

2.7.1: Water Absorption Capacity, Swelling Power and Solubility

The swelling power and solubility patterns of *D. sagittifolia* starch and its blends with *T. mantaly*s gum were determined as described in Kusumayanti *et al.* [11] at different temperatures (50, 60, 70, 80 and 90°C). Sample (0.5 g dry weight) was suspended in 20 ml water in centrifuge tube (50 ml) of known weight, heated for 30 min at specified temperature, swirling at every 5 min, and then centrifuged at 8000 rpm for 20 min using Beckman Coulter Centrifuge (Avant J-26 XPI, High Performance Centrifuge, USA). The supernatant was discarded and the sediment mass was measured as Wsd. The swelling power (g/g) was calculated as the ratio

of Wsd to the original sample weight (Ws). The volume of the supernatant was measured and was collected on a pre-weighed evaporating crucible dish, oven dried at 105°C for 12 h and the dried residue was weighed as Wd. The solubility was then expressed as a percentage of dried supernatant weight to the original sample weight (Ws). Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

$$\text{Swelling Power (g/g)} = \frac{Wsd}{Ws \text{ (dry basis)}}$$

$$\text{Solubility (\%)} = \frac{Wd}{Ws \text{ (dry basis)}} \times 100$$

Where, Wsd = dried sediment mass, Ws = original sample weight, Wd = dried residue

2.7.2: Least Gelation Concentration

The least gelation concentration (LGC) was determined by the method of Sathe *et al.* [12]. Suspensions of 2, 4, 6 and 8 up to 20 g/100 ml distilled water were prepared and 10 ml of each dispersion was transferred into a test tube. The test tubes were then heated for 1 h in a boiling water bath, followed by rapid cooling in ice and further cooling for 2 h at 4°C. The least gelation concentration was determined as the concentration when the sample in the inverted test tube will not slip.

2.7.3: Bulk Density/Particle Density

The bulk density (BD) of the sample was determined using the method described by Onwuka [13]. About 5 g of the flour sample was weighed into 50 ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top 10 times from a height of 5 cm. The volume of the sample was recorded.

$$\frac{\text{Bulk density (g/cm}^3\text{)}}{\text{weight of sample}} = \frac{\text{volume of sample after tapping}}{\text{volume of sample after tapping}}$$

2.7.4: Foaming Capacity

The foaming capacity (FC) was studied by the method of Coffman and Garcia [14] with slight modification. 2 g of the sample was weighed and added to 50 ml distilled water in a 100 ml

measuring cylinder. The resulting suspension was homogenized by properly shaking for 5 min to foam. The total volume after 30 seconds was recorded. The percentage increase in volume after 30 seconds is expressed as foaming capacity.

$$\text{Foaming capacity (\%)} = \frac{\text{volume after homogenization} - \text{volume before homogenization}}{\text{volume before homogenization}} \times \frac{100}{1}$$

2.7.5: Pasting Properties

Pasting characteristics were determined using a rapid visco analyzer (RVA) (Model RVA 3D+ Newport Scientific Australia). About 3 g of the starch samples were weighed into a previous dried canister and 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the rapid visco analyzer as recommended. Each suspension was kept at 50°C for 1 min and then heated up to 95°C with a holding time of 2 min. followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling were at a constant rate of 11.55°C per min. Peak viscosity, trough, breakdown, final viscosity and setback were read from the pasting profile with the aid of a thermocline for windows software connected to a computer.

2.8: Morphological Property

Morphological characterization of the free starch of *D. sagittifolia* and its blend were carried out via scanning electron microscopy (SEM) using a modular high vacuum coating system (model SU900, bal-Tech) and FEI quanta 600 FEG model microscope. Samples were prepared and fixed in stubs on double sided carbon tape and coated with platinum for plating in modular equipment at a pressure of 5.00 KV.

2.9: Statistical Analysis

Statistical treatment was performed by analysis of variance (ANOVA). Results were expressed as the mean $\pm$ standard deviation of triplicate determinations.

3.0: RESULTS AND DISCUSSION

3.1: Proximate Composition

The proximate composition of *D. sagittifolia* starch is shown in Table 1.

Table 1: Proximate composition (on dry basis) of starch from *D. sagittifolia*

Proximate composition	<i>D. sagittifolia</i> starch
% Moisture content (MC)	15.37 $\pm$ 0.09
% Dry matter	84.63 $\pm$ 0.09
% Crude protein (CP)	2.30 $\pm$ 0.11
% Ash	1.92 $\pm$ 0.04
% Crude fibre (CF)	1.34 $\pm$ 0.06
% Crude fat	0.56 $\pm$ 0.02
% Carbohydrate (CHO)	93.99 $\pm$ 0.11
% Amylose	23.65 $\pm$ 0.16
Energy value (Kcal/100 g energy)	389.76 $\pm$ 0.18

Values are means $\pm$ standard deviation of triplicate determinations.

The moisture content was found to be 15.37% and dry matter to be 84.63%. The moisture content estimates directly the water content and indirectly the dry matter of the samples. Moisture content values of 14.6 and 16.9% were reported by Schirmer *et al.* [15] for regular and

waxy potato starches respectively. According to Hayma [16], flours with moisture content less than 14% can resist microbial growth and help to improve storage stability. Therefore, the higher the moisture contents the higher the rate of spoilage. However, further drying will

enhance the moisture content acceptability of the sample. The crude protein was found to be 2.30%. The protein content of *D. sagittifolia* starch was low, showing that the sample is almost wholly starchy material. The ash content was found to be 1.92%. The low amount of ash implies a low amount of the presence of inorganic constituents since the ash content is a measure of the presence of inorganic matter of the sample [8]. The crude fat content was 0.56% which compares with a value of 0.32% reported by Ojo *et al.* [17] for cassava starch. The crude fibre content was found to be 1.34%. Ahmadu *et al.* [18] reported a range of 1.08 – 1.13% crude fibres content for three cultivars of *D. rotundata* starch. The carbohydrate content and energy value were found to be 93.88% and 389.76 Kcal/100 g respectively, showing that it is a carbohydrate class of food. The value of carbohydrate obtained in this study can be compared to a value of 89.62% reported for cassava starch by Ojo *et al.*, [17] and 93.4% reported for potato starch by Schirmer *et al.* [15]. Hoover [19], reported that the presence of low levels of lipid, protein and ash in starches from roots and tubers does not have significant effects on their functional properties. The low values of protein, ash, crude fat and crude fibre in this study suggests that the starch extracted

was of high purity and will not affect the overall functional properties of the starch.

The amylose content of *D. sagittifolia* starch was found to be 23.65%. Yam starches with amylose contents ranging between 11% and 30% have been reported [20]. The amylose content of yam starches has been shown to vary with cultivar, geographical location and planting season. Riley *et al.* [21] reported 23% as the amylose content of *D. alata* starch while Sibanda *et al.* [22] reported a value of 24.5 % amylose content for *D. Schimperiana* starch. The amylose content of *D. rotundata* starch has been reported by Farhat *et al.* [23] as 23% while Ahmadu *et al.* [18] reported a range of 22.86 – 23.16% amylose content for three cultivars of *D. rotundata* starch. These values compare with the value of amylose content obtained in this study for *D. sagittifolia* starch.

3.2: Functional Properties

Table 2 shows the functional properties of *D. sagittifolia* free starch and its blends.

Table 2: Functional properties of *D. sagittifolia* free and modified starch with *T. mantalys* gum

Starch/ Gum blend (g/g)	Water absorption capacity (WAC) (%)	Swelling power (SP) (g/g)	Solubility index (SI) (%)	Bulk/particle density (BD) (g/cm ³)	Least gelation concentration (LGC) (%)	Foaming capacity (FC) (%)
3.0:0.0	25.20±0.25	9.93 ± 0.1	33.78±0.53	0.54±0.01	28.25±0.21	14.67±0.13
3.0:0.5	26.85±0.65	9.39±0.53	16.50±0.30	0.85±0.03	14.63±0.81	3.89±0.03
3.0:1.0	25.25±0.70	9.45±0.50	15.90±0.28	0.86±0.10	16.20 ±0.60	3.70±0.04

Values are means ± standard deviation of triplicate determinations

3.2.1: Water Absorption Capacity (WAC)

Water absorption capacity is the ability of a sample to absorb water. The water absorption capacity improved when *D. sagittifolia* free starch was blended with *T. mantalys* gum although there was no significant difference in the values obtained. The values ranged from 25.20% for the free starch to 26.85% and 25.25% for the blended starch. Lawal [24]

reported that starch with a larger proportion of amorphous material would have more water binding sites and higher WAC. The presence of the gum distorted the initial amylose and amylopectin ratio in the free starch. Hydrophilic constituents such as polysaccharides have been reported to be responsible for high WAC exhibited by certain flours [25]. The difference in WAC observed could be as a result of increase in polysaccharides made possible by

modification with *T. mantalys* gum. The value of 25.20% WAC reported herein for *D. sagittifolia* starch compares with a value of 27.50% reported by Eke [26] for sweet potato starch.

3.2.2: Solubility Index (SI)

There is a significant difference between the solubility of *D. sagittifolia* free starch (33.78%) and the composite blends (16.50 and 15.90% for 3.0:0.5 and 3.0:1.0 starch/gum ratio respectively). Solubility is an indicator of degree of dispersion of granules after cooking [27]. The solubility decreases with increase in the blend. High solubility has been associated with high content of amylose which is believed to leach out easily during the swelling process [28]. Therefore the decrease in solubility of the composite blends may be as a result of low content of amylose in the composite blends. The value of 33.78% SI observed in this study for *D. sagittifolia* free starch is much higher than the values of 14% and 12% reported by Eke [26] for Irish potato and cassava starches respectively.

3.2.3: Swelling Power (SP)

The swelling power is a measure of the ability of starch to absorb water and swell. No direct correlation was observed between the solubility index and swelling power of the free starch and their composite blends. There was an insignificant decrease in swelling power after blending. The values ranged between 9.39 g/g and 9.93 g/g which indicate a clear resistance to swelling. The result showed that the free starch had higher swelling power than the composite blends. Highly associated starch granules with an extensive and strongly bonded structure have been reported to exhibit resistance toward swelling [29]. Also, Umar *et al.* [30] reported that highly associated starch granules display a greater resistance towards swelling owing to an extensive and strongly bonding micelle structure which affects the film forming capabilities of starch. Hence, the lower SP observed in this study could be due to stronger association or bonding forces in the starch granules of both the free and modified ones. The value of 9.93 g/g SP of the free starch of *D. sagittifolia* compares with a value of 8.05 g/g SP reported by Eke [26] for cassava starch.

3.2.4: Least Gelation Concentration (LGC)

The least gelation concentration is the lowest concentration required for the formation of a self-supporting gel [17]. The blended starch samples showed lower values of gelation capacity (14.63 and 16.20%) than *D. sagittifolia* free starch (28.25%). Boye *et al.* [31] reported that samples with lower least gelation capacity have greater gelling capacity. Therefore the blended samples in this study would have better gelling capacity than the free starch. Variation in gelling properties has been associated to the relative ratio of different constituents such as proteins, lipids and carbohydrate [32]. It was observed that the higher the LGC, the higher the quantity of flour needed to form a gel and the lower the LGC the better the gelling ability of the flour. The value of LGC of 28.25% reported for the free starch of *D. sagittifolia* is different from the values of 18.53 and 18.73% reported by Ojinnaka *et al.* [33] for purple and white cultivars of aerial yam (*Dioscorea bulbifera*) respectively.

3.2.5: Bulk Density (BD)

As shown in Table 2, the bulk density of the free starch was 0.54 g/ml but increased to 0.85 g/ml and 0.86 g/ml in starch/gum ratios of 3.0:0.5 and 3.0:1.0 respectively. Bulk density (BD) is the amount of powder by weight that is present in a defined volume. It helps to ascertain the sample heaviness, handling requirement and the type of packaging materials suitable for storage and transportation of food materials. A high bulk density is very important in packaging and transportation, and is desirable as it can significantly reduce costs. Modu *et al* [34] reported bulk density values of 0.51 g/ml and 0.76 g/ml for cocoyam (*Colocasia esculenta*) and yam (*Dioscorea spp.*) respectively. These values are comparable to the value of bulk density obtained herein for *D. sagittifolia* starch.

3.2.6: Foaming Capacity (FC)

Foaming capacity (FC) is used to determine the ability of the starch to foam which is dependent on the presence of the flexible protein molecules which decrease the surface tension of water [35].

The foaming capacity of the free starch was 14.67%. This value decreased to 3.89 and 3.70% for starch/gum ratio of 3.0:0.5 and 3.0:1.0, respectively. The gum must have reduced the protein content of *D. sagittifolia* starch giving rise to lower values of FC.

3.2.7: Pasting Properties

The pasting properties of *D. sagittifolia* starch and its blends with *T. mantalys* gum are shown in Table 3.

Table 3: Pasting properties of *D. sagittifolia* free starch and starch/gum blends

Test	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time(mins)	Pasting Temp. (°C)
ADS	39.33	30.25	9.08	79.08	48.83	7.00	95.00
BDS	26.17	19.00	7.17	73.25	54.25	7.00	92.80
CDS	77.33	59.33	18.00	154.58	95.25	7.00	90.45
DDS	171.58	148.50	23.08	243.42	94.92	7.00	88.05
EDS	246.75	221.75	25.00	290.67	68.92	6.87	88.15

ADS: *D. sagittifolia* free starch i.e. 100 % starch (without gum)

BDS: *D. sagittifolia* starch/gum blend (3.0: 0.25)

CDS: *D. sagittifolia* starch/gum blend (3.0: 0.50)

DDS: *D. sagittifolia* starch/gum blend (3.0: 0.75)

EDS: *D. sagittifolia* starch/gum blend (3.0: 1.00)

The RVA was used to study the pasting properties of *D. sagittifolia* starch and its blends with *T. mantalys* gum. During the test, the starch was heated in an aqueous medium to gelatinize it with consequent rise in viscosity, subject to high temperature and controlled shear during which its stability was revealed, and then cooled to provide an indication of setback. During gelation, samples were assessed for pasting temperature, peak viscosity, trough viscosity, peak time, breakdown, setback and final viscosity.

Viscosity is low at the beginning of gelatinization but it increases as the temperature increases. The temperature at which the viscosity of the stirred starch/flour slurry begins to rise is the pasting temperature. It gives an indication of the minimum temperature required to cook a given flour/starch sample and this has implications for the suitability of other food components [19]. The pasting temperature for the free starch was 95°C while that of the blends ranged between 88.05 and 92.8°C. Pasting time is the measure of the cooking time [36]. The pasting time of the free starch was 7.00 min and that of the blends ranged from 6.87 to 7.00 min. The values of pasting temperature and peak time

observed in this study were higher compared to what was reported by Otegbayo *et al.* [37] for varieties of *D. rotunda* and *D. alata*. The higher values of pasting temperatures and peak time for *D. sagittifolia* starch suggest a higher gelatinization temperature and a longer cooking time. However, blending reduced the pasting temperatures. Starches with low pasting temperature and pasting time are always preferred for economic reasons.

Peak viscosity is the maximum viscosity attained by the paste during the heating cycle due to starch granules swelling and leaching out of the soluble components into the solution. It reflects the ability of starch granules to swell freely before their physical breakdown [38] and often correlates with product quality. The peak viscosity was observed to range between 26.17 and 246.75 RVU. The free starch had a peak viscosity of 39.33 RVU. Aside from the starch fraction blended with 0.25 g of gum, there was an increase in peak viscosity with increased amount of gum. The peak viscosities are generally low. This could be as a result of the lower swelling power observed in this study. The relatively longer time taken for *D.*

sagittifolia starch and its blends to paste, further indicates stronger bonding forces in their starch granules. Trough viscosity is the minimum viscosity value that measures the ability of paste to withstand breakdown during cooling [17]. The values of trough viscosity obtained ranged from 19.00 to 221.75 RVU. The free native starch had a trough viscosity of 30.25 RVU.

The breakdown is established as the difference between the peak and trough viscosity and shows the stability of the starch paste during heating. The breakdown values ranged from 7.17 to 25.00 RVU. The free starch had a value of 9.08 RVU which is very low compared to what was reported by Ojo *et al.* [17] for cassava starch. These low values are expected since the peak viscosities were low, which in turn, are related to the degree of swelling of the starch granules during heating. A low breakdown value however suggests the stability of starches under hot conditions [17]. This means that *D. Sagittifolia* starch can withstand a great deal of shear stress during cooking.

The setback is established as the difference between final viscosity and trough viscosity and shows the stability of the starch paste during cooling. The setback values ranged between 48.83 and 95.25 RVU. The free

starch had the lowest setback value of 48.83 RVU. This value increased in the presence of the gum registering a highest value of 95.25 RVU at 0.5 g gum weight. The values of setback obtained in this study are very low compared to what is available in literature for other starches [9,39].

The viscosity after cooling cooked paste to 50°C is the final viscosity. Starch paste increases in viscosity when cooled. The increase in viscosity is not only caused by simple kinetic effect of cooling but also by re-association of molecules, particularly amylose [19]. Final viscosity is the most commonly used parameter to determine the quality of starch-based samples because it indicates starch/flour ability to form a gel after cooking. The final viscosity values obtained herein ranged from 73.25 to 290.67 RVU. The free native starch had a final viscosity of 79.08 RVU. This value is very low. The study revealed that final viscosity of the starch blends improved with increase in the amount of the gum in the blends.

3.3: Morphological Properties

The morphological properties of *D. sagittifolia* starch granules are shown in Figure 1A while that of the modified granules are shown in Figure 1B.

Figure 1A: Morphology of *D. sagittifolia* free starch (100% starch) – (1500×)

Figure 1B: Morphology of *D. sagittifolia* starch modified with *T. mantalys* gum – (1500×)

SEM was used to study the morphological characteristics of the starch granules. Figure 1A shows that the morphology of *D. sagittifolia* free starch granules has cylindrical, rod-like or oblong and oval shapes that are symmetrical with smooth surfaces and with lengths between 134 and 179 μm . Riley *et al.* [21] reported similar shapes for certain cultivars of *Dioscorea alata*. Starches high in amylose are many times more elongated [40]. A value of 23.65% amylose obtained in this study is high enough to warrant the elongated shapes observed herein.

Variations in starch granule morphology are usually attributable to the biological origins of the plants [9]. The morphology of starch granules depends on the biochemistry of the chloroplasts or amyloplasts, as well as plant physiology [9,38]. Other factors capable of influencing the starch granule properties are temperature, storage and cultural practices [41]. Fatokun [40] reported that the sizes of granules of starch have been observed to range from small (2–10 μm), medium (10–60 μm) to large (extending to 200 μm usually from rhizomes and tubers). The lengths of starch granules of 134–179 μm observed in this study showed that

the starch granules of *D. sagittifolia* are large. Figure 1B shows *D. sagittifolia* starch granules modified with *T. mantalys* gum. The morphological characteristics of the modified granules found in this study were similar to that of the free starch. There are no appreciable changes in shapes and sizes of the starch granules after modification with *T. mantalys* gum.

4.0: CONCLUSION

The proximate compositions, functional and morphological properties of a novel starch from *D. sagittifolia* have been studied. The proximate analysis revealed the nutritional value of the starch. The starch possessed high calories of energy. However, it had low peak, trough and final viscosities but high pasting temperature and time indicating high duration of cooking which is economically undesirable. Summarily, the functional properties of the starch were found to be poor but got improved when blended with *T. mantalys* gum for specific food and industrial applications. Further work may be required to fully authenticate the properties of *D. sagittifolia* starch.

REFERENCES

- [1] S. K. Hahn, D. S. O. Osiru, M. O. Akoroda and J. A., Otoo (1987). Yam production and its future prospects. *Outlook on Agriculture*, 16(3), 105-110
- [2] D. G. Coursey (1983). Yams: In: Hand book of tropical foods. Chan H.T. (eds). Marcel Dekker, New York, USA. Pp. 555-601
- [3] O. Girardin, C. Nindjin, Z. Farah, F. Eshcher, P. Stamp and D. Otokore (1998). Effect of storage on system and sprout removal on post-harvest yam (*Dioscorea spp*) fresh weight losses. *Journal of Agricultural Science*, 130, 329-336
- [4] E. O. Farombi, J. O. Nwankwo and G. O. Emerole (1997). Possible moderate effect of browned yam flour diet on chemically induced toxicity in the rat. *Food and Chemical Toxicology*, 35, 975-979.
- [5] H. M. Burkil (2004). The useful plants of West Tropical Africa. Royal Botanic Gardens; Kew.
- [6] I. R. M. Bensi, M. T. Labuschagne, A. G. O. Dixon and N. M. Mahungu (2004). Stability of native starch quality parameters, starch extraction and root dry matter of cassava genotypes in different environments. *Journal of Science, Food and Agriculture*, 84, 1381-1388
- [7] AOAC (2000). Official methods of analysis, Association of Official Analytical Chemist, Washington D.C. Pp. 40-60
- [8] C. S. James (1995). Experimental methods in analytical chemistry of foods, Chapman and Hall, New York, Pp. 28-30
- [9] B. Valcárcel-Yamani, G. G. Rondán-Sanabria and F. Finardi-Filho (2013). The physical, chemical and functional

characterization of starches from Andean tubers: Oca (*Oxalis tuberosa* Molina), ulluco (*Ullucus tuberosus* Caldas) and mashua (*Tropaeolum tuberosum* Ruiz & Pavón). *Brazilian Journal of Pharmaceutical Sciences*, 49(3), 453-464.

[10] D. R. Osborne and F. Vooght (1978). The analysis of nutrients in foods. London: academic press.

[11] H. Kusumayanti, N. A. Handayani and H. Santosa (2015). Swelling power and water solubility of cassava and sweet potatoes flour. *Proc Environ Sci.*, 23, 164–167

[12] S. K. Sathe, S. S. Deshpande and D. K. Salunkhe (1981). Functional properties of black gram (*Phaseolus mungo*, L) proteins. *Lebensm-wiss. U. Technol.* 16, 69-74.

[13] B. O. Onwuka (2005). Physicochemical and functional properties of winged bean flour and isolates compared with soya isolate. *Journal of Food Science*, 53(2), 450-454.

[14] C. W. Coffman and V. V. Garcia (1977). Functional properties and amino acid content of protein isolate from mung bean flour. *Journal of Food Technology*, 12, 472-483

[15] M. Schirmer, A. Höchstätter, M. Jekle, E. Arendt and T. Becker (2013). Physicochemical and morphological characterization of different starches with variable amylose/amylopectin ratio. *Food Hydrocolloids*, 32, 52-63

[16] J. Hayma (2003). The storage of tropical agricultural products. Agromosafoundation: Wageningen, Netherlands; Pp. 84

[17] M. O. Ojo, C. C. Ariahu and E. C. Chinma (2017). Proximate, functional and pasting properties of cassava starch and mushroom (*Pleurotus Pulmonarius*) flour blends. *American Journal of Food Science and Technology*, 5(1), 11-18.

[18] U. Ahmadu, O. Agbomeji, M. Yahya and O. A. Odeku (2018). Physicochemical and material properties of starches from three

cultivars of *Dioscorea rotundata*. *Agriculture and Natural Resources*, 52(1), 79-83.

[19] R. Hoover (2001). Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. *Carbohydrate Polymers*, 45, 253-267

[20] C. K. Riley, P. S. Bahado-Singh, A. O. Wheatley and H. N. Asemota (2014). Physicochemical properties of low-amylose yam (*Dioscorea* Spp.) starches and its impact on α -amylase degradation in vitro. *International Journal of Nutrition and Food Sciences*, 3(5), 448-454.

[21] C. K. Riley, A. O. Wheatley and H. N. Asemota (2006). Isolation and characterization of starches from eight *Dioscorea alata* cultivars grown in Jamaica. *African Journal of Biotechnology*, 5, 1528-1536.

[22] S. Sibanda, S. Sibanda, and B. Sychawska (2000). A comparative study of wild yam starch from *Dioscorea schimperiana*. *Journal of Applied Science of South Africa*, 6, 79-86.

[23] I. A. Farhat, T. Oguntona and N. J. Roger (1999). Characterisation of starches from West African yam. *Journal of the Science of Food and Agriculture*, 79, 2105-2112

[24] O. S. Lawal (2004). Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acid thinned new cocoyam (*xanthosoma sagittifolium*) starch. *Food chemistry*, 87, 205-218.

[25] M. O. Aremu, S. K. Basu, S. D. Gyar, A. Goyal, P. K. Bhowmik and B. S. Data (2009). Proximate composition and functional properties of mushroom flours from *Ganaderma spp*, *Omphalotus olearius* (DC) sing and *Hebeloma mesophaeum* (Pers) (Quel) used in Nasarawa State Nigeria. *Malaysian Journal of Nutrition*, 15(2), 233-241.

[26] E. J. Eke (2015). Functional properties of starches, physico-chemical and rheological properties of glucose syrup made from cassava and different potato varieties. *International*

Journal of Recent Scientific Research, 6(6), 4400-4406

[27] S. K. Bhupender, B. Ranesh and S. Y. Balject (2013). Physicochemical, functional, thermal and pasting properties of starches isolated from pearl millet cultivar. *International Food Research Journal*, 20(4), 1555-1561

[28] R. L. Soni, S. S. Sharma, D. Dun, M. M. Gharia and A. M. Ahmedabad (1993). Physicochemical properties of *Quercus leucotricophora* (Oak) starch. *Starch/Starke*, 45(4), 127-130.

[29] H. W. Leach, L. D. McCoven and T. J. Scoch (1959). Structure of the Starch granule, swelling and solubility patterns of various starches. *Cereal Chemistry*, 36, 534-544.

[30] S. Umar, N. Farah, G. Adil and F. A. Masoodi (2016). Art and science behind modified starch edible films and coatings: A Review. *Comprehensive Review in Food Science and Food Safety*, 15(3), 568-580.

[31] Z. F. Boye and A. Pletch (2010). Pulse protein processing and characterization, functional properties and application in foods and feed. *Food Research International*, 43, 414-431

[32] C. F. Chan and P. K. Cheung (1998). Functional properties of flours from three Chinese indigenous seeds. *Food chemistry*, 61, 429-433.

[33] M. C. Ojinnaka, E. N. Odimegwu and R. Ilechukwu (2016). Functional properties of flour and starch from two cultivars of aerial yam (*Dioscorea bulbifera*) in South East Nigeria. *Journal of Agriculture and Veterinary Science*, 9(8), 22-25

[34] S. Modu, H. Hauwa, H. H. Laminu, A. S. Falmata, B. P. Bintu, M. Babakura, G. Chamba and M. Babagana (2016). Studies on the production and evaluation of starch from yam (*Dioscorea spp.*) and cocoyam (*Colocasia*

esculenta) tubers cultivated in Nigeria. *EC Nutrition*, 3(2), 572-588

[35] S. M. Asif-Ul-Alam, M. Z. Islam, M. M. Hoque and K. Monalis (2014). Effect of drying on the physicochemical and functional properties of green banana (*Musa sapientum*) flour and development of baked product. *American Journal of Food Science and Technology*, 2, 128-133.

[36] A. A. Adebawale, L. O. Sanni and S. O. Awonorin (2005). Effects of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science and Technology International*, 11(5), 373-382

[37] B. Otegbayo, J. Aina, R. Asiedu and M. Bokanga (2006). Pasting characteristics of fresh yams (*Dioscorea spp.*) as indicators of textural quality in a major food product.-‘pounded yam’. *Food Chemistry*, 99, 663-669

[38] N. Sing, J. Singh, L. Kaur, N. S. Sodhi and B. S. Gill (2003). Review: morphological, thermal and rheological properties of starches from different botanical sources. *Food Chemistry*, 81, 219-231

[39] O. J. Ikegwu, P. E. Okechukwu and E. O. Ekumankama (2010). Physicochemical and pasting characteristics of flour and starches from (Achi) *Brachystegia* seed. *Journal of Food Technology*, 8 (2): 58-66

[40] O. T. Fatokun (2019). Micrometrics and morphological properties of starch, chemical properties of starch, Martins Emeje, IntechOpen, DOI: 10.5772/intechopen.90286. Available from: <https://www.intechopen.com/books/chemical-properties-of-starch/micrometrics-and-morphological-properties-of-starch> Food Agric 79, 2105-1212.

[41] A. Kaur, N. Singh, R. Ezekiel and N. S. Sodhi (2009). Properties of starches separated from potatoes stored under different conditions. *Food Chemistry*, 114, 1396-1404