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# Analysis of different extraction solvents: Influence on some properties of aerial yam (*Dioscorea bulbifera*) starch

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**Starch was extracted from aerial yam (*Dioscorea bulbifera*) using water, sodium hydroxide, ammonium oxalate, and oxalic acid as extraction solvents, oven-dried at 45°C for 24 h, and milled to flour. The starch obtained was evaluated for yield, chemical and functional properties using standard procedures. The sensory attributes of the starch cooked pastes were also determined. Aerial yam extracted with oxalate gave the highest yield of 20.20% and high amylose content was observed in the water extracted aerial yam samples. A higher purity of 90.45% was observed in the aerial yam starches extracted with oxalate. Water extracted aerial yam starch had the highest swelling power and solubility index of 48.44% and 25.75 g/g with the least gelation capacity of 4% with high pasting viscosities and also low pasting temperature and time. The cooked paste of the starch extracted with oxalic acid was the most acceptable in terms of appearance (8.60) and overall acceptability (8.16). The starch extracted with water had higher swelling power and a solubility index than other starches extracted. Extraction of aerial yam starch with different solvents resulted in variations in the characteristics of the starch, which can find wide applications in both food and non-food industries.**

**Key words:** Aerial yam starch, extraction solvents, yield, chemical, functional, sensory properties.

## INTRODUCTION

The carbohydrate cache is starch, which is one of the most important and necessary carbohydrates in the

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human diet. Starch is commonly obtained from sources like grains, legumes, and tubers, but it may also be derived from different portions of plants, including fruits, leaves, seeds, and roots (Karmakar et al*.,* 2014; Malumba et al*.,* 2017). Starch is a versatile commodity with numerous non-food and food applications. Approximately 70% of all starch used globally is used in the food business, with typical starches like corn, wheat, and potatoes serving as the primary sources in the majority of countries (Malumba et al*.,* 2017; Sanful and Engmann, 2016; Mahmood et al., 2017). Starch is a low-cost material that is used as a gelling agent, thickener, emulsion stabilizer, and water binding agent (Sanful and Engmann, 2016; Mahmood et al., 2017). Starch is a crucial raw ingredient for the food industry, but it is also widely used in the paper, chemical, textile, pharmaceutical, and biotechnological industries (Jiang et al*.,* 2020).

In Nigeria, yam (*Dioscorea* species) is the fifth-most-harvested crop. As a result, cultivation is primarily focused on these types. The primary carbohydrate in yam tubers is starch, which can make up to 80% of the dry mass (Zhu, 2015). The use of yam starches for various food and industrial purposes is receiving more attention (Otegbayo et al*.,* 2014). The aerial yam (*Dioscorea bulbifera*), sometimes known as potato yam or cheeky, is one of the marginalized, underutilized, and less-cultivated yam species but is recently attracting interest in food applications (Zhu, 2015; Ojinnaka et al*.,* 2016). According to Ojinnaka et al*.* (2016), it is being grown in West Africa, South East Asia, and South and Central America. In addition, it is being grown in Asia and Africa. *D. bulbifera* tuber contains a significant amount of amylose and amylopectin as well as a rich source of starch that serves as an essential dietary supplement. In order to address the growing need for starch with high functionality and with a growing population, the current focus is on finding options for producing starch with improved physicochemical and functional qualities (Makroo et al*.,* 2021). Starch must now be obtained from less well-known and underutilized sources due to expanding demand, rising costs from traditional sources, and starch's essential role in both the food and non-food industries. The use of starches from unusual sources, such as aerial yam, for commercial applications may provide a substitute for labor-intensively produced conventional starches, as well as cost savings in industries, as has been suggested for underutilized crops (Makroo et al., 2021). There is therefore a need to explore the starch properties as the physicochemical properties of starch differ with its source, starch purity, and isolation with the practiced extraction procedures or processes, which involve three successive phases viz., anatomic fragmentation, cell breakage, and finally separation/purification processes (Liu, 2005). In general, the alkali and acid isolation methods are typically the two techniques that have been employed most frequently in the food sector, with various adjustments over time (Cardoso et al., 2006; Wang and Wang, 2001).

Researchers are exploring alternative sources for the extraction of starch due to the increased demand for this polysaccharide and the expanding range of its possible applications (Betancur-Ancona et al*.*, 2001). An unconventional source of starch derived from aerial yam starch may be viable at the industrial level; therefore, its properties must be thoroughly researched in order to have concrete viability and diverse application in industries. This may also be one of the recently developed, non-conventional starches that add value to the neglected sources. The physicochemical properties of starch differ with its source (Guinesi et al., 2006) and with the commonly extracted extraction procedures or processes. Successive characterization of starch depends on its purity and isolation. The type of starch selected for specific industrial purposes is selected based on its availability and physicochemical properties; these are influenced by the source from which the starch is extracted (Tao et al., 2019).

The rise in the population has stimulated a corresponding growing demand for starch with high functionality. Because of rising demand, rising costs from traditional starch sources, and the critical role of starch in the food and non-food industries, starch must now be sourced from previously unknown and underutilized sources. The trend toward adding value to underutilized food crops, such as *D. bulbifera* starch, is essential because it has a lot of potential in terms of the nutritional and functional qualities that might be used to create a variety of industrial products. The starch could be investigated for food applications as higher demands for conventional starch sources like cassava and corn increase. According to Sanful and Engmann (2016), the underutilization of aerial yam may be caused by a lack of available studies pointing out potential applications. Therefore, this study will provide information on yield, composition, and other quality characteristics of the aerial yam starch with the ultimate aim of promoting its usage, production, and suggesting plausible products that it could be incorporated into for the creation of new products and varieties.

## MATERIALS AND METHODS

### Materials procurement, preparation and handling

Aerial yam (*D. bulbifera*) bulbils were purchased from a farm in Gboko Local Government of Benue State and species identified at the College of Agriculture Yandev (AOCAY) Gboko, Benue State.

### Extraction of aerial yam starch

The wet extraction method described by Ojinnaka et al. (2016) was adopted with slight modification for the aerial yam starch extraction (Figure 1). One kilogram of aerial yam bulbils was used for each of the extraction solvents. Aerial yam bulbils were sorted and washed to remove extraneous particles and adhering soil, and the skin was

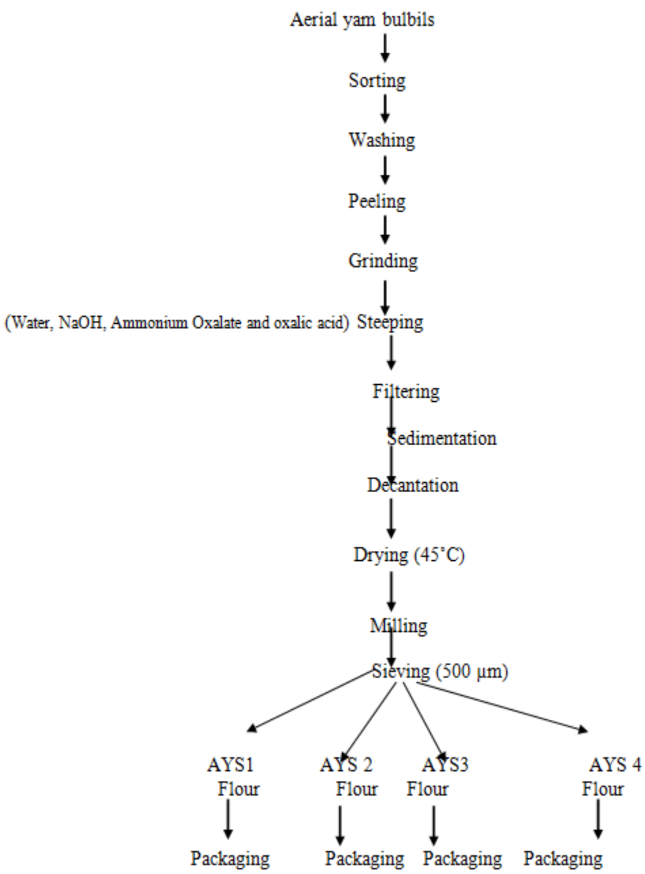


**Figure 1.** Aerial yam starch extraction using different solvents. AYS1 = Aerial yam starch extracted with water, AYS2 = Aerial yam starch extracted with sodium hydroxide (NaOH), AYS3 = Aerial yam starch extracted with ammonium oxalates, AYS4 = Aerial yam starch extracted with oxalic acid.
Source: Ojinnaka et al. (2016) modified.

peeled. The peeled aerial yam was ground using an attrition mill to a pulp with a ratio of 1:2 (aerial yam: water) for all the samples. The pulp was collected and steeped in the different extraction solvents (0.05 NaOH, ammonium oxalate, and 0.025 oxalic acids were prepared for the extraction and 0.25) for 5 h. The pH of the chemically extracted slurries was adjusted to 6.4, which corresponds to the pH of the control (water extracted starch). This also ensures that the starch fraction is unaltered at the extremes of pH. Then, the slurry was filtered through a sieve of 500 µm to separate the filtrate from the residue. The residue was allowed to sediment for 2 h, after which the supernatant liquid was decanted. The sedimentation and decanting processes were repeated twice to ensure that starch was not lost in the extraction solvents. The starch was then dried in an air convection oven (PEK medical) at 45°C for 24 h. This was followed by milling in an attrition mill (Model R175A) and weighing to obtain the various flours. The flour samples were packaged in polyethylene bags before further analysis.

### Yield of extracted aerial yam starch

The amount of extracted starch from 1 kg of weighted aerial yam bulbils was used to calculate the starch yield.

$$\text{Yield capacity (\%)} = \frac{DW}{Weigh\ of\ edible\ portions} \times 100 \qquad (1)$$

Where DW = Dry weight of starch recovered from the extraction.

### Aerial yam starch analysis

#### *Chemical analysis*

#### Determination of proximate composition:

The method described by AACC (2003) was adopted for the proximate composition analysis and the degree of purity was calculated from the difference between 100 and the percentage of moisture, crude protein, lipids, fibre and ash content using the following equation:

% Purity = 100- (% moisture content + % crude protein + % lipids + % ash + crude fibre) (2)

#### Determination of amylose and amylopectin in starch

The amylose content of the extracted aerial starch samples was determined using the iodine colorimetric method reported by Zakpaa et al. (2010). A standard curve for amylose was prepared using different concentrations ranging from 0 to 70 mg of pure amylase. These were weighed into separate 100 ml volumetric flasks and 1 ml of ethanol, 10 ml of distilled water, and 2 ml of 10% sodium hydroxide were added. This was then heated in the water bath until a clear solution was obtained. The solution was cooled and diluted to the 100 ml mark with distilled water. Five millilitres of the solution was measured into a 500 ml volumetric flask and 100 ml of distilled water and acidified with drops of 6 M HCl and mixed thoroughly, followed by the addition of 5 ml of iodine solution, and this was made up to the 100 ml mark with distilled water. A spectrophotometer (UV - visible model 754, China) at a wavelength of 640 nm was used in measuring the absorbance of each. Then 100 mg of the aerial starch was weighed into a volumetric flask and the aforementioned procedures were repeated. The concentration of amylose was calculated from the standard curve. The percentage of amylopectin was calculated from the amylose obtained:

% Amylose = %Amylose of standard × Absorbance of sample Absorbance of standard (3)

While amylopectin was calculated as:

Amylopectin (%) =100 − Amylose (%) (4)

#### Determination of functional properties of aerial starch

The swelling power (SP) was determined using the method reported by Asogbon and Akintayo (2012). While the method described by Onwuka (2005) was adopted for the determination of solubility index (SI) and least gelation capacity (LGC).

#### Pasting properties determination

The pasting properties of the various aerial yam starches were determined using the Rapid Visco Analyzer (RVA, Perten Instrument) as described by Newport Scientific (1998) with slight modification. A starch sample of 3.5 g was weighed into the RVA canister. Twenty-five millilitres of distilled water was added and thoroughly mixed into the slurry in the RVA can. The canister containing the starch slurry was then fitted into the RVA and the slurry was held at 50 to 95°C before being cooled back to 50°C for 12 min while being continuously stirred with a plastic paddle revolving at a speed of 160 rpm. The parameters evaluated were peak viscosity, setback viscosity, final viscosity, trough viscosity, pasting temperature, and time to reach peak viscosity.

### Cooked starch paste preparation

Fifty grams of aerial yam starch were dissolved in 20 ml of water to form a water-starch mixture and heated for 10 min to acquire a cooked starch gel (Ojinnaka et al., 2016).

### Sensory properties

The sensory properties of the cooked aerial yam starches were evaluated using the method described by Ihekoronye and Ngoddy (1985). Thirty (30) untrained panelists of the staff and students from the Department of Food Science and Technology University of Mkar, Mkar, Nigeria were recruited for the sensory evaluation using a 9 point Hedonic scale (1 = Extremely disliked to 9 = Extremely liked). Sensory parameters measured were appearance, aroma, mouthfeel, and general acceptability of the cooked aerial yam starch gel.

### Statistical analysis

All analysis in this work was carried out in triplicates. Data were analyzed using the analysis of variance (ANOVA), while the means were separated by Duncan Multiple Range Test (DMRT), using the Statistical Package for Service Solutions (SPSS) Version 20.

## RESULTS AND DISCUSSION

### Yield and chemical properties of the various extracted starches

The result of the yield and chemical properties of the various extracted starches is presented in Table 1. The starch yield was calculated as the percentage of starch recovered. The yield of the starches ranged from 15.09 to 20.20% with AYS4 having the highest yield. Starch extraction using NaOH (AY2) had the lowest yield. Low extraction yield in NaOH may be explained mainly by loss of starch into the aqueous phase, which may be attributed to the presence of the alkali nature of the solvent and the existence of viscous water-soluble non-starch polysaccharides that impede the filtering process, thereby reducing the rate of sedimentation and carrying of the starch granules over into the wastewater (Ojinnaka et al., 2016). When the grated aerial yam was steeped into aqueous oxalic acid solutions, it was easier to separate the starch slurry for residual mass, probably because of the reduced viscosity which speeds up the settling rate, hence a high starch yield of 20.20% in oxalic acid. The yield values in this study fall within the range of 10.86 to 17.57% of the yield reported by Azima et al. (2020), although a slightly higher yield value for AYS4 is observed. A higher yield ranging from 42.59 to 62.92% was reported by Daiuto et al. (2005) for different solvent extractions of yam starch and 26.61 to 41.73% by Rugchati and Thanacharoenchanapas (2010) for yam tuber starch in Thailand.

All starch flours had moisture content ranging from 8.44 to 8.72%, with AYS1 having the lowest. The moisture content values were <10%. This supports starch stability at room temperature, shelf stability, and extended safe storage (Tortoe et al., 2019; Hayma, 2003). The crude protein content and ash of the samples varied significantly between 0.61 and 0.89% and 0.24 to 0.38%, respectively. The main factor influencing the extraction of starch has been identified as starch granule-associated protein. Proteins may be difficult to remove because they adhere to the surface of starch (Baldwin, 2001). The crude fat and fibre were only detected in the water extracted starch (AYS1). All the starch samples had high percentage purity values in the range of 90.08 to 90.45%, with AYS1 having the lowest percentage purity value. High purity indicates high starch content and signifies the quality of the starch product and also the efficiency of the solvent used in removing other polysaccharides, e.g. cell wall polysaccharides, proteins, and inorganic salts. This is important because the presence of other components could interfere with the functional properties of starch (Tapia et al., 2012). This could also be used to determine the efficiency of the solvents used with respect to aerial yam starch extraction. The extraction solvent had a significant impact on the amylose:amylopectin ratio, which was 23.03:66.05% (AYS1), 20.69:69.47% (AYS2), 20.03:70.42% (AYS3), and 20.10:70.29% (AYS4). There was a significant ($p< 0.05$) difference among the starch samples. The amylose content falls within the range of 17 to 33% and 18 to 29% for tapioca and potato, as reported by Vamadevan and Bertfort (2014). Starch functional properties such as swelling are mainly determined by two main components; these are the amylose and amylopectin ratio (Azima et al., 2016). Amylose content has been reported to influence starch resistance to digestion; it is less digestible than amylopectin (Faulks, 2003). Therefore, higher digestibility may be obtainable in AYS2, AYS3, and AYS4. The low amylose content of the samples indicates that when these starches are incorporated into food products, the swelling of starch will be enhanced (Addy et al., 2014). Since amylose tends to retrograde when foods are frozen and thawed, food with high amylopectin content will be useful in the preparation of foods for freeze-thaw processes (Woo et al., 2021).

### Functional properties of aerial yam starches extracted

The results obtained for swelling power, solubility index, and gelation concentration of aerial yam starches extracted are shown in Table 2. The swelling power and the solubility index of the starches ranged from 36.98

**Table 1.** Effect of extraction solvents on yield and chemical composition of aerial yam starches.

| Parameter (%) | AYS1 | AYS2 | AYS3 | AYS4 |
|---|---|---|---|---|
| Yield | $17.39^{b} \pm 1.15$ | $15.09^{d} \pm 0.55$ | $16.01^{c} \pm 0.96$ | $20.20^{a} \pm 0.03$ |
| Moisture content | $8.44^{c} \pm 0.02$ | $8.71^{a} \pm 0.01$ | $8.72^{a} \pm 0.01$ | $8.55^{b} \pm 0.04$ |
| Crude protein | $0.73^{b} \pm 0.01$ | $0.89^{a} \pm 0.01$ | $0.64^{d} \pm 0.00$ | $0.67^{c} \pm 0.01$ |
| Ash | $0.38^{a} \pm 0.02$ | $0.24^{c} \pm 0.00$ | $0.25^{c} \pm 0.02$ | $0.30^{b} \pm 0.05$ |
| Fat | 0.25 ± 0.32 | ND | ND | ND |
| Crude fibre | 0.12 ± 0.00 | ND | ND | ND |
| Purity | 90.08 | 90.16 | 90.39 | 90.45 |
| Amylose | 23.03 ± 0.25 | 20.69 ± 1.02 | 20.10 ± 0.50 | 20.03 ± 0.78 |
| Amylopectin | 66.05 ± 0.25 | 69.47 ± 1.02 | 70.29 ± 0.50 | 70.42 ± 0.78 |

Values are means ± standard deviation of triplicate determinations. Values in the same row with different superscripts are significantly different ($p<0.05$). AYS1 = Aerial yam starch extracted with water; AYS2 = Aerial yam starch extracted with sodium hydroxide (NaOH); AYS3 = Aerial yam starch extracted with amonium oxalates; AYS4 = Aerial yam starch extracted with oxalic acid.
Source: Authors

**Table 2.** Effect of extraction of solvents on some functional properties of aerial yam starches.

| Starch sample | SP (%) | SI (g/g) | LGC (%) | | | |
|---|---|---|---|---|---|---|
| | | | 2 | 4 | 6 | 8 |
| AYS1 | $48.44^{a} \pm 1.50$ | $25.75^{a} \pm 0.35$ | - | + | + | + |
| AYS2 | $44.23^{c} \pm 0.82$ | $24.73^{b} \pm 0.52$ | - | ± | + | + |
| AYS3 | $45.70^{b} \pm 0.50$ | $25.40^{a} \pm 0.10$ | - | ± | + | + |
| AYS4 | $36.98^{d} \pm 0.73$ | $19.82^{c} \pm 0.01$ | - | - | ± | + |

Values are Means ± standard deviation of triplicate determinations. Values in the same column with different superscripts are significantly different ($p<0.05$). **+ =** gel formed**,** ± = gel slightly formed and - = No gel formed. AYS1 = Aerial yam starch extracted with water; AYS2 = Aerial yam starch extracted with sodium hydroxide; AYS3 = Aerial yam starch extracted withamonium oxalates; AYS4 = Aerial yam starch extracted with oxalic acid SI= Swelling power; WAC = Water absorption capacity; LGC= Least gelation concentration.
Source: Authors

(AYS4) to 48.44% (AYS1) and 19.82 (AYS4) to 25.75 g/g (AYS3), respectively. There was a significant ($p<0.05$) difference in all the starch samples. High swelling capacity has been reported as part of the criteria for a good quality product (Princewill-Ogbonna and Ezembaukwu, 2015). Swelling power and solubility provide evidence of the magnitude of the interaction between starch chains within the amorphous and crystalline domains. The swelling power of starch depends on the water-binding capacity of starch molecules by hydrogen bonding (Lee and Osman, 1991). Srichuwong et al. (2005) stated that solubility could be attributed to the amount of amylose leaching out as the starch swells, the higher the solubility and the water uptake ability of the starches or the degree of dispersion of granules after cooking. The variations could be attributed to the differences in amylose content and extraction solvents.

Starch gelation is as a result of the re-association of hydrated and dispersed starch molecules. There were variations in the gelation concentration of the various starches. According to Otegbayo et al. (2014), starch's ability to form gel increases as LGC decreases. Firm gels were observed between 4 and 8%. AYS1 had the highest gelation capacity among the starches extracted and AYS4 recorded the lowest. Low gelation capacity starches (4-8%) will easily form gel, implying that they can find wide applications in industries where gelation is highly desired, such as pharmaceuticals and paper, as well as in food industries as thickeners, stabilizers, or gelling agents. They can also be used industrially with slight or no modification (Wang and Wang, 2001; Lawal, 2004). The LGC result compares favourably with starches extracted from different yam (*D. bulbifera*) species in Nigeria, which ranged from 2 to 10% (Otegbayo et al., 2014) and cassava starch (8%) reported by Ojo et al. (2017).

### Effect of extraction solvent on the pasting properties of aerial yam starches

The pasting properties of aerial yam starches extracted with different solvents are shown in Table 3. Pasting

**Table 3.** Effect of extraction solvents on the pasting properties of aerial yam starch.

| Sample | Pasting parameters (RVU) | | | | | $P_{temp}$ (0°C) | $P_{time}$ (min) |
|---|---|---|---|---|---|---|---|
| | PV | TV | BV | FV | SV | | |
| AYS 1 | 302.17[a] ± 0.06 | 152.40[c] ± 0.00 | 149.73a ± 0.06 | 381.20[a] ± 0.00 | 228.80[a] ± 0.00 | 77.20[c] ± 0.10 | 5.23[b] ± 0.03 |
| AYS 2 | 259.40[c] ± 0.06 | 139.80[d] ± 0.00 | 119.60b ± 0.01 | 328.33[c] ± 0.58 | 188.53[c] ± 0.58 | 81.50[a] ± 0.06 | 5.47[a] ± 0.02 |
| AYS 3 | 255.37[d] ± 0.29 | 156.40[b] ± 0.01 | 98.96[d] ± 0.28 | 305.50[d] ± 0.00 | 149.10[d] ± 0.01 | 80.08[b] ± 0.00 | 5.33[b] ± 0.01 |
| AYS 4 | 265.00[b] ± 0.30 | 160.47[a] ± 0.06 | 104.52[c] ± 0.33 | 356.80[b] ± 0.00 | 196.33[b] ± 0.06 | 80.10[b] ± 0.03 | 5.33[b] ± 0.01 |

Values are Means ± standard deviation of triplicate determinations. Values in the same column with different. Superscripts are significantly different (p<0.05). PV= Peak viscosity, TV= Trough viscosity, BV= Breakdown viscosity, FV= Final viscosity, SV= Setback viscosity. Ptemp = Pasting temperature**,** Ptime= Pasting time, AYS1 = Aerial Yam Starch extracted with Water, AYS2 = Aerial Yam Starch extracted with NaOH, AYS3 = Aerial Yam Starch extracted with Ammonium oxalates, AYS4 = Aerial Yam Starch extracted with Oxalic acid.
Source: Authors

properties of starch are of importance as they influence the amount of energy required to process starch, the stability of the starch during processing as well as the stability of the products with its probable use in the food industry (Crosbie and Ross, 2007; Atwijukire et al., 2019). The pasting properties are also dependent on the rigidity of starch granules, which in turn affects the swelling potential of granules (Ritika et al., 2010). The peak viscosity and trough viscosity ranged from 255.37 (AYS3) to 302.17 RVU (AYS1) and 139.80 (AYS2) to 160.47 RVU (AYS4), respectively while the breakdown viscosity ranged from 98.96 (AYS3) to 149.73 RVU (AYS1). The peak viscosity indicates the highest viscosity attained by starch slurry during heating. The high peak viscosity values recorded for AYS1 starch are not surprising as high peak viscosities are associated with the degree of swelling of the starch granules during heating (Chandrasekara and Kumar, 2016). Peak viscosity may be associated with starch crystalline structure and amylopectin branch chain distribution. During gelatinization, the crystallinity of starch is lost and amylose leaches out of amylopectin, hence leading to an increase in viscosity. Trough viscosity is related to the degree of gelation of cooked starches and it also measures the ability of the paste to withstand breakdown during cooling (Cornejo-Ramirez et al., 2018). Breakdown viscosity measures the susceptibility or vulnerability of the cooked starch sample to disintegration. A high peak viscosity value is associated with a high breakdown viscosity. High breakdown value is desirable in products that are to be kept at high temperatures for a long time (Princewill-Ogbonna and Ezembaujkwu, 2015). The final viscosity of the various starches studied ranged from 305.50 RVU (AYS3) to 381.20 (AYS1) and setback viscosity ranged between 149.10 (AYS3) and 228.80 RVU (AYS1). Among the aerial yam starch samples, AYS1 had the highest setback value. This means that they are more predisposed to retrogradation. AYS1 could find more use in comparison with the AYS2, AYS3, and AYS4 starches in this study in food products such as noodles where high retrogradation is desired and products which undergo loss of viscosity and precipitation as a result of retrogradation for example soups and sauces. Other attributes closely associated with the pasting properties of starch are the peak temperature and time. The peak temperature ranged from 77.20 (AYS1) to 81.50°C (AYS2). The peak temperature is the lowest temperature at which maximum starch granule swelling is attained (Crosbie and Ross, 2007). High pasting temperature indicates high resistance to swelling. The low pasting temperature recorded for AYS1 implies that starch reached maximum swelling much earlier than the other solvents extracted starches. This is advantageous as it implies lower energy use when used in food applications. The results for pasting behaviour showed that higher amylose content was associated with a lower pasting temperature and a higher peak viscosity in these starches. The peak time, which is related to cooking time, ranged between 5.23 (AYS1) and 5.47 min (AYS2). Interestingly, the pasting time and temperature range are in agreement with those reported for a different cultivar of *D. bulbifera* by Otegbayo et al. (2014).

## Sensory properties of aerial yam starches cooked paste

The results obtained for the sensory properties of aerial yam starch cooked paste are presented in Table 4. The appearance, mouthfeel, flavour and general acceptability of the cooked starch paste ranged from 5.75 (AYS1) to 8.60 (AYS4), 6.15 (AYS4) to 6.85 (AYS3), 6.50 (AYS4) to 6.95 (AYS3) and 7.10 (AYS3) to 8.16 (AYS4), respectively. There was a significant difference ($P \leq 0.05$) among the cooked starch pastes with respect to appearance and overall acceptability. The flavour and mouthfeel were not affected by the extraction solvents as there was no significant difference among the cooked pastes. Aerial yam starch extraction using oxalic acid was recorded as the highest in appearance and acceptability. Visually, the starch sample extracted using oxalic acid resulted in a striking white colour due to its bleaching

**Table 4.** Mean sensory scores of aerial yam starch cooked paste as influenced by extraction solvents

| Sample | Appearance | Mouth feel | Flavour | Overall acceptability |
|---|---|---|---|---|
| AYS 1 | $5.75^{cd} \pm 0.41$ | $6.65^{ab} \pm 1.10$ | $6.70^{a} \pm 0.15$ | $6.20^{c} \pm 0.24$ |
| AYS 2 | $6.15^{c} \pm 0.30$ | $6.25^{ab} \pm 0.90$ | $6.75^{a} \pm 0.26$ | $7.23^{b} \pm 0.40$ |
| AYS 3 | $7.85^{b} \pm 0.45$ | $6.85^{a} \pm 0.25$ | $6.95^{a} \pm 0.55$ | $7.10^{b} \pm 0.60$ |
| AYS 4 | $8.60^{a} \pm 0.25$ | $6.15^{ab} \pm 0.72$ | $6.50^{a} \pm 1.03$ | $8.16^{a} \pm 0.18$ |

Values are Means ± standard deviation of triplicate determinations. Values in the same column with different superscripts are significantly different ($p<0.05$). AYS1 = Aerial Yam Starch extracted with water, AYS2 = aerial yam starch extracted with NaOH, AYS3 = aerial yam starch extracted with ammonium oxalates, AYS4 = aerial yam starch extracted with oxalic acid.
Source: Authors


**Plate 1.** Visual presentation of aerial yam starch flours using different extraction solvents. AYS1 = Aerial yam starch extracted with water, AYS2 = Aerial yam starch extracted with sodium hydroxide (NaOH), AYS3 = Aerial yam starch extracted with amonium oxalates, AYS4 = Aerial yam starch extracted with oxalic acid.
Source: Authors

ability as a reducing agent, while the starch sample treated with water, sodium hydroxide and ammonium oxalate gave a less appealing sight (Plate 1) probably because of the less effect on enzymatic browning. These visual colour differences could restrict the use of the starch samples in products where the colour changes are not desired.

## Conclusion

This study showed that aerial yam starches extracted using different solvents showed appreciable differences in their yield, chemical, and functional properties. Aerial yam starch extraction was considerably faster, with ammonium oxalate giving the highest yield of 18.01%. This could be more economical with functional properties, revealing the diverse applications in both food and non-food industries. The cooked paste from aerial yam starch extracted using oxalic acid as extraction solvent was the most acceptable.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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