CHARACTERISATION OF MICROWAVED AND OVEN DRIED AERIAL YAM (*Dioscorea bulbifera*) STARCH

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CERTIFICATION

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DEDICATION

This report is dedicated to God Almighty, the one who is, who was, who is yet to come, for bringing me this far, for his mercies, steadfast love that endures forever, and for his grace and privilege over my life, Halleluyah to Jesus, Amen.

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All praises to God Almighty, my all sufficient God, Creator, Sustainer and Controller of all that exists.

They say men are built by the people they pass through and people that pass through them.

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ABSTRACT

Native Starch was extracted from Aerial yam (*Dioscorea bulbifera).* The starch extracted was dried using oven (at 30^0C for 24 hours) and microwaved for (30, 45, 60 seconds). Starch obtained using different drying methods and conditions were analysed for their physicochemical, functional properties and pasting characteristics. Results obtained showed that amylose, amylopectin, colour, pH, bulk density, swelling power, least gelation capacity, oil absorption capacity, water absorption capacity ranged from 26.87% to 32.77%, 66.89% to 73.12%, 40.35 to 53.65, 5.67 to 5.68, 0.568 to 0.704 g/cm^3, 7.26 to 8.43%, 9 to 15%, 112.89 to 121.98%, 164.39 to 306. 46% respectively. The pasting properties ranged from 48.9 to 80.7^0C for pasting temperature, 10.9 to 20.50 minutes for pasting time, 493 to 545 BU for peak viscosity, 355 to 823 BU for final viscosity, 315 to 341 BU for breakdown viscosity, 178 to 217 BU for setback viscosity. The effect of different drying methods and conditions on the physico-chemical properties of the starch showed that oven dried starch has a relatively low bulk density compared to microwaved starch, and this implies that oven dried starch is better in terms of storability and transportation while higher bulk density of the microwaved starch showed that it will be a greater ease of dispersibility and reduction in paste thickness. The higher swelling power of the oven dried starch is a very important criteria for a good quality starch and water intake of the starch. The oven dried starch had better gelation capacity, because the lower the gel, the better the sample, and this is for starch granules to rise when incorporating into food products. The oven dried starch had higher water absorption capacity than the microwaved starch, in which it is suitable to entrap large amount of water during processing. The oven dried starch had higher advantages than microwaved dried aerial yam starch.

CHAPTER 1

1.0 INTRODUCTION

Roots and tubers crops provide a substantial part of the world's food supply, and also an important source of animal feed and industrial products (FAO, 2016). It include yam (*Dioscorea spp*), in which Aerial yam (*Dioscorea bulbifera*) is a specie, sweet potato (*Ipomea batatas L*), potato (*Solanum spp)* and edible aroids (*Colocasia spp*) and *Xanthodomia sagittifolium*) (FAO, 2016). Root and tuber crops are second only in importance to cereals as a global source of carbohydrates that basically provides energy in the human diet. They also provide some minerals and essential vitamins (Chandrasekara and Kumar, 2016).

Aerial yam (*Dioscorea bulbifera*) is an underutilized yam among the edible yam species and less consumed by a small number of communities and generally counted among the underutilized plant species (Sanful and Engmann, 2016). It is known with some common names such as potato yam, cheeky yam, bulbils- bearing yam because of its bulb structure, and it is cultivated in West Africa Nigeria, Southeast Asia, South America and Central America (Nwosu, 2014).

On a global basis, approximately 45% of root and tuber crop production is consumed as food, with the remainder used as animal feed and for industrial processing of products such as starch, distilled spirits and a range of minor products (FAO, 2014).

Starch is a polysaccharide carbohydrate that consists of a large number of glucose units joined together by glycosidic bonds (Abbas, 2010). The two macromolecular components of starch are amylose and amylopectin (Jaroslav, 2008).

In food processing industry, **s**tarch derived from roots and tubers, cereal grains, fruits, serves as ingredients used in impacting some specific functional properties in a wide range of food products such as a gelling agent, a thickening agent, a stabilizing agent and emulsifiers (Sanful and Engmann, 2016), and also a major dietary source of carbohydrates that provides large proportion of daily caloric intake (Addy *et al*., 2014).

It is hydrolyzed to glucose by amylolytic enzymes in the digestive tract and then absorbed in the small intestine to be used as a source of energy in the body (Yongfeng, 2013).

Abbas (2010) reported that starch is an important raw material for a number of industries including pharmaceuticals, textiles, paper, and adhesives. It is present in a granular form and varies in appearance depending on its source.

Microwave radiation is the electromagnetic radiation in range from 3000MHz to 30GHz (Lewicka *et al*., 2015). It allows fast transfer of energy into interior of the material where the energy is converted into heat, along with significant reduction of processing time when compared to conventional processes. It saves energy consumption by reducing the drying time from 8 hours to 90 minutes, bacterial counts are also 15 times lower and it also removes the last traces of moisture from material without over drying and that it would have no adverse effect on the functional properties of the material (Sajilata *et al*., 2006). The major advantages of using microwaves for industrial processing are rapid heat transfer, volumetric and selective heating, compactness of equipment, speed of switching on and off and environmentally friendly (Lewicka *et al*., 2015).

Generally, a lot of research has been carried out on aerial yam oven dried starch, but there is little or no information on microwave aerial yam starch.

The objectives of this work are to:

- isolate starch from aerial yam.
- determine the functional and physico-chemical properties of microwaved and oven dried aerial yam starch.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Roots and Tuber Crops

Root and tuber crops, including cassava, sweet potato, potato and yam are the most important food crops for direct consumption in Africa (FAO, 2016). These four crops account for about 95% of the total root and tuber crops production in Africa and produce more than 240 million tons annually on 23 million hectares (FAO, 2014). They have short growing cycle which enables them for flexible planting and harvesting, and also permits quick production of foods to augment "hunger months "that is, a period of several months between harvests when people lack enough food to satisfy their hunger and meet their basic caloric and nutritional needs according to (Sanginga, 2015).

In many developing countries (FAO, 2014) root crops have national consideration benefit and potentials and an increase in production and consumption of domestically produced food staple such as roots and tubers will increase food supplies and broaden the food base of household and national level.

The four crops have common and unique challenges related to quality seed production, new variety adoption, losses due to insects and diseases, low productivity in poor soils, tolerance to stress associated with heat and drought, consumer preferences, and storage of harvested products (FAO, 2016).

There are many compelling reasons for encouraging these humble root and tuber crops for sustainable food production in Africa which are: They are grown in varied agro-ecologies and production systems ranging from highland densely populated regions to lowland drier areas prone to droughts or floods.

Root and Tuber crops are versatile staples to address food and nutrition security and produce more food per unit area of land, compared to many other crops. These crops are also capable in efficiently converting natural resources into a more usable product, caloric energy in the growing season, and is the highest of all major arable crops (Sanginga, 2015).

Roots and tuber production is consumed as foods, the remainder is used as planting materials, animal feed or in the production of starch, distilled spirit, alcohols and a range of other minor products. FAO (2016) stated the roles of roots and tuber which are that: they meet local food preferences (nutrition requirement) i.e. providing an important part of the diet as they produce more edible energy per hectare daily than any other crops groups, they play an important role in food security nutrition and climate change adaptation, they provide important sources of employment and income through direct sale and value addition via processing for food and non-food uses.

Yam, cassava, potato and sweet potato are cheap but nutritionally rich staple foods that contribute protein, vitamin C, vitamin A, zinc, and iron towards the dietary demands of the region's fast-growing towns and cities (Chandrasekara and Kumar, 2016). Another advantage of these crops is that they are largely traded locally and nationally, as opposed to internationally. Starchy root and tuber crops are second only in importance to cereals as global sources of carbohydrates (Sanginga, 2015). They play an essential role in the diet of populations in developing countries in addition to their usage for animal feed and for manufacturing starch, alcohol, and fermented foods and beverages.

Root and tubers adapt to a wide range of uses such as cash crops, raw materials for industrial uses and from fresh to high end processed products. The general characteristics of Root and tubers are as follows according to FAO, (2014): they have high moisture content typically 70 to 80% which makes them difficult to store for a long time, they have large unit size typically 100 grams to 15kg, this makes it difficult to handle and transport to distance market, they have soft texture which can easily be bruised, they are perishable goods and their natural shelf life is a few days to few months.

In the world today, Nigeria produces yam (*Dioscorea spp*.) with an aggregate of 50% annually (FAO, 2016) and out of this, about 50-60 species of yam are found available but only 5 or 6 species are said to be important as food in Nigeria (Addy *et al*., 2014). This happened because some of this food crops has been under-exploited for their values, an example of such is Aerial yam (*Dioscorea bulbifera*) according to Princewill-Ogbonna and Ezembaukwu, (2015).

Therefore, importation of roots and tuber starch has been greatly increased, this can be reduced by employing under-utilize crops that would supply a large percentage of the requirement, lessen the burden of its importation and improve the usage of this crop from going into extinction.

2.2` History of Aerial Yam (*Dioscorea bulbifera)*

Aerial yam (*Dioscorea bulbifera*) is commonly called potato yam or cheeky yam (Ojinnaka *et al*., 2016). It is a specie of yam grown throughout the world. This bulbils-bearing yam which belongs to the Order Dioscoreal, Family Dioscoreaceae, and Genus Dioscorea is an unpopular specie among the edible yam species. In South- Eastern States in Nigeria it is known as “Adu”, Western-Nigeria it is called “Emina” while in south- south Nigeria it is called “Odu” , it is also known as Igname bulbifere, igname pousse enl` air (France), brotwurzel, karotoffel-yam (Germany) Gaithi, karu-kunda, ratalu (Portugal), Inhame (Hindu). Where as in Spanish speaking countries, it is called criollo (Venezuela) De Aire (Colombia); De Gunda, Volador (Cuba), papa Cimarrona (Mexico)” (Nwosu, 2014).

It is cultivated in the West Africa, consumed by a small number of communities in some other parts of Nigeria, South East Asia, and South and Central America. The wild form also occurs in both Asia and Africa (Ojinnaka *et al*., 2016). This yam has been known to be an unpopular yam among the edible yam species because it is not well known to all communities.

Aerial yam is always available and cheap during the dry season (November-April). It is purchased in the rural markets and taken to urban centers by retailers (Mbaya *et al*., 2013).

It is among one of the most underutilized food crops in the world where it grows and appears in both the wild and edible forms. Unlike the other yam species, *Dioscorea bulbifera* has a long vine and it produces bulbils which grow at the base of its leaves (Sanful *et al*., 2015). This species of yam is not popular among farmers or consumers and does not enjoy the patronage that some of the other edible yam species enjoy.
Aerial yam are eaten boiled or fried or even roasted (Princewill-Ogbonna and Ibeji, 2015).

2.2.1 Botanical Description

Aerial yam is a vigorously twining herbaceous vine, often arising from an underground tuber. Freely branching stems grow to 60 ft. in length. Stems are round or slightly angled in cross section and twine to the left (counter-clockwise). Aerial bulbils freely form in leaf axils. Bulbils are usually roundish with mostly smooth surfaces, and grow up to 5 in. x 4. Leaves are long stalked, alternate;

blades to 8 in. or more long, broadly heart shaped, with basal lobes usually rounded and with arching veins all originating from one point (Langeland and Meisenburg, 2014).

Dioscorea bulbifera is distinguished from all other species by having specialized aerial bulbils on the base of petioles (Beyene, 2013).

Aerial yam is grown on free draining, sandy and fertile soil, after clearing the first fallow.

Planting is done by seed yam or cut setts from ware tubers. One day before planting, the tubers are subjected to treatment with wood ash to prevent damage to the soils. The setts are planted at an interval of 15-20 centimeters with the cut facing up. Manual weeding by hoeing is done three or four times depending on the rate of weed growth. Harvesting is done before the vines become dry and soil becomes dry and hard.

The bulbelates of *Dioscorea bulbifera* have very high dry matter content and produces bulbilates 4-6 months after planting (Beyene, 2013).

Kingdom: Plantae

Order: Dioscoreales

Family: Dioscoreaceae

Genus: Dioscorea

Species: bulbifera

Scientific name: *Dioscorea bulbifera*

2.3 Nutritional Composition of Aerial Yam (*Dioscorea bulbifera*)

The level of nutrients such as crude protein, carbohydrates, crude fiber, and ash content are (3.4%, 27.51%, 7.50% and 2.94%) and also minerals as calcium, magnesium, potassium, and phosphorus are (0.82, 0.98, 0.53, and 0.38 mg/gm) respectively (Subhash *et al.*,2014).

Dioscorea bulbifera which have been regarded as a non-edible yam by people as a result of belief, culture or chemical constitutes has been observed from (Subhash *et al.*,2014) to be edible. These yam contains not only the essential; nutrients like protein, fat, crude fiber they also contain photochemical which help fight against most disease of man, minerals and vitamins (Princewill-Ogbonna and Ibeji, 2015). They also have low moisture content which makes them store for a long time. Despite its underutilization, *Dioscorea bulbifera* has been shown to possess a myriad of compounds that have also been attributed to several health benefits (Panduraju *et al*., 2010).

Aerial yam (*Dioscorea bulbifera*) has said to be widely used in the Chinese medical system as a valuable herb in the process of rebuilding and maintaining kidney function. It was also useful to have a beneficial effect in treating diseases of the lungs and spleen, and many types of diarrhea improving digestion and metabolism (Princewill-Ogbonna and Ezembaukwu, 2015). In Asia, this herb has been used for treating diabetes, obesity disorders, providing a more sustained form of energy and better protection against such diseases. *Dioscorea bulbifera* is used in Bangladesh for the treatment of leprosy and high tumors (Subhash *et al.,* 2014).

In Zimbabwe, this plant is used as an infusion to apply on cuts and sores, both for humans and animals while in Cameroon and Madagascar, the pounded bulbs are applied to abscesses, boils and wound infections (Subhash *et al.,* 2014).

This yam specie can also be converted into convenient forms like flour to render it useful in industries, which can be consumed by human and used as animal feeds (Nwosu, 2014) and starch (Ojinnaka *et al.,* 2016) to have good functional and nutritional properties which can be of high importance in food manufacturing industries.

Aerial yam (*Dioscorea bulbifera*) serves as supplement to meals and household income towards poverty alleviation especially at crucial moments at the ending and beginning of a year. The nutritional value of aerial yam suggests that it can be fully incorporated into the cropping system by farmers in areas where it is found to be adapted (Mbaya *et al*., 2013).

Marketing of aerial yam is mostly by women and children usually placed alongside with non-timber forest products either by hawking in motor parks or placed on the ground waiting for buyers along major high ways or mini markets.

Plate 1: Aerial Yam (*Dioscorea bulbifera*).

2.4 Microwave Drying

Microwave technology is an extremely efficient method of drying (Jones, 2016) and has been in existence as an innovative method over many traditional processing techniques (Kaushal *et al.*, 2015). In all Drying systems, no matter how complex, all have the same core function: they remove moisture from a material. One of the most common methods for removing moisture is evaporation and this happens naturally on its own over time, but the process can be speed up with the application of heat to the material, either by direct or indirect measures (Jones, 2016). The growing tendency to spend less time on food preparation, greater convenience and time saving has lead the food processors, confectioners and household users to go for microwave processing (Bhatt *et al.*,2008).

Microwaves are electromagnetic waves of radiant energy which lie between the radio and infrared waves on electromagnetic spectrum and produces heat as a result of orientation of the dipoles in alternating electromagnetic field (Marra *et al.,* 2010).

Microwaves are not forms of heat but rather forms of energy that are manifested as heat through their interaction with materials. Microwave energy does not heat the room; only the desired material with no harmful greenhouse gas emissions from the heat source (Kaushal *et al.,* 2015).

Microwaves are electromagnetic waves having a wavelength varying from 1 millimeter to 1 meter. Frequency of microwaves (Jones, 2016) and (Kaushal *et al.,* 2015), lies between 0.3 GHz and 3 GHz. 1GHz = 1,000 MHz, a domestic microwave operates at 2450 MHz (a wavelength of 12.24 cm.), industrial/commercial microwave systems typically operate at 900 MHz (a wavelength of 32.68 cm). Kaushal *et al*. (2015) considered the use of microwave as the fourth generation drying technology. And a complete microwave drying process consists of three drying periods which include:

A heating-up period in which microwave energy is converted into thermal energy within the moist materials, and the temperature of the product increases with time.

Rapid drying period during which a stable temperature profile is established and thermal energy converted from microwave energy is used for the vaporization of moisture.

Reduced drying rate period during which the local moisture is reduced to a point when the energy needed for moisture vaporization is less than thermal energy converted from microwave.

Applications where microwave processes prove beneficial include: dehydration, sterilization, pasteurization, tempering (thawing), blanching and cooking (Kaushal *et al*., 2015). In dehydration, the main purpose is to remove water. With pasteurization and sterilization microwave systems are designed to raise the product temperature to a certain level to destroy pathogens, Other applications include blanching where the product is heated then cooled rapidly or when maintained at an elevated temperature, as in cooking, tempering or sintering (Jones, 2016).

Microwave processing has grown beyond expectations due to increasing consumer demand for newer types of convenience food with more nutritional value and improved sensory quality. During microwave drying, microwave energy is transmitted by waveguides into the chamber that contains the material to be dried (Bhatt *et al*., 2008).

Microwave drying of osmotic dehydrated products has been shown to improve the drying rate and retain product quality compared to air drying.

2.4.1 Advantages of Microwave Drying

Microwave processing offers several distinct advantages over conventional methods which are as enlisted under: Speed, microwave drying works fast. This is because instead of applying energy only to the outside of the product, microwaves work directly to dry material *from the inside out* (Lewicka *et al.,* 2015).

Microwaves also require no heat-up or cool-down time, meaning less waiting and more efficient use of time (Marra *et al.,* 2010). Less start-up time is required and heat penetration is quick. Microwave processing has substantial enhancement in reaction and diffusion kinetics.

It is energy efficient and needs much shorter process time. Overall microwave energy efficiency is approximately 50% (Sajilata *et al.,* 2006).

Higher quality products and ecology friendliness: microwave heating avoids degradation of product strength and surface properties caused by exposure to high temperatures (Marra *et al*., 2010).

Selective heating and food with high nutritional quality: Since different materials absorb microwave energy at different rates, a product with many components can be heated selectively. Space savings with precise process control.

Combination with conventional methods: Microwave energy may be added before, after, or inside conventional heating or drying units to decrease processing time by 75%.

Microwave drying offers opportunities to shorten the drying time and improves the final quality of the dried products, bacterial counts are also 15 times lower and it also removes the last traces of moisture from material without over drying (Sajilata *et al.*, 2006).

Microwaves are more compact: they requires a smaller equipment space, and can be located in a dry safe area. Microwaves require easy clean up and maintenance: less chemical and water usage, more production time available.

2.4.2 Disadvantages of Microwave Drying

The tendency of microwave to give uneven heating is a severe limitation from the food safety and spoilage point. To gain the advantage of uniform heating the hot and cold spots must be minimized by using rotating turntables (Geedipalli *et al.*, 2007).

Dehydrating the food by using the food's water molecules, for this reason foods with a high moisture content tend to cook more successfully in microwaves (Lewicka *et al.*, 2015).

2.4.3 Health Effects of Microwave on the Body

Microwaves radiation heats body tissues the same way it heats food. Microwaves can heat the body by adding thermal energy to the water molecule in the body. This heating can be damaging if it is not controlled, most of the body is protected from slow heating because the blood in the body carries heat away from any local hot spots so that you warm evenly. The cornea of the eye is a good example, because the lens of the eye is particularly sensitive to intense heat, and exposure to high levels of microwaves can cause cataracts. Exposure to high levels of microwave energy can alter or kill sperm producing temporary sterility (Lewicka *et al.*, 2015). These injuries such as burns, cataracts, and temporary sterility can only be caused by exposure to large amounts of microwave radiation, much more than can leak from a microwave oven.

2.5 Starch

Starch is the main component of yam and provides large proportion of daily caloric intake. The value of the yam as a basic food has been attributed to the high digestibility of its starch, which is present in the form of small granules (Addy *et al.*, 2014).

Starch is one of the most abundant biomasses on earth, is the major carbohydrate for energy storage in plants (Yongfeng, 2013). Starch can be found in grains, roots and tubers, stems, leaves, and fruits which is present in the form of small granules. Starch is available as one of the most economical materials in the industry. Since yam tubers contain about 70–82% starch (Addy *et al*., 2014). The cooking and processing characteristics of yams, the eating and storage quality of yam-containing products, and perhaps the physiological effectiveness of the bioactive ingredients involved will be greatly dependent on starch properties.

Starch is an important raw material for a number of industries including food, pharmaceuticals, textiles, paper and adhesives and it's important to these major industrial uses of starch are the amount and quality of starch obtained from the crop. Starch is used in industries as a gelling agent, thickener, emulsion stabilizer, and as a water binding agent (Sanful and Engmann, 2016).

Starch owes much of its functionality to two major high-molecular-weight carbohydrate components, amylose and amylopectin, as well as to the physical organization of these macromolecules into the granular structure.

Starch is a polysaccharide carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds. It comprises of amylose and amylopectin as it macromolecules. Starch is produced by all green plants as an energy store and is an important energy source for humans. It is found in potatoes, wheat, rice and other foods, and it varies in appearance, depending on its source.

Amylose and amylopectin represent approximately 98–99% of the dry weight of starch granules (Yongfeng, 2013). Amylose and amylopectin have different structures and properties. Amylose is a relatively long, linear α-glucan with few branches, containing around 99% (1→4)-α- and up to 1% of (1→6)-α- linkages and differing in size and structure depending on botanical origin. Amylose has a molecular weight range of approximately 1×10^5 - 1×10^6 while Amylopectin with a molecular weight of $1 \times 10^7 – 1 \times 10^9$ is a much larger molecule than amylose (Yongfeng, 2013). Amylopectin has a heavily branched structure built from about 95% α-(1→4) and 5% α-(1→6) linkages (Jaroslav, 2008). Amylose fraction is responsible for the structure and pasting behaviour of starch granule (Addy *et al*., 2014). The greater the percentage of amylose ratio, the less expansion potential and the lower the gel strength for the starch concentration and vice versa (Jaroslav, 2008). Amylose is most commonly determined in starches by the potentiometric, or colorimetric measurement of the iodine binding capacity of amylose. Amylopectin–iodine complexes are also formed, which reduces the concentration of free iodine measured by the non-colorimetric methods. The general low content of amylose in samples indicates that when these starches are incorporated into food products, swelling of starch will be enhanced (Addy *et al.*, 2014). Amylose contents that were recorded from four varieties of yam are 27.48, 31.55, 30.36 and 28.57%, Amylopectin content ranged from 68.45 to 72.52% as reported by Addy *et al*., (2014). Elvis (2014) reported that the amylose levels of plantain starch ranged from 29.96 - 30.91%, and for amylopectin that was significantly higher with a value of 70.04%. This simply means that starch is made up of both amylose and amylopectin, but amylopectin ratio is greater in most cases.

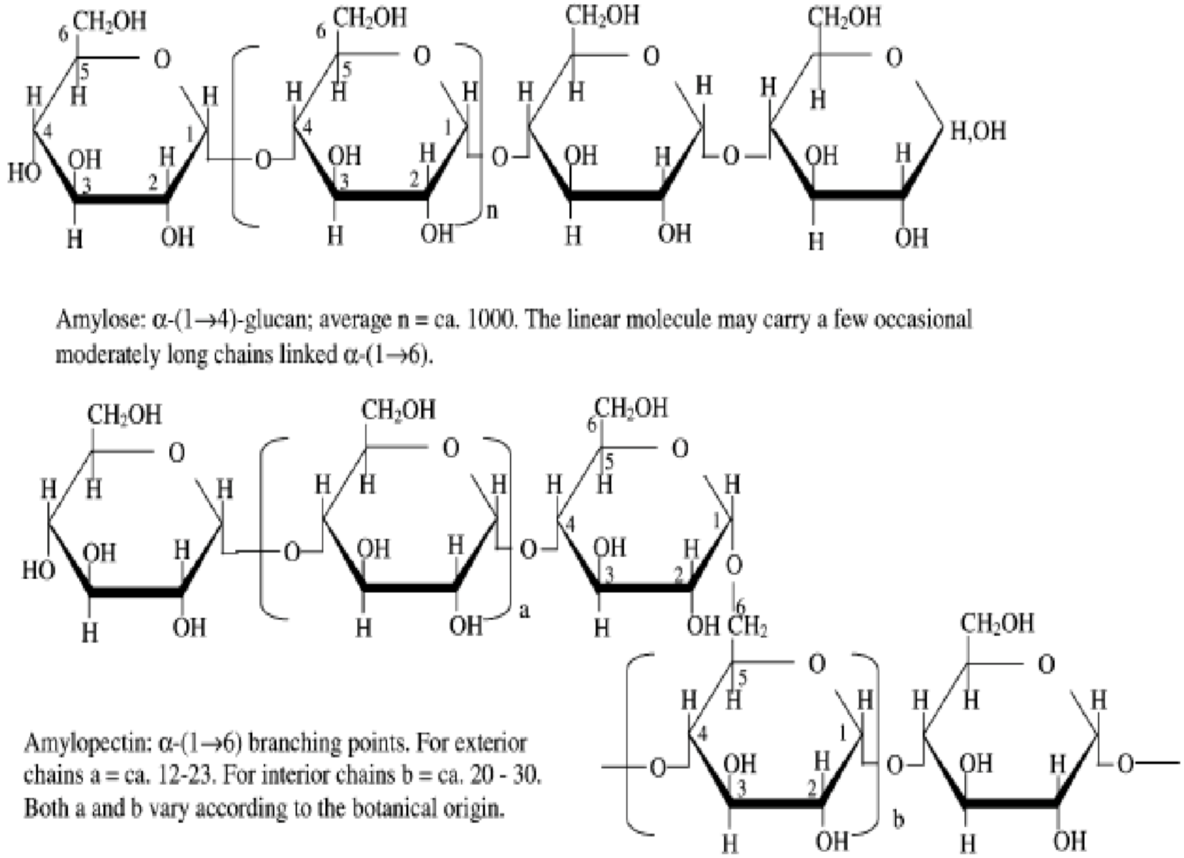

Figure 1: Structure of Amylose and Amylopectin (Jaroslav, 2008).

2.6 Pasting Properties

Pasting properties is an important functional characteristics of starch. And this is defined as an aqueous suspension of starch that occurs during heating above a critical temperature, the granules then swell irreversibly and amylose leaches out into the aqueous phase, resulting into an increased viscosity (Addy *et al.,* 2014). It can be evaluated using an amylograph, such as Rapid Visco-Analyzer (RVA) or a Brabender Amylograph. Pasting property is important because it reflects the strength of starch pastes and starch with low paste stability has very weak cross-linking within the starch granules and requires less cooking time. Pasting properties is also an important index in determining the quality of starch (Elvis, 2014). Pasting profile include:

Pasting temperature provides an indication of the minimum temperature required for sample cooking, energy cost involved and other components stability (Ikegwu *et al.*, 2009). It also gives an indication of the gelatinization time during processing (Odedeji and Adeleke, 2010). The higher the pasting temperature, the longer the pasting time.

The pasting temperature and time reported by Addy *et al*., (2014) ranged from 75.10 to 77.30°C at (19.25 min) and this temperature makes it suitable for the production of foods that require shorter processing time.

Peak viscosity is defined as a measure of the ability of starch to form a paste or the ability of starch to swell freely before their physical breakdown (Ikegwu *et al.,* 2009). It is important because it indicates the strength of the paste formed from gelatinisation during food processing (Jimoh *et al*., 2009). High starch damage results in high peak viscosity. Peak viscosity gotten from four yam varieties were 726, 614, 685 and 639 BU respectively (Addy *et al.*, 2014).
Final viscosity determines a particular starch based sample quality. High viscosity value starch is useful in pharmaceutical companies especially, as tablet binders (Addy *et al.*, 2014). And property that is from extruded starch is to be used as an ingredient in foods that require cold thickening capacity like instant creams, sauces etc. Final viscosity formed at the end of cooling is 50°C and is also called cold paste viscosity (CPV).

Hold-period also called holding strength, hot paste viscosity or trough due is often associated with breakdown in viscosity. It is an indication of breakdown or stability of the starch gel during cooling (Princewill-Ogbonna and Ezembaukwu, 2015). It is a period when the sample is subjected to a period of constant temperature (usually 98ºC) and mechanical shear stress. It is a minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand breakdown during cooling.

Setback viscosity measures the re-association of starch. Jimoh *et al.,* (2009) reported that a high setback value is associated with a cohesive paste while a low value is an indication of a non-cohesive paste.

Breakdown viscosity measures the ability of starch to withstand collapse during cooling or the degree of disintegration of granules or paste stability (Jimoh *et al.,* 2009). And the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking.

2.7 Physicochemical Properties of Starch

Physicochemical properties are physical and chemical properties of matter. They include:

2.7.1 pH

PH is to know the level of acidity and alkalinity of a substance. It is an essential measurement of eating quality and it contributes to taste, and it is used primarily to calculate approximately consumption quality and hidden attributes of foods (Addy *et al.,* 2014). The pH value gotten from aerial yam starch reported by Ojinnaka *et al.,* (2016) ranged from 5.99 – 6.06 and for Elvis (2014), pH values fall between 4.46 and 5.50**.**

Acids contribute to the post-harvest quality of foods like fruits as taste is primarily a balance between sugar and acid content, therefore post-harvest assessment of acidity is necessary in evaluating taste (Ojinnaka *et al.,* 2016).

2.7.2 Bulk Density

Bulk density is dependent upon the particle size of the sample. It is important for determining packaging requirements, material handling and application in wet processing in the food industry (Jimoh *et al.,* 2009) and Ojinnaka *et al.,* (2016). Bulk density of food increases with increase in starch content. Starch with high bulk density are used as thickeners in food products and reduction of paste thickness while those of low bulk density is an advantage in the bulk storage and transportation of the flour (Oluwalana *et al.,* 2011). The starch samples from the aerial yam cultivars had higher bulk densities of 0.81g/ml – 0.84 g/cml for purple and white aerial yam cultivars (Ojinnaka *et al.*, 2016).

2.8 Functional Properties of Starch

2.8.1 Water Absorption Capacity

Water absorption capacity is important in texture and quality of foods for stabilizing starches against effects such as syneresis, which sometimes occur during retorting and freezing, and assures product cohesiveness (Princewill-Ogbonna and Ezembaukwu, 2015) and Odedeji and Adeleke, (2010). Water absorption capacity is considered critical in viscous foods such as soups and gravies and baked products.

The water absorption capacity of the plantain starches ranged from 54.40 - 65.50% (Elvis, 2014). Water absorption capacity is the ability of flour particles to entrap large amount of water such that exudation is prevented. It can also be described as an important processing parameter that has implications for viscosity. Zakpaa *et al.,* (2010) reported that the water absorption capacity value of 54.40% was obtained for cadaba and the value of 54.07% obtained for giant horn.

2.8.2 Oil Absorption Capacity

Oil absorption capacity is useful in food preparations that involves oil mixing like bakery products where oil is an important ingredient (Princewill-Ogbonna and Ezembaukwu, 2015). Approximately 0.6 g of oil was absorbed per g starch recorded by Oyeyinka *et al.,* (2015).

2.8.3 Least Gelation Capacity

Gelatinization affects digestibility and texture of starch containing foods, leaching amylase enhances susceptibility of starch to enzyme attack and the textural quality when starch is incorporated in food products such as creams, soups, puddings, pie fillings and many sauces in viscosity (Ojinnaka *et al.,*2016). Gel capacity increases with increase in concentration of the starch samples. The highest gelation capacity was recorded for the starch samples from cultivars white and purple ranged from 18.53% – 18.73% (Ojinnaka *et al.*, 2016).

2.8.4 Swelling Power

Swelling power provides evidence of the magnitude of interaction between starch chains within the starches (Addy *et al*., 2014). It depends on the water intake of the starch (Nwosu, 2014). Eke-

Ejiofor and Owuno (2014) also described swelling power as a factor of the ratio of amylose to amylopectin, the characteristics of each fraction in terms of molecular weight/distribution, degree/length of branching and conformation.

Swelling power of starch is negatively affected by the presence of fat and protein in the sample (Sanful and Engmann, 2016). High swelling capacity has been reported as part of the criteria for a good quality product (Princewill-Ogbonna and Ezembaukwu, 2015). The swelling capacity of the aerial yam starch sample ranged from 7.47% -8.24% (Ojinnaka *et al.*, 2016). Sanful and Engmann (2016) reported that swelling power for starch extract had 8.19% swelling capacity.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Materials

Aerial yam (*Dioscorea bulbifera*) bulbils were purchased from a farm in Ogbagi Akoko market, a town in Akoko North –West Local Government, Oke Agbe in Ondo State.

3.2 Methods

3.2.1 Extraction of Aerial Yam Starch

The wet extraction method described by Ojinnaka *et al*., (2016) was adopted and modified for the starch extraction. The bulbils were weighed, peeled to remove the skin, washed to remove adhering soil and undesirable materials, sliced into smaller pieces and well grinded with water ratio of 1:3 using a warring blender. The pulp was collected and sieved using a sieve of 250μm for the starch extraction and centrifuged to separate the filtrate from the residue. The wet starch was obtained and divided into four portions in which they were microwaved at 2450 MHz for 45, 60, 70 and 95 minutes respectively. And the control wet starch was oven dried at 30^0C for 24 hours. The starch was weighed, packaged in polyethylene bags prior to further analysis.

The flow chart for the production of Aerial yam starch is shown in figure 2.

3.2.2 Yield Capacity

Yield capacity was determined as the percentage starch recovered after extraction from a weighed kilogram of Aerial yam bulbils.

$$\text{Yield Capacity (\%)} = \frac{\text{Dry weight of starch recovered from extraction}}{\text{Weight of Aerial yam tubers}} \times 100$$

$$\text{Yield Capacity} = \frac{1500}{5000} \times 100 = 30\%$$

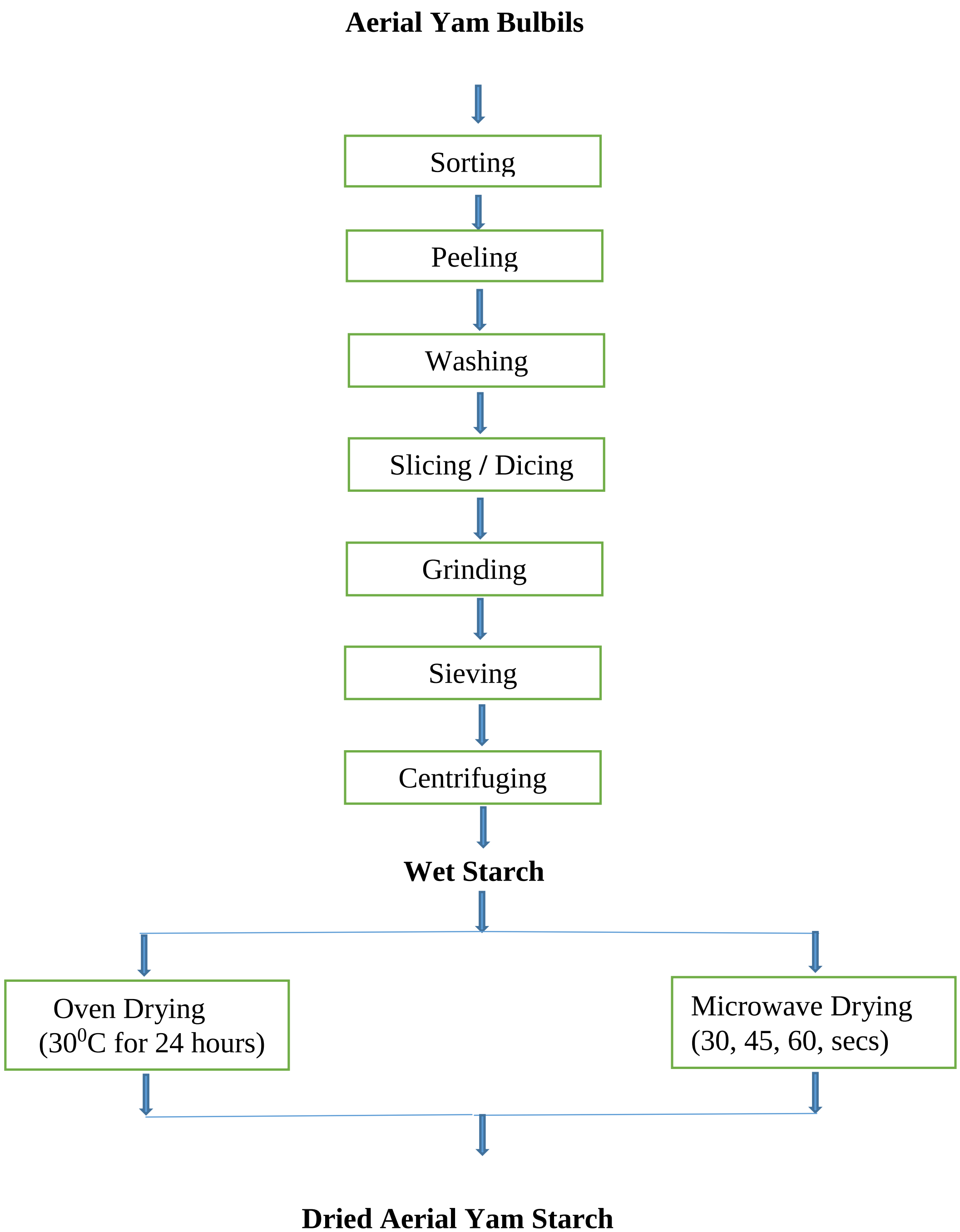

Figure 2: Flow chart for the Production of Aerial Yam Starch, Ojinnaka *et al*., (2016).

3.3 Physicochemical Properties

3.3.1 Determination of Amylose in Starch

The amylose content of starch extracted from the Aerial yam bulbils was determined using the iodine colorimetric method as reported by Elvis, (2014). A standard curve for amylose was prepared using different concentrations ranging from 0 - 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% NaOH were added. The flask with their contents was heated in water bath until a clear solution was obtained. The samples were cooled and diluted to mark with distilled water. 5 ml of the solution was measured into a 500 ml volumetric flask and 100 ml of distilled water added and immediately acidified with few drops of 6 M HCl. The contents were mixed before 5 ml of iodine solution was added and made up to mark with distilled water. The absorbance of the standard was measured using a spectrophotometer at a wavelength of 640 nm. The concentration of amylose was calculated from the standard curve.

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

3.3.2 Determination of Amylopectin in Starch

The amylopectin content of starch extracted from the Aerial yam bulbils was determined using the iodine colorimetric method as reported by Elvis, (2014). 100 mg of the starch sample was weighed into 100 ml volumetric flask and 1 ml of ethanol, 10 ml of distilled water and 2 ml of 10% NaOH were added. The flask with their contents was heated in water bath until a clear solution was obtained. The samples were cooled and diluted to mark with distilled water. 5 ml of the solution was measured into a 500 ml volumetric flask and 100 ml of distilled water added and immediately acidified with few drops of 6 M HCl. The contents were mixed before 5 ml of iodine solution was added and made up to mark with distilled water. The absorbance of each standard was measured using a spectrophotometer at a wavelength of 640 nm. The percentage amylopectin was calculated from the amylose obtained in the above procedure.

$$\text{Amylopectin } (\%) = 100 - \text{amylose } (\%)$$

3.3.3 Pasting Properties

A Rapid Viscography Analyzer Model 3D (RVA) was employed as described by Odejobi *et al*., (2014) and modified to determine the pasting properties of the starch sample. 3.5 grams of the starch sample was weighed and dispensed into the test canister, 25.0 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA (Rapid Visco-Analyzer), the slurry was held at 50ºC for 1 min, heated and cooled within 8 minutes and rotated at a speed of 160 rpm with continuous stirring of the content with a plastic paddle. The parameters evaluated were peak viscosity, setback viscosity, final viscosity, pasting temperature and time to reach peak viscosity. The Rapid Visco analyzer was switched on and the pasting performance of the starch was automatically recorded on the graduated sheet of the instrument.

3.3.4 Colour

Tristimulus $L^* a^* b^*$ parameters of starch were determined after standardization using a colorFlex spectrophotometer. Snap shots in duplicates were taken and values were read directly from a digital print. Averages of the readings were computed as reported by Oyeyinka *et al*., (2015).

3.3.5 Bulk Density

The bulk density of aerial yam starch was determined using the method described by Ocheme *et al*., (2010). 50g of the starch sample was weighed into a 100ml measuring cylinder. The cylinder was tapped 40 times and the bulk density was calculated as weight per unit volume:

$$\text{Bulk Density}\left(\frac{\text{g}}{\text{ml}}\right) = \frac{\text{mass of sample}}{\text{Volume of sample}}$$

3.3.6 pH

Five grams of starch sample was weighed and mixed with 50 ml of distilled water to obtain slurry. The pH was then determined using pH meter by inserting the pH probe into the slurry, method described by Addy et al., (2014).

3.4 Functional Properties

3.4.1 Swelling Power (SP)

2 grams of the starch sample was weighed into 10 ml measuring cylinder and the volume it occupied was recorded as (V_1), distilled water (27ºC) was added until the 10 ml mark was reached. The cylinder containing the samples and distilled water was left to stand for 45 min after which a new volume V_2 was recorded. The swelling power was expressed as the ratio of the final volume over that of the initial volume (Princewill-Ogbonna and Ezembaukwu, 2015).

$$\text{Swelling Power} = \frac{\text{volume occupied by sample after swelling}}{\text{Volume occupied by sample before swelling}}$$

3.4.2 Least Gelation Capacity

The method described by Ojinnaka *et al*., (2016) was adopted in the determination of gelation capacity. A sample suspension of 2.20% (w/v) using the concentration between 2-10% in 5ml of distilled water was prepared in test tubes. The samples were heated for 1h in a boiling water bath followed by rapid cooling. The test tubes were then cooled further for 2h at 4ºC. The gelation capacity is the least gelation concentration determined as the concentration when the sample from the inverted test tube will not fall or slip.

3.4.3 Water Absorption Capacity

The water absorption capacity was determined using the method described by Princewill-Ogbonna and Ezembaukwu, (2015). 10 ml of distilled water was mixed with 1g of the starch sample in a mixer and then homogenized for 30 seconds and allow to stand at room temperature for 30 minutes and centrifuged at 5000 rpm for 30 minutes. The volume of the supernatant in a graduated cylinder was noted. The amount of water absorbed (total minus free) was multiply by its density for conversion to grams. Density of water was assumed to be 1 g/ml.

$$\text{Water Absorption Capacity} = \frac{\text{V1} - \text{V2}}{\text{w}} \times \text{density of water}$$

Where:

V_1 = Initial volume of water (10 ml)

V_2 = Final volume after centrifugation w = weight of sample (1 g)

3.4.4 Oil Absorption Capacity

The oil absorption capacity was determined using the method described by Princewill-Ogbonna and Ezembaukwu, (2015). 1g of the starch sample was mixed with 10 ml of corn oil or canola oil. The oil and starch sample was mixed and then homogenized for 30 seconds and allowed to stand for 30 minutes at room temperature and then centrifuged at 5,000 rpm for 30 minutes.

The volume of free oil (supernatant) was noted directly from the graduated centrifuge tube.
The amount of oil absorbed (total minus free) was multiplied by its density for conversion to grams. Density of oil was taken to be 0.88 g/ ml for bleached palm oil.

$$\text{Oil Absorption Capacity} = \frac{\text{V1} - \text{V2}}{\text{w}} \times \text{density of oil}$$

V_1 = Initial volume of oil

V_2 = Final volume after centrifugation

w = Weight of sample.

3.5 Statistical Analysis

All experiments in this work are reported in triplicates. Data were analysed using the analysis of variance (ANOVA) while their means were separated by Duncan's multiple range test. All statistical analysis was performed at using the Statistical Package for Social Sciences (SPSS) Version 15.0.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4. 1 Physicochemical Properties of Aerial Yam Starch

The results for amylose, amylopectin content and colour of aerial yam starch extract are presented on Table 1. From the table, starch extracted from aerial yam dried at 30^0C for 24 hours (oven dried) was significantly higher ($P \leq 0.05$) in amylose ratio with 32.77%, lower in amylopectin ratio with 66.89% than those of microwaved dried aerial yam counterpart which ranged from 26.87% to 29.41% in amylose and 70.58% to 73.12% in amylopectin ratio. The amylose and amylopectin content of oven dried starch sample in this work is similar to 37.50% and 62.50%, aerial yam starch extract as reported by Sanful and Engmann, (2016).

Amylose and Amylopectin form the major constituents of starches and their amounts vary based on the type of plant species and varieties (Jaroslav, 2008). The amylose and amylopectin content of a food material greatly influences its pasting and viscosity attributes. Higher pasting consistency and viscosity are achieved when the amylopectin ratio of a food commodity is higher than that of its amylose content (Sanful and Engmann, 2016). The low amylose content of the samples indicates that when these starches are incorporated into food products, swelling of starch will be enhanced (Addy *et al.*, 2014). And since amylose tends to retrograde when foods are frozen and thawed, high amlyopectin content foods will be useful in the preparation of foods for a freeze thaw proces (Jaroslav, 2008).

The results of colour of the starches are shown in Table 1 .The colour brightness coordinate L* measures the degree of whiteness, ranging between black (0) and white (100). The chromaticity coordinate a* measures red when positive and green when negative, while b* measures yellow when positive and blue when negative. Consumer acceptability is affected by the presence of colour in starch, which is an indication of low quality.

The relatively high brightness value of the starch extract and low value of the chromaticity coordinate (a*) is desirable. From Table 1, the colour brightness (L*) of the oven dried starch extract was significantly higher (53.65) than that of the microwaved starch extract ranged from 40.35 to 45.54).

Table 1. Amylose, Amylopectin, Colour of Aerial Yam Starch

Samples	AMYLOSE	AMYLOPECTIN	COLOUR		
			L	a	b
A	32.776±0.34^{a}	66.891±0.66^{d}	53.65±0.77^{a}	4.623±0.87^{a}	12.903±0.55^{a}
B	29.418±0.54^{b}	70.582±1.05^{c}	45.54±0.76^{b}	3.95±0.45^{b}	6.01±0.99^{c}
C	28.091±0.91^{c}	71.909±0.06^{b}	43.34±0.55^{c}	3.647±0.85^{c}	6.073±0.43^{c}
D	26.874±0.99^{c}	73.126±1.06^{a}	40.35±0.92^{d}	3.253±0.44^{d}	7.347±0.39^{b}

Values reported are means ± standard deviation of triplicate determinations.

Mean values with different superscripts within the same columns are significantly ($p \leq 0.05$) different.

KEY

A: **Oven dried for 30^{0}C @ 24 hours**

B: **Microwaved @ 30 seconds**

C: **Microwaved @ 45 seconds**

D: **Microwaved @ 60 seconds**

The results for pH, bulk density of aerial yam starch samples are presented on Table 2.

The pH values ranged between 5.67 to 5.68 in oven dried starch extract and starch microwaved for 60 seconds. The pH values of oven dried aerial yam starch is similar to 5.99 – 6.06 in aerial yam starch extract reported by Ojinnaka *et al*., (2016). The pH is used primarily to calculate approximately consumption quality and hidden attributes of foods (Addy *et al.,* 2014). Acids contribute to the post-harvest quality of foods like fruits as taste is primarily a balance between sugar and acid content (Ojinnaka *et al*., 2016), therefore post-harvest assessment of acidity is necessary in evaluating the taste of starch.

The bulk densities results of oven dried starch extract is 0.568g/ml, microwaved starch extract are 0.675g/ml, 0.697g/ml, and 0.704g/ml at 30, 45, 60 seconds respectively. The microwaved starch extract had higher values compared to oven dried starch extract. Ojinnaka *et al.,* (2016) reported higher bulk densities of 0.81g/ml to 0.84 g/ml for purple and white aerial yam cultivars. Higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness while low bulk density are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Oluwalana *et al.*, 2011). Low bulk density is advantageous for the infants as both calorie and nutrient density is enhanced per feed of the child, high bulk density is a good physical attribute when determining mixing quality of particulate matter (Jimoh *et al.*, 2009).

Table 2. pH, Bulk density of Aerial Yam Starch

Samples	pH	Bulk Density$\left(\frac{g}{ml}\right)$
A	5.67±0.43[a]	0.568±0.03[c]
B	5.68±0.42[a]	0.675±0.08[b]
C	5.68±0.65[a]	0.697±0.02[b]
D	5.68±0.49[a]	0.704±0.04[a]

Values are means ± standard deviation of triplicate determinations

Mean values with different superscripts within the same column are significantly ($p \leq 0.05$) different

Pasting characteristics of aerial yam starch extract is presented in Table 3.

The pasting temperature and pasting time were higher in the oven dried starch sample (80.7^{0}C and 20.5 minutes) compared to the microwaved starch extract ranged from (48.9^{o}C – 57.7^o C and 10.9-15.5 minutes). This observation agrees with earlier findings (Addy *et al.*, 2014) to the effect that, as pasting temperature increases, there is a corresponding increase in the pasting time.

This pasting temperature suggests the likely gelatinization time during processing (Sanful and Engmann, 2016) and gives an indication of the least temperature needed for cooking, energy cost and the stability of other components. Addy *et al.,* (2014) reported that pasting temperature is the temperature at which viscosity begins to rise whiles pasting time provides an indication of the minimum time required to cook a given food sample.

Peak viscosity is the water binding capacity of starch (Mahasukhonthachat *et al*., 2010) and the ability of the starch to form a paste. It also indicates the strength of the paste formed from gelatinisation during food processing (Oke *et al*., 2013). The value of peak viscosity observed for the starch samples ranged from 493BU – 599BU. Peak viscosity 597BU reported by Sanful and Engmann (2016). The peak viscosity observed for the samples indicates its suitability for food products that needs high gel strength and elasticity. Okechukwu *et al.,* (2010) reported that setback viscosity of the starch makes it suitable for the production of non-wheat noodles.

Final viscosity formed at the end of cooling at 50°C is called cold paste viscosity (CPV). This viscosity is an important property if extruded starch is to be used as an ingredient in foods that require cold thickening capacity like instant creams, sauces (Addy *et al.,* 2014).

The increase in CPV of all the samples could be attributed to the high retrogradation property of yam starch during cooling.

Breakdown measures the ability of starch to withstand collapse during cooling or the degree of disintegration of granules or paste stability. Addy *et al.,* (2014) reported that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking.

Setback measures the re-association of starch. A high setback value is associated with a cohesive paste while a low value is an indication of a non-cohesive paste. Low setback values are useful for products like weaning foods, which require low viscosity and paste stability at low temperatures.

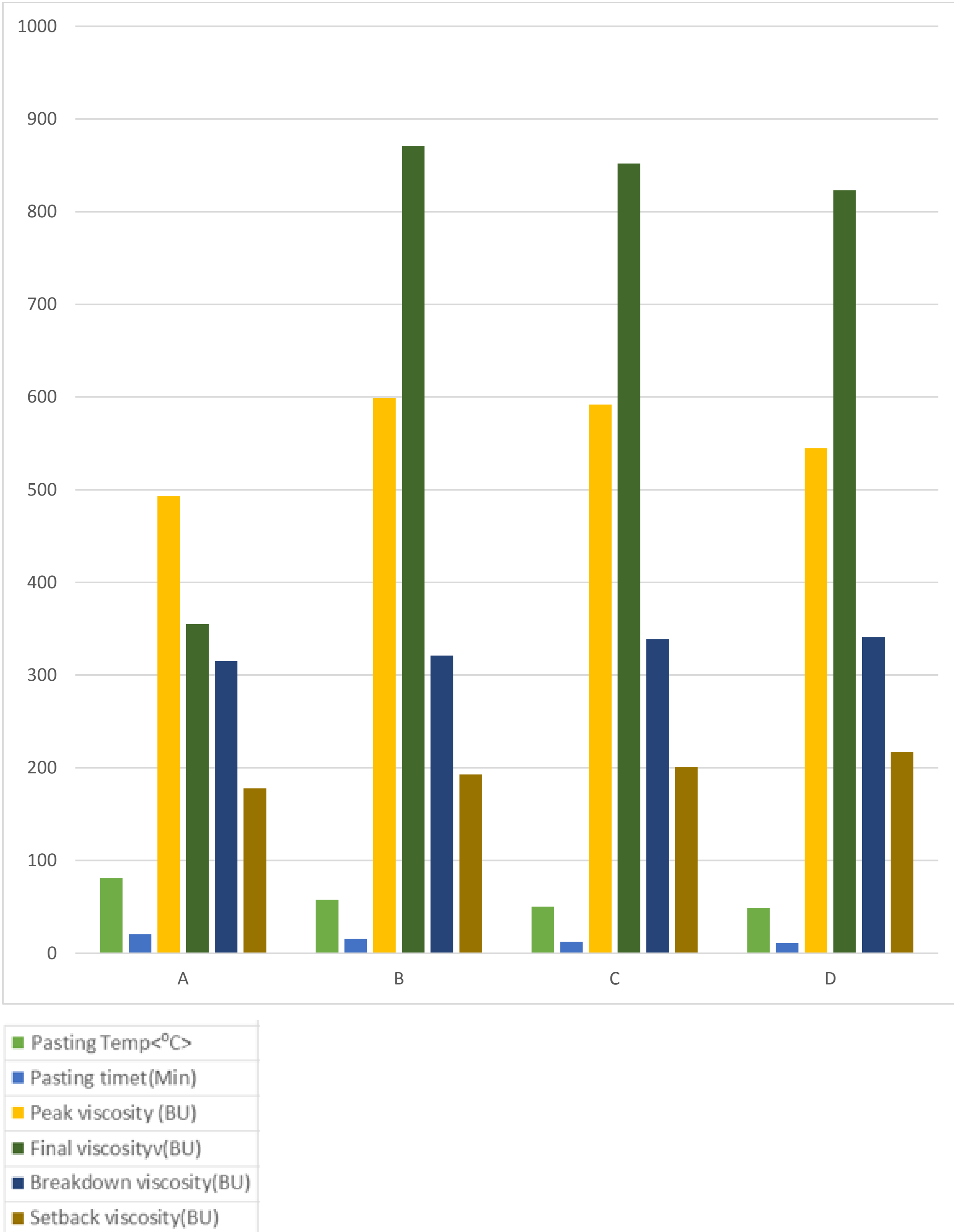

Figure 3. Pasting Properties of Aerial Yam Starch

4.2 Functional Properties of Aerial Yam Starch

The results obtained for functional properties of aerial yam starch samples are shown in Table 3. The swelling power of the starch samples ranged from 7.26% to 8.43% in starch microwaved for 60 seconds and oven dried starch extract. The swelling power of oven dried aerial yam starch compared favorably to 8.19% and the range of 7.47%-8.24%, swelling power reported by Sanful and Engmann (2016) and Ojinnaka *et al*., (2016) respectively. Subjection of starch to microwave significantly reduced the swelling power. As the length of the time the starch sample was microwaved increases, the swelling power reduces.

High swelling power has been reported as part of the criteria for a good quality product (Princewill-Ogbonna and Ezembaukwu, 2015). Swelling power also depends on the water intake of the starch. The swelling power indicates the hydration capacity of the insoluble starch fraction in water and expressed in grams of water absorbed per gram of insoluble fraction (Nwosu, 2014).

The least gelation capacity results for oven dried starch is 9%, and microwaved aerial starch samples ranged from 13% to15%. Gelatinization influences the textural quality when starch is incorporated in food products such as creams, soups, puddings, pie fillings and many sauces in viscosity (Ojinnaka *et al*., 2016).

The water and oil absorption capacity of the starch samples ranged from 164.39 to 306.46 and 112.89 to 121.98 for starch microwaved at 60 seconds and oven dried starch extract. Subjection of starch to microwave reduced the water and oil capacity. Water absorption capacity is relevant in ensuring that food products possess good texture as well as having the ability to stabilize starches, which invariably reduces retrogradation and syneresis during storage, retorting and freezing (Odedeji and Adeleke, 2010). Oil absorption capacity is useful in food preparations that involves oil mixing like bakery products where oil is an important ingredient (Princewill-Ogbonna and Ezembaukwu, 2015).

Table 3. Functional Properties of Aerial Yam Starch

Samples	SP (%)	LGC (%)	OAC (%)	WAC (%)
A	8.43±1.54^{a}	9±0.00^{c}	121.98±0.96^{a}	306.46±1.02^{a}
B	8.16±1.02^{b}	13±0.00^{b}	119.41±0.59^{b}	295.25±1.04^{b}
C	7.60±1.11^{c}	13±0.00^{b}	117.00±0.96^{c}	268.94±1.11^{c}
D	7.26±1.40^{d}	15±0.00^{a}	112.89±1.02^{d}	164.39±1.13^{d}

Values reported are means ± standard deviation of duplicate determinations. Mean values with different superscript within the columns are significantly ($P < 0.05$) different.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Aerial yam, an underutilized food crop, can also serve as an alternate source of starch based on its unique characteristics, can be used for diverse products in manufacturing industries and thus, prevent the yam from going into extinction. The amylopectin ratio of both starches are higher than the amylose ratio and the low amylose content indicates that when these starches are incorporated into food products, swelling of starch will be enhanced.

The effect of different drying methods and conditions on the physico-chemical properties of the starch showed that the oven dried starch has a relatively low bulk density compared to microwaved starch, and this implies that oven dried starch is better in terms of storability and transportation while higher bulk density of the microwaved starch showed that it will be a greater ease of dispersibility and reduction in paste thickness. The higher swelling power of the oven dried starch is a very important criteria for a good quality starch and water intake of the starch. The oven dried starch had better gelation capacity, because the lower the gel, the better the sample, and this is for starch granules to rise when incorporating into food products. The oven dried starch had higher water absorption capacity than the microwaved starch, in which it is suitable to entrap large amount of water during processing.

In conclusion, based on the properties of the starch, oven dried starch had higher advantages over microwaved dried aerial yam starch.

5.2 Recommendation

Further studies should be carried out on the proximate composition of microwaved and oven dried starch extract to know the nutritional significance.

Modification of aerial yam starch for improved functionality and industrial application should be looked into.

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APPENDIX

Pasting Properties of Aerial Yam Starch

	A	B	C	D
Pasting Temp<°C>	80.7	57.7	50.1	48.9
Pasting timet(Min)	20.5	15.5	12.3	10.9
Peak viscosity (BU)	493	599	592	545
Final viscosityv(BU)	355	871	852	823
Breakdown viscosity(BU)	315	321	339	341
Setback viscosity(BU)	178	193	201	217