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PROSPECTS OF DOMESTICATION OF POLYNESIAN ARROWROOT (*Tacca leontopetaloides* L.) IN NIGERIA

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Abstract
Polynesian Arrowroot (*Tacca leontopetaloides* (L.) Kuntze), popularly known as *Gbache*, *Amora* or *Aduro susun* by some ethnic nationalities in Nigeria, is a tuber bearing perennial herb that grows in the wild as solitary plants in open fields, under tree shades or on hilltops across the tropical rainforest and guinea savannah agro-ecologies of the country. Starch extracted from the tubers are used to prepare different local delicacies by some indigenous people of north-central Nigeria. It also has pharmaceutical, medicinal, and sundry applications. In recent years, the plant population in the wild has dwindled probably due to increasing use of herbicides, urbanization and climate change. This coupled with the increasing recognition of the industrial quality of its starch have brought to the fore the need to domesticate the plant. This paper reviews the prospect of domesticating the crop, highlighting its usefulness, geographical distribution, folk biology, morphology, propagation, tuber storage and starch extraction, and nutritional qualities that can be harnessed towards its domestication. The implications of some morphological attributes of the crop on its domestication were also discussed.

***Keywords**: Polynesian Arrowroot, 'Amora', Domestication, Starch, Tacca leontopetaloides*

Introduction

Polynesian Arrowroot (*Tacca leontopetaloides* (L.) Kuntze) belongs to the genus Tacca and family Taccaceae (IPNI, 2005). However, some taxonomists group it with the yam family Dioscoreaceae (Caddick *et al*., 2002). Its synonyms are *T. involucrata*, *T. hawaiiensis*, *T. oceanica* and *T. pinnatifida* (Raji and Ahemen, 2016). It is a perennial, herbaceous, monocot. It is native to tropical Africa, Indian subcontinent, Papua New Guinea, Indonesia, Malaysia, Philippines, Australia, Micronesia, Fiji, and Samoa (Meena *et al*., 2010; USDA, 2021). It is a diploid with chromosome number 2n = 30 (Jukema and Paisooksantivatana, 2016). It is popularly known as *Gbache* by the Tivs and *Amora* by other ethnic nationalities of north central Nigeria. In the southwest Nigeria, it is known as *Aduro susun*. It is found as a vegetative plant only in the rainy season because from September through the dry season the shoot dies off, and the tubers become dormant; new shoots sprout and emerge at the onset of rains the following year. It can be propagated both by seed and by tuber. In Nigeria, as in other parts of Africa, these plants grow in the wild as solitary plants in open fields, under the shade of trees or on hilltops (Satdom and Ajala, 2020). It is found in the tropical rainforest and guinea savannah agro-ecologies of Nigeria. The plant is spread wider in the middle belt (Manek *et al*, 2005) and in the southwest States (Borokini *et al*., 2014). Specifically, Olojede *et al*. (2009) and Pate *et al*. (2014) reports that it is found widely in Plateau and Nassarawa states. They have also been collected from the wild in Anyamelu LGA of Anambra State and Bende LGA of Abia State (Amadi *et al*., 2018). They are virtually underutilized, with an annual production estimated at over 20 million MT (Omolaja, 2013). In Plateau State, the tubers are a delicacy to the people of Shendam, Langtang and other members of the lower Plateau and are eaten especially when other staple foods are scarce (Ogbonna *et al*., 2017). The tubers are rich in starch which varies according to growing conditions and soil substrate. It ranges from 10% to 30% of tuber weight (Spennemann, 1994; Zaku *et al*., 2009). Although the tubers are poisonous, the poison is removed by soaking or washing the starchy tubers in water and repeatedly rinsing, Once they can be processed for food (Borokini and Ayodele, 2012).

The indigenous people of middle belt of Nigeria who consume the starch from the tubers of Polynesian arrowroot see this plant as a gift from God as it is always there in the wild for them to gather. They have therefore seen no need to domesticate it. However, in recent years, the plant population in the wild has dwindled, probably due to the increasing use of herbicides, urbanization, and climate change. This is coupled with the increasing recognition of the industrial quality of its starch for pharmaceutical purposes (Kunle *et al*., 2003; Vu *et al*., 2017); food and drug systems (Ukpabi, *et al*., 2009; Ogbonna *et al*., 2017); and bioplastics (Nurul Shuhada *et al*., 2013); have brought to the fore the need to domesticate the plant.

National Root Crops Research Institute (NRCRI) Umudike and Raw Material Research and Development Council (RMRDC) Abuja are collaborating in the pilot effort to cultivate Polynesian arrowroot in order to harness its potentials and encourage its domestication. This paper reviews the prospects of domestication of Polynesian Arrowroot in order to ensure its preservation and enhance its contribution to food security.

Importance of Polynesian Arrowroot

As Food

In Northern Nigeria, the tubers of Polynesian arrowroot are consumed as food, especially when other staple foods are scarce (Kay, 1987). Olojede *et al*., (2009), reports that it is used as food in five northern states namely Plateau, Benue, Niger, Nasarawa and Yobe (Table 1). It is a cherished food for many communities in the southern parts of Plateau State (Ogbonna *et al*., 2017). When dried, the starch is used to prepare various types of puddings, porridge, and ceremonial foods amongst the Tivs of north-central Nigeria (Ahemen and Raji, 2008; Amadi *et al*., 2018). Almost all the varieties are used as a delicacy for newly wedded couples (Pate *et al*., 2014). In India *T. leontopetaloides* tubers are usually cooked, boiled with leaves of guava or tamarind to avoid the irritating property of the tubers, or roasted as vegetables (Misra and Misra, 2014). In Hawaii the tubers are used as famine food (Bevacqua, 1994), and it is a staple food in Mozambique (Bruschi *et al*., 2014). The flour has been mixed with wheat flour for making bread, cakes and other sweet meals (Vimala and Nambisan, 2005) and was used in the past for bread making in Europe (Omodamiro *et al*., 2021). In Fiji, undried starch is wrapped in leaves and buried into the ground to ferment before being eaten. Starch is also used to make sweetmeats (Flach, 1996). In Gabon, the fruit pulp is eaten by children. Sometimes the leaves are used as a vegetable.

Table 1: Polynesian Arrowroot germplasm collection by states and utilization

State	Frequency of collections	% of total collections	Utilization
Adamawa	1	4.8	–
Benue	4	19.0	Food
Cross River	1	4.8	–
Nasarawa	2	9.5	Food
Niger	3	14.3	Food
Taraba	1	4.8	–
Yobe	1	4.8	Food
Oyo	4	19.0	–
Ogun	2	9.5	–
Plateau	2	9.5	Food
Total	21	100.0	

Source (Olojede et al., 2009)

Medicinal Uses

The medicinal value of taccalin found in the tuber needs further investigation (Ukpabi, 2009). On many Polynesian islands, the bitter raw tubers are used to treat stomach ailments, mainly diarrhoea and dysentery (Kay, 1987, John-Rey, 1997), guinea worm infection, hepatitis and an antidote for snake bite. Its infusion is used to treat hepatitis and sores of guinea worm infections. Raw tubers and starch have been used to treat vomiting and diarrhoea in traditional Hawaiian communities (Krauss, 1998). Roots and flower are used to treat snake bite. Traditional rulers also use it for rituals and as an aphrodisiac (Bosha *et al*., 2015). Recently it has been discovered that the marc of Tacca has antidiabetic effects (Bosha *et al*., 2013). The rhizome has medicinal virtues of detoxification, diminishing inflammation and acesodyne, can cure abscesses of the stomach and duodenum, high blood pressure, hepatitis, gastralgia, scalds, burns, tumefaction and ulcers (Zhang *et al*., 2007). Because of its potential medicinal benefits, phytochemistry studies had been carried out. Scheuer *et al*. (1963) found *T. leontopetaloides*, contained þ-sitosterol, ceryl ethanol, and one unknown compound of Taccalin. Over 134 compounds with different bioactivities have been isolated from Tacca species comprising of steroids, terpeniods, diaryheptanoids and taccalonolidesare said to have the potential of becoming anti-cancer drugs (Abdel *et al*., 1990; Abdallah *et al*. 1990; mTinley *et al*.,2003).

Sundry Uses

It is used as laundry starch to stiffen fabrics. The water from the grating is used as a detergent (Burkil, 1994). The sapogenins of *T. leontopetaloides* have been reported to show a strong muluoscidal activity against snails (*Bulinus truncatus* and *Biomphalaria pfeifferi*) (Flach, 1996), root extracts are used as insecticides and arachnicides (Burkil, 1994). It can also be grown as an ornamental plant (Ruffo *et al*., 2002). The petioles and peduncles yield fibres used to make hats and fishing utensils (Flach, 1996). In Samoa, fresh starch is used as a kind of glue between thin layers of beaten bark of the paper mulberry (*Broussonetia papyrifera* (L.) Ventenat) to make bark cloth ('tapa' or 'siapo') (Flach, 1996).

Germplasm collection

Polynesian arrowroot is indigenous to Nigeria based on its abundance in the wild species and diversity of genotypes that are found across the derived savannah and rainforest agro-ecologies of the nation. Olojede *et al*. (2009) reported making more collections from Benue (19), and Oyo (19) states followed by Niger (14.5) (Table 1). Collections were also made from Zakibiam in Benue State, Anyamelu LGA of Anambra State, and Bende in Abia State in 2018 (Amadi *et al*., 2018); and from Ondo and Osun States (Borokini and Ayodele, 2012). Map of Nigeria showing the states from where Polynesian Arrowroot has been collected is shown in Figure 1. Considering that the expedition by Olojede *et al*. (2009) is over a decade ago, it is necessary to undertake a more extensive expedition across the country to collect accessions of Polynesian Arrowroot for conservation, characterization, evaluation, and evaluation multiplication.

Traditional knowledge about Polynesian Arrowroot

Much of what is known today about the usage of Polynesian Arrowroot is based on folk science. A rural woman at Zaki-biam in Benue State described it as a gift from God. They see the plants spring up in their bush every year and simply digs them up at harvest time hence they saw no need to cultivate it. Women undertake the scavenging for the roots in the wild and bring them home to process or store to meet their family food requirements especially at times of scarcity. They store the tubers buried in moist soil around the homestead and remove them for processing and utilization as and when needed. Traditionally, the starch consumed as the principle product is extracted by washing the tubers, then grating and soaking in water before sieving. The starch is allowed to settle and the supernatant liquid is decanted, more water is added and decanted several times to get rid of all the bitterness. It is then sun-dried to give an immaculate white flour. To prepare for consumption, the starch is gelatinized in boiling water to form a translucent pap, which is then cooled, broken into lumps, and mixed with boiling sauce to produce a much cherished delicacy. A porridge made from Polynesian Arrowroot is shown in figure 2. It is important to document indigenous knowledge of its processing and utilization as a prelude to domestication.

Morphology of Polynesian Arrowroot

Amadi *et al*. (2018) reported extensively on the morphology of Nigerian ecotypes of Polynesian arrowroot based on the plants grown on one-hectare farm (Figure 3) at Umudike in Abia state from a collection of tubers from Zaki-biam LGA of Benue State. It is acaulescent, with 2-7 leaves extending from the underground tuber's apex. Peduncles subtend at their apex an umbellate inflorescence bearing from 10-50 flowers (Figure 4a). Fruits are ovoid, ribbed, with persistent tepals at the apex (Figure 4b). Fruits are many sometimes up to 20 per plant. Each fruit is a berry and contains numerous striated brownish seeds that were dormant at harvest. Tubers mostly one per plant though some produced two or more, are spherical and somewhat flattened at the apex and are subtended by stolons which grow down vertically from the base of the apex of the mother tuber (Figure 5). Tubers weighed mostly between 200-600g each but a few weighed up to 900g. The main roots are adventitious, ranging from 20-50, and grow to lengths ranging from 10-25cm. There are roots on the surface of developing tubers. Two distinct forms have been reported from the Pacific Islands, one producing a single large tuber, the other with a number of smaller (potato-sized) tubers (Kay, 1987). Many variants of the plant were identified in the collection studied by Amadi *et al*. (2018) both in terms of plant type, number of peduncles, number of tubers and tuber skin colour.

Propagation and Agronomy of Polynesian arrowroot

Polynesian Arrowroot can be grown on a wide range of soils and usually requires a high amount of organic matter in soil (Rana and Kumar, 2017). It is usually propagated by seed tubers, though propagation by true botanical seeds is possible. The size of tubers to be used for planting is important as growth and yield of tuber crops are affected by seed tuber size (Masarirambi *et al*., 2012). In an experiment carried out to study the effects of 4 levels of NPK fertilizers (O kg, 100kg, 125kg and 150kg) and 3 seed tuber sizes (< 45, 60 and 100g) on the growth and yield of Polynesian Arrowroot in Jos South Local Government Area of Plateau State Nigeria, Satdom and Ajala (2020) reported that there were significant differences within the means due to seed tuber sizes for parameters such as Stem girth at 14 WAP, Number of Tubers and Mean weight of Tubers at harvest (Table 2). Working with minitubers, Aziz and Susanto, (2015) found that large tubers (5.1 - 20 g) had significantly greater mother and daughter tuber weight, mother and daughter tuber thickness than small tubers (1-5 g). Large propagules (5.1-20 g) produced 166.52 and 54.61 % larger mother and daughter tubers, respectively, than small propagules (1-5 g), and the mother and daughter tubers produced were 29.86 and 59.93% thicker than the initial mini-tuber propagules. Plants from larger seed potato tubers exhibited greater physiological growth and yield than smaller seed tubers because they had a larger nutrient base to mobilize at their early stages of growth. Kay, (1987) reported that tubers are often planted about 15 cm deep at a distance of 45 cm in rows 75-90 cm apart. Pate *et al*. (2014) evaluated the response of Polynesian Arrowroot to intra-row spacing (20, 25, and 30 cm) and recommended 20 and 25 cm as the most appropriate for tuber production. At Umudike, in Abia State Nigeria, good yield was obtained from planting one tuber per stand on inter and intra row distance of 1m and 0.5m respectively. In order to optimize the interception of sunlight for optimal productivity, closer spacing is required; considering the relatively small plant size and fragile foliage of Polynesian arrowroot. More research on appropriate plant spacing and plant population for optimum productivity is required.

Tuber yields of Polynesian Arrowroot are enhanced by organic and inorganic manure application. Pate *et al*. (2014) evaluated the response of Polynesian Arrowroot to five fertilizer sources (NPK, poultry manure, goat manure, cow dung, and control) and recommended NPK and poultry manure as the most appropriate for tuber production. Satdom and Ajala (2020) reported that fertilizer application increased the number of tubers and mean tuber weight compared to the unfertilized control (Table 2) suggesting that yield of Polynesian Arrowroot can be increased by fertilizer application. Weeding is important and partial shading is believed to be beneficial (Kay, 1987; Jukema and Paisooksantivatana 2016). In Nigeria, the tubers break dormancy and begin sprouting in the wild by February with the onset of rains and are harvested about 8 months later around September – October after senescence of the leaves. However, it has been reported to take as much as 10.5 months to reach maturity under some conditions (Kay, 1987). Multiplication by true seed is not widespread because of poor seed germination, around 20% as reported by Borokini *et al*. (2011). Plants grown from seed first produce palmately incised young leaves, and the mature leaves are 3- lobed with each lobe pinnately lobed; such plants do not start flowering until 2-3 years old. Most probably, pollination is affected by insects (Flach, 1996).

Nutritional Composition

Although fresh tubers are inedible because of the presence of bitter toxic substances, they can be eaten after thorough preparation or, more important, an edible starch can be extracted from them.

Proximate Analysis

The proximate composition of freshly harvested and stored tubers, starch, marc, and peels of Polynesian arrowroot reported by various authors (Zaku *et al*., 2009, Bosha *et al*., 2015, Ubwa *et al*., 2011) is presented in Table 3. Expectedly, carbohydrate predominates followed by moisture and traces of protein, fats, and minerals (ash), indicating that the tubers are a good source of calories that can help energize both man and livestock if domesticated. The principal amino acids present in the protein are arginine, glutamic and aspartic acids, leucine, Iysine and valine (Kay, 1987).

Compared to other minor root and tuber crops like Rizga (*Plectranthus esculenta* N.E. Br) and Hausa Potato (*Solenostemon rotundifolius* Poir) that have been domesticated, the crude protein and Carbohydrate (NFE) of Polynesian Arrowroot tubers are higher as shown by data from Olojede *et al*., (2009) (Table 4). The protein content of tubers of Polynesian Arrowroot was reportedly higher than those of some major root and tuber crops, including cassava, yam sweet potato, and cocoyam (Olojede *et al*., 2009).

Anti-nutritional Factors

In addition to these nutrients, tuber of Polynesian Arrowroot also contains high levels of anti-nutritional substances which may make their consumption a threat to humanity thus making the knowledge of their nutritional status and toxic levels imperative before their domestication (Ubwa *et al*., 2011; Bosha *et al*., 2015). Tubers are unpalatable, taste bitter, produce inflammation and show occasional toxicity (Raymond, 2018). The tuber peels contain high levels of anti-nutritional factors including Cyanogenic glycoside (43-45 mg kg^{-1}), Saponin (31.50-35.00 mg kg^{-1}), Phytate (28.50-29.50 mg kg^{-1}), Haemogglutinin (20.00-23.00 mg kg^{-1}) and Oxalate (15.50-19.00 mg kg^{-1}) (Ubwa *et al*., 2011). The high levels of anti-nutritional factors especially cyanogenic glycosides may be responsible for their perceived toxicity hence they require processing before they can be feed to livestock. A bitter extract (about 2.2%) was also isolated from the tuber, containing ß-sitosterol, cerylic alcohol, taccalin (a rather unusual, bitter principle in plants), alkaloids and steroidal sapogenins. Small young tubers are said to be more bitter than large older ones (Flach, 1996).

Economic and Industrial Potentials

The economic importance of Polynesian arrowroot is invisible in official statistics but research reports show that it is undoubtedly important at the local level as a reserve and ceremonial food. Its ability to produce edible starch on marginal soils is of interest. A (measure) of the prepared starch that weighed approximately 1kg was sold between N100 (US$0.78) and N120 (US$0.94) as far back as 2009 (Olojede *et al*., 2009). The physicochemical properties of tacca starch also indicated that it could be suitable in processed foods like pies and puddings (Omojola, 2013). The high paste clarity of Polynesian arrowroot starches at higher starch concentrations indicates a potential for application in food products like pies and puddings where clarity is desirable (Nwokocha *et al*., 2011). The extracted starch (over 30 % wt/wt basis) and the modified derivative (citrate) have been found to be better disintegrants in drug formulations than corn starch, because of higher swelling power, and amylose content, almost zero fat and lower gelatinization temperature (Omojola, 2013). Adebiyi *et al*. (2011) prepared tacca starch citrate derivatives to further improve its swelling properties and make it a better disintegrant in tablet formulations. The water absorption capacity, browning and charring temperatures of the modified starch were found to be higher than that of the native tacca starch. The citrate derivative had a higher swelling capacity than the unmodified starch at lower temperatures of 50-70oC. Since increase in swelling power is indicative of suitability of a starch being used as a disintegrant in the pharmaceutical industry, tacca starch citrate might be a better disintegrant in the formulation of tablets, than the tacca native starch. Abba *et al*. (2014) that acetylation treatment made *T. leontopetaloides* starch more suitable for use in remoistenable adhesive applications by increasing their tack strength and reduction in syneresis. Some selected physicochemical which are important for industrial use of starch from Polynesian arrowroot is shown in Table 5.

Rapid multiplication studies

Most Polynesian arrowroot plants produce only one tuber per plant. Considering that tuber is the economic and consumable part of the plant and at the same time the main means of propagation, 1:1 multiplication ratio poses a major limitation to domestication. Efforts have been made to develop alternative methods of rapid multiplication to increase the multiplication ratio. Borokini *et al*. (2011) obtained seed embryo germination of 57% as against 20% for germination under conventional sowing by culturing them on Murashige & Skoog basal media augmented with various concentrations of single or combined growth hormones. The best shoot proliferation was obtained using media fortified with 0.1 mg/L 6-benzyl amino purine and 0.01 mg/L naphthalene acetic acid, while the best rooting was obtained with MS media supplemented with 0.1 mg/L indole butyric acid. Callus formation was not observed on plantlets in vitro, indicating much easier and less challenging in vitro plant propagation. Furthermore, Hlásná *et al*. (2015), optimized highly effective micro-propagation method for the production of true-to-type plants of *T. leontopetaloides* using MS medium supplemented with zeatin (0.1 mg l-1) in combination with NAA (0.05 mg l-1) (5.00 ± 0.38 roots/explant). Since the plant is only actively growing in the rainy season, in vitro propagation ensures cultivation and multiplication in the off-season, thereby increasing yield potential and breaking the limitation of the planting period so that all-year-round planting becomes possible.

Methods of storage

Unprocessed tubers can be stored for up to six months, after which they begin to sprout (Spennemann, 1994). Tivs of North central store unprocessed tubers in pits dug in moist areas of their homes until when needed. In a study in which tubers were stored in 3 different types of pits for 6 months, Raji and Ahemen, (2016) reported that pit air temperatures decreased with increase in air vents inserted in the pits, being lowest in the two vent pit followed by one-vent pit. Cumulative weight loss (%) and Rot incidence also decreased with increase in number of air vents for five months of the storage period. Sprouting index of >80% was recorded in all the pits in the fourth month of storage. They concluded that underground storage of Polynesian arrowroot tubers can be safely achieved in 3 months. The live tubers bitterness means animals will not eat them which is good for storage. Another option for storage is to process it into starch and then store it as starch. Provided the processed starch is kept dry and away from weevils, ants, cockroaches, and the like, it will keep indefinitely, making it a suitable trade item (Spennemann, 1994).

Starch extraction and fortification studies

The process for the production of clean white starch from Polynesian arrowroot tubers are schematized in figure 6. Omodamiro *et al*. (2021) reported that the process gave a clean white amora starch, with starch yield 22.57±0.09%; residue (fibrous chaff) yield 7.41±0.08%; moisture content 11.9±0.22%; pH 6.8±0.10 with an average of peel loss 14.63±0.19%. In addition, the pH values along the processing chain were of the fresh tuber 6.30; grated mash 6.55; starch slurry 6.80 and dried starch 7.29. The pH values decreased with processing, which could be due to the removal of bitterness. The fermented residue also gave good flour. Raymond, (2018) reported a pH value of 6.9 for Polynesian Arrowroot experimental starch which was close to the 6.8 reported by Omodamiro *et al*. (2021). The starch grains are simple polyhedrons or hemispheres, with diameters ranging from 8 to 40 microns, average 20 microns (Flach, 1996). Nwokocha *et al*. (2011), isolated starch from white and yellow tuber variants of *Tacca involucrata* and found that their granule morphology was the same but they differed in granule size distribution: white tacca (6.13–18.12m), yellow tacca (4.19–11.98m). Yellow tacca exhibited an A-type X-ray diffraction pattern but white tacca had a C-type diffraction pattern. White tacca had a slightly higher weight average Mw (2.12 × 107 g/mol) than yellow tacca (1.85 × 107 g/mol). Yellow tacca had lower gelatinization temperature, higher swelling power, higher amylose leaching, and higher freeze–thaw stability than white tacca. However, the flow characteristics and small deformation mechanical spectra of the starch gels did not differ greatly.

Prospects of Domestication

Generally, the plants were upright, growing to a medium size and as such will tolerate closer spacing and increased plant population for increased productivity per unit area. Closer spacing will improve canopy coverage trapping optimum amount of sunlight for assimilate production in addition to good weed control. Planting one tuber per stand at 70 cm inter and 30 cm intra row spacing or plant population density of 47,620 plants per hectare is suggested for Amora production investigation.

The floral structures become established before the foliage, suggesting that the plant places a premium on the production of sexual seeds over the production of tubers. Since most of the early resources mobilized from the mother tuber go to establish the floral structures at the detriment of the foliage, removing the floral structures as soon as they emerge above ground may lead to more robust foliage that will result in the production of more assimilate which if channelled to tubers will result in higher yield. Most plants produce only one tuber per plant. Considering that tuber is the economic and consumable part of the plant and at the same time the main means of propagation, 1:1 multiplication ratio poses a major limitation to domestication. However, few plants were found to produce multiple tubers suggesting the existence of variability upon which selection can be imposed to improve the number of tubers. In addition, cut sets of large tubers that were used as planting materials sprouted, suggesting that these tubers may be amenable to rapid multiplication using the miniset technique currently in use for its close relative, yam. Furthermore, multiple stolons produced by a good number of plants indicate it has the potential to produce more than one tuber under favourable conditions. New tubers are formed beneath the mother tubers and are therefore less prone to exposure, this coupled with the moderate tuber size, means it can be cultivated with minimum tillage where the top soil is deep and soft. It may not need big ridges or mounds as in the case of yam. Polynesian Arrowroot can be propagated by true seed; however, they will grow for two or more seasons for tubers of reasonable size to be obtained. The fact that seed tubers can be generated from the botanical or sexual seed is a plus for domestication.

Conclusion

Polynesian Arrowroot has the potential to play an important role in the nutritional and economic well-being of rural dwellers and meet industrial starch needs for pharmaceutical and textile industries if it is domesticated and commercially produced. Certainly Polynesian Arrowroot has helped to feed our people especially in lean times and can do much more if brought into cultivation. Its domestication to enhance its contribution to the Nigerian economy is long overdue and cannot be overemphasized.

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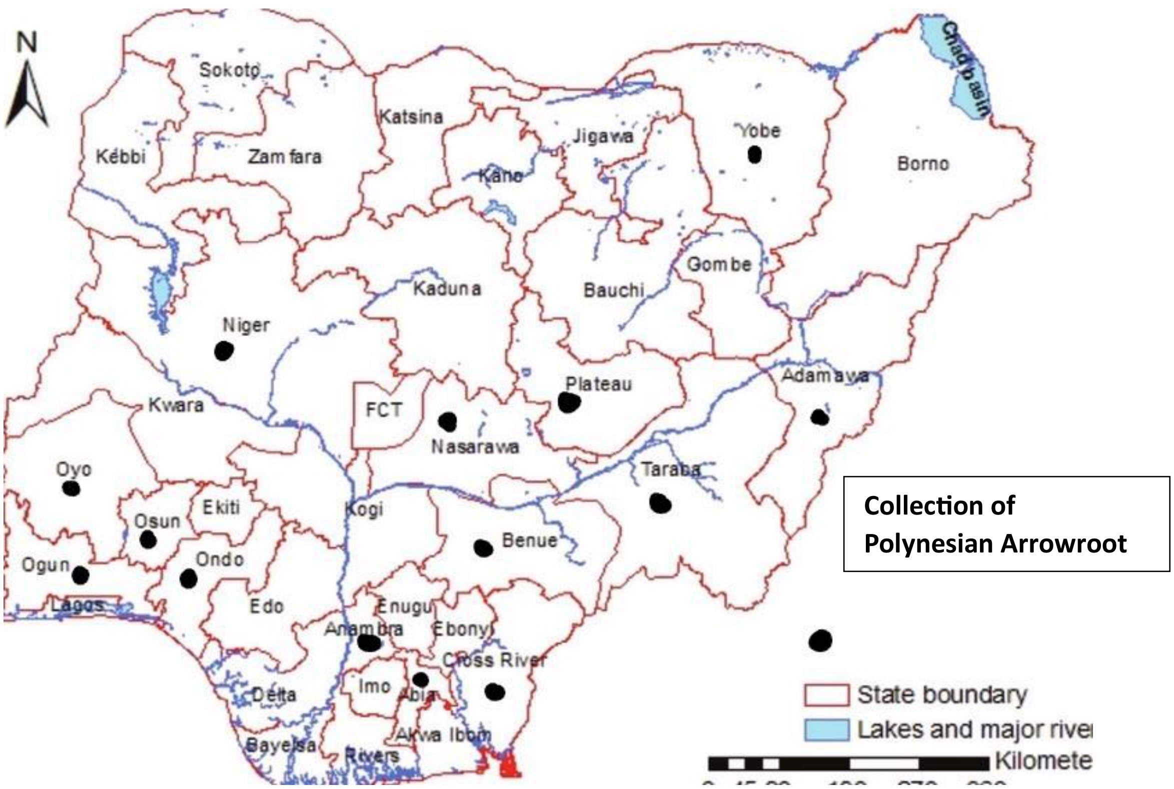

Figure 1: Map of Nigeria showing with black dots the states where Polynesian Arrowroot have been collected

Figure 2. Porridge from starch of Polynesian Arrowroot made by village women at Zakibiam

Figure 3: Polynesian Arrowroot showing good field establishment at Umudike

Figure 4 a & b: Umbellate Inflorescence and Developing fruits of Polynesian Arrowroot

Figure 5: Stolon subtending tubers; Plants with single and multiple tubers of Polynesian Arrowroot

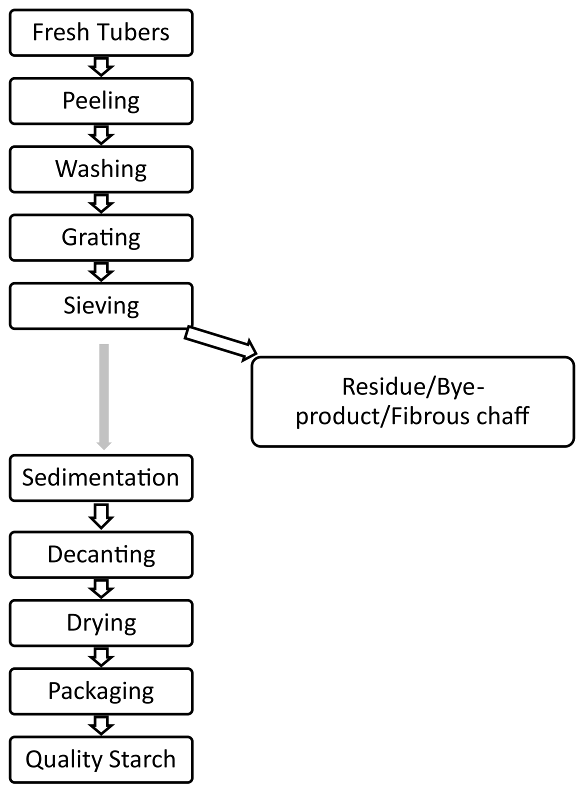

Figure 6: Flow chart for production of quality starch from freshly harvested Polynesian Arrowroot tubers (Adapted from Omodamiro et al., 2021)

Table 2: Effect of Seed Sizes and NPK Fertilizer Level on some growth at 14 (WAP) and yield parameters of Polynesian Arrowroot at Harvest

Treatment	Length of Leaf Petiole	Length of Flower Stalk(cm)	Stem Girth Length	Number of Leaves	Number of Leaflets	Number of Flowers	Number of tubers	Mean Weight of Tubers
Seed Size(g)								
Small	17.6	30.6	2.02b	2.42	7.25	9.58	0.75b	20.7ab
Medium	25.3	45.1	2.55a	2.17	6.25	12.3	1.25a	15.7b
Large	25.2	54.2	2.57a	2.25	6.25	12.3	1.25a	36.6a
Significance	NS	NS	*	NS	NS	NS	*	*
LSD	-	-	0.50	-	-	-	0.29	16.7
Fertilizer NPK								
0 kg h-1	22.2	37.4	2.26	2.22	6.00	9.78	0.44c	9.78
100 kg h-1	21.4	60.1	2.67	2.44	7.33	13.4	1.11b	33.5
125 kg h-1	17.4	25.9	2.33	2.11	6.00	9.56	1.67a	20.7
150 kg h-1	29.8	51.9	2.62	2.33	7.00	12.8	1.11b	33.3
Significance	NS	NS	NS	NS	NS	NS	*	NS
LSD	-	-	-	-	-	-	0.41	-

Means with the same letter(s) within the same column and treatment are not significantly different at 5% levels of probability using LSD (Least Significant difference). NS – Not significant. Source (Satdom and Ajala, 2020)

Table 3: Proximate compositions of Freshly harvested tuber, Tuber after 4-month storage, Starch, Marc and Peels from tuber of Polynesian Arrowroot

Parameter	Composition
Fresh tuber g/100g dm (Ukpabi *et al*., 2009)	
Crude protein (%)	1.10 + 0.1
Crude fibre (%)	0.68 + 0.3
Lipids (%)	0.10 + 0.0
Ash (%)	2.7 + 0.1
Carbohydrate (%)	95.42 + 1.8
Energy (Cal/100g)	388.70 + 1.8
Tuber after 4-month storage g/100g dm (Ukpabi *et al*., 2009)	
Crude protein (%)	1.50 + 0.2
Crude fibre (%)	0.28 + 0.0
Lipids (%)	0.08 + 0.3
Ash (%)	1.73 + 0.2
Carbohydrate (%)	96.42 + 0.1
Energy (Cal/100g)	392.5 + 1.9
Starch (Zaku *et al*., 2009)	
Moisture (%)	9.15 ± 0.02
Ash (%)	0.20 ± 0.04
Crude protein (%)	0.39 ± 0.02
Crude fiber (%)	2.10 ± 0.06
Total lipids (%)	0.09 ± 0.01
Carbohydrate (%)	88.07 ± 0.03
Aqueous pH	5.80 ± 0.03
Marc (Source Bosha *et al*., 2015)	
Moisture (%)	10.83 ± 0.3
Ash (%)	1.93 ± 0.3
Fats (%)	1.06 ± 0.05
Fibre (%)	4.42 ± 0.04
Crude protein (%)	6.12 ± 0.06
Carbohydrates (%)	75.64 ± 0.25
Peels (Ubwa *et al*., 2011)	
Moisture (%)	20.79 ± 2.56
Ash (%)	6.29 ± 0.75
Fats (%)	2.58 ± 0.40
Fibre (%)	1.73 ± 0.25
Crude protein (%)	0.15 ± 0.13
Carbohydrates (%)	67.83 ± 0.25

The results are means of triplicate determinations ± standard deviation

Table 4. Average proximate composition of some minor root crops germplasms collected from various locations in Nigeria

Chemical Composition g/100g dm	Rizga	Hausa potato	Amora
Moisture	7.85	7.76	8.07
Crude protein	10.52	7.58	10.53
Crude fibre	14.07	11.07	5.69
Lipids (fat)	0.24	0.24	0.41
Total ash	4.77	6.80	3.01
NFE	70.40	60.23	80.40
Ca	0.34	0.33	0.27
P	0.37	0.36	0.27

Source (Olojede et al., 2009)

Table 5. Selected physicochemical (Industrial) properties of the starch from Polynesian Arrowroot

Parameter	Composition
Bulk density (g/cm3)	0.81 ± 0.03
Amylose content (%)	28.07 ± 0.04
Swelling power (g/10ml)	3.4 ± 0.01
Solubility power (%)	66.6 ± 0.02
Water-binding capacity (%)	56 ± 0.01

The results are means of triplicate determinations ± standard deviation