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Cocoyam (taro and tannia): Staples with untapped enormous potentials-A Review

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Abstract

Within the past seven decades, taro and tannia were a household food in Nigeria. They were consumed and cherished for their rich taste, and their nutritional values. They were then an important most frequently eaten dish of the rural southern Nigerians. Apart from the established nutritional advantages of the crops in medical nutrition therapy, they offer distinct advantages as potential therapeutic agents for the treatment of eczema, rheumatism, and bone fracture. Moreover, applications of taro extracts over snake bites and septic wounds accelerate healing and purifying processes. Furthermore, their anthelmintic, antihypoallergic, anticancerous and antioxidative properties has been profiled by many authors, in addition to their now evolving roles in industrial products formulations. This paper reviews the evolution of cocoyam as an orphan crop, their potentials as an evolving industrial crop, their various food forms and the nutritive and medicinal benefits of the crops.

Keywords: Allergic infants; diabetic patients; elderly; orphan crops; small granules; soluble dietary fibre; *Colocasia esculenta*; *Xanthosoma sagittifolium*.
Abbreviations: Ca_Calcium, PPB_Participatory plant breeding.

Introduction

In the ‘beginning’ there were taro and yam in Nigeria. Taro competed favourably with yam both in cultivation and consumption. Both reigned as the staple food of the people until the arrival of banana, and plantain, followed by maize, cassava, tannia and later sweetpotato. These new comers were elegant and easier to grow. They gained recognition and acceptance as staple foods. Thus, cassava and sweetpotato superseded yam and taro respectively (Ezedinma, 1987). Dating back to the early years in agricultural production in Nigeria, the use of taro crop by the people of southeastern Nigeria as food was mainly as an adjunct either as soup thickener or mixed with yam, banana or plantain in fufu preparation. In those early years, taro was also used for sacrifices but has never ranked equal with yam as a major staple, whereas tannia was even less favoured as a farm crop, but rather popular as intercrops in tree crop plantations. Consequently, the ‘new’ crops particularly cassava is becoming increasingly preferred as dietary staples. More recently, rice which was the last to arrive attained the status of essential food commodity and has successfully supplanted all other staples (Ezedinma, 1987).

Cocoyam is a herbaceous perennial crop growing to a height of 1.5 to 2 m with an underground starchy corm and long robust petioles supporting a whorl of heart-shaped leaves. They are one of the most widespread of the root and tuber crops cultivated almost everywhere throughout the tropics (Wang, 1983) and in over 65 countries of the world (Pollock, 2000). There are two major aroids of importance in Nigeria. They are taro (*Colocasia esculenta* var *esculenta*) and tannia (*Xanthosoma sagittifolium*). The two prominent botanical cultivars of *Colocasia esculenta* that are commonly recognized are: *Colocasia esculenta* var *esculenta* and *Colocsaia esculenta* var *antiquorum*. The corms and cormels of *C. esculenta* var. *antiquorum* are rarely eaten due to high degree of acridity and to further distinguish between the two groups, *C. esculenta* var. *esculenta* cultivars have generally twenty eight chromosomes whereas forty two chromosomes were reported in *C. esculenta* var. *antiquorum* (Wang, 1983). Described as a very ancient crop with origin in the Asian regions of the world (Onwueme, 1978, Wang, 1983, Cable 1984), taro is a staple food for about 400-500 million people in the world. By contrast tannia is relatively new, and is believed to have originated in the northern south America (Clement, 1994; Giacometti and León, 1994) and later diffused to West Africa. Taro is less acrid compared with giant swamp taro, but contains only one-tenth the amount of calcium oxalate and a large amount of trypsin inhibitor. The generally lower levels of defensive chemicals of taro, as compared with giant swamp taro, may account for the greater susceptibility of taro to diseases (Bradbury and Holloway, 1988). By comparison, tannia corms are less susceptible to pests and diseases than taro, even though both have about the

Table 1: Major cocoyam (Dasheen and eddoe) producers by volume (MT) 2011

Countries	Production (MT)
Nigeria	3,265,740
China (mainland)	1,650,000
Ghana	1,299,645
Cameroon	1,568,804
Cuba	132,000
Venezuela	90,336
EL Salvador	42,961
Peru	34,771
Caribbean aggregate	18,718
Others	1,520,863
World Total	**9,623,838**

Source: FAOSTAT, 2013.

Fig. 1: Healthy growing cocoyam plants
A: Tannia (*Xanthosoma sagittifolium*)
B: Taro (*Colocasia esculenta*)

same levels of calcium oxalate and acridity, but tannia has much less trypsin inhibitor (Bradbury and Holloway, 1988). Perhaps the low level of pests and diseases of tannia could be associated with its relatively recent introduction compared with taro that has been indigenous for many hundreds of years (Bradbury and Holloway, 1988). On food value, they contribute about 1.6 percent of the total food energy of the tropics and subtropics, whereas in the Pacific island the aroids constitute a very high proportion and are a major staple. However, in many of the islands in the Philippines, taro ranks third in tonnage among locally-grown root crops, and has shown substantial increases. Similarly, in some Caribbean islands, taro is of considerable importance, accounting for about 60 percent of all root crop production in St. Vincent and 45 percent in St. Lucia. As crop species, they are among the most shade tolerant of all terrestrial food crops. Agronomically, taro needs fertile soil and a rainfall of at least 2000 mm/annum whereas tannia could thrive in less fertile soil and drier conditions for optimum yield.

The growth patterns of cocoyam (taro and tannia) are typified by 3 major growth cycles. Growth during the first 2 months is generally slow. It begins with the sprouting of shoots and terminates with corm formation. This phase requires high rainfall during the first 20 weeks which triggers maximum leaf development, followed by drier conditions until harvest

(Lebot, 2009; Ubalua et al., 2016). During this early establishment period, growth and development improves remarkably under shade, although production is higher when exposed to direct sunlight at the later stages of growth. The 2nd phase of the growth cycle is marked by a rapid increase in shoot growth till 6-7 months during which maximum leaf areas and height of the plant is attained (Castro, 2006). Towards the end of 6-7 months, the shoot gradually decreases, with rapid increase in growth and development of the corms and cormels. As the dry season draws near, the shoot gradually senesces marking the 3rd phase of the growth cycles which is between 9 to 12 months after which the crop can be harvested. An average tuber yield of 6 to 10 tonnes per hectare has been reported by traditional methods of cultivation, but by cultivating disease-free planting materials and following standard package practices the yield can go up to 20 to 50 tonnes per hectare.

Taro can be cultivated both on upland and lowland, waterlogged conditions because of its ability to transport O_2 from the leaves to the roots (Onwueme, 1999). Tannia by comparison is a robust and an easy upland growing plant reaching heights of 2m or more compared to the height of 1.5 m for taro (Figs. 1A & 1B). The crop is hardier and often higher yielding than taro and its average yield on a world basis is about 12-20 tonnes per hectare. Agronomically,

Table 2: Characteristics of the tropical roots and tuber crop

Characteristics	Cassava (*Manihot esculenta*) *Euphorbiaceae*	Sweetpotato *Ipomoea batatas* *Convolvulaceae*	Yams (*Dioscoreae* spp.) *Dioscoreaceae*	Aroids *Colocsaia esculenta* and *Xanthosoma sagittifolium* *Araceae*
World production in 2007 (Millions tons)*	226	124	51	13
World cultivated area (millions ha)	18.6	9.0	4.6	1.9
World average yield (fresh tons/ha)	12.2	13.7	11.2	6.7
Yield potential (fresh tons/ha)	90	120	110	110
Growth period (months)	8-36	3-6	8-36	6-16
In-ground storage life	Long	Moderate	Moderate	Long
Postharvest storage life	Very short	Short	Long	Moderate
Dry matter (% fresh weight FW)	30-40	20-35	20-40	20-30
Starch (% FW)	27-37	18-28	20-25	15-25
Starch grain (in microns)	50-55	2-40	1-70	1-6
Amylose (% starch)	15-30	8-32	10-30	3-45
Gelatinization temperature (^{0}C)	49-73	58-65	69-88	68-75
Proteins (% FW)	0.5-2.0	1.0	0.5-1.0	0.1-1.5
Energy (kj/100g/FW)	600	500	440	400
Fibres (% FW)	1.0	1.0	0.6	0.5-3.0
Minerals (% FW)	0.5-1.5	1.0	0.5-1.0	0.5-1.5

Adapted from Lebot, 2009

Fig. 2: Some food forms of Cocoyam in Nigeria
A: Steam vegetable *Xanthosoma;* B: Roasted *Xanthosoma* + red oil, mixed with spices, pepper & sliced fermented African oil bean (*Pentaclethra macrophylla*); C: Roasted *Xanthosoma* + steamed & spiced vegetable; D: *Xanthosoma* chips; E: *Colocasia* flakes (Achicha ede); F: *Xanthosoma* flakes; G: Better leaf (*Veronia amygdalina*) soup ; H: Boiled vegetable *Colocasia;* I: Ora soup; & & J: Vegetable yam.

tannia cultivars are differentiated mainly by leaf pigmentation, plant size, cormel shape and number, cormel tip shape and pigmentation, spatial arrangement of cormels and cormel flesh pigmentation. On storage, taro does not store satisfactorily for more than 2 weeks in tropical conditions irrespective of storage treatment, whereas tannia could be stored for 6 weeks (Passam, 1982). The unique attribute of cocoyams are that both the tubers and the leaves are very tasty with substantial amounts of minerals. There seem to be a consensual agreement that cocoyams are orphan crops of utmost importance, essential for food security and that they represent an untapped potential for further economic development (Lebot, 2009). Grown in the wetter areas of the south eastern/south western/south south parts of Nigeria, to the Michika in Gongola northern state of Nigeria, cocoyams has not received appropriate research attention. The attraction for cassava, yam and sweetpotato crops that enjoys international leverage in research and development is a major challenge to the future of cocoyams as a major contributor to the diet and economy of all the producing nations. Traditionally, taro and tannia have been of subsistence status and this may explain to some extent their marginalization even though they are nutritionally and medicinally important. This situation is now changing with the renewed interest in cultivation, processing and consumption following increased awareness of their importance in medical nutrition therapy. Turning attention now to the food forms of cocoyams, boiling and roasting are the common methods of preparation in Nigeria. Though cocoyams are toxic when raw like most cassava cultivars, edible when cooked, the crops calcium oxalate crystals (raphides) may act as a toxic or chemical

Table 3: Estimated alcohol yield per tonne (wet weight) and cropping cycle for selected crops

Crop	Alcohol yield (litre .t^{-1})	Cropping cycle (months)
Taro	142	9-15
Sweetpotato	142	5
Sugarcane	67	10-12
Sweet sorghum	76.7	4
Cassava	180	12
Corn	385	3.5
Spring wheat	368	4
Grain sorghum	389	3.5

Modified from Wang, 1983

defense against grazing invertebrates or mammals. Their consumption may prove fatal and this has been ascribed to their content of oxalic acid and could cause sharp irritation and burning of the throat and mouth on ingestion. Usually, acridity is greater if the crop experiences adverse growing conditions such as drought or poor soil. Often, the calcium oxalate content of taro's leaf is ten times that of the corm, but the former has no trypsin inhibitor (Bradbury and Holloway, 1988). They are consumed either directly after boiling or roasting with red palm oil, spices and salt, or mixed with steamed green leafy vegetables or in the case of taro as soup thickener. But in Cameroon, taro is usually consumed in the form of "achu"- a thick porridge obtained by cooking and pounding to a smooth and homogenous paste (Njintang et al., 2007), whereas in Hawaii, taro is used to produce "poi"- a steamed pudding made from grated taro and coconut. Though the crops provide adequate calories when consumed as food, there are experimental evidence to demonstrate their importance in medical nutrition therapy. Interestingly, the crop taro has indirectly made even bigger contribution to world nutrition through the accidental discovery of rice as weed in flooded taro fields (Wang, 1983). By comparison tannia has successfully displaced taro due to its higher yield, taste and its ability to mimic yam (*Dioscorea* spp.) in its various food forms, especially in fufu preparation. Recently tannia's food products have been expanded to include crisps making using instant dehydration and in the area of tannia flour production. It is therefore predicted that with the application of technology, tannia can be used to make a series of industrial products similar to those obtained from taro. Currently in Puerto Rico and Philippines, tannia is replacing sweetpotato, yam and plantain due to its unique flavour and texture. Other special quality attributes of aroid is starch which is important for industrial application. Thus, aroid starch could be exploited industrially in the production of syrups, cosmetics, gums, modified atmosphere packaging film, fillers/modifiers for plastics and renewable energy (Opara, 2003). Despite all these positive attributes, these evolving industrial crops are underexploited and neglected. Cconsequently their traditional medicinal uses and food values are diminishing at a frightening rate. Yet taro and tannia offers compelling potentials for reducing hunger, poverty and malnutrition. But to promote the crops to be at par with the other root and tuber crops, a positive attitude towards increased research funding and incentives becomes a necessity.

The evolution of cocoyam as an orphan, underutilized or neglected crop

Domestication of food plants in the past was predicated on choice, convenience and serendipity by our early farmers. It is therefore imaginable that a potential food plant has to be nutritious, easy to grow and "good" to eat for it to be attractive for domestication. Similarly, it is possible that a plant with fewer pests would be an attractive candidate for domestication (Jones, 1998). But in the present evolution of our staple food crops, emergence of diseases and pests of food plants are almost disregarded. The practice of monoculture encourages rapid evolution of pests, irrespective of the natural defenses of the crop plant (Ubalua, 2010). Unarguably, the discovery of Mendel's laws propelled the conscious or unconscious research that gave birth to orphan, underutilized or neglected crops. By definition, plant breeding is "evolution guided by man" and plants are an integral part of human history (Ceccarelli, 2009) and the deliberate or inadvertent actions of breeders has even fuelled further this phenomenon of marginalization. Interestingly, the progressive decrease of biodiversity by man has had a significant influence, unconscious in the beginning and deliberate in modern times. Prior to domestication, man the hunter-gatherer was part of the natural order and most likely had, if any, a limited effect on diversity. But the discovery of Mendel's laws revolutionized agriculture. This discovery led to man's definitive role over evolution with the help of more sophisticated technologies. This remarkable period provided the necessary platform that produced two major changes that affected the evolution of plants, particularly of domesticated crops. Firstly, plant breeding was moved from farmers' fields to research stations and from farmers to scientists. Activities done by very many farmers in many different places were now done by relatively few scientists in a few places. Secondly, plant breeding gradually moved from publicly to privately funded. As a consequence not all crops were treated equally, and some became "orphan crops" neglected by science (Ceccarelli, 2009). During all these changes, there were no evidence that the local knowledge accumulated over thousands of years were adhered to or even accommodated.

In conventional plant breeding, new varieties are selected at research stations by breeders and the final products are tested on-farm. Adoption occurs at the end of the breeding process. In participatory plant breeding (PPB) new varieties are selected in farmers' fields jointly by breeders and farmers and adoption occurs during the breeding process. Interestingly, PPB uses old varieties (landraces) that often have disappeared from the field but are still available in gene banks. Following the progress of PPB, an old Eritrean farmer recalled and lamented that "PPB is "to bring back into farmers' hands that science which was taken from them many years ago". In other words, we are reversing the change that has occurred in the last 100 years or so, when "breeding", done by many farmers in many different places, was taken over by a few scientists at a few places. Defined as "evolutionary breeding", PPB allows crops to continue to evolve and to adapt to new agronomic techniques, new uses and eventually new climates (Ceccarelli, 2009). Therefore, involvement of farmers in breeding offers two main advantages; firstly, they can readily identify progenies that are suitable for their location. Secondly, the identified material will be used as parent's in future breeding cycles. Thus, as the breeding cycles progress the levels of horizontal resistance increases. By comparison, PPB is advantageous because genotype x location interactions is greatly reduced because selection is always the target and most importantly it ensures that all traits of relevance to farmers are evaluated. Furthermore, PPB also ensures quick delivery of cultivars to farmers while in conventional plant breeding it can take up to 10 years to be accomplished.

The potentials of taro and tannia crops

Between 1960 and 1980, cocoyam production in Nigeria ranked third to cassava and yam in supplying the dietary energy intake among the root and tuber crops. In those past years, yields under peasant culture ranged between 6 to 10 tonnes per hectare, but presently, yields of 20-50 tonnes per hectare is attainable where disease-free and good sized planting materials are used and cultural practices optimal (Inyang, 1987, Ubalua et al., 2016). Similarly, in Hawaii, yields of nearly 50 tonnes/ha on heavily fertilized plots have been reported (de la Pena and Plucknet, 1967). Thus, cocoyams have potentials to feed the ever increasing world populations. Besides, the income derivable from cocoyam is comparable to that of yams, an advantage that makes cocoyam, a ready source of income to the rural peasant farmers in Nigeria, underscoring the need for increase in research funding in the drive towards food sufficiency. Production of cocoyam has not been given priority attention in many countries of the world probably because of its inability to earn foreign exchange as well as its unacceptability by some developed countries for both consumption and for research funding. One possible way to increase cocoyam production in Nigeria is to increase the total hectarage devoted to cocoyam. To increase consumption of the crops, diversification of their uses through postharvest processing and improved access to markets both locally and internationally will stimulate demand. Other approaches should be on availability of research funds and incentive packages to support the resource-poor-farmers that are engaged in the production.

Statistically, Nigeria occupies the number one position as the world's foremost producer of cocoyam with an average production figure of 3,265,740 mt. in 2011 (FAOSTAT, 2013) (Table 1). In 2004 alone, Nigeria accounted for 35.5% of the world's total production of cocoyam (FAO, 2005), although none has ever made it to the international trade market. Ironically, about 72% of cocoyam produced in Nigeria is known to be consumed as food locally, the balance is often wasted through postharvest rot. Over the past two decades, there has been a steady trend in cultivation and consumption of cocoyam. Compared with other starchy food crops, cocoyam produces high yield with a minimum of labour. Recently the cocoyam yield potential has appreciated most dramatically compared with cassava, sweetpotato and yams suggesting that the output of cocoyam can be easily doubled. Projections on world average yield of cocoyam compared with world cultivated area, yield potential, in-ground storage, dry matter, gelatinization temperature, proteins, and fibres are as presented in Table 2 suggesting a very bright prospect for cocoyam. Thus, cocoyam competes favourably with cassava, yam and sweetpotato not only in average yield but also in yield potential, necessitating an urgent need for proper funding of the crop as an incentive to increase their production and productivity. Advances in the application of science and technology in the last 125 years have led to significant increases in the yields and quality of several crops through the use of superior cultivars, fertilizers, pesticides, irrigation and mechanization. Unfortunately, cocoyam does not seem to benefit from such developments in science and technology. A closer look at Table 2 indicates that cocoyam competes favourably with cassava, sweetpotato and yam in dry matter content, starch, amylose content, gelatinization temperature, proteins, fibres, minerals and energy. Besides the nutrition value of cocoyam in traditional foods, cocoyam can empower rural communities, especially women that are principally involved in cocoyam cultivation. As food, taro takes a longer time to cook than tannia and much less palatable. However, the unique nutritional and medicinal qualities of taro corms and cormels are valued by the elderly on accounts of its easy digestibility in the gastro intestinal tract, its anti-diabetic and hypoallergenic properties. In addition, the carbohydrate fraction of taro consists of 2.6% pentosan which makes it a probable candidate for industrial pentosan used in confectionery. Plucknett (1979) reported that taro flour may be superior to cassava, maize or potato starch for the manufacture of polystyrene, polyethylene and polyvinyl plastics. "Achicha"(taro biscuit) a special delicacy in Nigeria consumed during lean periods is not commonly prepared in recent years because of the drudgery in processing that are involved. Besides, the ready access to garri, maize and rice makes the process an avoidable option. Thus, the search for improved mechanized method of processing could therefore provide sustainable solution for increased availability and utilization of cocoyam products. Moreover, the leaves are used as a styptic and poultice and the stem sap is also used for treating wasp stings (Wilbert, 1986), while poi, a fermented product made from corm shavings, is used to improve muscle tone (Gosh et al., 1988; Plowman, 1969). Apart from taro's significant role in nutrition, the corm also possesses anthelmintic properties and is useful in the treatment of tuberculous ulcers, pulmonary congestion, crippled extremities, and fungal abscesses in animals (Thinh, 1997). Comparing the two cocoyam species, tannia can be roasted, fried or boiled, while taro can be boiled or sun dried after blanching before cooking. On the basis of flavour and texture, tannia is valued as a superior species. Surveys carried out in Puerto Rico show that the rural population prefers tannia to sweetpotato, yam, and plantain because of its flavour (Melese et al., 2016). Currently, tannia is largely replacing taro especially on the Atlantic coast of the United States, the Philipines, Puerto Rico and Nigeria because the tubers are larger, tastier and more mealy (Giacometti and León, 1994, Ubalua et al., 2016). Apparently, the recent shift from taro to tannia in Nigeria is mostly because tannia mimics yams (*Dioscorea* spp.) in its various food forms especially in the production of the popular fufu, even though its starch is less readily digested compared with taro starch but richer in mineral elements. Thus, the use of taro as dietary staple has declined in favour of tannia. Surprisingly tannia still remains the lesser known while taro on the contrary has enjoyed universal publicity through historical and fictional accounts of life on the Pacific Islands. Tracing back to its arrival and domestication in Nigeria, taro paste has been a popular soup thickener in the southern Nigeria but can now be produced in dehydrated form and dried slices for stability, convenience and ease of preparation. Such intermediate products like taro flour and dried slices could be reconstituted and further extruded into convenient ready-to-use, stable forms such as rice, noodle and macaroni (Wang et al., 2008). These extruded products when stored at 38^{0}C or below in polyethylene packs, stores for 12 months. Moreover, the minute granule size of taro starch has been exploited in face powder production. Originally rice starch has been the prime candidate of choice with a size of about 5 micrometers mean diameter. Comparatively, taro starch varies from 3.5 to 5 micrometers with higher gelatinization temperatures than rice starch, an attribute that could make taro starch a preferred choice (Griffin and Wang, 1983). In alcohol production for fuel, Wang and Nagarajan, (1981) reported on their integrated model system for fresh taro/swine/alcohol production. Roughly, the starch-to-alcohol conversion ratio has been identified as 1.76 kg of starch to 1 liter of alcohol. Milfont, and Brown, 1978, and 1980 respectively estimated the cost of alcohol production from cassava, and sugarcane to be \$0.15/liter or \$0.57/gallon which is similar to that of taro. Comparatively, the estimated cost of ethanol production from corn is \$0.43/gallon, suggesting that taro starch could be a competitor in alcohol production. These breakthroughs have been developed and documented in many countries of the world especially in the South Pacific Islands. Furthermore, the industrial exploitation of taro starch in the manufacture of biodegradable plastics has successfully pushed taro up the ladder as emerging industrial crop. Taro's mucilage has also been experimented on and profiled by some researchers (Ferguson et al., 1992; Huang et al., 1994; Opara, 2003; Hernandez-Uribe et al., 2014) as binders for pills. In this regard, Opara, (2003) reported that taro's mucilage dissolves as fast as or even faster than pills prepared with acacia gum. In addition, the mucilage acts as an emulsifying, thickening and smoothing agent for creams, suspensions and other colloidal food preparations. Thus, taro crop offers distinct advantages as a potential staple for industrial exploitation. Despite the contributions of taro and tannia as food, renewable energy source, and as an industrial raw material, the evolution of agro-industries based on cocoyam as a major contributor remains elusive.

Food forms of cocoyam in Nigeria

Food plays a major role in the concepts of illness and good health and provides macronutrients and micronutrients required for proper growth, development and homeostasis (Eigner and Scholz, 1993). They provide us with restorative powers to fight off illnesses and diseases. Over the years, foods prepared with cocoyam have been beneficial in medical nutrition therapy. Apart from the rich tastes of most food forms of cocoyam, they are also valued for their nutritional and medicinal qualities. The corms and cormels of both taro and tannia can be cooked and pounded sole or mixed with yam and plantain and eaten as fufu with soup. Tannia's cormels can be processed into various food forms. They can be boiled, fried, baked, roasted, pounded into a paste or prepared as flour, chips, pepper soup, or porridge. In Hawaii, taro is processed into packaged food 'poi', a sour paste made from boiled pounded taro corm (Brown and Valiere, 2004). The grain size is uniquely small conferring its starch easy digestibility estimated to be 98.8%. Though taro corm is low in fat and protein; however its protein is comparable or slightly higher than that of yam, cassava and sweetpotato (Deo et al., 2009). Nutritionally, taro's protein is rich in some essential amino acids, but low in isoleucine, tryptophan and methionine (Onwueme, 1978). A regular meal of taro corm was reported by Cho et al., (2007) to provide a good source of calcium and iron.

In the context of diet formulation, taro and tannia competes favourably with other root and tuber crops and could even be diversified further when appropriate technologies are used for their processing. Opara, (2003), described some recipes based on taro products. Technically, it appears that taros unique small starch grains (1-4µm) may perhaps be the reason why it is most widely processed into more consumable forms like flour, cereal base food products, poi, beverage powders, chips, sun-dried slices, grits and drum-dried flakes. The small starch grains (1-4µm) compared to the large grain size of tannia (17-20µm) recommends taro to be suitable for several food products, especially as food for potentially allergic infants and persons with gastro-intestinal disorders (Opara, 2003). Tannia the new comer is less readily digested than taro, but is richer in mineral elements but has approximately the same protein content. Some special quality attributes of aroid starch, which are important for industrial application includes particle size, pasting temperature and amylose content (Opara, 2003). Comparatively, several taro varieties have particle size of 1-6.5µm mean diameter, compared with rice starch at about 5µm which is the finest of the commonly available starches (Griffin and Wang, 1983). But tannia starch has relatively large grains with average diameter of 17-20µm. As pasting temperature of starch is also important during processing and industrial application, the combination of aroids properties especially taro's high pasting temperatures and particle size could provide a unique combination. Thus, aroid starch could be exploited industrially in the production of syrups, cosmetics, gums, modified atmosphere packaging film, fillers/modifiers for plastics and renewable energy (Opara, 2003).

As food, tannia mimics yams in its various forms of usage while taro is used mainly as a soup thickener. Such soups when prepared with bitter leaves (*Veronia amygdalina*) (Fig. 2G) or ora leaves (Fig. 2I), stock fish, dried fish, pepper, red palm oil, meat, crayfish, salt, fermented ogiri (*Ricinus communis*) and eaten with fufu is a popular relish in Nigeria especially among the Ibos and Yorubas. Taro can also be kneaded and prepared into biscuits (Achicha ede) (Fig. 2E). Processing cocoyam (taro) into 'achicha ede' begins with cooking the tubers for about 12 h (usually overnight) until brownish in colour. The outer skin is then removed and the flesh sliced and dried in the harmattan wind (December to February) for a period of about 4 to 5 days. The dried taro flakes are stored over the fire-place for a period of 3-4 months until properly dried and chocolate in colour. When dried, they can be stored in earthen pots for up to 6 months to provide food during lean periods. They are cooked with beans (*Phaseolus* spp.), sliced fermented African oil bean (*Pentaclethra macrophylla*), spices and red palm oil, pepper and salt. Interestingly, a meal of vegetable taro (Fig. 1H) or roasted (Fig. 2B), boiled or fried tannia (Figs.2D & F) is comparable to that of yam or even better. The prepared vegetable taro meal is nutritious, stomach friendly and a delight. It is usually prepared while celebrating "annual cocoyam festival" in Nimo, a town in the southeastern, Nigeria. However, with the renewed awareness creation and realization of the crops nutritional benefits, the corms and cormels are currently scarce and expensive.

Across the producing and consuming countries of the world, the cormels of tannia can be roasted, boiled or baked and are eaten in various forms according to communities. The leaves, petioles, stolons and the inflorescence are important delicacy and represents an important source of vitamins especially folic acid in some countries and communities (Martin et al., 1998). Tannia leaves especially the young succulent parts are a delicacy among the Efiks of Eastern Nigeria. They are cooked with grated water yam or grated cormels of tannia, dried fish, periwinkles and various condiments and eaten as a delicacy known as "Ekpang Nkwukwo". Arene (1987) pointed out that these leaves are rich in thiamine and that the thiamine provides a vital nutritional contribution to human food. Also produced and consumed in Nigeria are tannia chips (Fig. 2D) and flakes (Fig. 2F) similar to the popular potato chips and flakes respectively. The vitamin content of taro corms has been exploited in industrial food formulations. Payne et al., (1941) and Plucknet (1979) reported on the use of taro's vitamins (A and B), Ca and phosphorus, as a base for infants' industrial food preparations. Moreover, the easy digestibility of taro's flour confers its suitability for use as food by diabetic patients, potentially allergic infants and persons with gastro-intestinal disorders (FAO, 1990). Taro flour has also been adjudged to be superior to cassava, maize or potato starch for the manufacture of polystyrene, polyethylene, and polyvinyl plastics. In addition, Plucknet et al., (1979) also reported on its ability to reduce dental decay in children. Similarly, Onwueme in 1978 reported that in bakery, taro flour has been effectively used in baking and confectionery due to its pentosan content while Griffin and Wang in 1983 reported on the significance of the granule size of taro starch which makes it ideal for industrial use in the manufacture of face powders and cosmetics. In Hawaii, dehydrated cooked taro has been used as a base to produce "beverage powder" marketed under the name RA-RO-CO as chocolate flavoured taro beverage with sugar, cocoa, milk and salt as added ingredients (Payne et al., 1941). Other useful applications include its use as a nourishing tasteful ingredient in ice creams, and in syrups and alcohol production and also as fillers for plastics and taro gums. The mucilage from taro has also been reported to be useful in pharmaceutical, plastic and paper industries (Gooding, 1987; FAO, 1990).

Nutritional and medicinal benefits of cocoyam

Nutritionally, taro is superior to tannia but not inferior to yam or cassava. The starch granule of cocoyam especially taro is small and very easily digestible, making it ideal for it to be a source of carbohydrate for people with digestive problems especially the elderly. The amazing health and medicinal benefits of cocoyam is the attraction when compared with the other roots and tuber crops. Compared to cassava and yam, taro contains reasonable amount of potassium, vitamin C and zinc, thiamin and folate (Hunter, 2012). It is adjudged a veritable source of fibre which could help control blood sugar in diabetics and can also reduce blood lipids which are a risk factor for heart disease (Kumaran, 2012). According to Lange, (2012), taro's corm is a natural source of fluoride and also contains calcium that could help in strengthening bones and teeth especially in children. Taro is an excellent source of energy and starch. As taro starch is characterized by extremely small granule size, it enhances its digestibility and as such a candidate for making baby foods and special diets for invalids. Moreover, taro and tannia possess higher protein content than the major competing staples (yams, cassava and sweetpotato) even though it is still low in absolute terms, it should in combination with the easy digestibility recommends taro for more aggressive exploitation as a specialist food.

Cocoyams therapeutic properties have been experimented and profiled by many authors. For example, in 2008, Wang and co-workers characterized the inhibitory mechanism and antifungal activity of phytocystatin tarocystatin, a defense protein from taro against phytopathogenic nematodes and fungi. Similarly, Kundu et al. (2012) purified a water soluble compound from taro root that exhibited anti-metastatic activity. Thinh, (1997), further documented other important medicinal uses of taro corms that include treatment of pulmonary congestion, crippled extremities, tuberculous ulcers, and as an abortifacient. It has also been implicated as an anthelmintic with potent activity against fungal abscesses in animals. Other uses of taro in medicinal practice, especially the leaves are as a styptic and poultice and also in the use of its stem sap in the treatment of wasp stings (Wilbert, 1986). Another potential medicinal use of taro is in the production of poi, a pastry starch made from the cooked, mashed corm of the taro crop which is hypothesized to have the potential as a probiotic (Brown and Valiere, 2004). Of importance also is the predominant bacteria (*Lactococcus lactis* (95%) and *Lactobacilli* (5%)) in poi which are lactic acid producing bacteria. It is reported to contain significantly more of these bacteria per gram than yoghurt, implying that it is suitable for use in medical nutrition therapy and also shows promise in infants with allergies or failure-to-thrive. The fact that poi is easily digested due to the small size of the starch granules may benefit certain health conditions involving the gastrointestinal tract (Abbott and Hawaii, 1992; Ferguson et al., 1992). In addition, lack of gluten in poi has been suggested to be the reason for its suitability as an ideal substitute for cereals in patients with celiac disease especially among Caucasians than Asians (Glaser et al., 1967).

Besides tannia's superior organoleptic characteristics over taro as food, tannia has been traditionally used to prevent and treat bone diseases, such as osteoporosis (de Oliveira et al., 2012) whereas Nishanthini and Mohan, 2012 reported on the potent superoxide radical scavenging activity of tannia corm extracts. Caxito et al., (2015) also corroborated on tannia's chelating activity and *in vitro* antitumor activity suggesting that tannia leaves may have practical application in cancer therapy. Thus, tannia has antiproliferative properties towards human cancer cell lines and is reported to be effective in curbing the growth and spread of cancer. Similarly, Schmourlo et al. (2005) also demonstrated antifungal activity of tannia aqueous leaf extract as well as its iron-chelating activity and inhibition of nitric oxide production. Despite all these medicinal benefits, the crops are still neglected and underutilized. Yet taro and tannia as staples possesses numerous nutritional and medicinal properties for curbing malnutrition, poverty, diseases and hunger. As a consequence of neglect, their traditional medicinal uses, local knowledge, and food values are diminishing at a frightening rate. Therefore, approaches on its increase in consumption should be on consumer education based on their nutritional and health advantages. Moreover, maximizing the potentials of these crops through increase in research and proper funding, incentives and diversification of its uses through processing will translate into making them more commercially competitive with the crops that are already enjoying international research attention.

Conclusions

The roles of taro and tannia in the food basket of Nigeria, their nutritional and medicinal values and their evolving contributions as industrial crops are summarized. The potentials for increase in cocoyam production are not yet fully exploited. Their food uses can be further expanded through increased diversification of their food forms based on improved processing rather than on direct use of fresh corms and cormels. This will stimulate more efficient marketing and economic benefits. To be at par with the other root and tuber crops, new developments in science and technology must be continually applied both in their production and processing. If not, the crop will inevitably slip further back to a more casual and more occasional food item in our food basket.

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