Prospects for Industrial Utilization of Tacca (Tacca involucrata) in Nigeria

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Abstract
Tacca involucrata (L.) Kuntze is a species of flowering plant. It is commonly known as Polynesian arrow-root (English). In Nigeria, the plant is more widely spread in the middle , south west and in the south eastern states. The need to develop non tree forest products that have food and industrial use potentials has become imperative in parts of Africa. This is due to the fact that millions of people in many developing countries do not have enough food to meet their daily requirements. This has led to assiduous research on the development of some non-timber forest plant species to ascertain their food and industrial potentials. The phytochemical analysis of tacca, reported the presence of reducing sugars, tannins, flavonoids, steroids, glycosides and hydrogen cyanide at 195.65 ± 0.5, 3.44 ± 0.2, 1.29 ± 0.5, 0.83 ± 0.4, 1.36 ± 1.0 and 0.00985 ± 0.3 (mg/100g), respectively. The study on proximate analysis of the marc showed it to contain moisture, ash, fats, fibre, crude protein and carbohydrate in the range of 10.83% ± 0.3%, 1.93% ± 0.6%, 1.06% ± 0.5%, 4.42% ± 0.4%, 6.12% ± 0.6% and 86.07% ± 0.3%, respectively. The proximate analysis also showed it to be a good candidate for nutrition with 76% carbohydrate, 6% protein, 4% fibre, 2% ash and about 1% fats. Various studies on tacca have shown it to contain about 30% starch. Most of the studies indicated that the starch had low lipid content (0.09%). They also reported amylose content of 36% and gelatinization temperature of 52–65 °C for the starch. The biscuit produced from wheat–tacca flour composite at varying compositions of tacca flour ranging from 5 to 20% incorporations levels (TEB5%, TEB10%, TEB15 and TEB20%) showed that all the samples substituted with modified tacca flour had better haematological properties, in vitro antioxidative properties and lipid peroxidative properties compared to the 100% wheat biscuit. Specifically, the sample TEB20% (20% tacca flour incorporation) had the best nutritional qualities. Toxicological studies showed that samples with tacca flour incorporation are better than 100% wheat flour biscuit and basal diet. This indicated that tacca flour could successfully supplement wheat flour in the production of nutritionally rich and toxicologically safe biscuit with over 70% overall sensory acceptability. Likewise, the incorporation of tacca flour in spaghetti production may reduce the risks of obesity, cardiovascular diseases and diabetes. In addition being gluten free, tacca may replace wheat in certain food applications to reduce the incidence of celiac disease (CD) or other allergic reactions to gluten. These developments indicated that tacca can assist in alleviating hunger and the cost of importation of various raw materials, most especially, starch in Nigeria.
Keywords: Tacca involucrata, starch, gelatinisation, swelling power, biscuit and pasta.
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1.0 Introduction

Tacca involucrata (L.) Kuntze is a species of flowering plant. It is commonly known as Polynesian arrow-root in English. *T. involucrata* is the underground stem tuber with a short-lived storage and regenerative organ developing from a shoot that branch off a mature plant. Tacca is a perennial plant with a tuberous underground rhizome from which arises two stems; a petiole of about 60-90 cm long that has deeply lobed leaf blades consisting of three main segments and an inflorescence born on a long stalk 70-100cm with small flowers surrounded by six or more bracts and numerous thread like puplish inner bractes (NTBG, 2011; Kunle *et al,* 2003). It originated from Malaysia and Pacific Islands, but is now distributed from West Africa through Southeast Asia to northern Australia (Ukpabi *et al.* 2009; NTBG, 2011). It is widely spread in the savanna zone from Central Africa to Chad, Nigeria and Cameroun. Tacca comprises of approximately 15 species of acaulescent forest understory herbs. The tubers were known to be a staple foodstuff in Polynesia and were also used as a source of starch. It is of the family Dioscoreaceae but formerly classified under the family Taccaceae until 2003 (Burkil, 1994).

In Nigeria, the plant is more widely spread in the middle belt and in the south west and south eastern states. It is found in solitary forms on open fields or under the shade of trees or hill tops. Although, the crop is grown at subsistent level in the Eastern part of Nigeria, it is yet to be domesticated in many regions of Africa where it is found predominantly in the wild and reproduces asexually (Raji and Ahemen, 2011). The plant is found mainly in the rainy season (March to August), while dormant through the dry season (from September to February). Apart from tuber, the plant also produces fleshy sweet tasting fruits which are dispersed by birds and mammals (Drenth, 1972). In the Pacific Islands, it is an economic food crop which has been domesticated (Kay, 1987) with selections carried out to produce improved strains.

T. involucrata is an under-utilized crop with a high potential as a source of industrial starch. The common variety has an orange-yellow tuber, but the isolated starch is white and similar to potato starch. The tubers are believed to be poisonous and contain a bitter principle, Taccalin and toxic saponins (Yisa *et. al*, 2010). Aside its nutritional content, it is believed to contain some levels of anti-nutrients which could be toxic to the human body, thereby acting as threat to the health of an individual if taken. However, Caddick *et. al*. (2002) reported that the poisonous component of the tubers could be removed by soaking, washing and rinsing repeatedly in clean water before being processed for food.

The need to develop non tree forest products that have food and industrial use potential has become imperative in parts of Africa. This is due to the fact that many people in many developing countries do not have enough food to meet their daily requirements and many more are deficient in one or more micronutrients. As a result, efforts are being made towards to solve the problem of hunger in developing countries, most especially, those in Africa. Although, some of these efforts are directed towards improving the production and productivity of conventional sources of food such as rice, sorghum, cassava, corn, etc, the need to supplement these sources with numerous underutilized plants have become imperative (Ogunwusi and Ibrahim, 2016). In Nigeria, there are more than 7000 underutilized plant species some of which can contribute effectively to the food supply chain if adequately developed. In various communities in Africa, locals exploit some of these wild plants as a measure to avoid hunger and malnutrition. Evidence abound that most rural populations (where these edible wild plants exist) depend on them to meet their hunger and nutritional needs (Burkil, 1994; Ujowundu et al. 2008).

The high food insecurity rate in Africa which is due to factors such as low agricultural productivity, harsh climatic conditions, slow economic growth, poor governance, a dearth of research and innovation, and many other factors have necessitated the need to expand the available food sources and sources of industrial raw materials. According to Red Cross (2023) many communities across Africa including Kenya, Nigeria, Ethiopia and Somalia are facing the worst food crisis seen in 40 years. Sub-Saharan Africa is facing a high rate of undernutrition as one in five people face hunger. Among the drivers of hunger in some of the communities are conflicts, drought, surging food prices and weak infrastructure. drive hunger in many communities across Africa. ***I***n January 2023, the United Nations (UN) estimated that more than 25 million people in Nigeria could face food insecurity this year. This culminated in 47% increase from the 17 million people who were already at risk of going hungry. Factors such as climate, the escalating conflict in Ukraine, inflation around the world and a surge in global food prices have caused devastating ripples across the globe, making extreme hunger a major problem in communities across developing countries. On its part, climate change is intensifying food insecurity across sub-Saharan Africa (SSA) with adverse macroeconomic effects, especially on economic growth and poverty. Successive shocks from the war in Ukraine and COVID-19 pandemic have increased food prices and depressed incomes, raising the number of people suffering from high malnutrition and unable to meet basic food consumption needs by at least 30 percent to 123 million in 2022 or 12 percent of SSA's population (IMF, 2023).

To address these problems, it is mandatory for countries to look inwards and develop available resources with adequate potential to provide resilience to problems of hunger and dependence on importation of industrial raw materials. One of such plant resources that can be developed to address the twin problems of hunger and high dependence on raw materials imports in Nigeria is *T. involucrata*. This paper reviews the potential of the plant for use as food and as industrial raw material in Nigeria.

2.0 Conventional uses of *T. inolucrata*

Globally, root and tuber crops provide a substantial part of the world food supply and are also an important source of animal feed and industrial products. On a global basis, approximately 45% of root and tuber crop produced are consumed as food, with the remainder used as animal feed or for industrial processing for products such as starch, distilled spirit, alcohol and fermented beverages including beer and a range of minor products. *T. involucrata* had a long history of being a major source of carbohydrate in the savanna belt of Nigeria until the advent of cassava. However, its importance has waned. The tuber is first boiled to remove the toxic element and then converted to flour and used in a variety of food preparations (Burkil, 1994). In most parts of the savannah region, the tubers are consumed by processing it after digging from the ground. The process consists of peeling, grating and soaking in fresh water. Thereafter, it is filtered and the filtrate is dried, cooked and served as a staple food among the people.

In the traditional folk medicine, roots and flower are used to treat snake bite. The fruits are eaten by children when they are ripe. It is also used for rituals and as an aphrodisiac. The water from the grating is used as a detergent (Burkil, 1994). Its tuber and starch are traditionally used for treatment of diarrhoea and bleeding (internal and external). Its stems are also useful for making mats while the leaves are used for treatment of nausea and vomiting. Despite these numerous uses, the marc from the processed tubers is considered very poisonous to both human and animals such that it is usually discarded by deep burial or thrown far away from human settlement where it is assumed that domestic animals will not come in contact with. In the course of processing it is repeatedly washed as a local way of reducing the poison and in many communities in Nigeria, a lot of people eat the root after adequate processing. As a result tacca roots are found in local markets in many communities where they are traded and provide income for people harvesting, processing and trading in them.

3.0 Properties and Uses of *T. involucrata*

3.1 Chemical and Functional Analysis

Bosha et al. (2015) in a study carried out on the phytochemical analysis of tacca, reported the presence of reducing sugars, tannins, flavonoids, steroids, glycosides and hydrogen cyanide at 195.65 ± 0.5, 3.44 ± 0.2, 1.29 ± 0.5, 0.83 ± 0.4, 1.36 ± 1.0 and 0.00985 ± 0.3 (mg/100g), respectively. According to the authors, The elemental analysis of the root showed it to contain potassium, sodium, magnesium, selenium, manganese, vanadium and some heavy metals like lead, aluminium, arsenic and mercury at 36.45 ± 0.1, 44.04 ± 0.1, 1.52 ± 0.2, 0.80 ± 0.9, 0.52 ± 0.7, 0.27 ± 0.7, 0.07 ± 0.6, 0.008 ± 0.05, 0.085 ± 0.6 and 0.026 ± 0.6 (mg/100g), respectively. The vitamin analysis showed the presence of vitamins A, B1, B2, B3, C and E in various amount as 2.26 ± 0.8 µg, 0.83 ± 0.8 mg/100g, 0.58 ± 0.4 mg/100g, 0.33 ± 0.6 mg/100g, 9.80 ± 0.4 mg/100g and 6.86 ± 0.9 mg/100g, respectively. Bosha *et. al.* (2015) study on proximate analysis of the marc also showed it to contain moisture, ash, fats, fibre, crude protein and carbohydrate in the range of 10.83% ± 0.3%, 1.93% ± 0.6%, 1.06% ± 0.5%, 4.42% ± 0.4%, 6.12% ± 0.6% and 86.07% ± 0.3%, respectively.

Although, the study shows the presence of hydrogen cyanide and some heavy metals in traces amount which are considered poisonous to livestock and humans, the marc contains some elements, vitamins, phytochemicals and nutrients which are pharmacologically and nutritionally important. The marc also contain some heavy metals that can be toxic to the body of humans and animals like lead, arsenic, mercury, aluminium, etc. Some of the heavy metals like lead have been associated with poisoning in humans. However, most of the heavy metals do not exceed the recommended daily allowance by the American Chemical Society (Bosha et al, 2015). The recommended daily allowance for most of these heavy metals is 0.1 mg/day. The result of the study indicated that none of the heavy metal is up to that quantity per 100 g. Thus, it was concluded that marc of *Tacca involucrata* has all the potential of a good source of food for humans and animals. However there is need for it to be well processed before consumption.

Apart from the above, the marc also contains flavoniods and saponnins which are known antioxidants. Antioxidants prevent the damage caused by free radicals to cells and can mediate in most cases of chronic diseases such as cancer and diabetes. They also slow or even can stop the proliferation of cancer cells (Caddick et al, 2002; Mathew et al, 2014, Krishnaiah et al, 1993). According to (FAO, 2004), saponnins also help in lowering cholesterol levels, thereby preventing arteriosclerosis and hypertensions. It is antitumor and antimutagenic, although, it can interfere with the metabolism of vitamin E and causes gastroenteritis manifesting in diarrhoea and dysentery (Bosha et al, 2015).

From the results of the study, the elemental analysis showed that the marc contain some elements that are beneficial effect in the body. For example, iron apart from been needed by blood carrying haemoglobin also help in immune responses (Mathew et al, 2014). Zinc, vanadium and manganese help in diabetes, while selenium in conjunction with vitamin E are good sources of antioxidant (Krishnaniah 1993). The marc of tacca was also shown to contain a reasonable amount of vitamins A, C, E which are all antioxidant vitamins these will have a positive effect on the body of humans and animals that consume it. Antioxidant normally scavange the free radicals from reactive oxygen species in the body. Tacca also contain some traces of the B vitamins.

The proximate analysis also showed it to be a good candidate for nutrition with 76% carbohydrate, 6% protein, 4% fibre, 2% ash and about 1% fats. High level of fibre in food help in treating constipation by expanding the inside walls of the colon, absorbing large amount of water resulting in softer and bulkier stool. It also lowers cholesterol levels in the blood and reduces the risk of cancers and other bowel diseases. In Nigeria, more than 20 million tonnes of the tubers are produced annually. This can be used to ameliorate the increasing hunger in various communities in the country.

4.0 Potential of *Tacca involucrata* for Starch Production

Starch is the second most abundant biomass material in nature. It is found in plant leaves, stems, roots, bulbs, nuts, stalks, crop seeds, and staple crops such as rice, corn, wheat, cassava, tacca and potato. Starch is widely used in the food, textiles, cosmetics, plastics, adhesives, paper, and pharmaceutical industries. In the food industry, it is used as a thickener, gelling agent, to being a stabilizer for making snacks and meat products. The different industrial usage of starch is premised on its availability at low cost, high caloric value, inherent excellent physicochemical properties and the ease of its modification to other derivatives.

Various studies on tacca have shown it to contain about 30% starch. As a result it could be used as a major raw material for starch production. Globally, the industrial application of starch is expanding. For instance, the Industrial Starches Market size is expected to grow from USD 54.28 billion in 2023 to USD 70.60 billion by 2028, at a CAGR of 5.40% during the forecast period (2023-2028). This necessitates the need to expand the raw material base to accommodate the increasing demand. Currently, a wide range of starches are available in the market, in the form of native starches, modified starches, malt dextrin, starch-based sugars, and others. These starches have expanding applications, primarily in the beverage and confectionery industries and the pharmaceutical and fermentation industries, among others.

Presently, starch derived from corn is in high demand and contribute about 80% of total global starch production as a result of its textural properties, especially as a thickening agent in industries such as dairy and beverages. The corn starch also gains an edge in the development of gluten-free products, which is a challenge for starch sourced from wheat, considering the potential remains of traces during extraction. Corn starch is mostly produced in the United States of America which is the highest producer of corn across the globe. Although, corn was introduced to Africa a long time ago, its production is constrained as a result of dependence on a number of inputs such as agrochemicals, fertilizers, etc.

These developments have led to assiduous and spirited research into the production and properties of starch from tacca in Nigeria in order to ascertain its industrial utilization potential. For instance, Zaku *et. al.* (2009) isolated 30.23% of starch from *T. involucrata* tubers and reported the proximate composition. The study indicated that the starch had low lipid content (0.09%). Attama and Adikwu (1999) reported that the starch granules were predominantly oval with a single, double or triple cleft hilum. They also reported amylose content of 36% and gelatinization temperature of 52–65 °C for the starch, while Manek *et. al*. (2005) observed the mean granule size of 2.64 µm, an A-type X-ay diffraction pattern with 35% crystallinity and a gelatinization temperature of 68.56 °C. Kunle *et. al*. (2003) compared the swelling power and solubility of tacca starch with maize and potato starches and reported higher values for tacca starch. Ofoefule *et. al*. (2004) also studied the effect of physical and chemical modification on the efficiency of *T. involucrata* starch as a pharmaceutical disintegrant and reported that the pregelatinized starch to have a higher efficiency.

Likewise in a study of the granule characteristics of both white and yellow tacca starch, Nwokocha *et. al*. (2011) observed that both starches contained oval and polyhedral granules. Compound granules were visible in white tacca starch. The granules of white tacca were bigger than yellow tacca starch granules. The granule size of white tacca was reported to range from 6.13 to 18.12 µm with average size of 12.32 µm while yellow tacca starch granules ranged from 4.19 to 11.98 µm with granule average of 6.89 µm (Nwokocha *et. al*. 2011). The results indicated that both white tacca and yellow tacca differed in granule size distribution, X-ray diffraction pattern, gelatinization temperature, swelling power and amylose leaching, and freeze–thaw stability; while the flow characteristics and mechanical properties of the starch pastes did not differ greatly. The properties of tacca starch indicated it could be suitable for use in processed foods like pies and puddings. The high paste clarity of tacca starches at higher concentrations also indicated a potential for application in food products like pies and puddings where clarity are desireable (Nwokocha *et. al.,* 2011)

Omojola (2013), reported that 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 the amylose content, almost zero fat and lower gelatinization temperature. He noted that the starch could also be used in the textile industry for stiffening fabrics. According to Omojola (2013), the swelling capacity affects the use of starch in industrial applications. Starch with high swelling capacity would improve digestibility and could be used for the improvement of dietary properties of food products such as noodles. It would also be a good disintegrant for pharmaceutical products such as solid dosage drug. Also, the low moisture content of the starch is another advantage for it to be used for pharmaceutical purpose as low moisture content preserves drugs active ingredient.

Maneka et al., (2005) observed that the weak associative forces stabilizing tacca starch granules could be explored for its potential use as a disintegrant in the pharmaceutical sector. The physicochemical and functional properties of tacca starch reveals that it can be compared favourably with corn and cassava starches, thereby freeing cassava tubers to produce staple foods that will alleviate hunger in many African countries especially in Nigeria. This will enable tubers like tacca to be maximally utilized for food and industrial starch production. Among the attributes of tacca starch are low fat and fibre contents compared to the other materials. The protein content is far lower than that of corn and comparable with that of potato and tapioca. On a dry basis, the starch contents of corn and wheat are higher than tacca, whereas that of potato and tapioca are lower. The physicochemical properties of tacca starch showed potential usefulness of the starch in aqueous and hydrophobic food and drug systems (Ukpabi *et. al.,* 2009) as the quality of most preserved foods depends to a great extent upon their, chemical, microbiological and physical stability. This stability is mainly a consequence of the relationship between the equilibrium moisture content (EMC) of the food material and its correspondence water activity (aw), at a given temperature.

The physicochemical analysis of isolated starch compounds in the study reported by Ameen *et. al*. (2018) on T. involucrata revealed a swelling power of 8.5, gelatinization temperature of 73 ˚C , pasting temperature of 79.96 ˚C, with a pH of 5.8 and bulk density 0.76 g/cm3. The microscopic and X-ray diffraction analysis indicated that the starch granules are generally small in size, with clustered arrangement. The starch compounds were observed to be slightly off white in colour with no smell and the yield was considered to be appreciable, especially, when compared with starch compounds from other sources such as cassava, 30 % (Fakir et al., 2012) corn, 66.31 % (Khan et al., 2014) and Mesua ferrea, 5.85 % (Sayeed et al., 2004). Amylose and amylopectin composition varied in the starch compounds with values from 20.68 to 30.30 % and 75.60 to 90.70 %, respectively. The amylose content as reported was higher than 20.68 % from cassava starch. Thus, according to Vignaux *et al*., (2005), the starch compound would be suitable for the coating of fried products, pasta, sweet and bread production

Also, Ameen *et. al*. (2018) noted that high value of bulk density supported their suitability as drugs binder and disintegrant in pharmaceuticals. Other physicochemical attributes of the starch include sttarch yield (%) 28.15; pH 6.50; gelatinization temperature (^{0}C) 75.00; pasting temperature (ºC) 77.89; Amylose (%) 24.40 and Amylopectin (%) 75.60. The granular shapes of *Tacca involucrata* starch granules were heterogeneous, oval and polyhedral shapes. From particle size distribution analysis of the starch compounds, the results showed a mean granule size of 6.49 µm. This clearly showed that the starch compounds are smaller than cassava starch which has a mean granule size of 11.82 µm and average range of 1.05 – 36.08 µm. Granule size and particle size distribution of starch influences the functional properties of starc. This includes swelling power, solubility and digestibility (Moorthy et al., 2002). Small and medium sized starch granules have been reported to have varied utilization in the food and pharmaceutical industries (Omojola *et al*., 2010) and this gives credence to the industrial potential of the starch. The x-ray diffractogram of the starch compounds showed that Tacca gave characteristic peaks at 10.8°, 18.2°, 20.5°, 24.0°, 24.8° 2θ which are diffraction peaks corresponding to A-type diffraction pattern. Cassava starch was also reported by Rocha *et al.* (2010) to exhibit A-type diffraction pattern. According to Ameen *et. al.* (2018) the swelling power increased with increased temperature (60 to 100 °C). The solubility profile also shows an increase in solubility with temperature rise which relaxes at 90 °C. Solubility has been shown to positively correlate with swelling. According to Srichuwong *et al.,* (2005), this indicated that solubilization occurred along with granular swelling. Increased swelling power is an indicative of the suitability of the starch for use as a disintegrant in the pharmaceutical industry. It can therefore be stated that the results of the physicochemical and functional properties of starch compounds from tacca starch granules can compare favourably with starch from cassava plant, thus confirming the potential of the starch compounds from tacca in both food and non-food industries.

5.0 Biscuit Production from Wheat and Tacca Composites

Biscuits are bakery products that are consumed globally. Production of quality and acceptable biscuits depend largely on the flour and the processing pathways that are followed.

In a study reported by Ojewumi *et. al.,* (2022) in which tacca flour was subjected to physical, chemical and enzymatic modifications and supplemented into wheat flour for production of wheat-flour biscuits, the results show that while native tacca flour had the best proximate composition, the flour sample from enzymatic modification had the best antioxidants properties. The biscuit produced from wheat–tacca flour at varying compositions of tacca flour ranging from 5 to 20% incorporations (TEB5%, TEB10%, TEB15 and TEB20%) (Tacca Enzymatically Modified Biscuit) showed that all the samples substituted with modified tacca flour had better haematological properties, in vitro antioxidative properties and lipid peroxidative properties compared to the 100% wheat biscuit. Specifically, the sample TEB20% (20% tacca flour incorporation) had the best nutritional qualities. The toxicological studies showed that the samples with tacca flour incorporation are better than 100% wheat flour biscuit and basal diet. This indicated that tacca flour would successfully supplement wheat flour in the production of nutritionally rich and toxicologically safe biscuit with over 70% overall sensory acceptability.

The result indicated that the DPPH [Diphenylpicrylhydrazyl] of wheat-tacca biscuit ranges from 59.89% in control-78.40% in Tacca Enzymatically Modified Biscuit [TEB20%] which shows a significant increase in the DPPH scavenging activity with substitution of wheat flour with enzymatically modified flour. The result of the study was reported to be similar to previous works of Medoua *et. al*. (2007) who observed increase in DPPH of biscuits with increased supplementing Cladode Flour (CF) of *Opuntia ficusindica*. Flavonoids of Wheat-enzymatically modified tacca flour biscuits ranged from 0.11mg/g in control to 0.48mg/g in TEB 20%. The increase in the flavonoids with increase in the addition of enzymatically modified tacca flour might be attributable to the presence of varying phytochemicals including steroidal, diarylheptanoids, phenolic, flavonoids, sesquitepenoids, triterpenoids and starch (Nduoyang et. al. 2015). The result also agrees with the studies of Nabil *et. al.* (2020), Betalini *et al*. (2016) and Jamaludin and Mohamad (2016) that reported the presence of flavonoid in tacca tuber extract as well as justify the role of the phytochemical present in tacca in controlling high blood pressure (Ojewumi et al, 2022).

The phenols present in wheat-enzymatically modified tacca flour biscuits ranged from 4.93mg/g in control to 15.60mg/g in TEB20%. Similar trend was reported by Yao *et. al.* (2003) and Vidak *et. al.* (2015) where there was a significant increase in the phenol with substitution of ginger in composite flour used to produce biscuits.

Phenolic compounds are vital in defense responses, such as anti-aging, anti-inflammatory, antioxidant and antiproliferative activities (Fabusiwa, 2018). Hence, wheat-tacca flour composite biscuit may be good source of anti-aging and anti-inflammation supplement (Delgado et. al. 2019). Fe^{3+} in the wheat-enzymatically modified tacca flour biscuits ranged from 3.03mg/g in control -7.39mg/g in TEB 20%. Where 100% wheat flour biscuits were used as control, and it exhibited Fe^{3+} reducing ability of 3.03mg/g. The reducing ability was in dose dependent manners which increase with increase in the substitution of wheat flour with enzymatically modified tacca flour. Fe^{3+} reduction power is often used as an indicator in-vitro determination of reducing power of pure food substances (Lim, 2016). The reducing power usually relied solely on the presence of a reducing agent (antioxidant) which crystallizes antioxidant activity by breaking the free radical chains through donation of a hydrogen atom. It was observed from the results that TEB20% exhibited the highest Fe^{3+} reducing power and next to it is TEB15% biscuit samples with increase in the enzymatically modified tacca flour, although there was a slight increase in the alkaloid content in TEB20% when compared with TEB10% and TEB15% (Ojewumi et. al. 2022). The phytate content of wheat-tacca biscuits ranged from 4.22mg/g in control to 0.98mg/g in TEB20%. There was a significant reduction of pTEB10%>TEB15%>TEB20. It was observed that the reduction was proportional to the substitution of wheat flour with enzymatically modified flour, which suggests that enzymatically modified flour might have phytate content less that than that in wheat flour. This resulted to a lower phytate recorded in wheat enzymatically modified tacca flour biscuits. Hence the biscuit may be regarded as safe for consumption as not having any deleterious effect on iron, calcium and Zinc bioavailability as the phytate content is less than recommended per day requirement of 2500mg (Abeshu and Kefala, 2017).

Oxalate content in composited wheat-enzymatically modified tacca biscuits were reported to ranged from 38.80mg/g in TEB5%-41.20mg/g in TEB20%, while biscuit made with 100% wheat flour used as control has 42.40mg/g oxalate. Saponin content of wheat- enzymatically modified tacca flour ranged from 517.00mg/g in TEB5%-453.00mg/g in TEB20%, while its content in biscuits made with 100% wheat flour as control is 570.00mg/g. There was a reduction in the saponin content with increase attributed to the level of enzymatically modified flour being added. Tannins in wheat-enzymatically modified tacca flour ranges from 0.10mg/g in TEB5% and 0.08mg/g in TEB20%. Its content in biscuits made with 100% wheat flour as control was 0.11mg/g. Thus, the findings revealed a significant increase. The significant increase was reportedly consistent with substitution of wheat flour with tacca flour ranging from 20%>15%>10%>5%, while the antinutritional composition also reduces with substitution. The reduction was also consistent with increase in substitution (Ojewumi et al. 2022). The authors therefore concluded that the cookies characteristics for all the samples demonstrated the suitability of the wheat tacca blends up to 20% to produce health friendly cookies.

6.0 Pasta production with tacca composites

One of the plausible industrial uses of tacca flour is for pasta production. Pasta is a staple food made from durum wheat semolina or flour, mixed with water or eggs to form dough that is then shaped into various forms. It is commonly kneaded and extruded through dies to create different pasta shapes like spaghetti, penne, and farfalle. The dough can also be rolled and cut into sheets for dishes like lasagna. Pasta provides a source of complex carbohydrates, which are essential for energy. It also contains essential nutrients such as B vitamins, iron, and dietary fiber, aiding digestion and promoting gut health.

The global pasta market is influenced by the changing consumer preferences towards convenient and ready-to-cook food options. This is further bolstered by the growing global population and urbanization. This is reinforced by pasta's long shelf life and cost-effectiveness which makes it an attractive option for both consumers and food service providers. In line with this, increasing disposable incomes and burgeoning demand for premium and specialty pasta offerings are propelling market growth. In view of this, the global demand for pasta is increasing steadily. The global pasta market size reached US$ 22.8 Billion in 2022. Looking forward, IMARC Group expects the market to reach US$ 25.8 Billion by 2028, exhibiting a growth rate (CAGR) of 1.5% during 2023-2028.

In view of the increasing popularity of pasta, a number of authors have investigated the utilization of tacca composite in spaghetti production. According to Iombor *et. al.,* (2019) the incorporation of tacca flour in spaghetti production may reduce the risks of obesity, cardiovascular diseases and diabetes. In addition being gluten free, it may replace wheat in certain food applications to reduce the incidence of celiac disease (CD) or other allergic reactions to gluten (Hung and Morita, 2005).

7.0 Storage stability of tacca starch

In a study reported by Famurewa and Oladejo (2019) it was observed that moisture of tacca starch content was lower at 40 °C. This this showed that tacca starch can be best stored in the tropics. It was concluded that based on the results, tacca starch can best be stored at 40 °C, a temperature little above the ambient temperature experienced in the tropical regions.

8.0 Tacca Value Chain Development In Nigeria: RMRDC Initiatives

The Raw Materials Research and Development Council (RMRDC) is a Federal Government parastatal under the Federal Ministry of Science and Technology. The mandate of RMRDC is to promote sustainable development of locally available raw materials for industrial use. In line with this, the Council initiated a number of programmes and projects that runs concurrently for the achievement of this mandate (RMRDC, 2020). Among these is the identification of all the raw materials required in all the ten industrial sectors of Nigeria's economy, determine the extent of their local availability and supply to the nation's industries, identify gaps in demand and supply status and initiate programmes and projects to develop available raw materials to fill the gaps and produce surplus for exports (RMRDC, 2018).

Studies by RMRDC indicated that a major raw material used for starch production in Nigeria is cassava. It is also referred to as tapioca, manioc or yucca in other parts of the world. It is one of the most important food crops in the humid tropics. It is highly adaptable to conditions of low nutrient availability and it is able to survive drought conditions. However, with over 200 million MT of world cassava root production, cassava starch contributes less than 8% of the world starch production compared to starches derived from other plants in spite of its greater paste clarity, viscosity, freeze-thaw stability and its high stability in acidic products. It also has excellent properties for use in non-food production such as in pharmaceuticals and in thermo bio-plastics. In addition, its processing technique is simpler and cost of production lower than corn starch. Nevertheless, on a weight per weight basis, cassava yields about 30% starch, compared to corn that yields about 65%. One of the major disadvantages cassava utilization for starch production is that the root must be processed within 2 – 3 days of harvesting. Also, the use of cassava for starch production faces stiff competition in many African countries where it is used to produce many staple products that yield more income for farmers. Nigeria for example, is the highest producer of cassava with over 40 million MT/annum, yet it contributes less than 2% of the global cassava starch production. The implication of this is that if Africa must compete in global starch production, newer sources of raw materials must be exploited among the carbohydrate crops that are not fully utilized as staple food crops. As a result of this, the Raw Materials Research and Development Council in collaboration with Sheda Science and Technology Complex (SHESTCO) and the National Institute for Pharmaceutical Research, Idu (NIPRD), carried out extensive search for alternative indigenous crops for starch production. The research and development initiatives were focused extensively on the properties of relatively underutilized plants such as *Icacina trichantha*, *Tacca involucrata* and *Anchomanes difformis* growing in Nigeria. The result of the R&D efforts showed tacca tuber as the most plausible alternative for starch production. As a result of this, a multi-institutional and multi-disciplinary programme was embarked upon to develop tacca as a complimentary raw material for industrial starch production in the country (Ibrahim, 2022).

Among the objectives of the programme achieved so far are the extraction and production of pharmaceutical and industrial grade starches from tacca roots and utilizing them as excipients in drugs formulation and in other industrial applications. In addition, extraction and production of glucose syrup and other forms of adhesives from tacca starches have been done. Efforts are ongoing to domesticate and encourage the cultivation of the plant in the most adaptable areas in the country for sustainable industrial use.

8.1 The Imperative of Starch Production from tacca

Tacca plants consist of species such as *Tacca involucrata* and synonyms such as: *Tacca leontopetaloids*, *Tacca hawaiiensis* and *Tacca cristata.* In Nigeria the plants grow in the wild, with an annual production estimated at over 20 million MT. The consumption of the plant species is not very popular, making their possible uses as industrial raw materials for industrial starch production highly plausible. Thus, as the plant species are not widely consumed as food, their development will boost starch production locally as present efforts point towards possible production of starch of high industrial potentials from the species. So far efforts to boost tacca production are yielding good results and considerable volume of tacca are being harvested from farms established locally for this study (RMRDC, 2022). It is planned that before the end of 2024 planting season, a lot of other achievements would have been recorded (RMRDC, 2022). This will make it possible to promote tacca farming and free cassava for food security purposes.

Out of three synonyms, *Tacca involucrata* has been well researched and most research and development efforts are targeted towards its utilization for starch production. The proximate composition and other compositional analysis aligned with what were reported by several other researchers as outlined in this paper. For instance, results of the study by RMRDC showed the fresh tuber of *Tacca involucrata* showed it to contain protein, ash, fibre, and carbohydrate. It also show the tubers to yield about 30.23% starch on dry weight basis. These values compare favourably with those of some starchy materials presently being utilized as the commercial sources of starch. Likewise the studies indicated that *Tacca involucrata* also has lower fat and fibre contents compared to the other materials. The protein content was observed to be far lower than that of corn and comparable with those of potato and tapioca. On dry weight basis, the starch contents of corn and wheat are higher than that of *Tacca involucrata*, whereas that of potato and tapioca are lower. In addition, literature review of the physicochemical and functional properties of the *Tacca* starch and its derivatives has revealed them to compare favorably with corn and cassava starches. This indicated the possibility of freeing cassava tubers to produce staple foods that will alleviate hunger in Nigeria, while, tubers like *Tacca*, could be maximally deployed for the industrial starch production (RMRDC, 2022).

8.2 Tacca Development Project Implementation Procedure

This project was initiated by RMRDC as a national programme that involves several organizations that were relevant to the development of tacca value chain in Nigeria in various forms of collaboration. The organizations' and private sector companies were incorporated into the programme in a Public-Private-Partnership (PPP) arrangement and are working directly in their areas of competence to ensure the success of the initiative. For the purpose of proliferation and boosting of tacca production, the Council mandated Bio-crops Technology Limited to develop protocols for tacca plantlets production. As at 2022, 13,000 plantlets have been produced and are being planted in plantations established in Umudike and Otobi.

As Umudike has the mandate for root crops development in Nigeria, it was made the centre for development of tacca plantations. As a result, all plantation development activities are being coordinated by the organization. Apart from the plantlets being established in the plantation, multi-locational and agronomic studies are also being carried out at Otobi, Benue State. Several tonnes of tubers were acquired and planted at the two sites. Out of these, approximately 2 tonnes of tacca have been harvested and sent to Shestco while about 6 tonnes were processed for starch production.

Within the intricate web of this programme, 40kg of tacca starch produced at Shestco was sent to Federal University of Agriculture, Abeokuta (FUNAB) for production of glucose syrup. The syrup produced had been tested at industrial level and the result compared favourably with cassava glucose syrup. Also, RMRDC in collaboration with the Federal University of Agriculture, Abeokuta, have developed a 150 litres bioreactor that is being tested for optimization purposes. So far, Alpha and glucose Amylose enzymes have been produced and tested out of the starch used for glucose syrup production. The syrup has been found to reduce reaction time significantly. Some of the tacca starches produced at Shestco were also sent to Golden Empress Cold Water Starch Production Company, in Warri, for trial production of cold water starch. The results compared favourably with cassava cold water starch. Also, some of the tacca starch produced at Shestco was used for physicochemical and viscosity studies, at NIPRD, Idu. The pharmacopeia studies exhibited good characteristics, comparable to cassava starch, and the pharmaceutical grade starch produced have been used for production of paracetamol tablets.

The Council is planning that before the end of 2024, all the integrated developmental work on tacca starch production would have been completed and the project commercialised. The remaining aspects of the project are being pursued assiduously. These include production of more tacca starch for tests and analysis, large scale production of packaged and branded cold water starch, production of large scale glucose syrup and completion of the test analyses on samples of paracetamol produced from the pharmaceutical grade starch, including, the stabilization of the alpha and glucose amylase enzymes. The work on the development of the agronomic characteristics of tacca is also on-going and this may be concluded by second quarter of 2024. In view of the potential industrial use of the plant species locally and the possibility of exporting it to other countries, the Council has initiated advocacy programmes on tacca planting by local farmers.

9.0 Conclusion

The food and industrial potential of *T. involucrata* have been reported by various studies reviewed in this paper. The development of tacca for both uses will assist in alleviating hunger and the cost of importation of various raw materials, most especially, starch in Nigeria.

It is a well-known fact that the African region does not have advantage in corn production because of the high production cost arising from high requirements of fertilizer and pesticides coupled with severe drought. Investment in tacca plantation and tacca industrial starch production can complement the cassava initiative revolution that is presently going on in Africa as a sustainable strategy to alleviate hunger and improve the economic growth of the continent. It would not be an exaggeration to say that cassava starch has been extensively utilized if not over-patronized for starch-related purposes, yet the global need for starch remain insatiable. Hence, the need for an appropriate and preferably less exploited alternative source of starch with suitable physicochemical properties.

The first intention of RMRDC in embarking on this programme is to save foreign exchange expended on starch importation. When successfully concluded and commercialized, the initiative will save the country billions of dollars annually. The project will also expand the scope and profitability of local farmers by incorporating tacca into the agro-industrial complex in the country and free cassava and corn for food security purposes.

Another very important component of this programme is its job creation and other poverty alleviation potential. The nation's starch manufacturing companies will have access to low cost raw materials as the issue of competitive use of tacca may not arise as the tubers are not widely consumed as food in Nigeria. However, these initiatives to be achievable, there is need for private sector investment in plantation establishment of *T. involucrata* using the protocols being established by RMRDC and other collaborators and in tacca starch production.

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