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Cultivation, Nutrition, and Market Trends of the Multi-Faceted Tubers: Tiger Nuts

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A B S T R A C T

Tiger nut (*Cyperus esculentus*) is a widely cultivated tuber crop with significant economic and nutritional importance, particularly in developing countries like Nigeria. Despite its global popularity, there is a limited exploration of its utilization, especially in terms of its health and economic benefits. This review provides a comprehensive report of the cultivation, market trends, and nutritional properties of tiger nuts. Tiger nuts are rich in carbohydrates, dietary fiber, and essential macromolecules, making them a valuable component of a balanced diet. The low concentration of antinutrients enhances their nutritional significance. Moreover, tiger nuts exhibit notable antioxidant properties, attributed to their phytochemical content, including vitamin C. The potential health benefits include protection against oxidative stress, enhancement of eye health, and support for collagen production. The tuber's low glycemic index makes it suitable for individuals with hyperglycemia and those aiming for weight loss. Beyond nutritional aspects, tiger nuts possess bioprotective, bioproductive, thrombolytic, antiarteriosclerosis, wound dressing, and antimicrobial properties. The review also explores the industrial applications of tiger nuts, such as soap making, alcohol production, and serving as a substitute for coffee beans. Additionally, tiger nut milk emerges as a cost-effective source of probiotics in poverty-stricken regions. The review highlights the potential of locally cultivating probiotics from tiger nut milk to address malnutrition and enhance food quality in resource-constrained settings. Overall, the diverse properties of tiger nuts underscore their potential as a valuable and versatile crop with significant implications for both nutrition and industry.

Introduction

Tuber crops are commonly cultivated throughout the world especially in developing countries, their abilities to adapt to climatic change and production of moderately high glycemic index edible part, made them crop of choice (Mani *et al.,* 2016). In Africa, especially Nigeria, tuber crops are widely cultivated because of their nutritional properties and locally the main constituent of more than half major cuisines in the country which in turn have contributed to their economic values. As popular as tuber crops appear to be throughout the world,

there is a dearth of utilization report of some among which tiger nut is (Gambo & Da'u, 2014). Tiger nut (*Cyperus esculentus*) also known as earth almond, locally called many names in Nigeria; "Aya" in hausa dialect, "Ofio" in yoruba dialect, and "Akiausa" in Igbo language (Umerie *et al.,* 1997) is a common grass-like tuber crop, cultivated and harvested in some parts of the world majorly in Southern Europe, West African Countries, South America (Figure 1) and Arabian Peninsula to mention a few (Sanchez-Zapata *et al.,* 2012; De-Castro *et al.,* 2015). Furthermore, Spain in Southern Europe and Nigeria in Western Africa have been reported to be the highest cultivating and exporting countries of tiger nuts (Seair, 2023; Tridge, 2023); these countries export in thousands of kilograms yearly (Table 1). Tiger nut is popular for its sweet and nutritious edible rhizomes (Abaejoh *et al.,* 2006; Adejuyitan, 2011) highly nutritious, economically friendly and available all year round (Rosello-Soto *et al.,* 2018).

Taxonomic Properties of Tiger Nut (*Cyperus esculentus*)

Tiger nut (*Cyperus esculentus*) is a perennial tuber crop (Gambo & Da'u, 2014) which belongs to the division: Magnoliophyta, Order: cyperales and family: Cyperaceae (Belewu & Belewu, 2007). Tiger nut could be propagated through seed, rhizomes or tubers, the shoot system of solitary stem could grow more than three feet (over 90 cm) above the soil and the leaves are slender. The spikelet inflorescences are characterized with distinctively oval flat seeds (Sanchez-Zapata *et al.,* 2012). The root systems are made up of scaly nutlike edible rhizomes and fibrous roots system characterized with spherical tubers with basal bulbs attached. Tiger nut can produce up to several hundreds to thousands of yellow, brown or black tubers with size ranges of approximately 0.4 to 2.0 diameters (Renne & Tracy, 2006; Oldfield & Evans, 2016).

Climatic Requirements and Cultivation of Tiger nut (*Cyperus esculentus*)

Tiger nuts commonly grow in tropical and Mediterranean regions (Sanchez-Zapata *et al.,* 2012) around the world because it requires mild temperature. Although, tiger nut is considered a weed (Ogunlade *et al.,* 2015) in some part of the world especially in developed countries like United States and the Caribbean (Belewu & Belewu, 2007; Sanchez-Zapata *et al.,* 2012) where it grows intrusively on peanuts farms, but it is planted commercially in many countries like Spain, Mexico, Chile, Brazil, Lebanon, India, Ivory coast, Gambia, Ghana, Cameroon, Mali and Nigeria to mention a few (Obadina *et al.,* 2008; Gambo & Da'u, 2014; Ogunlade *et al.,* 2015). Tiger nut thrives best on sandy and moist soils, at pH rages of 5.0 to 7.5 with zero tolerance to salinity, mostly cultivated around April (Sanchez-Zapata *et al.,* 2012; Oldfield & Evans, 2016).

The tubers of Tiger nut can grow deep into the soil at a depth of over 34cm with stratified layered root network, a feature that made it almost impossible to eradicate completely. Tiger nut can survive droughts, flood and low soil temperature about -5^{0}C. Cool temperature, low illumination intensity or shade, and prolonged photoperiods have been reported to adversely affect the flowering and tubers production of the plants (Sanchez-Zapata *et al.,* 2012; Oldfield & Evans, 2016); the normal photoperiod for flowering are 12 to 14 hours per day, also, high concentration of nitrogen and gibberellic acid adversely affect the tubers of tiger nut. Cool climate adversely affects and kills the foliage, roots and rhizomes of tiger nut but the tubers often survive when the temperature slightly increases (Sanchez-Zapata *et al.,* 2012; Oldfield & Evans, 2016).

The tuber of tiger nut develops around 5 to 8 weeks after germination and the plant has been reported to thrive well around July and August. It takes tiger nut 80 to 110 days to reach maturation. The harvesting of tiger nut is done by pulling out of the shoot system from the ground to collect the rhizomes which are small and tuberous, the yield could be around 9 and 19 t/ha (Pascual-Seva *et al.,* 2012). The harvested rhizomes are washed to be eaten raw, roasted, squeezed to extract the milk, dehydrated to preserve or mill into tiger nut flour (Adejuyitan, 2011; Pascual-Seva *et al.,* 2012). The dehydration of tiger nut prevents rot, spoilage and infection and as a result increase the shelf life, the drying is done through natural process for example sun drying (Gambo & Da'u, 2014).

Market Segmentation of Tiger nut (*Cyperus esculentus*)

Tiger nut consumption and utilization have been dated back to Barogue periods down to the romantic period in south Europe and Africa (Adejuyitan, 2011; Sanchez-Zepata *et al.,* 2012), and now it is cultivated around the world. Countries like Canada, Germany, China, Japan, Spain, Mexico, Chile, Brazil, Lebanon, India and United States of America have all been reported to massively

cultivate and utilize tiger nut rhizomes both in human and animal food (Elom & Ming, 2017; SRTNM, 2021). In Africa, tiger nut has been reported to be cultivated in Ghana, Nigeria, Senegal, and Togo (Asare *et al.,* 2020) to mention a few.

The production, market value and consumption rate of tiger nuts have been increasing in this dispensation due to its nutritional and economical values fueled by crop improvement, innovations and technology. According to Sample Report of Tiger Nuts Market (2021) the tiger nut market all around the world was well over 20 million dollars in 2019, it has been predicted on the evidence of the immense local and industrial demands the market value will be doubled by 2026 (SRTNM, 2021); the little increment is due to the dearth of exploitation of the crop's health and economical properties. The tiger nut market value is not increasing on the demand and utilization factors alone but on research/ technological advancement too, all these pivotal factors are contributing to the market growth of tiger nut year in year out. The market segmentation of tiger nut centers major areas in Europe, Latin America, North America, Asia, East and West Africa, these countries have been the main market bloom for tiger nut in the world (Elom & Ming, 2017; Asare *et al.,* 2020; SRTNM, 2021).

Nutritional Properties of Tiger nut (*Cyperus esculentus*)

Tiger nut is highly nutritious and medicinal suitable for man and animal consumption on the evidence of its phytochemicals and macromolecules like vitamins, carbohydrates, and mineral oils (Elom and Ming, 2017), it contains all the bioactive organic compounds needed for a balanced diet (Manok *et al.,* 2012). Larger constitution of Tiger nut is carbohydrates, which is represented as 43.3g/100g which is within the confines of that of cassava but twice that of potato (Sanchez-zapata *et al.,* 2012) and the energy value ranges from 400-413.8kcal/100g (USDA, 2018).

Tiger nut's dietary fiber is 8.81g/100g unlike other nut and tubers which has 0.66-2.55g/100g (Rosello-Soto *et al.,* 2018). Tiger nuts contains 5.04 to 6.67 protein content which are found to be higher in tubers but relatively lower in nut which is approximately 25.8% in peanuts (Sanchez-zapata *et al.,* 2012). Illustrated in Figure 2, tiger nut contains approximately 67% starch, 26% lipids and 7% protein (Kim *et al.,* 2007; Yeboah *et al.,* 2012; Arafat *et al.,* 2009; Rosello-Soto *et al.,* 2018)

Tiger nut has been reported to have low concentration of antinutrients like oxalate, phytate, saponin, tannins and cyanogenic glycosides which inhibit the absorption of essential nutrients by the body. Antinutrients cause nutrient malabsorption, haemolysis and abnormal haemopoesis to mention a few which occur as a result of liver damage (Chukwuma *et al.,* 2010). The low concentration of antinutrients establishes the nutritional significance of tiger nut (Chukwuma *et al.,* 2010). It has been reported that the raw tiger nut contains phytochemicals like alkaloids, saponins, sterols and tanins unlike the roasted tiger nut which only alkaloids and resins were detected, more reasons why fresh tiger nut tuber is nutritionally advised (Chukwuma *et al.,* 2010).

Microbial Hazards Associated with Tiger Nut and Tiger Nut Based Products

In recent years, the popularity of tiger nuts and their derived products has surged, driven by their nutritional richness, appealing taste, and versatile culinary applications. While celebrated for their potential health benefits, it is imperative to recognize the potential microbial hazards associated with these intriguing tubers and the products derived from them (Pondei & Ariyo, 2021). Microbial contamination poses a significant concern in the food industry, and tiger nuts, with their increasing utilization, have not escaped scrutiny. The microbial landscape of these nuts and their derivatives can be influenced by various factors, including cultivation practices, processing methods, storage conditions, and transportation (Ire *et al.,* 2020; Samuel *et al.,* 2020). Table 2 and 3 explain a closer examination of the microbial hazards associated with tiger nuts in producing countries in order to ensure the safety and quality of the end products reaching consumers.

Medicinal Properties of Tiger nut (*Cyperus esculentus*)

Antioxidant Properties

The body generates free radicals i.e reactive oxygen species (ROS) and reactive nitrogen specie (RNS) (Victor *et al.,* 2004; Ifeanyi, 2018) easily as a result of food intake, xenobiotic, air pollution, and stress etc. (Van-den *et al.,* 2011; Ifeanyi, 2018). The reactive oxygen species (ROS) and reactive nitrogen species generated are very injurious to human's health because they cause oxidative and nitrosative stress in the body

when highly produced beyond the balancing ability of the enzymatic antioxidants (Ifeanyi, 2018).

The methanolic extract of tiger nut tubers have been reported to have free radical scavenging properties against 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Owon *et al.,* 2013), vitamin C, one of the common effective antioxidant has been reported to be present in tiger nut in good amount (Abaejoh *et al.,* 2006; Elom & Ming, 2017).

Vitamin C (ascorbic acid) is a water soluble vitamin with the ability to scavenge for free radicals in the body thus protecting the body from oxidative stress, nitrosative stress, fatigue and cancer (Victor *et al.,* 2004; Ifeanyi, 2018).

Bioprotective and Bioproductive Properties

Furthermore, the vitamin C present in tiger nut also protects the eye lens and the nucleic acids especially the DNA (Muhammad *et al.,* 2017). Vitamin C is essential for the production of collagen and also makes iron bioavailable through transformation into a form in which it can be easily absorbed by the intestine (Muhammad *et al.,* 2017; WHF, 2017).

The presence of a fat soluble vitamin E in the tiger nut helps protect lipoprotein from oxidative damage (Muhammad *et al.,* 2017). Consumption of tiger nut milk is rich in calcium, phosphorus and Potassium (Gambo & Da'u, 2014; USDA, 2018; Rosello-sotto *et al.,* 2018). Phosphorus is an element that forms essential component in the ATP (adenosine triphosphate), nucleic acids and phospholipids (Soetan *et al.,* 2010). Potassium is also an essential cofactor in protein synthesis, and activation of enzymes (Soetan *et al.,* 2010). Tiger nut contains high content of calcium which is important in helping the body maintain skeletal muscles and strong bones integrity (Pravina *et al.,* 2013).

Low Glycemic Index and Weight Loss Properties

Tiger nut milk has been reported to be suitable for hyperglycemic patients due to its low glycemic index properties (Imam *et al.,* 2013). Tiger nut milk is refreshing because it is sweet in taste and better still, sugar free, a feature that makes it a good nutritional beverage for diabetic patients (Imam *et al.,* 2013) and individuals striving to reduce the level of cholesterol in their body or working out to lose some weights (Beniwal, 2004).

Thrombolytic and Antiarteriosclerosis Properties

Tiger nut has been reported to protect the circulatory system against thrombosis by protecting the heart and helping the body activates blood circulation (Chukwuma *et al.,* 2010). Consumption of tiger nut milk could help reduce the risk of arteriosclerosis (Imam *et al.,* 2013).

Wound Dressing and Treatment Properties

Dried and pounded tiger nut tubers have been reported to be used in wound treatment and dressing (Imam *et al.,* 2013). The synergistic effect of pounded tiger nut tubers and tobacco leaves have been reported to be effective in the treatment of athlete's foot (Stern *et al.,* 2003).

Antimicrobial Properties

Owon *et al.,* (2013) reported the antibacterial activities of phenolic compounds extracted from tiger nut against *Bacillus subtillis* and *Pseudomonas spp*. Also, the phenolic compounds inhibited the mycelia growth of *Aspergillus niger,* a toxigenic fungi known for its toxic secondary metabolite; Aflatoxin (Owon *et al.,* 2013).

Bamigboye *et al.,* (2020) reported the antimicrobial properties of fermented tiger nut waste mediated silver nanoparticles against pathogenic *Escherichia coli, Proteus spp*., and *Staphylococcus epidermidis.* Due to the bio-reducing properties of tiger nut as a result of the constituted organic compounds, the tiger nut waste mediated silver nanoparticles showed mild inhibitory activities against these clinical isolates at 10µg/ml.

Industrial Properties of Tiger nut (*Cyperus esculentus*)

Tiger nut is highly rich in vitamin E, a property that makes it essential in soap making (Lasekan & Abdulkarim, 2012). Tiger nut tubers can be fermented to produce alcohol (Des-Vries, 1991).

Roasted tiger nut tubers can be used as substitute for coffee beans in beverage industries (Imam *et al.,* 2013). Biodesiel can be produced from tiger nut oil (Nag, 2008).

Table.1 Leading Producing Country of Tiger Nut

S.No.	Producing country	Production quantity	Export (weight in kg)	Export/production	Reference
1.	Spain	4140 bags	97,362.52	Tiger nuts	Seair, 2023; Tridge, 2023
2.	Spain	5 bags	5375.00	Organic peeled tiger nuts	Seair, 2023; Tridge, 2023
3.	Nigeria	760 bags	23000.00	Organic whole peeled tigernuts	Seair, 2023; Tridge, 2023

Figure.1 Major Continents Known for tiger nut cultivation and Utilization (Sanchez-Zapata *et al.,* 2012; De-Castro *et al.,* 2015)

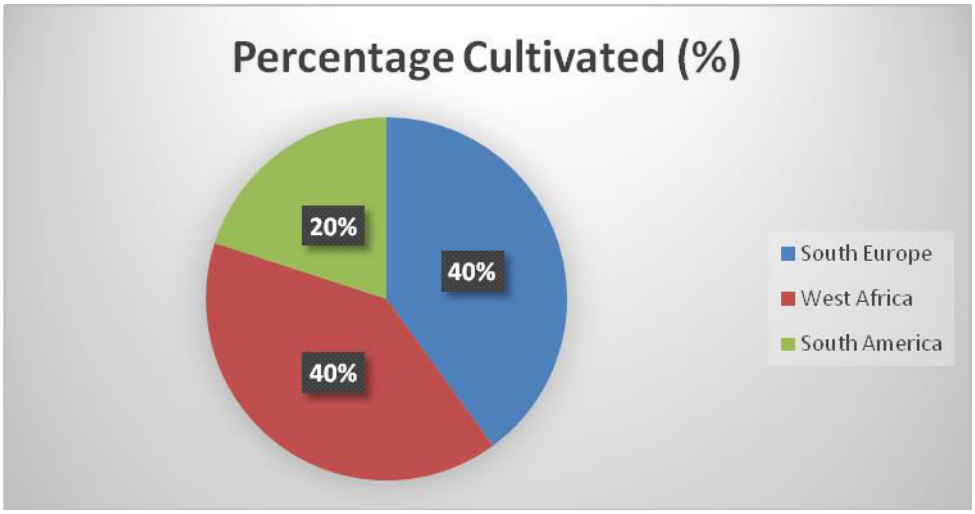

Figure.2 Fresh tiger nut macromolecule constituents

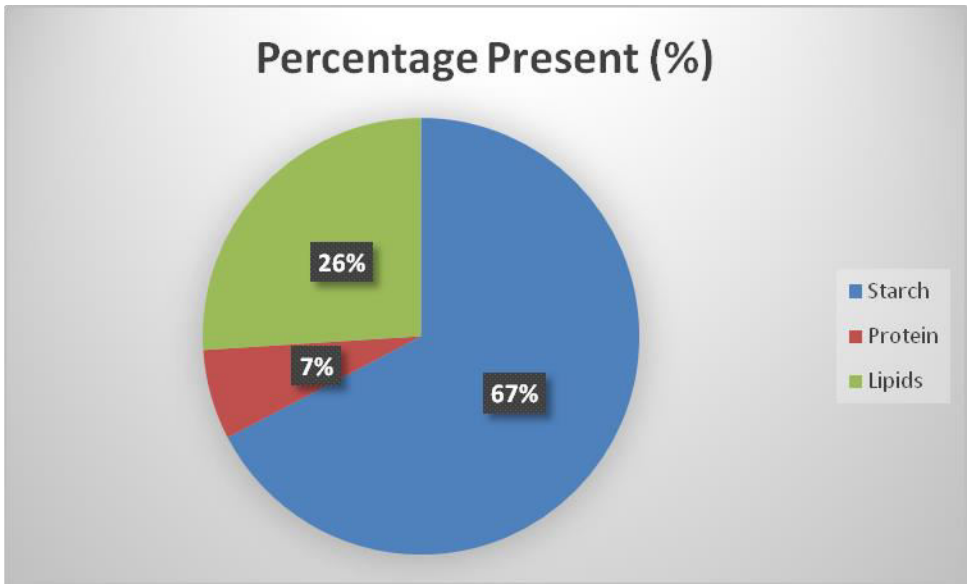

Table.2 Presence of Microbial Hazards in Tiger Nut and Tiger Nut Based Products

Country	Product	Sample collection point	Number of samples	Number of contaminated samples	Coliforms present	Salmonella/Shigella sp. Present	Identification method	reference
Nigeria	Tiger nut drink	local vendors, Portharcot metropolis, Nigeria	Thirty (30)	Thirty (30)	*Escherichia coli, Klebsiella sp, Enterobacter sp.*	*Salmonella sp*	Characterization based on cultural and morphological characteristics and Biochemical tests	Ire *et al.*, 2020
Nigeria	Tiger nut milk	Open Market vendor, latitude 4.9186^{0}N and longitude 6.2673^{0}E	Eight (8) samples	Eight (8) samples	*Escherichia coli.*	*Shigella spp., Salmonella spp.*	Characterization based on cultural and morphological characteristics and Biochemical tests	Pondei and Ariyo, 2021
Ghana	Tiger nut tuber	Two major market; Kotokuraba and Abura Market, cape Coast, Ghana.	Twenty four (24) samples	Twenty four (24) samples	*Escherichia coli, Enterobacter cloacae*	None	Characterization based on cultural and morphological characteristics and Biochemical tests	Nyarko *et al.*, 2011
Nigeria	Tiger nut tubers	Open Market; Rimimarket, Kano, Nigeria	One sample	One sample	*Escherichia coli*	None	Characterization based on cultural and morphological characteristics and Biochemical tests	Sa'id *et al.*, 2017
Nigeria	Tiger nut Milk	MudaLawal Market, Bauchi, Bauchi State.	One Sample	One Sample	*Escherichia coli*	None	Characterization based on cultural and morphological characteristics and Biochemical tests	Samuel *et al.*, 2020

Table.3 Mycotoxins Contamination in Tiger Nut-Products

Country	Food product	Number of collected samples	Number of contaminated samples	Toxigenic fungi present (mold)	Suspected Mycotoxins type	Pathogenic fungi present (yeast).	Number of positive samples (%)	Mean (ug/kg)	Reference
Nigeria	Tiger nut drink	Thirty (30) samples	Thirty (30) samples	*Aspergilus sp., Fusarium sp., Penicillium sp.*	Aflatoxin, Fumonisin, Ochratoxin.	*Candida sp.*	100		Ire *et al.*, 2020
Nigeria	Tiger nut tuber	Twenty (20) samples	Twenty (20) samples	*Aspergillus spp., Mucor spp.*	Aflatoxin, Ochratoxin	None			Ike *et al.*, 2017
Nigeria	Tiger nut tubers	One sample	One sample	*Aspergillus flavus, Aspergillus niger, Fusarium solani.*	Aflatoxin, Fumonisin, Ochratoxin	*Candida pseudotropicalis*			Onovo and Ogaraku, 2007
Spain	Tiger Nut beverages	Twenty five (25) samples	Twenty five (25) samples	*Aspergillus sp., i.e. Aspergillus niger, Aspergillus flavus, Aspergillus fummigattus, Aspergillus terreus*	AflatoxinsB(1), B(2), G(1) and G(2).	none	100	0.13 to 0.57ug/kg	Sebastia *et al.*, 2010

Tiger nut Milk, A Cheap Source of Probiotic in Poverty Infested Country

Poverty in this dispensation is on the increase, a lot of people in developing countries are poor and malnutrited based on factors like war, climate change, political instability, unemployment and overpopulation (Oladipo & Ogunsona, 2020). Poverty has caused mortality in many nations than the plague, invoking malnutrition which has severely impaired intellectual and psychological development (WHO, 2006). The need for cheap and nutritionally balanced diets is of great necessity. The solution to malnutrition is beyond the confines of conventional approach, it is pivotal to enable people to utilize the naturally available resources to breach the gap of malnutrition, for example local cultivation of probiotics to augment the day to day frugal meal available.

The usefulness of microorganisms to augment food quality and nutrition is as old as creation, and since nature is endowed with the ubiquitousness of microorganisms, it should be sapient of man to survive exploring them to the fullest. Throughout the world, microorganisms like lactic acid bacteria have been used to ripen cheese, ferment vegetables and milk to produce yoghurt due to the fact that lactic acid bacteria are generally regarded as safe (Thantsha *et al.,* 2014). Lactic acid bacteria could be employed in food processes, but, a local farmer with six children living in a remote area knows nothing about lactic acid bacteria but through the rule of thumbs and local methods have employed these group of bacteria in fermentation of their local cuisines like fermented cereal meals or fermented local drinks.

The local cultivation of edible microorganisms known as probiotics is one of the key to augment food in local areas. Lactic acid bacteria have been reported to be cultivated using rice starch (Fukushima *et al.,* 2004) and also a local farmer has been reported to culture lactic acid bacteria locally from rice and cow milk (3:1) in a shade using a screw cap jar and a paper cover. The process was observed to be successful through a colour change and a sour smell (Fukushima *et al.,* 2004). The lactic acid bacteria cultured might not be characterized to obtain the names but the actions and activities can be channeled towards food enrichment locally. The addition of probiotics especially lactic acid bacteria in food or beverages, can improve the quality of the food through the addition of compounds like exopolysaccharides (Jeske *et al.,* 2018).

Probiotics have been reported to enhance the digestion of some nutrients. Vitamin B1, B2, B3, and B12 production have been reported to be enhanced by probiotics (Thantsha *et al.,* 2014). Probiotics have been reported in the treatment of constipation using *Lactobaciollus spp*., and *Propionibacterium freudenreichii* (Ouwenhand *et al.,* 2002) and *Clostridium difficile* caused diarrhea (Fuller, 2003). Probiotics are inevitable to man. There are plethora of reports on using probiotics especially lactic acid bacteria in fermentation of crops like cereals (Altay *et al.,* 2013; Marsh *et al.,* 2014), fruits (Fessard *et al.,* 2017; Randazzo *et al.,* 2016) and vegetables (Corona *et al.,* 2016) but little to none have been reported on tiger nut (Rosello-Soto *et al.,* 2018).

Tiger nut milk is rich in nutrients suitable for the growth of probiotics especially insoluble dietary fiber of 99.8% and also sucrose content of 13.03g/100g which is relatively higher in other tubers with approximately ranges of 0.35 to 5.0g/100g (Rosello-Soto *et al.,* 2018). Dietary fiber has been known to serve as prebiotics; prebiotic are group of compounds that induce and encourage the growth and activities of probiotics (Salmerion, 2017). The beverages that could be gotten from tiger nut have been reported to fall within the pH rage of 6.3-6.8 (Sanchez –Zapata *et al.,* 2012) which is relatively moderate for the cultivation of lactic acid bacteria. Tiger nut based milk is a suitable medium for probiotics to thrive. Tiger nut milk is rich in calcium content (40mg/100g) which is relatively high for a plant based milk (Rosello-Soto *et al.,* 2018).

The free radical scavenging properties of fermented tiger nut milk would go a long way in checking a lot of health complications induced through oxidative stress especially in developing countries where xenobiotics contamination in food through indiscriminate use of agro based chemicals and emission of hydrocarbons are rampant.

Tiger nut (*Cyperus esculentus*), one of the underutilized tuber crop commonly grown in some part of the world have been evaluated to have nutritional and industrial properties. On the evidence of these organic properties, tiger nut beverages could be exploited for its probiotic potential through fermentation process. Fermentation of tiger nut milk could be done locally and added to meals for enrichment, unlike other fermented crop based beverages, the nutritional properties of tiger nut milk especially the unsaturated fat, vitamins and phytochemicals rich in antioxidant molecules, will make the beverage a great cheap nutritional supplement in poor developing countries.

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Author Contributions

A. O. Oladipo: Investigation, formal analysis, writing—original draft. I. C. Oladipo: Validation, methodology, writing—reviewing. S. B. Ogunsona:—Formal analysis, writing—review and editing. O. B. Ogunleke: Investigation, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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