ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue VI June 2024

Safety of Tiger Nuts (*Cyperus Esculentus L.*) and Derived Products Sold in Sub-Saharan Africa

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DOI: https://doi.org/10.51584/IJRIAS.2024.906031

Received: 23 May 2024; Revised: 07 June 2024; Accepted: 12 June 2024; Published: 09 July 2024

ABSTRACT

Tiger nut (*Cyperus esculentus*) is a tuber csrop that is consumed as snack in sub Saharan African. It is known for its sweetness and numerous benefits. Despite the nutritional quality and health benefit of tiger nut (*Cyperus esculentus*) tuber crop, increased consumption integrated with the associated risk of disease to consumers is a matter of great concern because of the health practice of the harvester, consumers and vendors. Thus, if tiger nut is exposed to microbial contamination, it can impose public health treat. Contamination of tiger nut tubers could either be physical, chemical, microbial or a combination of any of them, through post-harvest processes, handling, packaging, storage and retailing. Consumption of contaminated tiger nut tubers and utilisation of the tubers to produce edible products will invariably result in contaminated tiger nut-derived products if no further treatment to reduce or completely eliminate the contaminants is applied. In order to boost the prospect of tiger nut tubers and assure safe tiger nut derived products in sub Saharan African countries, it is important to prevent tiger nut tubers and tiger nut-derived products from any form of contamination. Therefore, it is paramount to review recent research findings on contamination of tiger nut tubers and tiger nut-derived products in order to effectively implement prevention strategies. This will help to promote food safety and food security in sub Saharan African countries.

Key Words: Contamination; tiger nut products; prevention strategies; nutritional quality; food safety; food security.

INTRODUCTION

ORIGIN AND BOTANY OF TIGER NUTS

Tiger nut (*C. esculentus L.*) originates from the Mediterranean Coast in North Africa, and its plant mainly includes three parts: underground tubers, roots, and leaves above the ground. Tiger nut is a perennial monocotyledonous plant that grows to a maximum height of 24-55 cm and has a fibrous, upright and erect root system. It has a dimension ranging from 6 –10mm and turn out in distinct varieties. The botanical name of tiger nut is *Cyperus esculentus L.* which is a high-quality wholesome crop that contains lipids, protein, starch, fiber, vitamins, minerals and bioactive factors. The tiger nut is the tiny tuber of *Cyperus esculentus L.*, also known as the "underground walnut", it grows all over the world because of its high yield and broad prospects for comprehensive utilization. Tiger nut has other names and this depends on the tribe or region where the tuber is being cultivated and made use of. The genus name *Cyperus* is derived from an ancient Greek name Cyperus whereas the species name esculentus originate from a Latin word which means edible (Zhang et al, 2022). Tiger nuts (*Cyperus esculentus*) are non-conventional and under-exploited tubers belonging to the Cyperaceae family. They emerged from tropical and Mediterranean regions and generate rhizomes with spherical shape. The Cyperaceae family of plants is a great source of numerous nutrients, including vitamins and minerals, and digestive enzymes like catalase, lipase, and amylase, are sufficiently present (Oghenerukevwe et al, 2023).

CURRENT DISTRIBUTION AND YIELDS OF TIGER NUT IN SUB-SAHARAN AFRICAN COUNTRIES

Tiger nut is a perennial crop that has been cultivated since ancient times. Commonly known as "subterranean walnuts," due to their great yield and various prospective implementation are vastly cultivated throughout the

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world (Edo et al, 2023). It reproduces asexually through tuberous growth but can also reproduce sexually, although more rarely. Tiger nut is an edible sweet nut-like tuber that is most common in Nigeria, Senegal, Ghana, and Chile. They exist in three diversities (black, brown and yellow) amongst which the yellow one is the most sought for human and animal consumption in Africa, Europe and America (Fabrice et al, 2022). The black variety is mostly common in Ghana. It has many identities, as it is being cultivated both as a livestock feed and for human consumption, and is eaten raw or baked. It has been cultivated for centuries in North Africa, especially in Egypt and the surrounding environments (Negbi, 1992). In Nigeria, they are mainly grown in the Northern part of the country. Tiger nut tubers are used as a foodstuff, especially in the northern part of the country where they are an important food crop with certain tribes. They are eaten raw as snacks or fried and eaten mixed with roasted groundnuts (Abaejoh et al, 2006). About 6000 years ago, tiger nut tubers have been found in the tombs of Pharaohs of pre-dynastic times and are thought to be a part of the diet of our Paleo-ancestors (Ayeni, 2022). Tiger nuts are just about 1–2 cm long almond-like tubers, they have an egg-like shape when they appear wet and a non-uniform appearance when they are dried (Maksim et al., 2021). Tiger nuts also have other several names, such as earth-almond, chufa, edible galingale, yellow nutsedge, Zulu nuts and rush nuts (Pascual et al., 2000).

ECONOMIC IMPORTANCE OF TIGER NUT AND DERIVED PRODUCTS IN SUB-SAHARAN AFRICAN COUNTRIES

The economic gain of tiger nuts extends far beyond their nutritional value, it is based on the diverse products (both edible and non-edible) derived from tiger nut tubers. These tuberous “nuts” are mainly used to manufacture a milky beverage called ‘horchata de chufa. It is a drink that is very energizing and has a sweet taste, high fibre content, with no gluten and lactose and can also serve as an alternative for soya milk. Tiger nut is known as a minor crop in Ghana. In Ghana, the nuts are chewed like sweets, or made into a highly cherished milk-like beverage referred to as Atadwe milk (Asare et al., 2020). Despite these potential benefits of tiger nuts, the crop seems under-exploited and under-utilized in Ghana, because most people only find delight in chewing the nuts for various benefits. At the heart of the economic importance of tiger nuts lies their role in agriculture. Tiger nut farming provides a source of income for numerous farmers, fostering economic stability in regions where cultivation thrives (Obeng-Koranteng et al., 2017). Countries such as Nigeria, Niger, Burkina Faso, Benin, Mali, Togo and Ghana export tiger nut tubers to other countries (Yamwemba et al., 2020). It is very high in dietary fibre and effective in the cure and prevention of several diseases (Adejuyitan, 2011). Since 2015, the global market for tiger nut has grown appreciably. Among the top 10 importing countries, importation of tiger nut on the average increased by 27.9% between 2015 and 2020, with an overall import value of $1.82 B in 2020 (Tridge 2022). The global market for tiger nut is projected to reach Multimillion USD by 2030, as compared to 2022, when it was at an unexpected CAGR during 2022-2030. Regardless of the presence of intense competition, investors are still optimistic about this field, and it will still be more new investments entering the field in the future (Precision report, 2023).

Table 1. Tiger nut importation share and importation value in 2020

Country	**Import Share (%) (2020)**	**Import Value (US$M) (2020)**	**Five Year Growth in Import Value (%) (2015-2020)**
USA	30.68	660.48	26.52
China	16.51	355.47	4.02
Germany	8.67	186.73	28.77
Mexico	6.9	148.53	68.57
Italy	6.47	139.23	52.52
Netherlands	3.84	82.77	16.26
Canada	3.62	78.03	2.18

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UK	3.15	67.74	11.44
France	2.42	52.1	31.86
Spain	2.26	48.72	36.51
		Average Five-Year Growth in Import Value	27.90%

A five-year growth in import value among the top 10 importing countries (Source: Tridge-https://www.tridge.com/intelligences/tiger-nut/import, accessed on 27 January 2022).

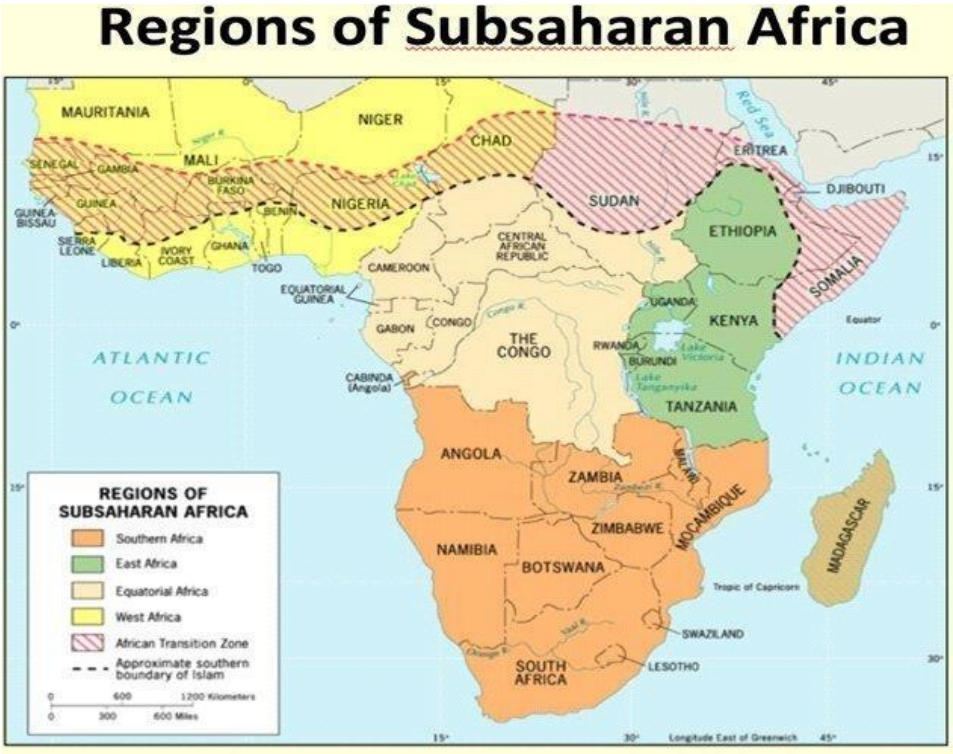

Fig 1: A map of various countries in the Sub-Saharan Africa. Culled from: Saharan Africa growth to Sub 10 rise **3.0** percent in 2018 -report -Eagle Online

NUTRITIONAL BENEFITS OF TIGER NUTS

Tiger nut has a high nutritional value, which contains 6.08–9.70% protein, 4.53–17.50% fiber, 19.79–37.83% fat and 30.90–59.18% carbohydrate (Nwosu et al., 2022, Gadanya et al., 2021, Oladele and Aina, 2007; Nina, 2019). About 100grammes of the nuts contain 409 kcal (1705.77 kJ) of energy (6.1% of which are of proteins, 23.7% fats/oils, 7.1% water, and 42.5% starch), and they contain an appreciable level of fibre (17.4%). They are also known to be rich in minerals such as sodium, calcium, iron, zinc, phosphorus, potassium, magnesium, copper and manganese (Poonam, 2022; oluwakemi et al, 2021). The nut can be eaten raw, roasted, dried or baked. They were confirmed to have good medicinal properties since they have been used as diuretic, stimulant, and in the treatment of disorders such as indigestion, constipation, flatulence, diarrhea, dysentery etc. (Fabrice et al., 2022). The lack of lactose sugar, casein protein, gluten and cholesterol in tiger-nut makes it fit for consumption for people who are hypertensive, lactose intolerant or allergic to gluten (Belewu and Abodunrin,2008; Gambo and Dau, 2014). The high calcium content present in tiger nuts is sufficient enough for formation of bone and teeth in babies (Oladele & Aina, 2007).

The consumption of tiger nuts is believed to have an impact in prevention of cancer and heart disease, as well as a positive influence in activating blood circulation (Chukwuma et al., 2010). The tiger nut tubers were confirmed to have good medicinal properties since they have been used as diuretic, stimulant, and in the treatment of disorders such as indigestion, constipation, flatulence, diarrhoea, dysentery e.t.c. (Viuda-Martos et al., 2010).

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Tiger nut milk has been used to assist normal menstrual period and treat successfully dental ulcers. Due to its unique flavor, tiger nut flour can be added to baits to improve its taste and moisture (Bamishaiye & Bamishaiye, 2011). Tiger nut could provide a basis for rural industries in Africa. The ground flour is mixed with sorghum to make porridge, ice-cream, sherbet or milky drink. In Nigeria, tiger nuts have been considered a neglected crop. Tiger nut drinks can be used as functional food based on their chemical composition (Oluwadunsin et al., 2021). Olagunju and Oyewumi (2019) recommended the use of a beverage containing tiger nut in the prevention of cardiovascular diseases. Gugsa and Yaya (2018) reported several compounds with antioxidant, anti-inflammatory, anticancer, antimicrobial and antiseptic properties in smoke from burned tiger nuts. It was reported that the leaves of *Cyperus esculentus* L. included flavonoids and various biological activities, such as antibacterial function, promoting blood microcirculation, and anticoagulant effect (Jing et al., 2020).

Table 1. Nutritional properties of Tiger Nut.

Nutrient	**Amount(g/10g)**	**Refs.**
Carbohydrates	**47**	**Bamigboye et al. (2020)**
Protein	**30.01**	**El-Anany and Ali (2012)**
Ash	**2.23**	**Pelegrin et al. (2022)**
Crude Fiber	**14.80**	**Adesakin Funmilola and Obiekezie Smart (2020)**
Moisture	**8.50**	**Allouh et al. (2015)**
Reducing sugar	**27.62(g/g)**	**Bazine and Arslanoğlu (2020)**
Starch content	**15.47(g/g)**	**Bamigboye et al. (2020)**
Sucrose	**13.55(g/g)**	**Bamigboye et al. (2020)**

Source: Edo et al. (2023)

CONTAMINATION OF TIGER NUT AND DERIVED PRODUCTS IN SUB-SAHARAN AFRICAN COUNTRIES

Food contamination occurs when there is presence of unwanted elements in food. Also when food gets in touch with dangerous microorganisms or substances which could be intentionally or accidentally contaminated. Far back as many years ago, food contamination has been in existence and it is still occurring till date. Human health is usually affected and in some cases results in death after consumption of contaminated foods. Globally, as human population is expanding, to guarantee 'food safety' is becoming more difficult (Hussain 2016; Majeed, 2017. Elkhishin et al., 2017). However, unsafe food containing potentially harmful microorganisms or chemical substances causes more than 200 diseases, ranging from diarrhoea to cancers. It also originates a violent cycle of disease and malnutrition, which particularly affects infants, young children, the elderly and the sick. Contamination of tiger nut tubers could occur in three phases, that is, the physical, microbial and chemical contamination.

Physical Contamination of Tiger nuts and derived products in sub-Saharan African countries

Physical contamination is one of the commonest type of contamination of tiger nut tubers. This usually occurs during harvesting of the tubers along with foreign materials such as stone, sand and animal droppings mixed with freshly harvested tiger nut tubers. Other sources of contamination could be from compost, organic matter, insects and soil. Microbial contamination of tiger nut tubers is most likely to be from physical contamination from these and other sources. However, physical contamination of tiger nut tubers could be considered as being rampant, as the contaminants involved is easily seen and removed (Ayeh-Kumi et al., 2014). Potentiality to

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design appropriate machinery and processing equipment for tiger nut tubers based on the engineering properties of the tubers could help reduce physical contamination of the tubers (Ince et al., 2017; Abano & Amoeh, 2011).

Microbial Contamination of Tiger nut and derived products in sub-saharan African countries

Most of the sub-Saharan African population still lives without access to clean water and sanitary facilities (Sente et al., 2016) and in many African households, especially the rural dwellers, untreated water is used for various purposes including drinking, cooking, washing of fruits and other fresh produce, bathing, and swimming which exposes them to not only protozoan parasites but other pathogens as well (Yongsi, 2010; WHO, 2014). Microbial contamination of tiger nut tubers freely take place and they are often not detected before the tubers are swallowed or consumed. The cause of microbial contamination could be from contaminated soil, infected fieldworkers, irrigation water, wash tanks, harvesting equipment, fecal materials and transport vehicles. Microbial growth in food is usually inhibited by factors such as temperature, gas volume ratio, initial microbial loads and type of flora, packaging, barrier properties, storage condition and biochemical composition of the food (Okore et al, 2014).

According to Maduka and Ire (2016), the use of water soiled with fecal matter to washing of knives, polyethene bags and trays could also be a source of microbial contamination of tiger nut tubers. Unhygienic practices of vendors and unsuitable storage conditions can contribute to microbial contamination of ready-to-eat tiger nut tubers. Also consuming fresh or dried tiger nut tubers contaminated with pathogenic microbes increases the chance of digesting mycotoxins such as aflatoxins, ochratoxins and fumonisins (Shamsuddeen & Aminu, 2016). Microorganisms that are isolated from exposed tigernut tubers include, *Bacillus subtilis, Staphylococcus aureus, Aspergillus flavus, A. niger, Fusarium solani, Saccharomyces cerevisiae, S. fibuligera* and *Candida pseudotropicalis.* An evaluation of wholesomeness of tigernut tubers imported into Nigeria as snack food was carried out by Shamsuddeen and Aminu (2016). Also, Ayeh-Kumi et al. (2014) also surveyed pathogens associated with exposed tiger nut tubers sold in a Ghanaian city. Findings from the study showed that four different parasites and five bacteria genera were present on tiger nut tubers being retailed in the markets. The presence of these pathogens in tiger nut tubers sold in the market signals a threat to public health.

Contamination of Tiger nut and derived products by bacterial isolates

Microbial contamination of tiger nut or its derived products many a time are undetected before they are consumed, this has caused food intoxication among the consumers and such organisms include; *Salmonella* species, *Bacillus cereus, Clostridium* species, *and Staphylococcus* species, *Acinetobacter* species, *Enterobacter* species, *Corynebacterium* species, *Neisseria* species, and *Aeromonas* species (Ibrahim et al, 2016). The menace posed by diseases spread via contaminated food is well known and the epidemiological effect of such diseases is significant. The presence of pathogenic microorganisms in tiger nuts as emerged as major public health concern especially for consumers (Mkangara, 2023). *Staphylococcus* species have been found to be dominant in tiger nut samples. These species include S.*simulans, S. schleiferi, S. cohnii* and *S. caprae*. These species are known to colonize the skin and upper respiratory tracts of mammals. They can cause a wide variety of diseases in both human and animals either through toxin production or penetration (Ibrahim et al, 2016). Bacterial contamination of tiger nuts can start from different sources such as bad water, handling unhygienically, poor storage systems, among others. In Ghana, Enterobacteria and *Staphylococcus* spp. were reported to be present in raw tiger nut tubers collected from street vendors and market places (Rosello-Soto et al, 2019). In Nigeria, three genera of bacteria were reported to be present in tiger nut derived product 'Kunun Aya' samples, which included, *E. coli, Salmonella* spp. and *S. aureus*. The presence of these pathogenic organisms poses a serious public health concern. *S. aureus* causes diseases in humans such as folliculitis, furuncles, carbuncles, erysipelas, cellulitis, scalded skin syndrome, impetigo, pneumonia, osteoporosis, toxic shock syndrome (toxemia), meningitis, and staphylococcal food poisoning ((Pandukur et al, 2019).

Contamination of tiger nut and derived products by fungal isolates

Any form of contamination of tiger nut tubers could impact on overall quality and shelf life of the tiger nut and its derived products. Fungi are ubiquitous microorganisms that bring about large scale spoilage of plants and

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animal products. Tiger nuts are a major source of nourishment and essential ingredient in healthy and balanced diets (Oladele and Aina, 2007), but retain various loads of microbial flora that can be a potential source of acute or chronic food borne illness when contaminated with pathogenic microorganisms or microbial product such as toxins. The presence of *Aspergillus nomius* was reported in some tiger nuts samples vended in Kaduna Metropolis, it was of great health concern because the organism causes a disease known as fungal keratitis if it finds its way into the eye through hand contamination. Bolarinwa et al. (2021), reported *Aspergillus niger, A. fumigatus, A. flavus* and *Penicillin citrinum* as the predominant fungal species in tiger nut flour during storage. According to Chukwu et al. (2013), fungi associated with fresh tigernut tubers include *Aspergillus niger, A. flavus* and *A. terreus* while that of dried tubers is *Penicillium citrinum* and *A.fumigatus*.

Table 3: Distribution of Microflora isolated from tiger nut-soy milk extract during storage

Microorganism		**Storage Condition A**	**B**	**C**	**D**	**E**	**F**
Bacillus subtilis	**Refidgerated**	+	+	+	+	+	+
	Ambient-stored	+	+	+	+	+	+
Bacillus cereus	**Refidgerated**	-	-	-	-	-	-
	Ambient-stored	+	-	+	+	+	+
Staphylococcus aureus	**Refidgerated**	-	-	-	-	+	+
	Ambient-stored	+	-	+	+	+	+
Penicillium notatum	**Refidgerated**	-	-	-	+	-	-
	Ambient-stored	-	-	+	-	-	+
Aspergillus Flavus	**Refidgerated**	-	+	+	-	-	-
	Ambient-stored	-	-	+	-	-	-
Rhizopus spp.	**Refidgerated**	+	+	+	+	+	-
	Ambient-stored	+	+	+	+	-	-
Saccharomyces spp.	**Refidgerated**	+	+	+	+	+	+
	Ambient-stored	+	+	+	+	+	+
Mucor Spp.	**Refidgerated**	+	+	+	-	+	+
	Ambient-stored	+	+	+	+	+	+

A=100% Tigernut milk + 0% Soy milk; B= 90% Tigernut milk +10% Soymilk; C= 80% Tigernut milk + 20% Soymilk; D= 705 Tigernut milk+30%Soymilk; E=60% Tigernut milk + 40% Soymilk; F= 50% Tigernut milk + 50% Soy milk. Source: Maduka and Ire (2019).

Chemical Contamination of Tiger nuts and derived products in sub-saharan African countries

Chemical substances used in the field can be a source of contamination of tiger nut tubers. Chemical residues in tiger nut tubers could have long term effect in the human body if ingested in large quantity. According to Asen and Kana (2018), in their studies reported the presence of heavy metals in exposed tiger nut tubers in Keffi metropolis, Nassarawa state, Nigeria. According to the result of their analysis, in exposed and refrigerated samples of tiger nuts, lead were found to range between 0.16 mg/kg and 0.09 mg/kg and copper (Cu) was also reported to be present in exposed samples of tiger nuts in the range between 0.1 mg/kg and 0.2 mg/kg

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respectively. The water used when applying fungicides and insecticides could also be a source of microbial contamination of tiger nut tubers (Akomolafe and Awe, 2017).

Contamination of tiger nuts and derived products by Mycotoxins

Possible contamination of tiger nut tubers are mycotoxins which is a major health concern due to tiger nut tubers is commonly eaten as raw tubers without subjecting the tubers to any treatment that will reduce the level of contamination. Mycotoxins are fungal secondary metabolites that are toxic to both human and animal and they are considerably a threat to food safety. Over 300 mycotoxins have been described, but aflatoxins, trichothecenes, zearalenone (ZEN), fumonisins, ochratoxin A (OTA), and patulin are considered as the most significant due to their high toxicity and frequent occurrence in food products (Gill-Serna et al., 2020). These mycotoxins often contaminate the raw tiger nut products used to prepare functional beverages including cereals, legumes, nuts, fruits. They are toxic compounds that are naturally produced by certain types of moulds (fungi). Moulds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Several species of mycotoxin-producing molds (*Aspergillus niger, Aspergillus fumigatus, Aspergillus flavus* and *Penicillium italicum*) were also reported to be present in raw tiger nut tubers in Ghana (Rosello-Soto et al, 2019).

Contamination of tiger nut and derived product by heavy metals

Heavy metals are components of earth's crust with a relatively high density that is deadly or hazardous at low doses Heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). Heavy metal contamination in foods and beverages originated from different routes. Environmental pollution, industrial waste, soil where plant-based foods are cooked, processing of foods etc. are some well-known sources of heavy metal contamination (Deka et al, 2023). The selling of food by the road side provides a source of cheap and fast foods for both urban and rural dwellers. Foods sold by the roadside are reported to have major health implications, which may arise from improper and unhygienic handling of foods by the vendors, as well as exposure to emission of metals by automobile and to atmospheric pollutants. In Keffi, copper and lead was reported to be present in exposed tiger nuts sold within the metropolis which indicated that food products exposed by the roadside are subject of contamination by automobile emission. Onakpa et al. (2018), emphasized that food sold on streets are known to contain high levels of lead, cadmium, arsenic, mercury, and copper a situation which exposes consumers to heavy metals bioaccumulation. Studies have shown that roadside or street vended foods have been implicated in several cases of food poisoning outbreaks. According to Rane (2011), 691 cases of food poisoning outbreaks was recorded which resulted from roadside or street vended foods with 49 deaths from 1983 to 1992 in Shangdong Province of China. Contamination of food by heavy metals can result in serious health issues such as Cardiovascular disease, diabetes, lung-cancer, hearing disorders, and visual impairment are some serious issues associated with heavy metal contamination. According to Al-Shaikh (2013), lead is regarded as a crucial pollutant of the environment which is suggested in industrial pollution. The accumulation of lead hinders the synthesis of haemoglobin in human body. Therefore, people are advised not to eat too much quantity of tiger nut tubers in order to reduce intake of large quantity of lead (Chukwu et al., 2013).

Contamination of Tiger nut and derived product by pesticides

Pesticides play a significant role in crop production. Modern agro-chemical inputs like pesticides potentially help farmers boost productivity significantly, particularly in regions like Sub-Saharan Africa (SSA) where modern input uptake has historically been limited and crops yields low. Modern agricultural intake such as inorganic fertilizer and pesticides potentially help farmers improve productivity remarkably (Sheahan et al, 2017). Pesticides are substances that can dramatically increase crop production and quality of produce and are also used for the protection of crops from various pests and diseases (Guler et al., 2010; Ahoudi et al., 2018). However, pesticides are also referred to as toxic chemicals that are designed to eliminate agricultural pests such as insects, rodents, weeds, bacteria, mould and fungus, and as well cause problems if they are consumed by humans in large amounts. In Gombe (2023), contents of pesticide residue were reported to be present in tiger nut vended, and it was below acceptable daily intake indicating no probable adverse health effect on both children

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and adult consumers but if taking in large amount it may pose serious health issue to consumers (Maigari et al, 2021).

Table 4: Interaction between heavy metals and pesticides on agicultural soil and plat.

Heavy Metals	Pesticides	Joint Interaction
	SOIL ORGANISMS	
Cd	**Λ-cyphalothrin Chlopyrifos, Athrazine**	**Antagonism Synergism**
Pb	**Acetochlor, Glyphosate**	**Synergism Antagonism**
Cu	**Acetochlor, Cypermethrine**	**Synergism Antagonism**
Zn	**Chlorpyrifos, 2,4DCP**	**Synergism Antagonism**
	PLANT PARTS	
Cd	**Acetochlor Bensulfuron-methyl**	**Synergism Synergism**
Pb	**Acetochlor**	**Synergism Antagonism**
Cu	**Glyphosate**	**Synergism Antagonism**
Zn	**Glyphosate**	**Antagonism**

Source: Alengebawy et al. (2021)

STRATEGIES TO PREVENT CONTAMINATION OF TIGER NUTS AND THEIR DERIVED PRODUCTS

Hygienic Harvesting

It is advisable that foreign contaminants gathered with tiger nut tubers should be carefully removed by either hand-picking of the good tubers or carefully removing all the foreign materials. These physical contaminants are normally removed by hand picking and the process is strenuous. Lately, industries have employed the use of automated systems such as sieving systems and the wet separating system for the processing of tiger nut tubers (Al-Shaikh et al., 2013). The taste and quality of tiger nut milk is affected if the foreign materials gathered alongside the tubers and the bad/cracked tubers are not removed (Maduka and Ire, 2019). However, dehulling of tiger nut tubers can notably reduce microbial load of the tubers (Djomdi et al., 2013).

Use of proper packaging materials

Plastic bags are mostly used by sellers to package fresh or dried tiger nut tubers to make the retailing of the product easier. Plastic bag is the most commonly and relatively cheap item for packaging in food and beverage industries. Akomolafe and Awe (2017), carried out a study to determine the effectiveness of using packaging materials such as polyethylene bags to reduce the level of microbial contamination of ready-to-eat fruits and vegetables including tiger nut tubers sold in some states in South Western Nigeria. It was reported that tiger nut tubers that had been washed, decontaminated and packed inside plastic bags were prevented from being polluted during retailing. From the study, it was revealed from their results that tiger nut tubers got at wholesale points

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue VI June 2024

were heavily contaminated compared with the samples from retail points. Also, tiger nut tubers sampled at the retail points recorded a lower microbial load which was attributed to washing of the tiger nut tubers with water by retailers. However, *Staphylococcus* spp. were recorded to be present in all the samples of tiger nut tubers packaged with polyethylene bags from the retail points.

Proper storage conditions

Conservation of tiger nut tubers is focused at slowing down unacceptable changes that occur in the tubers due to activities of spoilage microbes and chemical reactions. Different storage conditions are adopted in preserving fresh tiger nut tubers. The use of plastic bags by street vendors to sell and store tiger nut tuber is a usual practice in developing countries like Nigeria. The thickness of polyethylene bags differs and this can have influence on shelf life of tiger nut tubers. Akomolafe and Awe (2019), reported in their result that preserving tiger nut tubers inside polyethylene bags is not favourable for storage but beneficial in reducing recontamination of the tubers during retailing. It was reported that tiger nut tubers secured for 10 days inside a polyethylene bag that has a thickness of 1 µm experienced a major color change compared with that of 7 µm thickness which experienced no color change. Furthermore, storage of tiger nut tubers in a refrigerator or freezer maintained at a constant temperature will prevent the tubers from changing its original colour as well as slow down microbial growth on the tubers which normally leads to spoilage. Airtight containers filled with tiger nut tubers kept at ambient temperature (28±2ºC) is a suitable storage condition, and when artificial preservatives are used, it helps maintain the distinct qualities of tiger nut tubers during storage. Also, crinkled ‘tiger nut tubers that are perfectly dried can be stored for indefinitely long period without undergoing spoilage and tiger nut tubers soaked inside water and changed daily can remain fresh up to 10 days (Maduka and Ire, 2019). The taste of properly dried tiger nut is well appreciated by many consumers and they can stay for up to a year or more with little or no risk of being attacked by spoilage microorganisms. However, when the moisture content of fresh tiger nut tubers is reduced it guarantees that the activity of spoilage microorganisms in the tubers will be highly reduced during storage. Therefore, dried tiger nut tuber is easier to store than fresh tiger nut tubers. Large amount of tiger nuts stored under warm anaerobic storage condition is not appropriate due to the fact that it promotes microbes that naturally occur on tiger nut tubers that quickly ferment the tubers. Under that condition, chemical spoilage products mostly mycotoxins are released. However, if the environment where tiger nut tubers is stored is well ventilated and fumigated at least every six weeks against insects or bugs causing damage to the tubers, it can store up to two years (Maduka and Ire, 2019). Tiger Nut derived products such as tiger nut milk can be preserved using chemical preservatives such as sodium azide which has proven to be effective by extending the shelf-life of the tiger nut milk and maintaining its sensory characteristics (Akoma et al., 2016). Ibrahim et al. (2016) evaluated the effect of different preservation methods on the pH and microbiological quality of tiger nut milk. The results suggested that ultraviolet light and sterilization methods were more effective at eliminating most of the bacteria associated in milk spoilage.

Quality of water sources

Clean and uncontaminated water sources should be used during cultivation, processing and washing to prevent the introduction of pathogenic microorganisms. It is necessary and crucial that contamination of tiger nut tubers and tiger nut-derived products is reduced to a minimal level or completely eliminated before the product is consumed. Two methods to achieve this, include, removal of foreign materials mixed with tiger nut tubers and washing the tubers with potable water before using the tubers to produce tiger nut-milk drink (Akoma et al. 2016).

Industrial Processing

Products derived from tiger nut tubers could either be homemade or subjected to industrial processing. Home-made tiger nut beverage which is not usually subjected to sterilization methods of preservation showed that it had higher load of microbial contamination than the ones processed by beverage industries that practice strict good manufacturing practices (GMPs) which also involves thermal methods of treatment (Maduka and Ire, 2019). Some beverage industries that manufacture tiger nut-milk drink use gamma radiation for sterilization so as to assure the healthiness of the drink. The consequence of exposing tiger nut-milk drink to gamma radiation

in respect to its physicochemical, functional and sensory attributes was reported by Okyere and Odamtten (2014). The sugar content varied from 6.0 ± 0.3% to 15.00 ± 1.00% which was dependent on the irradiation dose that was applied. However, increase in dose increased the sugar availability but decreased viscosity of the milk prepared from the nuts. Microbial load in tiger nut-milk drink subjected to gamma irradiation can as well be pasteurized to further reduce microbial load in the drink.

CONCLUSION

Tiger nut tubers contamination could either be physical, chemical, or microbial. It could also be a combination of some of them. Utilization of contaminated tiger nut tubers to produce edible products without exception results in contaminated products of the tiger nuts if treatment to reduce or eliminate the contaminant is not applied. There is therefore a need for regular monitoring of the quality of such food items sold. To maximize the potential of tiger nut tubers and guarantee safe tiger nut-derived products, it is important to prevent tiger nut tubers and tiger nut-derived products from any form of contamination by consumers paying critical attention to proper washing and surface sterilization of the tiger nuts before consumption. Also proper storage of tiger nut tubers is important for the overall health benefits of humans, thus reducing disease outbreak in the society.

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