UNIVERSITY OF EDUCATION, WINENBA

EFFECT OF MICROBES AND SENSORY PROPERTIES ON VARIETIES OF TIGER NUT MILK

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MASTER OF EDUCATION IN AGRICULTURE

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A DISSERTATION IN THE DEPARTMENT OF CROP AND SOIL SCIENCES EDUCATION, FACULTY OF AGRICULTURE EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF EDUCATION IN AGRICULTURE

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AUGUST, 2022

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this dissertation is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

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ANKOMAH JOHN **DATE**

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this dissertation were supervised in accordance with the guidelines on the supervision of dissertation laid down by the University of Education, Winneba.

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DR. E.B BORKETEY - LA **DATE**

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DEDICATION

This work is dedicated to the Queen mother of Akim Osorase, NANA KUMIWAA KONKYE II for her unfailing support for me throughout my two–year course, May God bless her bountifully.

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LIST OF ABBREVIATIONS

$WSTM+P_{Ref.T}$	- Water-soaked Tiger nut Milk + Preservative at Refrigerated Temperature
$WSTM+P_{RT}$	- Water-soaked Tiger nut Milk + Preservative at Room Temperature
$WSTM_{Ref.T}$	- Water-soaked Tiger nut Milk kept at Refrigerated Temperature
$WSTM_{RT}$	- Water-soaked Tiger nut Milk kept at Room Temperature
$RTM+ P_{Ref.T}$	- Roasted -Tiger nut Milk + Preservative at Refrigerated Temperature
$RTM+P_{RT}$	- Roasted - Tiger nut Milk + Preservative at Room Temperature
$RTM_{Ref.T}$	- Roasted - Tiger nut Milk kept at Refrigerated Temperature
RTM_{RT}	- Roasted -Tiger nut Milk kept at Room Temperature

ABSTRACT

A study was conducted at the Multi – purpose laboratory at Takorase Research Station in the Eastern Region of Ghana from May 15, 2021 to December 30, 2021. The objective of the study was to determine the effect of microbiological activity and sensory qualities on tiger nut milk and its shelf life. Eight varieties of tiger nut tubers (treatments) such as Aduamoa brown, Bawjiase brown, Techiman type, Nkawkaw type, Kasoa type, Asiebu type, Aduamoa black, and North type were processed into 2 major groups through different processing treatments, water-soaked tiger nut milk (WSTM), roasted tiger nut milk (RTM). Each of these mixtures was divided into two portions, one treated with Nisin (an antibiotic preservative) and the other portion left untreated. The two portions were further divided into two treatments, one stored at refrigerating temperature and the other one at room temperature, making 8 different treatments in all and a total of 64 treatments samples and a total of 8 samples. The samples were subjected to sensory and microbial analyses. The results of the sensory analysis, colour, flavour, taste, and mouthfeel showed that the water-soaked tiger nut beverage samples were significantly different ($p<0.05$) from the other treatments. Microbiological analysis was carried out over a 3-week storage period. The products were microbiologically stable during the first week, but the rapid growth of microorganisms was observed after the first week which was high enough to cause spoilage. In conclusion it was observed that processing treatments have an effect on the stability and acceptability of tiger nut milk products.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Tiger nut (*Cyperus esculentus* L.) is underused perennial grass-like sedge. It's a member of the Cyperaceae family. The plant is also known by the names nutsedge, chufa, and earth almond, as well as yellow nutgrass (Belewu & Belewu, 2007; Odoemelan, 2003). According to Belewu and Abodunrin (2008), tiger nuts are a viable cereal grain alternative. The nut, which is grown all over the world, may also be found in northern Nigeria and other West African countries such as Guinea, Cote d'Ivoire, Cameroon, Senegal, and other areas of the world. Its likely origin is temperate zones of South Europe, and it has been established in Ghana, Nigeria, and Sierra Leone. It is grown in a few locations in Ghana, including Aduamoa in the Kwahu South District, Asukese in the Central Region, and Techiman in the Brong Ahafo. The nuts are prized for their high starch, dietary fiber, and carbohydrate content.

Odomasua, and Demso in the Afram plains, Agona Kwanyaarko, Bawjiase, and Elmina are all said to be abundant in the tiger nut (Belewu & Abodunrin, 2008). The percentage of nutrients found in the tiger nut are: fat (25.50 percent), and protein (8 percent). Mineral content (sodium, calcium, potassium, magnesium, zinc, and traces of copper) is also high in the nut (Noah & Oduobi, 2018).The uses of tiger nuts cannot be overemphasized. The tubers are often used as a staple food, especially in Africa, where they constitute a staple crop for some tribes. They can be eaten raw, cooked like a vegetable, roasted like groundnuts or shredded, and used to produce ice creams, as well as a milky beverage known in Ghana as 'Atadwe milk' and in Spain and Latin American nations as 'horchata.'.

According to Mason (2009), tiger nuts have long been acknowledged for their health benefits because they contain a high amount of soluble glucose and oleic acid, as well as a lot of energy (starch, fats, sugars, and proteins). They are also high in minerals like phosphorus and potassium, calcium, magnesium, and iron, which are important for bones, tissue repair, muscles, the bloodstream, and body growth and development, and they are high in vitamins E and C. Because of its high level of Arginine, which releases the hormone that creates insulin, sugar-free tiger nut milk is excellent for diabetics and also helps with weight control (Martinez, 2003). It contains digestive enzymes such as catalase, lipase, and amylase, which are beneficial to persons who suffer from indigestion, gas, and diarrhea. The high quantity of oleic acid lowers cholesterol levels, avoiding heart attacks and thrombosis, and activating soluble glucose levels in the blood. The consumption of tiger nuts lowers the risk of colon cancer. It keeps you from becoming constipated. Tiger nuts are high in vitamin B1, which helps to support the central nervous system and encourages the body to adapt to stress (Adebayo & Arinola, 2017).

Vitamin E, which is needed for both men's and women's fertility, is found in sufficient amounts in milk. Vitamin E also helps cell aging, ameliorates the elasticity of the skin, and aids to clear the appearance of wrinkles, acne, and other skin alterations. The black species of the tiger nut is an excellent medicine for breast lumps and cancer (any type of internal cancelation and inflammations). It can be used as an eye compress and to bandage wounds (Ade-Omowaye *et al*., 2008). Tiger nuts are in great demand for local consumption, and as a result, they are relatively expensive. There are signs that the crop has a sustainable export market once more. Tetteh & Ofori in 1998 did a baseline survey of tiger nut (*Cyperus esculentus*) production in the Kwahu South District of Ghana and came out that, Ghana earned 8,687.78 dolars from tiger nut in the year 1998. Farmers must be encouraged to satisfy local and export demands through a concentrated effort. Drought, irregular rainfall, and poor soils have all helped the crop acquire physiological, and structural adaptations that allow it to survive (Akabassi *et al*., 2021). Due to this adaptability to Ghana's drought circumstances, it becomes a key source of revenue for farmers and women in regions where they are cultivated throughout the dry season of the year. Women bundle them in rubber and sell them alongside truck stops in Kasoa, Bawjiase, and Nkawkaw, respectively, in Ghana's Central and Eastern regions. As a result, tiger nuts contribute to household income and serve as a solution to rural poverty. There is a clear need for tiger nut enhancement, which has gotten little attention from scientists and researchers, especially in Ghana.

1.2 Problem statement

In Ghana, Tigernut (Cyperus esculentus) is an edible perennial grass-like plant of the Sedge family. It is widely used for human and animal consumption as a nutritious food and feed in Africa, Europe and America (Belewu *et al.,* 2007). About 1.3 million cases of active diarrhoea in children less than five years in the developing world due to contaminated milk (Belloin, 1988). Milk contains a natural inhibitory system which prevents a significant rise in the bacteria count during the first 2 -3 h and if it is cooled within this period to 4℃, it maintains nearly its original quality. Timely cooling ensures that the quality of the milk remains good for processing and consumption (Asekan *et al.,* 2012). However, in rural places where there is no refrigerator facility people use traditional approaches to maintain the quality and safety of milk. Tigernut can be eaten raw, roasted, dried, baked or made into a refreshing beverage, which is very nutritive, healthy for both the young, and old. There were many attempts to industrialize the locally prepared Tigernut beverage, but the inability to preserve the drink for a long time

3 without spoilage has been a major drawback (Chukwu *et al.,* 2013). Despite the tiger nut's numerous economic and health advantages, little is known about its microbiological activity while stored in cans, as well as the most critical characteristics connected with its shell life. Varieties of microbes find their way into tiger nut milk, introduced from the soil in which they were grown, and during harvest, packaging, storage and handling. Bacterial contamination of fresh tiger nut can be due to non – availability of quality water in good quantity for washing and pre – disinfection of the fresh tiger nut. Microbial contamination of tiger nut milk drink stored in cans can be due to lack of portable water used in its production. The use of water polluted with faecal matter to wash knifes, polythene, trays could also be a source of contamination of tiger nut tubers. The microbiological activity and sensory qualities of tiger nuts should be determined to improve the quality of tiger nut milk.

1.3 General objectives

The fundamental goal of this study is to find out the effect of microbiological activity and sensory qualities on tiger nut (*Cyperus esculentus*) milk in Ghana.

1.3.1 Specific objectives

The specific objectives were to:

1. determine the microbial activity of tiger nut milk.
2. assess the shell life of the tiger nut milk.
3. determine the sensory properties of tiger nut milk.

1.4 Significance of the study

Knowledge of the diversity of landrace variations of tiger nut in Ghana, as well as an examination of their microbial activity and sensory properties, might be useful in improving milk quality. This research also uncovers the potential preservation impact of

Nisin, an antibiotic preservative that can help to reduce microbial activity in tiger nut beverage samples during storage. These findings will benefit the researcher in identifying the major factors that contribute to the rotting of tiger nut milk drinks, which many other researchers have been unable to investigate. As a result, a novel processing method for preparing tiger nut drinks might be explored.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution

In ancient Egypt, the tiger nut was a popular snack (Negbi, 1992). Tiger nut is an early domesticated crop that was mixed in with other Nile Valley products; their dry tubers have been discovered in tombs dating back to antiquity periods (approximately 6000 years ago) (Sabah *et al*., 2019). *Cyperus esculentustus* tubers were roasted and served as sweetmeat in Egypt at the time. There are essentially no current records of this species in other regions of the Old World, according to (Sabah *et al*., 2019). Tiger nut is a plant that has been grown for ages in southern Europe and many other nations across the world. Tiger nut is also grown in Chile (Ormeño-Núñez *et al*., 2008) and Brazil (Mittal *et al*., 2020), where it is mostly utilized for animal feed. It's also utilized in the production of 'horchata' in Florida (Mosquera *et al*, 1996).

The Arabs introduced it to Europe throughout the middle ages, and it quickly spread over northern Africa. Written documents from the 13th century indicate the drinking of a tiger nut drink in several Mediterranean locales, primarily the Valencia Region (southeast of Spain). This drink might be regarded as a forerunner of today's 'horchata' (Bosch *et al*., 2005). In recent years, the tiger nut has grown in popularity in tropical areas. Tiger nuts are now grown in Northern Nigeria, Niger, Mali, Senegal, Ghana, and Togo, where they are mostly served raw as a side dish (Noah & Oduobi, 2018). With roughly 2450 acres and an annual yield of 9000 metric tons, the tiger nut is a significant emblematic crop of the Spanish Mediterranean area (Sánchez & Zapata *et al*., 2012).

2.2 Botany

The tiger nut (L *Cyperus esculentus*) is a little-known crop that belongs to the Magnoliophyta division, Liliopsida class, Cyperales order, and Cyperaceae family. Earth almond and golden nutgrass are two more names for the plant (Belewu & Belewu, 2007). Tiger nut is a robust, fibrous-rooted perennial plant that grows 1 to 3 feet tall and reproduces by seeds, deep, narrow rhizomes that generate weak runners above ground, and little tubers or nutlets at the terminals of subterranean stems (Rubert *et al*., 2011). This unbranched natural perennial sedge grows to be half to two (2) inches tall. The core stem is upright, three-angled, and generally hidden behind the leaf sheaths. The leaves prefer to clump together at the plant's base.

The leaf is up to 1.5 inches long and 1/3 inch wide, light green and smooth, and it spreads outward from the stem. Each leaf blade, especially the bigger ones, has a visible groove along the center vein. The leaf sheaths are whitish-green, closed, and hairless, and they become pale crimson at the plant's base (Asare *et al*., 2020). The primary stem ends in an umbel or complex umbel of flower spikes, which can vary in height and form (on larger plants, it is usually several inches across). On straight branches of different lengths, each umbel includes 1–3 sessile spikes and 6–10 non-sessile spikes. There are many leafy bracts of varying lengths at the base of each umbel or complex umbel of spikelet; the longest bract is frequently longer than the inflorescence. Each floral spike is 2–3 inches tall and has four tiers of spikelets running along its center stalk (or rachis). The middle stalk is narrowly winged and flattened. The spikelets are perpendicular to the stem and range in length from 12 to 34 inches. The spikelets are yellow to golden brown in color, narrowly linear in shape, and flattened in shape, with 10 to 30 florets and their scales. Each spikelet's overlapping scales are 2.0–3.0 mm long and somewhat scattered throughout the length of the spikelet. Each floret has a curled style tip and a white tripartite style with yellowish-brown anthers. The flowering season lasts from the middle of summer until the beginning of autumn. Tiger nut tubers, whether fresh or rehydrated, are up to 30 mm long, brown on the outside with three enclosing leaf scars, and white on the inside with dark root initials (Owon *et al*., 2013). El Gharras *et al*. (2008) found that the average tuber diameter and length of tiger nut samples were 6.27 mm and 12.09 mm, respectively. The bulk density was 1.186 g/ml and the average weight was 0.257 g. The crisp texture of a tiger nut may be preserved by soaking it dry (Owon *et al*., 2013).

The wind is used to pollinate the tiger nut tree. Small achenes, 1.0–1.5 mm long, oblongoid or oblongoid–obovoid, and flattened, replace the florets. Fibrous, rhizomatous, and tuberous roots make up the shallow root system. The brown borders of the outer membrane give the white rhizomes a slightly segmented look; the rhizomes are attached to little globoid tubers up to 12 inches broad. Young tubers are white, whereas older tubers have a yellow outer membrane and can be found within 6 inches of the ground surface. Tubers and associated rhizomes are frequently used to form vegetative plant colonies. At maturity, the nutlets are virtually smooth and irregularly globe-shaped (Temple *et al*., 1990).

2.3 Climatic and soil requirements

The plant prefers wet sandy–loam soils, but will thrive in even the toughest clays, accommodates high soil moisture, and is shade-intolerant. The plant, like other sedges, prefers moist marshes along the borders of streams and ponds, where it grows in coarse clumps (Temple *et al*., 1990).

2.4 Tiger nut: Description and Cultivation

In several regions, tiger nut (*Cyperus esculentus*) is also known as chufa sedge, nutgrass, yellow nutsedge, Tiger nut sedge, or earth almond (Oderinde&Tairu, 1988). Tiger nut is also known by the names Zulu nut, yellow nutgrass, delicious rush, and rush nut (Eteshola & Oraedu, 1996). Tiger nut is a robust erect fibrous-rooted plant that grows 1 to 3 feet tall and reproduces by seeds and numerous deep-rooted slender rhizomes, according to Consejo (2006). It has single stems that sprout from a tuber and grow to a height of around 90 cm. It has triangular stems with delicate leaves varying in width from 3 to 10 mm. The Tiger nut plant's blossoms are unusual, with a bunch of flat oval seeds surrounded by four leaf-like bracts positioned 90 degrees apart.

Because of its rough and fibrous leaves, the plant is sometimes mistaken for grass (Hu *et al*., 2018). In her essay about Tiger nut, (Adejumo & Salihu, 2018) defined it as a little nut the size of a peanut growing at the plant's rhizome, rather than a nut as most people think of it. Many people in Spain and North Africa consume the tubers of Tiger nut regularly(Imam *et al*., 2013). The nuts are well-known for their high nutritional fiber, starch, and carbohydrate content. Nuts are also high in calcium, sodium, potassium, magnesium, zinc, and traces of copper,according to Omode *et al*, (1995). It belongs to the sedge family of plants. *Cyperus* *esculentus* is a weed that may be found in many places of the world due to its adaptability (Belewu & Abodunrin, 2008). In certain places, it is considered a weed, and it is strongly linked to the plant purple nutsedge (*Cyperus rotundus*) (Belewu & Abodunrin, 2008). Africa, Southern Europe, the Middle East, and the Indian subcontinent are all home to it. Tiger nut has rhizomes that finish in little subterranean tubers and have the usual scales. These tubers have fibrous roots protruding from them. The leaves of the tiger nut are about 85 cm long and 2 to 10 mm wide, and they grow from the base.

(Belewu & Abodunrin, 2008) reports that the plant produces sweet-scented yellowish-brown flowers, whereas (Oladele & Aina, 2007) reports that blooms are only abundant in the weedy type and rare in the cultivated variants. Cultivated varieties of C. *esculentus* contain tubers that grow immediately beneath the plant's branches, which is not the case with wild or weed types (Oladele & Aina, 2007). Directly beneath the soil surface, tubers can be found bunched together. According to Imam *et al*. (2013), tuber initiation is impeded by high nitrogen levels, lengthy photoperiods, and high amounts of gibberellin acid. On the other side, high soil moisture content encourages tuber start (Ak, E., 2009). Long photoperiods are required for C. *esculentus* to thrive. The tuber epidermis includes chemicals that prevent tubers from sprouting, inhibiting tuber development after harvest (Imam *et al*., 2013). According to Oladele and Aina (2007), there are three types of Tiger nut depending on the color of the rhizomes: yellow, brown, and black. According to Pascual *et al*. (2000) tiger nuts are classified as tiny (6-8 mm), normal (8-12 mm), and giant (>12 mm) in size (Dakogre, 2008). 'gegantafricana,' 'llarguetaalboraia,' and 'ametllabonrepos' are three frequent types that fall into the large-sized group. The 'ametllabonrepos' produces spherical tubers with a diameter of approximately 12.4 mm, whereas the 'llarguetaalboraia' produces oval tubers with a diameter of around 15.2 mm. The 'gegantafricana' variety is the biggest, with tubers measuring 17.3 mm in length and weighing 1.09 g. Tiger nut thrives in damp soils and has to be watered continuously throughout the growing season. According to Abano and Amoah (2011), tiger nut can survive in soil with high moisture, however, they don't perform well in the shadow. Tiger nut cultivation requires a long time of drying after harvest due to the usage of constant irrigation (Abano & Amoah, 2011). This post-harvest procedure guarantees that the product has a longer shelf life. According to Elshebini *et al*. (2010), evidence of its cultivation dates back to the sixth millennium BC in Egypt and many centuries in Southern Europe. Tiger nut yields vary from 0.8 to 14 tons per hectare depending on the cultivar Elshebini *et al*. (2010). This large range of yields is due to edaphic variables and cultivation size.

Tiger nut is grown in Ghana's Bawjiase, Techiman, Chiraa, Tanoso, portions of Northern Ghana, parts of the Central Region, and the Kwahu ridge, among other places. Other African countries that grow tiger nut include Niger, Nigeria, Togo, Benin, Burkina Faso, Egypt, and many others (Belewu & Belewu, 2007; Oladele & Aina, 2007). Tiger nut is mostly grown in Spain for the production of "horchata de chufa," a sweet, milk-like beverage (Muhammad *et al*., 2019). It is grown in large numbers in several places of Ghana for its edible tubers and medicinal benefits (Oladele & Aina, 2007). Tiger nut flour, oil, and milk may be made from it, and its fiber, which is a by-product of milk extraction, can be used in various culinary items (Oladele & Aina, 2007).

2.5 Types of Tiger nut

Tiger nuts come in a variety of shapes and sizes. There are three types in Nigeria: black, brown, and yellow, although only brown and yellow are frequently accessible. Because of its intrinsic characteristics, such as its larger size, appealing hue, and fleshier body, the yellow kind is favoured. It also produces more milk with reduced fat and greater protein content, as well as less anti-nutritional elements, including polyphenols (Musa & Hamza, 2013). Tiger nut is also known as "Atadwe" in Ghana. The Fante type and the Kwahu type are the two primary kinds of Tiger nut. The hue of the Kwahu kind is yellowish-brown. Kwahu Types 1, 2, 3, and 4 refer to the four separate sub-types of the Kwahu type. Type 1 nuts are tiny and spherical, Type 2 nuts are quite large and round, Type 3 nuts are huge and somewhat elongated, and Type 4 nuts are slender, long, and thin. The Fante variety contains a combination of dark brown and black nuts that are mostly spherical but vary in size (Tetteh & Ofori, 1998). They also stated that consumers favored the Kwahu variety over the Fante kind owing to the former's sweetness and appearance. Tiger nut is grown in areas including Kwahu South District's Aduamoa, Afram Plains' Asukese, Odomasua, and Demso, Central Region's Agona Kwanyaako, Bawjiase, and Elmina, and Brong-Ahafo Region's Techiman.

2.6 Sensory Characteristics

2.6.1 Colour

Tiger nut's colour is generated from natural pigments found in fruits and vegetables, many of which vary as the plant matures and ripens. The fat-soluble chlorophylls (green) and carotenoids (yellow, orange, and red) and the water-soluble anthocyanins (red, blue), flavonoids (yellow), and betalains are the major pigments that provide color quality (red).

Additionally, water-soluble brown, gray, and black colored pigments can be formed as a result of enzymatic and non-enzymatic fading processes. Polyphenol oxidase involves the oxidation of polyphenol molecules, while phenylalanine ammonia-lyase catalyzes the production of precursors to phenolic substrates. Chlorophylls are heat and acid-sensitive, but alkali-stable, whereas carotenoids are sensitive to light and oxidation, but rather heat stable. Carotenoids may be bleached by an enzyme called lipoxygenase, which catalyzes the oxidation of lipid compounds. Flavonoids are susceptible to oxidation but rather resilient to heat, whereas anthocyanins are sensitive to both pH and heat. Betalains are also heat sensitive (Chu & Clidesdale, 1976). Physical characteristics such as size, form, completeness, the existence of imperfections (blemishes, bruises, spots, etc.), finish or shine, and consistency all influence appearance. Size and form can be influenced by cultivar, maturity, production inputs, and the growing environment.

Fruits and vegetables should be of a consistent size and shape (Mitcham *et al*., 1996). Larger sizes are associated with greater quality by certain customers. Disease and pest exposure throughout the growth phase, as well as harvest and postharvest handling processes, would impact the wholeness and lack of deformities. Harvesting fruits and vegetables mechanically, for example, may result in more bruises and cracks than harvesting by hand. The capacity of a surface to reflect light is connected to fruit and vegetable gloss, and newly picked goods are frequently more glossy (Mitcham *et al*., 1996). Moisture content, wax deposition on the surface, and postharvest management procedures all influence gloss. Although consistency or smoothness can be used as an aesthetic phrase, it is most commonly employed to describe the thickness of semisolid items.

2.6.2 Flavour (Aroma and Taste)

Tiger nut includes resistant starch, a form of prebiotic fiber that does not break down until it reaches the large intestine, where it encourages beneficial microorganisms. They also include healthy fatty acids, such as those found in olive and avocado oils, as well as potassium, vitamin E, and iron. Furthermore, it is minimal in calories and fat. Tiger nut comes in first. Flavor is a mixed but unified sensory experience that comprises perceptions of taste, smell, and pressure, as well as often-cutaneous sensations like warmth, color, or slight discomfort. Aroma (odor) and taste are the most common ways to define flavor. Tiger nut is a light and sweet nut similar to coconut.

Because aroma components are volatile, they are predominantly received through the nose, whereas taste receptors are found in the mouth and are influenced when food is digested. While color and look may be the first qualities that draw us to a fruit or vegetable, flavor is likely to have the greatest influence on acceptance and desire to consume it again. Sweet, sour, salty, bitter are the five fundamental flavors that have been identified. Umami is a flavor that is related to amino acid and nucleotide salts (Yamaguchi & Ninomiya, 2000). Spicy, floral, fruity, resinous or balsamic, charred, and nasty are some of the more diverse and difficult to categorize odors. Several enzyme-catalyzed reactions that provide flavorful results. Hydroperoxidelyase, for example, catalyzes the formation of classic tomato tastes (Anthon & Barrett, 2003).

2.6.3 Texture

The sense of touch is used to assess the texture of fruits and vegetables, whether they are picked up by hand or placed in the mouth and eaten. These properties, unlike taste traits, are easily assessed using instrumental methods. A semi-permeable membrane and cell wall surround most plant components, which contain a large quantity of water and other liquid-soluble compounds. The turgor pressure of fruits and vegetables, as well as the composition of individual plant cell walls and the middle lamella "glue" that keeps individual cells together, determine their texture. cellulose, hemicellulose, peptic compounds, proteins, and, in the case of vegetables, lignin makes up cell walls. Tomatoes are fruit vegetable that contains around 93–95 percent water and 5–7% total solids, with the latter including roughly 80–90 percent soluble and 10–20 percent insoluble particles.

The insoluble solids, which are formed from cell walls, make the most contribution to the texture of tomato products. The three-dimensional network of plant cell walls is yet unsolved, but it is a hot topic among scientists since it influences the sense of consistency, smoothness, juiciness, and other qualities in fruit and vegetable tissues to a substantial extent (Waldron *et al*., 2003). According to Bourne (1982), a food's textural properties are a "group of physical characteristics that arise from the structural elements of the food, are sensed through touch, are related to the deformation, disintegration, and flow of the food under a force, and are measured objectively by functions of mass, time, and distance," and are "measured objectively by functions of mass, time, and distance." Although they represent somewhat distinct attributes, the phrases texture, rheology, consistency, and viscosity are sometimes used interchangeably. In practice, texture refers to solid or semi-solid meals;

nevertheless, most fruits and vegetables are viscoelastic, meaning they have features of both perfect liquids and ideal solids (deformation).

2.7 Plant-based and Organic food Products

Human health is mostly determined by the small decisions we make daily or our lifestyle. The food we consume is frequently the option that has the most impact on our health. Because there are so many diverse tastes, we must always choose which foods to eat and how they should be cooked. Having a thorough understanding of the many meals available makes it simpler to make the greatest decisions for our health. Many individuals are turning to plant-based and organic foods in significant numbers. Plant-based diets include elements that have pharmacological effects comparable to those of any other pharmaceutical, but with the added benefit of preventing and correcting disease predisposition, as well as therapeutic characteristics.

They also have no adverse effects. This modern world has a plethora of agronomic items that have the potential to turn into diamonds with both health and financial worth, as well as cure a variety of problems for the poor but have been overlooked due to their perishability. One of these goods is tiger nut. Organic and plant-based meals have several advantages. It offers a stronger and more energetic body because there are no chemicals, pesticides, or applied condiments inhibiting your system, meaning a lower hazard of illness, disease, and ailments in your body. Organic and plant-based food tastes better and is less expensive, even if certain organic foods and crops are more expensive. You will save money in a variety of ways, including not having to visit the hospital as frequently.

2.8 Uses and nutritional values of tiger nut

A vast variety of recipes and preparation methods are used to produce food based on tiger nuts. The creation of 'horchata de chufa' (tiger nut milk) is the best-known application of tiger nut in food technology (Arranz *et al*., 2006). It's also used effectively as an ice cream flavour. Roasted tiger nut flour is used in cookies and other baking goods, as well as in the production of oil, soap, and starch extracts (Kusano *et al*., 2002). Tiger nut was discovered to be beneficial in the manufacture of 'kunnu' by (Belewu & Abodunrin, 2008). Tiger nut was shown to be a viable alternative for cereal grains to compensate for the low nutritional content of kunnu made from cereals. Similar drinks are made in Ghana from both roasted and unroasted tiger nuts (Sanful, 2009b).

“Horchata de chufa” is excellent in nutritional value and so has a lot of promise in the food industry, except for its short shelf life (Selma *et al*., 2003). Oleic acid (75 percent of total fat) and linoleic acid (9 percent to 10% of total fat) are abundant, while arginine is the most abundant amino acid, followed by glutamic acid and aspartic acid. The necessary amino acids in natural "horchata de chufa" are higher than the quantity in the FAO's model protein for adults, except for histidine. Tiger nut "milk" has been used as a substitute for milk in fermented goods such as yogurt (Sanful, 2009b) and other fermented items popular in several African nations, as well as honey, nougat ("turron" in Spanish), jam, beer, and liqueur (Ukwuru & Ogbodo, 2011).The globoid rhizomes of *Cyperus esculentus* are utilized as an aphrodisiac and antivenin by the rural populace of Ceara in northeastern Brazil. They are also used in Brazil to cure measles and fever, however, they are more commonly served as a dessert due to their sweet flavor (de Abreu Franchini *et al*., 2008).

The dietary fiber content of tiger nut has been reported to be high (Alegría-Torán & Farré-Rovira, 2003), suggesting that it may be useful in the treatment and prevention of a variety of diseases, including colon cancer (Bolarinwa *et al*., 2009), coronary heart disease, obesity, diabetes, gastrointestinal disorders, and weight loss (Anderson *et al*., 2012). Tiger nut is a common food in Ghana and other West African countries, where it is crushed and cooked into porridge with the resulting white paste. Conventional methods are utilized to extract the nut's oil for use in home cooking on a small scale (Yeboah *et al*., 2011). The tiger nut has been demonstrated to be a good source of high-quality oil as well as a modest amount of protein (Oladele & Aina, 2007; Yeboah *et al*., 2011). It also contains vitamins E and C, as well as minerals such as potassium, phosphorus, and calcium(Belewu & Belewu, 2007).

Flatulence, indigestion, diarrhea, and dysentery have all been reported to be treated with tiger nut "milk" (Bixquert-Jimenez, 2003), and its starch content is thought to give prebiotic characteristics for colon bacteria (Alegría-Torán & Farré-Rovira, 2003). Furthermore, tiger nut has been shown to possess more necessary amino acids than those specified by the FAO in a protein standard for adult requirements (Bosch *et al*., 2005).Because its unsaturated fatty acid content is similar to that of olive oil (Zommara & Imaizumi, 2017)and its arginine is a precursor of nitric oxide, which helps the veins widen, tiger nut milk is beneficial for avoiding arteriosclerosis. Diabetics can drink tiger nut milk, often known as "horchata," since it contains low–glycemic carbohydrates (mostly starch) and arginine, which releases hormones that create insulin (Alegría-Torán & Farré-Rovira, 2003). Tiger nut milk is also a good choice for celiac patients who can't eat gluten, as well as lactose-intolerant people who avoid cow milk and other dairy products. Because it contains digestive enzymes such as catalase, lipase, and amylase (Bixquert-Jimenez, 2003), it may be beneficial to persons who have digestive issues, gas, or diarrhea. According to (Mason, 2009), tiger nuts have long been known for their health benefits because they contain a high amount of soluble glucose and oleic acid, as well as a lot of energy (starch, fats, sugars, and proteins). They are also high in minerals like phosphorus and potassium, calcium, magnesium, and iron, which are important for bones, tissue repair, muscles, the bloodstream, and body growth and development, as well as vitamins E and C. Because of their high level of Arginine, which releases the hormone that creates insulin, sugar-free tiger nut milk is excellent for diabetics and also helps with weight control (Borges, 2008; Chevallier, 1996; Martinez, 2003.

The high quantity of oleic acid lowers cholesterol levels, avoiding heart attacks and thrombosis, and activating soluble glucose levels in the blood.The consumption of tiger nuts lowers the risk of colon cancer. It keeps you from becoming constipated. Tiger nut is high in vitamin B1, which aids in the balance of the central nervous system and encourages the body to adapt to stress (David, 2010). Vitamin E, which is needed for both men's and women's fertility, is found in sufficient quantities in milk (Ahmed *et al*, 2009). Vitamin E also helps to prevent cell aging, increase skin suppleness, and reduce the appearance of wrinkles, acne, and other skin changes. Tiger nut milk is used as a liver tonic, a heart booster, and a potent aphrodisiac in China. It is consumed to treat significant stomach discomfort, promote normal menstruation, repair mouth and gum ulcers, and is used in Ayurvedic remedies (sexual stimulants) (Belewu and Belewu, 2007). The black tiger nut species is an effective treatment for breast tumors and cancer. Because they contain a large number of water-soluble flavonoid glycosides, the tubers have a high overall antioxidant capacity. Antioxidant consumption might preserve malnourished people's immune systems. Tiger nut also contains digestive enzymes such as catalase, lipase, and amylase, making it beneficial to individuals who have indigestion, gas, or diarrhea. According to studies, 100 grams of Tiger nut has 7% protein, 26% fat, 31% starch, and 21% carbs.It's also estimated to have around 26% fiber, including 12% soluble and 14% insoluble fiber (Childers, 1990). In Brazil, certain ethnic groups utilize tiger nut as an antivenin. Tiger nut's high fiber content can help avoid coronary heart disease, diabetes, colon cancer, and gastrointestinal issues (Adejuyitan *et al*., 2009; Anderson *et al*., 2009; Ekeanyanwu *et al*., 2010). Tiger nut fiber decreases calorie consumption while also helping people feel full.In Ghana, Nigeria, and Brazil, tiger nut is used as an aphrodisiac (Bamishaiye & Bamishaiye, 2011).

Tiger nut tubers have been thought to have appropriate characteristics for fighting breathing problems and some stomach ailments for many years. Horchata de chufa is still regarded as a good cure for diarrhea in Valencia, Spain, according to local legend. It encourages the production of urine, which is why it's used to treat cysts, prostrates, hernias, rectum deformities, and prolapsed (anal feature - little uncomfortable meat at the tip of the anus) as well as endometriosis, fibrosis, and fallopian tube obstruction. The oil lowers low-density lipoprotein – cholesterol (LDL – C) while raising high-density lipoprotein – cholesterol (HDL – C) (Belewu & Abodunrin, 2008). According to (Ekeanyanwu and Ononogbu,2010) tiger nut lowers triglyceride levels in the blood, and lowers the risk of blood clots, all of which help to avoid arteriosclerosis. Due to short and medium-chain fatty acids, oleic acid, and essential fatty acids, it also increases calcium absorption in bones and the formation of new skeletal material (Temple *et al*., 1990). Because of its high Vitamin E concentration and antioxidant properties in the cell membrane, it is also suggested for newborns and the elderly.

2.9 Food Applications

2.9.1 Tiger nut Oil

Tiger nut oil has historically been used as cooking oil, but only by a few individuals (Ezeh *et al*., 2014), as well as for non-food uses including lubricating machinery and making soap (Negbi, 1992). It is widely utilized in the UK fishing business, according to Ezeh *et al*., (2014). Tiger nut oil was extracted utilizing a hydraulic press, solvents (n-hexane, 2-propanol), and supercritical fluid extraction (Yeboah *et al*., 2012). Although solvent extraction increases oil recovery, there are concerns about the likelihood of solvents remaining in the oil (Ezeh *et al*., 2014). Lasekan and Abdulkarim (2012) researched to improve the extraction of Tiger nut oil using liquid carbon dioxide.

A combination of these parameters yielded the greatest oil yield of 36.2 percent: an extraction temperature of 80 °C, an extraction duration of 6 h, and a pressure of 40 MPa. The hue of fresh Tiger nut oil is golden brown (Ekeanyanwu and Ononogbu 2010). The oil's refractive index (at 25 °C) was found to be 1.47. (Ekeanyanwu and Ononogbu, 2010; Yeboah *et al*., 2012). The acid value of fresh Tiger nut oil is 0.31 mg KOH/g, while the iodine value is 105.8g I2/100 g. (Ezeh *et al*., 2014). Because it is low in polyunsaturated fatty acids, it has strong oxidative stability. Tiger nut oil has a total phytosterol level of 986.49 g/g and a Vitamin E concentration of 120.1 g/g, according to Yeboah *et al*., (2012). The primary phytosterols discovered were sitosterol, stigmasterol, and campesterol, with concentrations of 517.25 g/g and 161.35 g/g, respectively. Furthermore, amounts of 5- and 7-avenasterol above 17 g/g were discovered. According to Sanchez-Zapata *et al*., (2012), tiger nut oil has a higher phytosterol profile than olive oil, which only contains 100 g of phytosterols per gram of oil.

2.9.2 Tiger nut Flour and Fiber

Tiger nut flour is made by drying cleaned Tiger nuts in a solar dryer or an oven, then grinding them into flour (Oladele and Aina, 2007). Adejuyitan *et al*. (2009) used a process that involved soaking the Tiger nut in water for 24–72 hours before drying and grinding. Ade-Omowaye *et al*. (2008) milled Tiger nut nuts after they had been dried for 24 hours in a cabinet drier at 60 °C. Aguilar *et al*. (2015a) took a completely different approach. Before milling into flour, the tiger nut was cleaned, disinfected, and dried for 30 days at a low temperature of 20 °C. Tiger nut flour preserves a significant proportion of the nutrients found in raw Tiger nut tubers (Oladele *et al*., 2007). (Oladele *et al*., 2007) investigated the pasteability of Tiger nut flours. Tiger nut flour has a low breakdown and high viscosity, according to the study's findings.

This might make Tiger nut flour beneficial in high-temperature and shearing goods, as well as cold-storage foods. Due to its high foaming capacity and stability, gelation capacity, water absorption capacity, and oil absorption capacity, tiger nut flour might be used in goods like bread, ice creams, and confectioneries. In the preparation of cookies, the flour was combined with soybean flour and maize flour (Awolu *et al*., 2016). In the study, the most popular cookie included 5% Tiger nut. Ade-Omowaye *et al*. (2008) created composite flours by combining wheat flour and Tiger nut flour. The dough has good visco-elastic characteristics since it was made with 90% wheat flour and 10% Tiger nut flour. Bread made with this combination flour has similar quality features and sensory qualities to bread baked with 100% wheat flour. In gluten-free bread (Aguilar *et al*., 2015b), tiger nut flour can be utilized as an emulsifier and shortening. According to Aguilar *et al*. (2015a), tiger nut flour may be used to make gluten-free bread. Tiger nut fiber is created as a by-product of the production of Tiger nut milk. Sanchez-Zapata *et al*. (2010) looked into the usage of Tiger nut fiber in pork burger production. Tiger nut fiber was employed at five percent, ten percent, and fifteen percent concentrations. The nutritional content, cooking yield, and moisture retention of the pork patties were all greatly increased by tiger nut fiber. With higher degrees of Tiger nut fiber inclusion, however, undesired changes in color and texture were noted. The pork patties containing Tiger nut fiber had lower marks in greasiness, juiciness, and meaty taste during sensory evaluation. This had no discernible impact on the overall acceptability of the pork burgers. According to Aguilar *et al*. (2015a), adding Tiger nut fiber to bread enhances loaf volume, crumb properties, and sensory features.

2.9.3 Tiger nut Milk

In Ghana, tiger nut milk is known as 'atadwe milk.' It's a Tiger nut water extract that may be sweetened or left unsweetened. Tiger nut milk is a good source of vitamins and minerals. Tiger nut milk has a protein and fat concentration of 2 to 7% protein and 17 to 25% fat, respectively (Udeozor, 2012; Asante *et al*., 2014; Kizzie-Hayford *et al*., 2015). Tiger nut milk is lactose-free, making it an excellent choice for lactose-intolerant customers. Unlike soymilk, it has no known allergies. Tiger nut milk has been used in place of cow's milk in the manufacture of yogurt (Sanful, 2009; El-Shenawy *et al*., 2012). According to El-

Shenawy *et al*. (2012), a 10% replacement of Tiger nut for cow's milk resulted in yogurt with relatively high apparent viscosity and lower whey syneresis than a 100% cow milk yogurt. Experts say it's a healthy and nutritious drink that should be consumed at any time of year, but especially during the dry season (Bamishaiye & Bamishaiye, 2011). Vitamins C and E, minerals such as calcium, magnesium, potassium, phosphorus, iron, carbs, protein, and unsaturated fats are all abundant in the drink. Chevallier (1996) claims that the calcium, iron, and magnesium content of Tiger nut is higher than that of cow's milk. As a result, it can be an excellent alternative to cow milk. Tiger nut may be added to other beverages to increase their nutritional value, according to research. (Belewu & Abodunrin, 2008) looked at how Tiger nut affected "Kunnu," a non-alcoholic beverage made from millet and sorghum.According to their findings, "Kunnu" made from Tiger nut was more nutritious and palatable than "Kunnu" made from millet or sorghum (Abdel Nabey's, 2001). Tiger nut milk is healthy, however owing to its low protein level, it is not suggested for youngsters to drink it frequently (Katz *et al*., 2005).

Another study by Sanful (2009) looked at the manufacture of yogurt from cow milk, Tiger nut milk, and their composite, and found that the quality characteristics for the cow milk yogurt and the composite were the same. This indicates that Tiger nut might be added to cow milk to make a low-cost, high-nutrient yogurt. According to a study by Ikpeme - Emmanuel *et al*. (2012) on the use of soya bean flour and Tiger nut flour in the production of weaning diets, the formulated foods, particularly the mixture of 55 percent Tiger nut and 35 percent soya bean with 10% milk, contained significant amounts of macro and micro-elements and thus would be suitable for infants. Udeozor (2012) also made a drink from

Tiger nut and soymilk and discovered that owing to the high nutritional content, such as protein and fat, the milk made from Tiger nut and soybean may be utilized as a beverage for both young and elderly.

2.9.4 Plant-based Milk

Human health is mostly determined by the meals consumed. Diabetes, stroke, obesity, atherosclerosis, and other diseases and disorders have been related to eating choices. As a result, a growing number of individuals are turning to plant-based and organic foods. Tiger nut, broccoli, oats, and yogurt have all gotten a lot of attention due to their alleged health advantages (Hasler, 1998). Plant-based milk is described by Makinen *et al*. (2016) as aqueous extracts with a similar appearance to cow's milk that arise from the homogenization of plant sources. Many people choose plant-based milk products for health reasons or as a lifestyle choice (Makinen *et al*., 2016). The prevalence of lactose intolerance, which is caused by the presence of lactose in cow's milk and other types of animal milk, is one key health reason for this decision (Flores *et al*., 2013).

According to Jeske *et al*., (2017), allergies to cow's milk, as well as worries about veterinary residues in cow's milk, are driving the demand for dairy alternatives. Lactose intolerance is common over the world, according to Lomer *et al*. (2008). The prevalence is estimated from less than 5% among North Americans and Europeans to more than 50% among Asians and Africans. Lactose intolerance, along with the reduced calorie content and lack of cholesterol in plant-based milk, has increased plant-based milk's market share. Consumers are increasingly turning to plant-based milk as a result of ethical concerns raised by animal rights activists and vegans against animal goods (Jeske *et al*., 2017). Antihypertensive, anti-diabetic, anti-tumor, and antioxidant properties have been shown in plant-based milk (Seth *et al*., 2016). Hypocholesterolemic impact and immune system boost are two further health advantages (Seth *et al*., 2016). However, most plant-based milk is poor in protein. Despite this, more than two-thirds of Americans believe that plant-based milk is healthy for children (Jeske *et al*., 2017). The trend for children to be fed plant-based milk as a replacement for cow's milk has prompted Makinen *et al*., (2016) to demand improved consumer education. Kwashiorkor was caused by the widespread use of rice milk, a low-protein milk, in children's diets (Katz *et al*., 2005). Plant-based milk should be supplemented with proteins, calcium, and vitamins, according to Seth *et al*., (2016).

There is already a lot of plant-based milk on the market. Some examples include soymilk, sikhye, quinoa milk, flax milk, oat milk, hazelnut milk, and Tiger nut milk (Kim *et al*., 2012). Soymilk is the most widely taken of them (Makinen *et al*., 2016). Tiger nut milk ("horchata de chufa") is still the most common beverage in Spain and has a significant economic impact (Robert and colleagues, 2011). Dairy-free products had a market worth of $3.6 billion in 2010, according to Leatherhead Food Research (2011). According to Mintel Group (2011), while soymilk and soy beverages have a larger market share, new products such as coconut, almond, and oat are performing well. According to Jeske *et al*., (2017), around 14% of those who are allergic to cow's milk are also allergic to soy products. This opens up a big market for items made from other plants, such as almonds, coconuts, and tiger nuts.

2.9.5 Extraction of Tiger nut Milk

The washing of the Tiger nut, grinding, pressing, and inclusion of other ingredients are the four primary phases in the manufacturing of Tiger nut milk (Sebastia *et al*., 2012). Tiger nut was cleaned and blended by Belewu and Belewu (2007), who used 6 L of water to 1 kilogram of nuts. The resultant mass was centrifuged, and Tiger nut milk was extracted from the supernatant. Tiger nut milk was made by soaking the nuts overnight after they had been rinsed, according to Sanful, (2009). The nuts were then filtered after being mixed many times. Before bottling, the Tiger nut milk was pasteurized at 90°C for 15 minutes and then chilled to 43°C for 12 hours. Sanful (2009) toasted tiger nuts before proceeding to the primary processes of milk processing outlined above. The use of roasting in the process boosted the sensory appeal of Tiger nut milk, according to the findings of the research.

Tiger nut milk was created by Corrales *et al*. (2012) and Sanchez-Zapata *et al*. (2012) using the traditional Spanish "horchata de chufa" technique. Tiger nuts were washed and steeped for 8 hours before being crushed with liters of water per kilogram. After that, the material was crushed to yield a sugar-sweetened extract. A similar strategy was used by Bamishaiye and Bamishaiye (2011). During the blending process, these writers suggested adding 3 L of water to 1 kilogram of tiger nut, as well as additional spices like cinnamon and lemon. In a research on tiger nut-soy milk production, Udeozor (2012), however, skipped the soaking stage. Fresh tiger nut was crushed in the research after it had been cleaned. To make tiger nut milk, the extract was pasteurized at 72°C for 5 seconds before being homogenized. Djikeng *et al*. (2007), on the other hand, altered the soaking temperature of tiger nut (20–100 °C) before milk extraction. They discovered that as the soaking temperature was raised, the yield of tiger nut milk rose. However, because the study did not conduct a sensory assessment of the milk generated, it is impossible to say if the soaking temperature affects the sensory features of tiger nut milk. To optimize the procedure, Ukuwuru and Ogbodo (2011) experimented with various ways for generating tiger nut milk. Ukuwuru and Ogbodo (2011) fermented, pasteurized, and sterilized tiger nut milk in addition to the usual stages of washing, grinding, and pressing. Boiling the extracted milk at 80°C for 30 minutes yielded fermented tiger nut milk. The milk was cooled and fermented before being packaged and pasteurized. The tiger nut was sterilized by soaking it in water at 40°C for 3 hours. After that, the Tiger nut was combined with water and the milk extract was purified. The milk was then boiled for 30 minutes at 50 degrees Celsius, bottled, and sterilized for 10 seconds at 130 degrees Celsius. The sterilized milk was found to be the most desired product after sensory evaluation of the final goods.

Kizzie *et al*. (2015) used another procedure in which 50 g of tiger nut were first rinsed with deionised water. After that, the tiger nut was soaked in 400 mL of water and cooked for 24 hours at 40 °C. The nuts were cleaned a second time with deionized water before being mixed for 1 to 3 minutes. Kizzie-Hayford *et al*. (2015) use an ultra-turra mixer to further comminute the resultant mush. After that, the final mush was squeezed through a filter with a pore size of 4 m. The study found that milk generated using this approach had high colloidal stability and that the yield of milk improved when the blending time was increased. However, taking this technology from the lab to the factory floor may not be cost-effective.

2.10 Nutritional Composition of Tiger nut

The geographical origin of tiger nut has a significant impact on its nutritional makeup (Codina-Torella *et al*., 2015). Codina-Torella *et al*. (2015) discovered that the proximate composition of Tiger nut from Spain, Burkina Faso, and Niger differed significantly. Valencian tiger nut has much morefat, moisture, protein, and fiber than Burkina Faso and Niger tiger nut. The Valencian tiger nut, on the other hand, has a lower carbohydrate content than the other tiger nuts. Tiger nut is mostly made up of starch, which is a kind of carbohydrate. Tiger nut carbohydrate content has been found to range between 41.22 and 47.91 percent (Oladele and Aina 2007; Arafat *et al*., 2009; Adekanmi *et al*., 2009). Tubers are known for their high carbohydrate content. According to Ekeanyanwu and Ononogbu (2010), the carbohydrate content was roughly 30% lower.

Tiger nut's fat content is the second highest. The fat content of yellow and brown tiger nuts was 32.13 percent and 35.43 percent, respectively (Belewu and Belewu, 2007). Fat levels of 27.4% and 30% have been found by Adekanmi *et al*. (2009) and Arafat *et al*. (2009), respectively. A range of 22.8 to 32.88 g/100g was observed by Sanchez-Zapata *et al*., (2012). The components of tiger nut oil and olive oil were compared by Arafat *et al*. (2009). Tiger nut oil has a high concentration of unsaturated fatty acids, according to the results of the study (about 93 percent). The fatty acid concentration was 69.5 percent oleic acid, 14.5 percent palmitic acid, and 8.8 percent linoleic acid. These components are identical to the fatty acid profile of olive oil, as found by (Arafat *et al*. 2009). Tiger nut oil is therefore comparable to olive oil in terms of nutrition. Tiger nut oil's fatty acid composition is comparable to that of hazelnut oil and avocado oil (Dubois *et al*., 2007).

Table 2.1 Proximate composition of Tiger nut tubers (g/100g)

Moisture	Carbohydrate	Fat	Protein	Ash	Fiber	Total sugar
26.00	43.30	24.49	5.04	1.70	8.91	15.32

Alegria – Toran and Farre – Rovira (2003).

Tiger nut has around 5.04 percent protein (Sanchez-Zapata *et al*., 2012). Tiger nut from Nigeria has 4.27 percent protein, according to Adekanmi *et al*. (2009). Protein content of 5% was found by Arafat *et al*. (2009), who worked on Tiger nut from Egypt. Tiger nut tuber amino acid profiles were established by Arafat *et al*. (2009). 17 of the 20 dietary amino acids were discovered to have varying amounts. The most often discovered amino acids were glutamic acid, aspartic acid, and methionine. It is not a nut, but rather a tuber, and is known as Tiger nut. Tubers including potato, cassava, yam, and sweet potato have more fat, protein, and carbohydrate content than tiger nut (Sanchez-Zapata *et al*., 2012). Tiger nut contains less protein and moisture than hazelnuts, walnuts, pistachios, pine nuts, and peanuts when compared to other nuts (Ros, 2010). However, it has a larger carbohydrate and moisture content than the nuts described above (Ros, 2010). Tiger nuts mineral content was investigated by Arafat *et al*. (2009). Calcium (152 g/g) was the most prevalent mineral in the tuber. Sodium is 140 mg per gram, phosphorus is 123 mg per gram, and magnesium is 55 mg per gram. Manganese, zinc, iron, and copper were discovered at 41 g/g, 1 g/g, 2 g/g, and 1.3 g/g, respectively, in the micro minerals.

Table 2.2: Mineral and Vitamin composition of Tiger nut tubers

Mineral	**Composition (mg/100g)**
Component	
K	486
P	219
Ca	100
Mg	94.4
Na	34.3
Fe	4.12
Zn	3.98
Cu	0.92
Mn	0.26
Mineral	
A	0.21
C	7.30
D	0.42
E	0.74

Ekeanyanwu et al. (2010).

Anti-nutrients are in insufficient supply in tiger nut. Tiger nut's anti-nutritive composition was investigated by Adekanmi *et al*. (2009). Tannins were discovered to have 2.37 mg per 100g, whereas phytates were found to contain 21.42 mg per 100g. Oxalates and alkaloids were also found at 13.12 mg/100g and 2.63 mg/100g. Phytates were found to be 2.40 mg/100g, tannins 9.62 mg/100g, and cyanogenic glycosides 1.08 mg/100g, according to Ekeanyanwu *et al*. (2010). When the raw Tiger nut is treated, the amounts of these anti-nutrients are lowered dramatically. After roasting tiger nuts, Ekeanyanwu *et al*. (2010) found a 5% reduction in phytates and a 26% reduction in tannins. Cyanogenic glycosides were shown to have a 20 percent decrease.

To lower the anti-nutritional content of Tiger nut, Adekanmi *et al*, (2009) used a variety of treatment procedures. Tiger nuts were soaked in distilled water at room temperature for 12 hours, soaked in distilled water at 60°C for 6–7 hours, toasted in a 120°C oven, and toasted in an open pan for 10–30 minutes. Most tannins (71%) and oxalates (71%) were reduced after 30 minutes of open pan toasting (77 percent). Soaking in water at 60°C for 7 hours and oven toasting at 120°C for 30 minutes respectively decreased phytates (44%) and alkaloids (27%) the most.

2.11 Food Applications of Tiger nut Milk

Tiger nut milk is progressively gaining extra-scientific and technical attentiveness. Tiger nut is a healthy food, together with its derivative products. Nonetheless, the production of Tiger nut milk and its accompanying oil is being done with greater care. The continuous development of unique tuber products and the use of their derivatives are raising consumer awareness of this cuisine. Tiger nut's high dietary fiber content makes it useful in the treatment and prevention of a variety of ailments, including coronary heart disease, obesity, diabetes, gastrointestinal problems, colon cancer, and weight loss. Tiger nut has a moderate protein content and is a good source of minerals including potassium, phosphorus, calcium, and vitamins E and C. Tiger nut milk is intended to cure diarrhea, dysentery, gas, and indigestion, according to the manufacturer. For colon bacteria, the starch content is thought to give prebiotic characteristics. Furthermore, tiger nut has been shown to have more essential amino acids than those specified by the FAO in a protein standard for adult requirements. Because its unsaturated fatty acid content is similar to that of olive oil, and its arginine is a precursor of nitric oxide that helps veins form, tiger nut milk has been shown to help avoid cardiac issues and thrombosis, as well as activate blood circulation. Tiger nut milk is suitable for diabetics because it contains low-glycemic carbs and contains arginine, which frees hormones that make insulin. The milk is also suitable for gluten-intolerant celiac patients as well as lactose-intolerant people who avoid cow milk and other dairy products. Tiger nut milk is high in key nutrients that are necessary for children and people to flourish.

2.12 Non-food Applications of Tiger nut Milk

Tiger nut milk was used to make ethanol (Maduka *et al* 2018) . Animal feed is made from by-products of tiger nut milk processing (Sanchez-Zapata *et al*., 2012). Tiger nut milk and its compounds are widely employed in a variety of culinary products. Tiger nut milk ingredients, on the other hand, have a wide range of non-food uses, including the production of plastic materials (Southward and Walker, 1995),textile fibers (Feretti, 1997), and glues, or in the production of ethanol or methane. Some of these technological applications have long been recognized, such as casein-based glues used in ancient Egypt (Tague, 2006), but new applications are being proposed to expand the market for the components. In terms of structural and functional qualities, the majority of the technological applications are exclusive to one tiger nut milk component.

Separation and extraction procedures might be crucial in the process of valuing such individual components. In tiger nut milk and other dairy products, valuable components can be recovered by chemical and/or physical means: casein can be precipitated by lowering the pH to 4.6 (Kinsella, 1984), whey proteins can be recovered by ultrafiltration (Di Giacomo *et al*., 1996), and lactose can be concentrated and crystallized from whey (Hobman, 1994).

Whey is the liquid remaining after milk has been curdled and strained. Furthermore, several applications include non-food usage of fractions having many components, which substantially simplifies separation operations.

2.13 Microbial Activities

The constituents of milk, water, fats, proteins and vitamins allow for the growth of a variety of bacteria, especially psychotropic bacteria that are able to grow under cold conditions (Nyarko Mensah, 2018). Raw milk, pasteurized milk, cheese, and other dairy products support different and diverse groups of microorganisms which cause product spoilage. Light can also contribute to the spoiling of dairy products (Speake, 2015). There are many techniques, however, such as pasteurization and special packaging, which are used to protect these dairy products from adverse effects of microbial growth and light (Speake, 2015). Farmers, dairy processors, and consumers use many methods to measure the degree of spoilage and gauge milk quality.

Preventing microbial growth and extending shelf life can alleviate cost for producers, retailers and consumers, but can also limit the environmental impact of dairy production and consumption (Lu & Wang, 2017). Spoilage microorganisms include aerobic psychotropic gram-negative bacteria, yeasts, molds, hetero-fermentative lactobacilli, and spore-forming bacteria. Psychrotrophic bacteria can produce large amounts of extracellular hydrolytic enzymes, and the extent of recontamination of pasteurized fluid milk products with these bacteria is a major determinant of their shelf life (Lu & Wang, 2017). Fungal spoilage by dairy foods is manifested by the presence of a wide variety of metabolic byproducts, causing off-odours and flavours, in addition to visible changes in colour or texture (Ledenbach &

Marshall, 2009). Microbial contamination of tiger nut tubers easily occurs and often undetected before the tubers are consumed. The source of microbial contamination could be from infected field workers, contaminated soil, irrigation water, wash tanks, harvesting equipment, fecal materials and transport vehicles. Growth of microorganisms in foods is usually influenced by factors such as product temperature, product-to-headspace, gas volume ratio, initial microbial loads and type of flora, packaging, barrier properties, storage condition and biochemical composition of the food. The water used to apply fungicides and insecticides is a source of microbial contamination of tiger nut tubers.

According to Airaodion *et al*. 2020, the use of water polluted with faecal matter to wash knives, polyethene bags and trays could also be a source of microbial contamination of tiger nut tubers. Microbial contamination of ready-to-eat-tiger nut tubers is largely attributed to unhygienic practices of vendors and inappropriate storage conditions. Chewing fresh or dried tiger nut tubers contaminated with pathogenic microorganisms increases the risk of ingesting mycotoxins such as aflatoxins, ochratoxins and fumonisins. Microorganisms isolated from exposed tiger nut tubers are Bacillus subtilis, Staphylococcus aureus, Aspergillus flavus, A. *niger, Fusarium solani*, *Saccharomyces cerevisiae*, S. *fibuligera* and *Candida pseudotropicalis*. Isolation of Proteus vulgaris from exposed tiger nut tubers has a serious health implication in the sense that the bacteria demonstrated some level of multiple drug resistance. An assessment of wholesomeness of tiger nut tubers imported into Nigeria as snack food was carried out by Alade *et al.* (2022). Similarly, Ayeh-Kumi *et al*. (2014) also carried out a survey of 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 is a threat to public health.

2.13.1 Microbial Contamination of Tiger nut-Derived Products

Microbial contamination of tiger nut-derived products usually occurs as a result of unhygienic processing, handling, transportation and exposure of these products during retailing. Microbial contamination of tiger nut-derived products could be traced to microbial contamination of tiger nut tubers used for production. A study carried out by Arranz *et al* (1998), identified aflatoxin B from samples of 'horchata' sold in Southern Europe. This is an indication that the products were contaminated with fungi that produce mycotoxins. The bacterial load of tiger nut juice sold in some localities within Katsina metropolis in Nigeria is quite high. In Spain where tiger nut beverages have been commercialized, a comparative study between microbiological quality of commercial and home-made tiger nut beverage was determined. Sabastia *et al*, (2012) identified microorganisms associated with exposed and unexposed tiger nut-milk. Results from their study revealed that frequency of occurrence of *Bacillus subtilis, Staphylococcus aureus*, *Aspergillus flavus*, A. *niger*, *Fusarium solani*, *Saccharomyces cerevisiae*, S. *fubiligera* and *Candida pseudotropicalis* isolated and identified from tiger nut-milk samples

2.14 Shelf Life

The quality and shelf-life of pasteurized fluid milk is dependent on the quality of the raw tiger nut milk and other ingredients used and on an effective cleaning and sanitation program (Elbrhami Jr, A., 2016). A shortened shelf-life is most often due to inadequacies in cleaning/sanitizing programs that are likely to result in recontamination after the pasteurization process with organisms that grow under refrigeration and are capable of spoiling milk (Okpala, I. O. 2003). Some of these organisms grow relatively rapidly in tiger nut milk resulting in the breakdown of milk components and subsequent conversion to compounds detected as off-flavours. In the absence of post-pasteurization contamination, one of the most limiting factors for increasing shelf life are certain organisms that survive the pasteurization process and have the ability to grow and cause spoilage under refrigeration (thermoduric psychrotrophs) (Martin *et al.*, 2018). These organisms under proper refrigeration generally only cause defects later in shelf-life (that is >14 days). Because of eliminating these organisms from the raw tiger nut milk supply may not be practical, extending sell-by dates beyond 21 days is not recommended, even under the best of processing conditions.

The likely occurrence of these organisms that survive pasteurization and eventually cause spoilage can be minimized through proper raw tiger nut milk production and handling procedures, from the farm to the plant. Consumers purchase pasteurized fluid milk with the belief that they are taking home a wholesome, nutritious, good quality product (Markham *et al*, 2014). To the consumer, quality means that the product tastes good and that it keeps well in their home refrigerator or has a long "shelf-life." Shelf life can be defined as "the period of time that a product can be kept under practical storage conditions and still retain acceptable quality." In the case of pasteurized fluid milk "practical storage conditions" means held under refrigeration or less than 7.2°C (45°F) while "acceptable quality" means that product flavour, odour and appearance are satisfactory to the consumer (no consumer complaints) and that the milk is safe to drink. Current consumption and marketing patterns require that most dairy processors manufacture tiger nut milk that has a shelf-life of 14 days or more. Some plants are striving for 21 days. Achieving this goal requires stringent processing parameters, rigorous product handling procedures and extreme efficacy in cleaning and sanitation programs. Quality defects in pasteurized milk products are most often the result of microbial contamination, growth and spoilage. Microbial defects usually become evident in the finished product through shelf-life evaluations or consumer complaints (Ziyaina *et al*, 2018). Though poor-quality raw milk can result in defective products, post pasteurization contamination with psychrotrophic spoilage bacteria is most detrimental. In most cases, product contamination is the result of insufficient cleaning and sanitation of the processing equipment and plant environment. Product contamination may occur even when it appears that a well-designed sanitation and quality control program is in place.

In the absence of post-pasteurization, certain strains of microorganisms (that is *Bacillus* spp) that are capable of surviving pasteurization and growing under refrigeration (thermoduric psychrotrophs) can eventually grow and cause spoilage, generally later in shelf-life (Sørhaug *et al*, 1997). Tiger nut milk product quality is generally determined by sensory, chemical and microbiological analyses. These analyses are used from when the milk leaves the nut to when the final product is consumed. To determine shelf-life potential, fluid milk is most often held at marginal refrigeration temperatures of 6.1- 7.2°C (43-45°F) and evaluated by sensory and/or microbiological testing after the desired number of days (that is sell-by date plus 2-5 days). Though some prefer to evaluate shelf-life at more ideal holding temperatures of less than 3.3°C (38°F), marginal refrigeration temperatures allow potential product defects and sanitation deficiencies to become more evident. Sensory analyses requires that someone who is familiar with and is sensitive to milk off-flavours smell and/or taste the milk (Flavour and Odour Defects in Milk) (Govender, S. 2007). This type of evaluation is somewhat subjective, as people differ in their ability to detect off-flavours. In this regard, microbiological analyses can lend more insight into potential quality defects in dairy products. When pasteurized tiger nut milk shelf-life is reduced due to microbial growth, it is most often the responsibility of the processing plant quality control personnel to determine the cause and source of contamination (Okorie *et al.*, 2014).

2.15 Sensory Properties

Alvarez (2015) suggest that descriptive sensory evaluation methods such as mouth feel, taste, colour and flavour which are used to evaluate the characteristics of tiger nut milk and dairy products to monitor processing conditions and determine product quality are a valuable tool, especially for industry, because they are fast, practical, and simple. They further suggest that the sensory evaluation methods of dairy products of tiger nuts are evolving like other techniques (Alvarez, 2015). Sensory quality is the ultimate measure of product quality and success. Sensory analysis comprises a variety of powerful and sensitive tools to measure human responses to tiger nut and other products. Selection of the appropriate test, test conditions, and data analysis, result in the generation of reproducible, powerful, and relevant results (Drake, 2010). Appropriate application of these tests enables specific product and consumer insights and the interpretation of volatile compound analyses to flavour perception (Drake, 2010).

2.16 Canning

Canning is a technique of preserving food that involves processing the ingredients and sealing them in an airtight container. The technique is often characterized as a method of food preservation that involves sealing the food in air-tight jars, cans, or pouches, then heating it to a temperature that eliminates germs while preserving the item's health or spoiling potential. (Guo *et al*., 2021) also characterized canning as a method for achieving commercial sterility by sterilizing food by heating it in sealed containers. According to the scientists, this permitted the meal to be kept at room temperature for months, if not years, without jeopardizing its safety and sensory quality. Sterilization is a common term used to describe the process. This is because the heat treatment kills all bacteria, including those that are directly harmful to people and those that affect humans by producing poisons. Several studies' attempts to figure out how canning preserves food and gives it a longer shelf life than other food preservation methods have resulted in one of the following conclusions.

Apart from inhibiting the growth of undesired microbes, practically all food enzymes undergo deactivation, halting critical food degradation processes, according to most studies (Abbey, 2019). The impact of moisture loss on water activity, as well as the consequent degradation of oxygen-related deterioration responses, has been highlighted. Retort processing and out-of-container sterilization are the two types of scanning procedures that have been created. In-container sterilization is another name for retort processing. The food product is packed in containers such as metal cans and glass jars during in-container sterilizing. The pack is then heated in a retort or with steam until the product's core reaches the requisite temperature for sterilization. In most cases, retort processing may be used on any sort of food (Guo *et al*., 2021). Separate sterilization is done for both package and non-packaging items in out-of-container sterilization. Following that, aseptic packaging or filling and sealing are performed. Out-of-container sterilization is mostly used for liquid goods

(Guo *et al*., 2021).The heating phase, the holding phase, and the cooling phase are the three main phases of the process. During the heating process, water or steam is utilized to heat the product, raising its temperature from ambient to the desired sterilizing temperature. This temperature is then kept constant for the duration of the holding phase. The cooling phase introduces air or water as a cooling medium, lowering the product's temperature before storage (Guo *et al*., 2021). Canning is thought to yield food with a longer shelf life than most other food preservation methods. According to Abbey (2019), canned items normally have a shelf life of one to five years, while some have been observed to endure over thirty (30) years. Relying on heat treatment for microbe killing and food preservation appears to provide such items an endless microbiological shelf-life as long as the packaging is kept intact (Raseta *et al,* 2018).

People could now preserve almost everything with only one method: veggies, fruits, soups, sauces, seafood, and meats. The canning procedure was straightforward. First, food and fluids were placed in a tin can or glass jar (usually water). The container was heated and often put under pressure after it had been sealed. Any germs that may cause sickness or ruin food were destroyed throughout this procedure. When you take the can or jar out of the water, the air within compresses and seals the contents against the elements. The seal then protects the food from additional bacteria and oxidation caused by the air. After that, the meal may be easily kept and employed in the future. Metal cans, glass cans, thermostable plastic cans, multi-layered flexible pouches, and a variety of other packaging materials are used in the canning process. Canning has several benefits, including the ability can preserve the contents physically throughout storage, transit, handling, and distribution. The advantage of canning is that it allows you to have access to seasonal foods all year. Canning was the principal method of extending the shelf life of seasonal crops before the invention of refrigeration.

2.17 Safety of Canned Foods

Food safety refers to procedures for handling, preparing, and storing food that limits the risk of foodborne disease. Safe canning processes and effective and fast sterilizing procedures are the cornerstones of canned food safety. The two major concerns were lead poisoning and microbiological contamination; although, with the eradication of lead soldered cans in the foodservice industry, the important safety problem of concern is the latter. Although it is commonly understood that canning is intended to remove microbial contaminants to provide safe foods, poor chilling and pre-process spoilage can result in serious microbiological safety hazards during processing (Adaramola-Ajibola *et al*., 2019). It should be noted that canning also offers ideal circumstances for the proliferation of some germs. When some bacteria are first infected with their spores, high heat treatment, decreased oxygen concentration in cans, water activity, and pH of packed foods can allow them to proliferate.

Researchers in Nigeria were able to isolate organisms including B. *coagulans*, B. *cereus*, B. *subtilis*, C. *sporogenes*, and C. *perfringens* from canned goods in a study (Adaramola-Ajibola *et al*., 2019). Microbial contamination identified from various canned foods is listed in Table 3.2. The germ contamination levels, however, were below the permitted microbiological limit of 106, according to the researchers. The existence of the isolated organisms, on the other hand, was ascribed to the quality of the raw materials, underprocessing, pre-process contamination, and the amount of production stringency. *Clostridium botulinum* is the pathogen most commonly linked to canned goods. The organism possesses the following characteristics: Toxin-producing spore-forming bacteria thrive in the absence of oxygen, are heat resistant, and produce spores. These characteristics help to explain why most canned food manufacturers link the safety of their products to the presence or absence of *Clostridium botulinum*. Under moist low acid circumstances, less than 2% oxygen, and a temperature range of 4 – 40 °C, the vegetative phase of the organism multiplies fast, producing fatal poison in 3 – 4 days. When the organism is encased inside a spore, it can withstand temperatures as high as 100 °C and even temperatures as low as 5 °C. *Clostridium botulinum* is commonly employed as an indicator bacterium in canned foods.

2.18 Canning Milk from Tiger nuts

When it comes to preserving milk from nuts, there are two schools of thought. According to one school, the danger of salmonella is very low, but there is still a possibility, which is why the USDA canning standards do not include a technique for canning milk made from nuts. Except for green peanuts, the National Center for Home Food Preservation has withheld instructions on how to can any milk from the nut (which we all know are legumes). The danger comes from moisture getting into the jars during the canning process. So, while the second school of thinking may include some guidelines for preserving milk from nuts, do so with the idea that the USDA believes there to be some danger. You may vacuum 'can' the milk from the nut into canning jars if you have a Food Saver, Rival Seal a Meal, or other vacuum sealers. This keeps them healthier than if they were stored in a jar. Make sure to include an O_2 absorber and/or a silicone gel pack in each jar (to help reduce moisture).

You're not canning in the classic sense; instead, you're removing the air, which is one of the most common causes of spoilage.

2.19 Gaps in Literature

This chapter focused on plant-based milk and how it affects human health. It was stated that human health is mostly determined by the foods consumed since illnesses and ailments such as diabetes, stroke, obesity, atherosclerosis, and others have been connected to dietary patterns. As a result, it was found that many consumers were switching to plant-based and organic food items. According to Hasler (1998), foods like tiger nut, broccoli, oats, and yogurt, for example have gotten a lot of attention because of their alleged health advantages. Customers choose milk products made from plants (tiger nut), either for health purposes or as a lifestyle choice (Mäkinen *et al*., 2016). Many plant-based products, including tiger nut, are grown in Ghana, including Bawjiase, Techiman, Chiraa, Tanoso, parts of Northern Ghana, parts of the Central Region, and the Kwahu ridge, making the country rich in plant-based milk like Soy milk, sikhye, quinoa milk, flax milk, oat milk, and hazelnut milk. Although studies demonstrate that Tiger nut milk has a limited shelf life after harvesting, there is currently insufficient research on the manufacturing and preservation of Tiger nut milk. Canning as a method of food preservation allows the contents of the food to be prepared and sealed in an airtight container, preventing the product from spoiling. Researchers have focused their efforts on Tiger nut's derivatives and advantages (Bamishaiye & Bamishaiye, 2011), the impacts of Tiger nut's physical qualities (Abano & Amoah, 2011), and the morphological characterization and assessment of Tiger nut in Ghana

The closest that researchers have gotten is to look at the production and sensory assessment of Tiger nut beverages (Sanful, 2009b), the Physicochemical properties of flour obtained from Tiger nut fermentation (Bolarinwa *et al*., 2009), and the extraction of oil from Tiger nut with supercritical carbon dioxide (Abbey, 2019; Bolarinwa *et al*., 2009). The following chapter lays out the steps involved in making Tiger nut milk so that the microbiological and sensory qualities of canned Tiger nut milk may be evaluated, filling a gap in the literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The research was conducted at the Multi-purpose experimental laboratory at Takorase Research Station in the Eastern region of Ghana from the 15th May, 2021 to 30th December, 2021. The multi-purpose research facility can be found in Akyem – Takorase; south-eastern section. The region's average monthly temperatures range from 27.10 to 29.80 degrees Celsius. From November to April, the temperatures are at their highest, with average maximum temperatures in February and March, and the lowest in July.

3.2 Source of Materials

Fresh tiger nuts (*Cyperuse sculentus*) kinds employed were Bawjiase and Kasoa types in the Central region of Ghana, Aduamoa brown, Aduamoa black, Nkawkaw type in the Eastern region, Asiebu Nkroful type in the Western region, Techiman type in the Bono East and North type. The Food Science Laboratory, Microbiology Laboratory, and Product Development Laboratory at Takorase Research Station in Ghana provided the machines and chemicals needed. Ginger (*Zingiber officinale*) and cloves (*Evgenia coryphée*) are two of the spices utilized. Nisin was utilized as a chemical preservative.

3.3 Preparation of Tiger nut drink

For the study, a total of 8 kg of dried tiger nut was utilized, divided into two halves of 4 kg each. Foreign elements, bad nuts, and seeds were removed from the tiger nut, which might impact the drink's taste and storage quality. The tiger nut (4 kg) was properly cleaned with water to eliminate any remaining dirt, and then steeped for 2 hours in distilled water (3 L) at 30 degrees Celsius. Then, using a Marlex kitchen blender at full speed for 5 minutes, it was crushed to a paste in a 3:1 ratio (i.e., 3 L of water per a kilogram of nut) to an almost smooth slurry.After filtering the homogeneous slurry with a muslin cloth, the muslin cloth was sqeezed until no extract was collected.Sugar and flavouring were added to the mixture. All of the portions were prepared using the aforesaid way.

3.3.1 First portion

The fresh tiger nut was steeped in water for 2 hours. The filtrate was separated into two parts, one of which was treated with Nisin preservative (2 kg to 2 L) and the other of which was not dealt with any preservative (2 kg). Each of these two sections was split into two, one kept refrigerated and the other kept at room temperature, yielding four distinct treatments: Tiger nut milk soaked in water and preserved at refrigerated temperature ($WSTM+P_{Ref.T}$). $WSTM+P_{RT}$ stands for water-soaked tiger nut milk + preservative at room temperature. Tiger milk that has been soaked in water and kept refrigerated ($WSTM_{Ref.T}$). Tiger nut milk has been steeped in water and kept at room temperature ($WSTM_{RT}$).

3.3.2 Second portion

Fresh tiger nuts were roasted on an open pan at 110°C for 30 minutes. As with the first component, it was combined and mixed before being separated into four sections. RTM+ $P_{Ref.T}$) is roasted tiger nut milk with a preservative at refrigerated temperature. $RTM+P_{RT}$ stands for roasted tiger nut milk with preservative at room temperature. Tiger nut milk that has been roasted and kept refrigerated ($RTM_{Ref.T}$). At normal temperature, roasted tiger nut milk (RTM_{RT}). The sensory evaluation took place on the day of manufacturing, and the total microbiological count of the samples was evaluated every week for three weeks.

3.4 Experimental Design

The Completely Randomized Design (CRD) was the experimental design employed in this investigation. The study used eight different types of tiger nuts, each of which was weighed using a weighing scale. Eight treatments were used with each treatment replicated eight (8) times making a total of 64 samples (8x8). The treatments used were: $WSTM+P_{Ref.T}$, $WSTM+P_{RT}$, $WSTM_{Ref.T}$, $WSTM_{RT}$, $RTM+ P_{Ref.T}$, $RTM+P_{RT}$, $RTM_{Ref.T}$ and RTM_{RT}.

3.5 Analysis of products

3.5.1 Sensory evaluation

Thirty trained students were chosen from among 190 J.H.S students of St. Agatha's R/C Girls at Akim - Swedru who were familiar with drinks to evaluate eight samples of tiger nut milk. The pupils were given samples of tiger nut milk that were coded and served in white transparent disposable cups. In between examinations, water was supplied for mouthwash. Students were asked to rate the samples on a 9-point hedonic scale for color, flavor, taste, and mouth feel.

3.5.2 Microbial analysis

Every week for three weeks, plate counts of all samples were conducted. Aliquots from serially diluted samples were combined with plate count agar for bacteria and incubated at 37ºC for 24 hours; aliquots from serially diluted samples were mixed with potato dextrose agar for molds and cultured at 25ºC for 3 days. Counting colonies on the other side of the culture plates yielded total plate counts for both nutrient and potato dextrose agar. Colony-forming units per milliliter were used to indicate the total colony count (CFU mL -1).

3.6 Statistical analysis

Genstat version 11 was used to do a one-way analysis of varience (ANOVA) and the Least Significant Difference (LSD) test were used to separate the treatment means where significant treatment effects were observed. The threshold for statistical significance was set at $p < 0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The study's findings and their numerous associated arguments are presented in this chapter. Sensory measures (color/appearance, flavor, taste, and mouthfeel) were collected, and microbial growth was analyzed statistically (fungal and bacteria). In this chapter, such information is presented in the form of tables and graphs. The outcomes were described and discussed in a logical order, with the first aim coming before the others. Table 1 summarizes the findings of the sensory assessment of tiger nut milk. For all of the sensory qualities tested, the WSTM samples obtained the highest score. The RTM samples, on the other hand, received the lowest rating (Maillard, 1912). This is perhaps due to Maillard reaction that occurred during the roasting of the tiger nut causing browning in the final product (Maillard, 1912). Tables 4.2 and 4.3 show the findings of the bacterial and fungal counts (in CFU Ml-1) of the different tiger nut milk products.

4.1 Sensory Analysis

The influence of processing on the organoleptic qualities of the milk was evident in the majority of the quality criteria examined (figure 4.1). In terms of color and flavor, there was a significant difference ($p< 0.05$) between the various processing treatments, with the WSTM+P_{RefT} for Aduamoa brown and Aduamoa black-type having the highest mean score for color (8.5) and the WSTM+P_{RT} for Kasoa and Bono North type having the highest mean score for flavor (7.8), while the RTM+P_{RT} and RTM$_{RefT}$ for Bawjiase type having the lowest mean score for color (5.3) (Ukwuru *et al*, 2011). Ukwuru in 2011 encountered similar reaction during his experiment on effect of processing treatment on the quality of tiger nut milk.

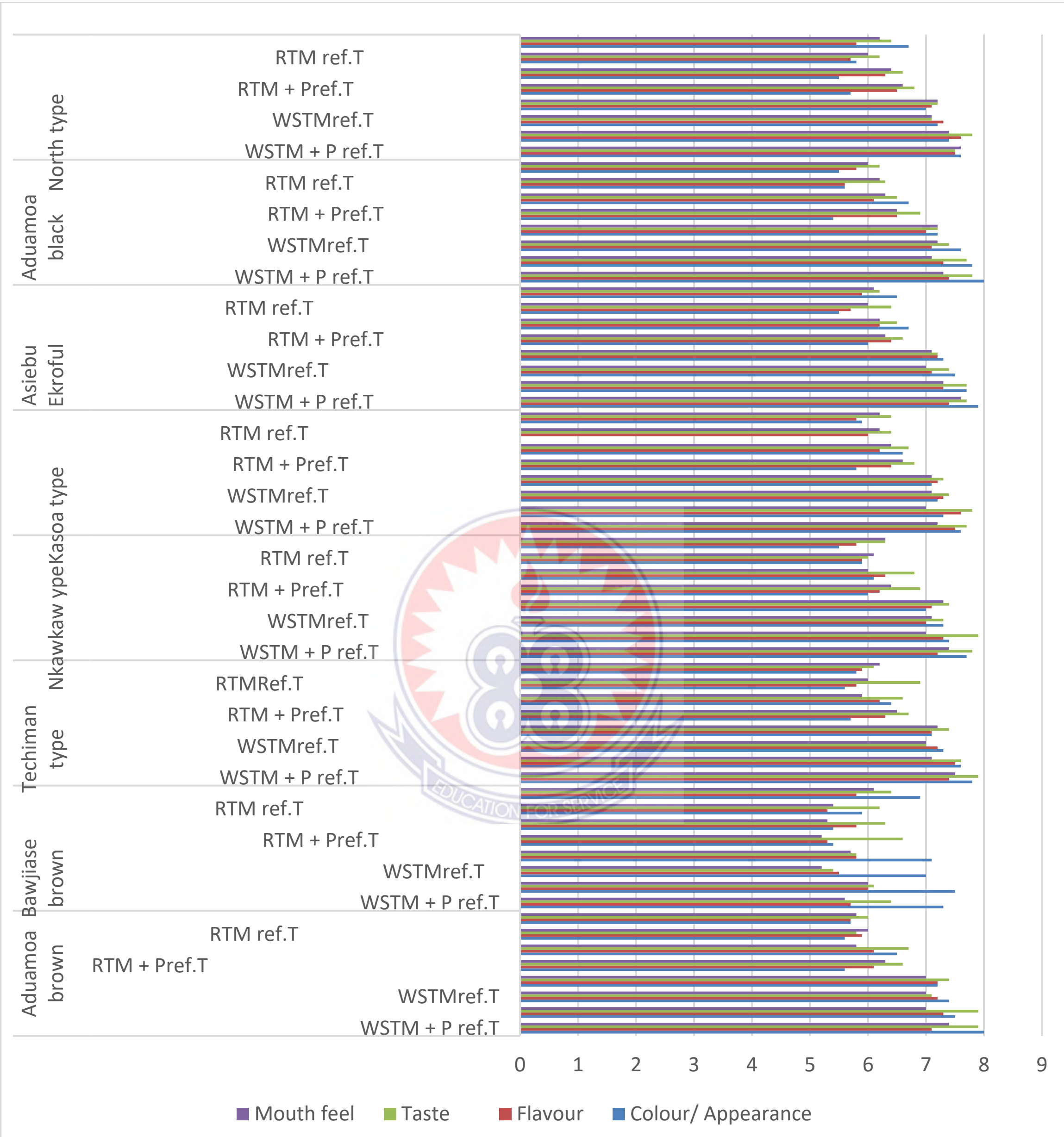

Figure 4.1: Sensory evaluations of tiger nut milk products obtained from various processing treatments

The highest mean taste score (7.9) was found in the WSTM+$P_{Ref.T}$ for Aduamoa brown and Techiman type and the WSTM+P_{RT} for Aduamoa brown and Nkawkaw type whiles the lowest mean score (5.4) for taste was found in the $WSTM_{Ref.T}$ for Bawjiase brown (Sarpong *et al*, 2017). Taste is necessary factor that has to be considered in all food sensory analysis. Apart from it being the pivot of the several other parameters, studies say it reserves a positive influence on consumer buying behaviour (Sarpong *et al*, 2017). The taste ratings suggest that a minimal influence on consumer purchase behaviour is possible. For mouthfeel, WSTM+P_{RefT} for North type got the greatest mean score (7.5), whereas $WSTM_{RefT}$ and RTM+$P_{Ref.T}$ for Bawjiase type had the lowest mean score (5.4 and 5.2, respectively) (Noal *et al*, 2018).

For both Aduamoa brown and Aduamoah black, the greatest mean score for overall acceptability was found in WSTB+P_{RefT}, while the lowest score was found in RTM+P_{RT} for Bawjiase type (Awolu *et al*, 2017). In comparison to the other treatments, the WSTM samples received the greatest scores for color, flavor, mouthfeel, taste, and overall acceptance whiles RTM received the lowest score (Amponsah *et al,* 2017). This perhaps reiterate the notion that certain inherent sensorial qualities of the tiger nut are not like by most consumers. The substantial fat content of WSTM might explain its high mean score (6.5 percent). This is because fat is proven to improve mouthfeel. The WSTM samples also received a high color score, indicating that they were creamier than dairy milk. Most sensory qualities, including color, flavor, and mouthfeel, earned the lowest mean score for roasted tiger nut milk samples. The heating (roasting) of the milk samples was blamed for this (Maillard, 1912).

Despite the large variances, the panelists agreed that all of the tiger nut milk items were good, but that the WSTM samples were the best and the RTM samples were the least liked (Lasekan, 2013). Like other phytomilks, tiger nut drinking drink has no beany flavor and throat-catching sensations (e.g., Soybean milk). Changes in process procedures, as expected, had a variable impact on the sensory appeal of the final product. In terms of color, it can be shown that the roasted tiger nut milk samples have substantially different mean scores ($P < 0.05$). This might indicate that the chemical changes caused by the heating and the open gas heating done before the extraction are identical. However, it should be noted that the average customer preference for color ranged from 5.3 to 8.5 (Martin *et al*, 2018). Borders around like slightly region to substantial similarities is translated in this way. (Okyere *et al*, 2014; Udeozor, 2012;) found that when they extracted milk from irradiated Tiger nut samples, Tiger nut-Soy milk drink, and chemical features of Tiger nut-Soy milk extract, they got comparable results.

Table 4. 1: Mean Sensory attributes score of tiger nut milk products obtained from various processing treatments

Cultivar	Treatment samples	Colour/Appearance	Flavour	Taste	Mouth feel
Kasoa type	WSTM + $P_{ref.T}$	7.6[a]	7.5[a]	7.7[a]	7.2[a]
	WSTM + P_{RT}	7.3[a]	7.6[a]	7.8[a]	7.0[a]
	$WSTM_{ref.T}$	7.2[a]	7.3[a]	7.4[a]	7.1[a]
	$WSTM_{RT}$	7.1[a]	7.2[a]	7.3[a]	7.1[a]
	RTM + $P_{ref.T}$	5.8[c]	6.4[b]	6.8[b]	6.6[b]
	RTM + P_{RT}	6.6[b]	6.2[b]	6.7[b]	6.4[b]
	$RTM_{ref.T}$	5.7[c]	6.0[b]	6.4[b]	6.2[b]
	RTM_{RT}	5.9[c]	5.8[b]	6.4[b]	6.2[b]
Bawjiase brown	WSTM + $P_{ref.T}$	7.3[a]	5.7[a]	6.4[a]	5.6[b]
	WSTM + P_{RT}	7.5[a]	6.0[a]	6.1[a]	6.0[a]
	$WSTM_{ref.T}$	7.0[a]	5.5[a]	5.4	5.2[b]
	$WSTM_{RT}$	7.1[a]	5.8[a]	5.8	5.7[b]
	RTM + $P_{ref.T}$	5.3[c]	5.3[a]	6.6[a]	5.2[b]
	RTM + P_{RT}	5.3[c]	5.8[a]	6.3[a]	5.3[b]
	$RTM_{ref.T}$	5.9[b]	5.3[a]	6.2[a]	5.4[b]
	RTM_{RT}	6.9[a]	5.8[a]	6.4[a]	6.1[a]
Techiman type	WSTM + $P_{ref.T}$	7.8[a]	7.4[a]	7.9[a]	7.5[a]
	WSTM + P_{RT}	7.6[a]	7.5[a]	7.6[a]	7.1[a]
	$WSTM_{ref.T}$	7.3[a]	7.2[a]	7.0[a]	7.0[a]
	$WSTM_{RT}$	7.1[a]	7.1[a]	7.4[a]	7.2[a]
	RTM + $P_{ref.T}$	5.7[c]	6.3[b]	6.7[b]	6.5[b]
	RTM + P_{RT}	6.4[b]	6.2[b]	6.6[b]	5.9[b]
	$RTM_{Ref.T}$	5.6[c]	5.8[b]	6.9[b]	6.0[b]
	RTM_{RT}	5.8[c]	5.9[b]	6.1[b]	6.2[b]
Nkawkaw type	WSTM + $P_{ref.T}$	7.7[a]	7.2[a]	7.8[a]	7.4[a]
	WSTM + P_{RT}	7.4[a]	7.3[a]	7.9[a]	7.0[a]
	$WSTM_{ref.T}$	7.3[a]	7.0[a]	7.3[a]	7.1[a]
	$WSTM_{RT}$	7.0[a]	7.1[a]	7.4[a]	7.3[a]
	RTM + $P_{ref.T}$	6.0[b]	6.2[b]	6.9[b]	6.4[b]
	RTM + P_{RT}	6.1[b]	6.3[b]	6.8[b]	6.0[b]
	$RTM_{ref.T}$	5.9[b]	5.9[b]	6.0[b]	6.1[b]
	RTM_{RT}	5.5[b]	5.8[b]	6.3[b]	6.3[b]

Aduamoa brown	WSTM + P $_{ref.T}$	8.5^{a}	7.1^{a}	7.9^{a}	7.4^{a}
	WSTM + P$_{RT}$	7.5^{b}	7.3^{a}	7.9^{a}	7.0^{a}
	WSTM$_{ref.T}$	7.4^{b}	7.2^{a}	7.1^{a}	7.0^{a}
	WSTM $_{RT}$	7.2^{b}	7.2^{a}	7.4^{a}	7.0^{a}
	RTM + P$_{ref.T}$	5.6^{d}	6.1^{b}	6.6^{b}	6.3^{b}
	RTM + P$_{RT}$	6.5^{c}	6.1^{b}	6.7^{b}	5.8^{b}
	RTM $_{ref.T}$	5.6^{d}	5.9^{b}	5.8^{b}	6.0^{b}
	RTM $_{RT}$	5.7^{d}	5.7^{b}	6.0^{b}	5.8^{b}
Asiebu Ekroful	WSTM + P $_{ref.T}$	7.9^{a}	7.4^{a}	7.7^{a}	7.6^{a}
	WSTM + P$_{RT}$	7.7^{a}	7.3^{a}	7.7^{a}	7.3^{a}
	WSTM$_{ref.T}$	7.5^{a}	7.1^{a}	7.4^{a}	7.0^{a}
	WSTM $_{RT}$	7.3^{a}	7.2^{a}	7.2^{a}	7.1^{a}
	RTM + P$_{ref.T}$	6.0^{c}	6.4^{b}	6.6^{b}	6.3^{b}
	RTM + P$_{RT}$	6.7^{b}	6.2^{b}	6.5^{b}	6.2^{b}
	RTM $_{ref.T}$	5.5^{d}	5.7^{b}	6.4^{b}	6.0^{b}
	RTM $_{RT}$	6.5^{b}	5.9^{b}	6.2^{b}	6.1^{b}
Aduamoa black	WSTM + P $_{ref.T}$	8.5^{a}	7.4^{a}	7.8^{a}	7.3^{a}
	WSTM + P$_{RT}$	7.8^{a}	7.3^{a}	7.7^{a}	7.1^{a}
	WSTM$_{ref.T}$	7.6^{a}	7.1^{a}	7.4^{a}	7.2^{a}
	WSTM $_{RT}$	7.2^{a}	7.0^{a}	7.2^{a}	7.2^{a}
	RTM + P$_{ref.T}$	5.4^{c}	6.5^{b}	6.9^{b}	6.5^{b}
	RTM + P$_{RT}$	6.7^{b}	6.1^{b}	6.5^{b}	6.3^{b}
	RTM $_{ref.T}$	5.6^{c}	5.6^{c}	6.3^{b}	6.2^{b}
	RTM $_{RT}$	5.5^{c}	5.8^{c}	6.2^{b}	6.0^{b}
North type	WSTM + P $_{ref.T}$	7.6^{a}	7.5^{a}	7.5^{a}	7.6^{a}
	WSTM + P$_{RT}$	7.4^{a}	7.6^{a}	7.8^{a}	7.4^{a}
	WSTM$_{ref.T}$	7.2^{a}	7.3^{a}	7.1^{a}	7.1^{a}
	WSTM $_{RT}$	7.0^{a}	7.1^{a}	7.2^{a}	7.2^{a}
	RTM + P$_{ref.T}$	5.7^{b}	6.5^{b}	6.8^{b}	6.6^{b}
	RTM + P$_{RT}$	5.5^{b}	6.3^{b}	6.6^{b}	6.4^{b}
	RTM $_{ref.T}$	5.8^{b}	5.7^{c}	6.2^{b}	6.0^{b}
	RTM $_{RT}$	6.7^{a}	5.8^{c}	6.4^{b}	6.2^{b}
LSD (P<0.05)		**0.4540**	**0.3278**	**0.4824**	**0.5132**

Means with the same superscript do not differ significantly (p>0.05) and means with different superscripts differ significantly (p<0.05) according to the Least Significant Difference (LSD) test.

However, consumers' preferences for the scent of the various samples differed from those for color. The average score varied from 5.3 to 7.6, with the range varying significantly depending on the area. However, there was a significant difference between the samples ($p<0.05$). This means that the processing techniques had an impact on the consumer's choice for Tiger nut's scent (Maduka *et al.*, 2018). The feeling created when volatile chemicals excite the olfactory receptors of the nasal cavity is known as smell. As a consequence, the findings suggest that the various processing processes yield comparable volatile chemicals. Consumers' perceptions of flavor or scent are often low in several sensory tests on Tiger nut milk (Ukwuru *et al*., 2011; Oranusi *et al*., 2012; Amponsah *et al*., 2017). This may reaffirm the view that Tiger nut's fundamental sensory attributes are disliked by the majority of customers (Enidiok *et al.*, 2017).

The 'aftertaste' followed a similar pattern to the taste, with customers' preferences for the parameter generally influenced by processing techniques. The sample RTM + $P_{ref.T}$ was the least acceptable in terms of aftertaste, with a mean score value of 5.2, despite no significant differences between washed soaking tiger nut milk and roasted tiger nut milk. The mouthfeel of a beverage refers to its ability to flow smoothly without lagging, especially in the case of insoluble particles. The WSTM sample had the highest mean score (8.5), which was substantially different from the RTM ($p<0.05$) (Maillard 1912). The RTM sample was chosen since it was the smallest (5.2). This might be because the moisture in these heat-treated samples was lost. The substantially higher mouthfeel ratings for these samples might be attributable to this moisture loss along with the release of fat molecules into solution as a result of the heating. Tiger nut has a greater fat content than other plant-based milk products, hence it was predicted to have higher mouthfeel scores, confirming that fat promotes mouthfeel. However, the low mouthfeel values were similar to those of (Udeozor, 2012). It is worth noting, even though, that the value ranges are still bordering on the same region, thus adjust to the procedures to increase these sensory ratings might be done.

4.2 Effect of processing on the microbial load of tiger nut milk drink:

Tables 4.2 and 4.3 illustrate the microbiological quality of tiger nut milk products after various processing methods (Rosello *et al*, 2018). Both tables 4.2 and 4.3 show a significant difference between the treatments ($p<0.05$). Microorganisms did not develop on the freshly produced samples (Ukwuru *et al*, 2011). After the first week of storage, both the refrigerated and room temperature samples showed a fast proliferation of bacteria. Table 4.2 shows total fungal count in the samples ranged from $7.2*10^5$ CFU mL^{-1} ($WSTM+P_{RefT}$) for North type to $9.1*10^5$ CFU mL^{-1} ($WSTM_{RefT}$) for Nkawkaw type for the first week, $7.6*10^5$ CFU mL^{-1} ($WSTM+P_{Ref.T}$) for both Kasoa and Techiman type to $8.9*10^5$ CFU mL^{-1} ($WSTM_{Ref.T}$) for Aduamoa black in the second week. $7.8*10^5$ CFU mL^{-1} ($WSTM +Pref_{.T}$) for both Aduamoa brown, Bawjiase, and Asiebu Nkroful type to $9.5*10^5$ CFU mL^{-1} ($WSTM_{Ref.T}$) for Nkawkaw type in the third week. Table 4.3 shows that bacterial growth was highest in $WSTM_{RefT}$ ($8.8*10^5$CFU mL-1) for Asiebu Nkroful type and lowest in $WSTM+P_{RT}$ for Aduamoa brown ($6.2*10^5$ CFU mL^{-1}) for all samples at 1st week, and highest in $WSTM_{Ref.T}$ ($8.9*10^5$CFU mL-1) for Asiebu Nkroful type and lowest in $RTM+P_{RT}$ ($6.9*10^5$ CFU mL^{-1}) for North type in the second week. In the third week, bacterial growth was highest in Techiman type $WSTM_{RefT}$ ($8.5*10^5$CFU mL^{-1}) and lowest in Aduamoa brown $WSTM+P_{RT}$ ($6.9*10^5$ CFU mL^{-1}).

Preservative-treated samples exhibited the least amount of bacterial and fungal development (both at room and refrigerated temperature) (Joy *et al*, 2018). In comparison to bacterial counts, the WSTM detected a higher number of fungal counts (Bukalo *et al*, 2015). In comparison, for the various processing treatments samples of the microbes, 8.9 and 9.5 bacterial and fungal counts, were over 1.2105 and 0.2105 CFU mL^{-1} microbial load. This means that the microbe counts (Table 4.2, 4.3) were higher than the Codex Alimentarius Commission's limit of acceptability for dairy milk, which is 2.0105 CFU mL^{-1} (Wakil *et al*, 2014).

Fungal account (CFU ml^{-1}), detected are (*Aspergillus flavus, Aspergillus terreus, Aspergillus niger*) of various tiger nut milk products stored under freezing and room temperature

Table 4. 2: Mean Storage period (3 weeks) of water-soaked tiger nut milk (WSTM), and roasted tiger nut milk (RTM)

Cultivar	Treatment samples	0	1	2	3
Kasoa type	WSTM + $P_{ref.T}$	NG	$7.4 * 10^{5\,b}$	$7.6 * 10^{5\,b}$	$7.7 * 10^{5\,b}$
	WSTM + P_{RT}	NG	$6.9 * 10^{5\,c}$	$7.5 * 10^{5\,b}$	$7.0 * 10^{5\,b}$
	WSTM $_{ref.T}$	NG	$8.7 * 10^{5\,a}$	$8.8 * 10^{5\,a}$	$8.3 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.3 * 10^{5\,a}$	$8.5 * 10^{5\,a}$	$8.0 * 10^{5\,a}$
	RTM + $P_{ref.T}$	NG	$7.4 * 10^{5\,b}$	$7.7 * 10^{5\,b}$	$7.4 * 10^{5\,b}$
	RTM + P_{RT}	NG	$8.2 * 10^{5\,a}$	$7.6 * 10^{5\,b}$	$7.3 * 10^{5\,b}$
	RTM $_{ref.T}$	NG	$8.5 * 10^{5\,a}$	$8.6 * 10^{5\,a}$	$7.6 * 10^{5\,b}$
	RTM_{RT}	NG	$8.6 * 10^{5b}$	$8.8 * 10^{5a}$	$7.2 * 10^{5b}$
Bawjiase	WSTM + $P_{ref.T}$	NG	$8.1 * 10^{5\,a}$	$8.1 * 10^{5\,a}$	$7.8 * 10^{5\,c}$
	WSTM + P_{RT}	NG	$7.9 * 10^{5\,a}$	$7.7 * 10^{5\,a}$	$8.6 * 10^{5\,a}$
	WSTM $_{ref.T}$	NG	$8.7 * 10^{5\,a}$	$8.2 * 10^{5\,a}$	$9.0 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.5 * 10^{5\,a}$	$8.4 * 10^{5\,a}$	$8.7 * 10^{5\,a}$
	RTM + $P_{ref.T}$	NG	$7.8 * 10^{5\,a}$	$7.8 * 10^{5\,a}$	$8.2 * 10^{5\,b}$
	RTM + P_{RT}	NG	$7.7 * 10^{5\,a}$	$7.7 * 10^{5\,a}$	$8.2 * 10^{5\,b}$
	RTM $_{ref.T}$	NG	$8.7 * 10^{5\,a}$	$8.5 * 10^{5\,a}$	$8.6 * 10^{5\,a}$
	RTM $_{RT}$	NG	$8.3 * 10^{5\,a}$	$8.3 * 10^{5\,a}$	$8.9 * 10^{5\,a}$
Techiman type	WSTM + $P_{ref.T}$	NG	$7.3 * 10^{5\,c}$	$7.6 * 10^{5\,b}$	$8.6 * 10^{5\,a}$
	WSTM + P_{RT}	NG	$8.1 * 10^{5\,b}$	$8.4 * 10^{5\,a}$	$8.3 * 10^{5\,a}$
	WSTM $_{ref.T}$	NG	$8.6 * 10^{5\,a}$	$8.2 * 10^{5\,a}$	$8.0 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.1 * 10^{5\,b}$	$8.3 * 10^{5\,a}$	$8.7 * 10^{5\,a}$
	RTM + $P_{ref.T}$	NG	$8.0 * 10^{5\,b}$	$8.2 * 10^{5\,a}$	$8.6 * 10^{5\,a}$
	RTM + P_{RT}	NG	$7.9 * 10^{5\,b}$	$8.0 * 10^{5\,a}$	$8.4 * 10^{5\,a}$
	RTM $_{ref.T}$	NG	$8.7 * 10^{5\,a}$	$8.6 * 10^{5\,a}$	$8.6 * 10^{5\,a}$
	RTM $_{RT}$	NG	$8.2 * 10^{5\,b}$	$8.4 * 10^{5\,a}$	$8.3 * 10^{5\,a}$
Nkawkaw type	WSTM + $P_{ref.T}$	NG	$8.4 * 10^{5\,a}$	$8.3 * 10^{5\,a}$	$7.9 * 10^{5c}$
	WSTM + P_{RT}	NG	$7.8 * 10^{5\,b}$	$7.9 * 10^{5\,a}$	$8.8 * 10^{5\,b}$
	WSTM $_{ref.T}$	NG	$9.1 * 10^{5\,a}$	$8.4 * 10^{5\,a}$	$9.5 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.7 * 10^{5\,a}$	$8.8 * 10^{5\,a}$	$9.0 * 10^{5\,b}$
	RTM + $P_{ref.T}$	NG	$7.6 * 10^{5\,b}$	$8.0 * 10^{5\,a}$	$8.4 * 10^{5\,b}$
	RTM + P_{RT}	NG	$7.5 * 10^{5\,b}$	$8.1 * 10^{5\,a}$	$8.6 * 10^{5\,b}$
	RTM $_{ref.T}$	NG	$8.8 * 10^{5\,a}$	$8.7 * 10^{5\,a}$	$8.9 * 10^{5\,b}$
	RTM_{RT}	NG	$8.5 * 10^{5a}$	$8.6 * 10^{5a}$	$8.3 * 10^{5b}$

Aduamoa brown	WSTM + $P_{ref.T}$	NG	$7.2 * 10^{5\ b}$	$7.8 * 10^{5\ b}$	$7.9 * 10^{5\ a}$
	WSTM +P_{RT}	NG	$6.2 * 10^{5\ c}$	$7.7 * 10^{5\ b}$	$6.9 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.5 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$8.1 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.1 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$7.8 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.5 * 10^{5\ b}$	$7.8 * 10^{5\ b}$	$7.3 * 10^{5\ a}$
	RTM + P_{RT}	NG	$8.0 * 10^{5\ a}$	$7.5 * 10^{5\ b}$	$7.1 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$8.3 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$7.5 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.4 * 10^{5\ a}$	$7.7 * 10^{5\ b}$	$7.2 * 10^{5\ a}$
Asiebu Nkroful	WSTM + $P_{ref.T}$	NG	$8.3 * 10^{5\ b}$	$8.2 * 10^{5\ a}$	$7.8 * 10^{5\ a}$
	WSTM + P_{RT}	NG	$7.7 * 10^{5\ c}$	$8.0 * 10^{5\ a}$	$8.9 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$9.0 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$9.4 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.5 * 10^{5\ b}$	$8.7 * 10^{5\ a}$	$9.2 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.5 * 10^{5\ c}$	$7.9 * 10^{5\ a}$	$8.3 * 10^{5\ a}$
	RTM + P_{RT}	NG	$7.7 * 10^{5\ c}$	$8.2 * 10^{5\ a}$	$8.5 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$8.6 * 10^{5\ b}$	$8.8 * 10^{5\ a}$	$8.7 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.1 * 10^{5\ b}$	$8.4 * 10^{5\ a}$	$8.0 * 10^{5\ a}$
Aduamoa black	WSTM + $P_{ref.T}$	NG	$8.2 * 10^{5\ a}$	$8.3 * 10^{5\ a}$	$8.0 * 10^{5\ a}$
	WSTM + P_{RT}	NG	$7.6 * 10^{5\ a}$	$8.1 * 10^{5\ a}$	$8.5 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.6 * 10^{5\ a}$	$8.9 * 10^{5\ a}$	$9.2 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.4 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$8.9 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.7 * 10^{5\ a}$	$7.9 * 10^{5\ a}$	$8.3 * 10^{5\ a}$
	RTM + P_{RT}	NG	$7.8 * 10^{5\ a}$	$7.7 * 10^{5\ a}$	$8.4 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$8.8 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$8.7 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.1 * 10^{5\ a}$	$8.2 * 10^{5\ a}$	$8.9 * 10^{5\ a}$
North type	WSTM + $P_{ref.T}$	NG	$7.2 * 10^{5\ b}$	$7.7 * 10^{5\ b}$	$8.8 * 10^{5\ a}$
	WSTM + P_{RT}	NG	$8.2 * 10^{5\ a}$	$8.3 * 10^{5\ a}$	$8.5 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.6 * 10^{5\ a}$	$8.7 * 10^{5\ a}$	$8.4 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.1 * 10^{5\ a}$	$8.7 * 10^{5\ a}$	$8.8 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.8 * 10^{5\ a}$	$8.2 * 10^{5\ a}$	$8.6 * 10^{5\ a}$
	RTM + P_{RT}	NG	$7.6 * 10^{5\ a}$	$8.1 * 10^{5\ a}$	$8.4 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$8.3 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$8.7 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.0 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$8.5 * 10^{5\ a}$
LSD (P<0.05)			**0.3571**	**0.3138**	**0.3912**

Means with the same superscript do not differ significantly (p>0.05) and means with different superscripts differ significantly (p<0.05) according to the Least Significant Difference (LSD) test.

Results showing the total plate counts for the nutrient and potato dextrose agar were done by counting colonies at the reverse side of the culture plates. Total colony count was expressed in colony-forming units per milliliter (CFU mL $^{-1}$) (figure 4.2).

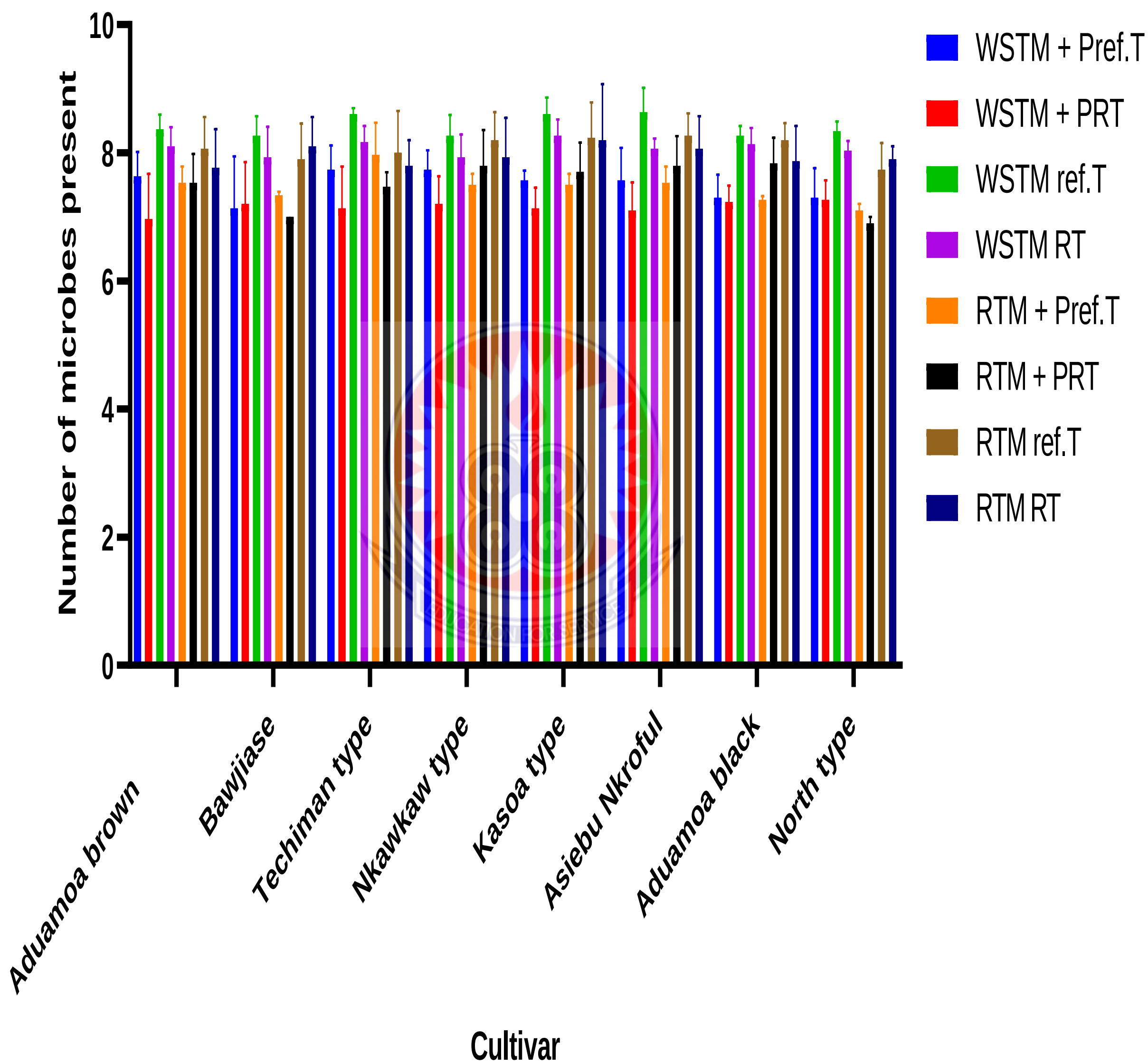

Figure 4.2 Number of microbes detected in the various treatments

Bacterial count (CFU mL^{-1}) detected are (*Bacillus spp, Stapply loccoci, and Lactoba*cilli of various tiger nut milk products stored under freezing and room temperature.

Table 4.3 Storage period (3 weeks) Water Soaked Tiger nut Milk (WSTM) and Roasted Tiger nut Milk (RTM). Mean score

Cultivar	Treatment samples	0	1	2	3
Kasoa type	WSTM + $P_{ref.T}$	NG	$7.4 * 10^{5\ b}$	$7.6 * 10^{5\ b}$	$7.7 * 10^{5\ b}$
	WSTM + P_{RT}	NG	$6.9 * 10^{5\ c}$	$7.5 * 10^{5\ b}$	$7.0 * 10^{5\ b}$
	WSTM $_{ref.T}$	NG	$8.7 * 10^{5\ a}$	$8.8 * 10^{5\ a}$	$8.3 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.3 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$8.0 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.4 * 10^{5\ b}$	$7.7 * 10^{5\ b}$	$7.4 * 10^{5\ b}$
	RTM + P_{RT}	NG	$8.2 * 10^{5\ a}$	$7.6 * 10^{5\ b}$	$7.3 * 10^{5\ b}$
	RTM $_{ref.T}$	NG	$8.5 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$7.6 * 10^{5\ b}$
	RTM $_{RT}$	NG	$8.6 * 10^{5\ a}$	$8.8 * 10^{5\ a}$	$7.2 * 10^{5\ b}$
Bawjiase	WSTM + $P_{ref.T}$	NG	$6.4 * 10^{5\ d}$	$8.0 * 10^{5\ a}$	$7.0 * 10^{5a}$
	WSTM + P_{RT}	NG	$6.6 * 10^{5\ d}$	$7.9 * 10^{5\ a}$	$7.1 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.2 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$8.0 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.3 * 10^{5\ a}$	$8.1* 10^{5\ a}$	$7.4 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.4 * 10^{5\ b}$	$7.3 * 10^{5\ b}$	$7.3 * 10^{5\ a}$
	RTM + P_{RT}	NG	$7.0 * 10^{5\ c}$	$7.0 * 10^{5\ b}$	$7.0 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$7.3 * 10^{5\ b}$	$8.4 * 10^{5\ a}$	$8.0 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.2 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$7.6 * 10^{5a}$
Techiman type	WSTM + $P_{ref.T}$	NG	$7.3 * 10^{5\ b}$	$7.9 * 10^{5\ b}$	$8.0 * 10^{5\ b}$
	WSTM + P_{RT}	NG	$6.5 * 10^{5\ c}$	$7.8 * 10^{5\ b}$	$7.1 * 10^{5\ b}$
	WSTM $_{ref.T}$	NG	$8.6 * 10^{5\ a}$	$8.7 * 10^{5\ a}$	$8.5 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.2 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$7.9 * 10^{5\ b}$
	RTM + $P_{ref.T}$	NG	$8.5 * 10^{5\ a}$	$7.9 * 10^{5\ b}$	$7.5 * 10^{5\ b}$
	RTM + P_{RT}	NG	$7.6 * 10^{5\ b}$	$7.6 * 10^{5\ b}$	$7.2 * 10^{5\ b}$
	RTM $_{ref.T}$	NG	$8.1 * 10^{5\ a}$	$8.6 * 10^{5\ a}$	$7.3 * 10^{5\ b}$
	RTM $_{RT}$	NG	$8.2 * 10^{5\ a}$	$7.8 *10^{5\ b}$	$7.4 * 10^{5\ b}$
Nkawkaw type	WSTM + $P_{ref.T}$	NG	$7.4 * 10^{5\ b}$	$8.0 * 10^{5\ a}$	$7.8 * 10^{5\ a}$
	WSTM + P_{RT}	NG	$6.9 * 10^{5\ c}$	$7.7 * 10^{5\ a}$	$7.0 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.4 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$7.9 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.3 * 10^{5\ a}$	$7.9 * 10^{5\ a}$	$7.6 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.3 * 10^{5\ b}$	$7.6 * 10^{5\ a}$	$7.6 * 10^{5\ a}$
	RTM + P_{RT}	NG	$8.4 * 10^{5\ a}$	$7.7 * 10^{5\ a}$	$7.3 * 10^{5\ a}$
	RTM $_{ref.T}$	NG	$8.5 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$7.7 * 10^{5\ a}$
	RTM $_{RT}$	NG	$8.6 * 10^{5\ a}$	$7.8 * 10^{5\ a}$	$7.4 * 10^{5\ a}$
Aduamoa brown	WSTM + $P_{ref.T}$	NG	$7.2 * 10^{5\ b}$	$7.8 * 10^{5\ b}$	$7.9 * 10^{5\ a}$
	WSTM +P_{RT}	NG	$6.3 * 10^{5\ c}$	$7.7 * 10^{5\ b}$	$6.9 * 10^{5\ a}$
	WSTM $_{ref.T}$	NG	$8.5 * 10^{5\ a}$	$8.5 * 10^{5\ a}$	$8.1 * 10^{5\ a}$
	WSTM $_{RT}$	NG	$8.1 * 10^{5\ a}$	$8.4 * 10^{5\ a}$	$7.8 * 10^{5\ a}$
	RTM + $P_{ref.T}$	NG	$7.5 * 10^{5\ b}$	$7.8 * 10^{5\ b}$	$7.3 * 10^{5\ a}$

	RTM + P_{RT}	NG	$8.0 * 10^{5\,a}$	$7.5 * 10^{5\,b}$	$7.1 * 10^{5\,a}$
	RTM $_{ref.T}$	NG	$8.3 * 10^{5\,a}$	$8.4 * 10^{5\,a}$	$7.5 * 10^{5\,a}$
	RTM $_{RT}$	NG	$8.4 * 10^{5\,a}$	$7.7 * 10^{5\,b}$	$7.2 * 10^{5\,a}$
Asiebu Nkroful	WSTM + $P_{ref.T}$	NG	$7.0 * 10^{5\,b}$	$7.7 * 10^{5\,a}$	$8.0 * 10^{5\,a}$
	WSTM + P_{RT}	NG	$6.6 * 10^{5\,c}$	$7.4 * 10^{5\,a}$	$7.3 * 10^{5\,a}$
	WSTM $_{ref.T}$	NG	$8.8 * 10^{5\,a}$	$8.9 * 10^{5\,a}$	$8.2 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.2 * 10^{5\,a}$	$8.1 * 10^{5\,a}$	$7.9 * 10^{5\,a}$
	RTM + $P_{ref.T}$	NG	$7.3 * 10^{5\,b}$	$7.8 * 10^{5\,a}$	$7.5 * 10^{5\,a}$
	RTM + P_{RT}	NG	$7.9 * 10^{5\,a}$	$8.2 * 10^{5\,a}$	$7.3 * 10^{5\,a}$
	RTM $_{ref.T}$	NG	$8.2 * 10^{5\,a}$	$8.6 * 10^{5\,a}$	$7.9 * 10^{5\,a}$
	RTM $_{RT}$	NG	$8.6 * 10^{5\,a}$	$8.0 * 10^{5\,a}$	$7.6 * 10^{5\,a}$
Aduamoa black	WSTM + $P_{ref.T}$	NG	$6.9 * 10^{5\,c}$	$7.4 * 10^{5\,a}$	$7.6 * 10^{5\,b}$
	WSTM + P_{RT}	NG	$7.0 * 10^{5\,b}$	$7.5 * 10^{5\,a}$	$7.2 * 10^{5\,b}$
	WSTM $_{ref.T}$	NG	$8.1 * 10^{5\,a}$	$8.3 * 10^{5\,a}$	$8.4 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.4 * 10^{5\,a}$	$8.1 * 10^{5\,a}$	$7.9 * 10^{5\,b}$
	RTM + $P_{ref.T}$	NG	$7.2 * 10^{5\,b}$	$7.3 * 10^{5\,a}$	$7.3 * 10^{5\,b}$
	RTM + P_{RT}	NG	$8.2 * 10^{5\,a}$	$7.9 * 10^{5\,a}$	$7.4 * 10^{5\,b}$
	RTM $_{ref.T}$	NG	$8.3 * 10^{5\,a}$	$8.4 * 10^{5\,a}$	$7.9 * 10^{5\,b}$
	RTM $_{RT}$	NG	$8.5 * 10^{5\,a}$	$7.5 * 10^{5\,a}$	$7.6 * 10^{5\,b}$
North type	WSTM + $P_{ref.T}$	NG	$6.8 * 10^{5\,b}$	$7.4 * 10^{5\,a}$	$7.7 * 10^{5\,a}$
	WSTM + P_{RT}	NG	$7.0 * 10^{5\,b}$	$7.6 * 10^{5\,a}$	$7.2 * 10^{5\,a}$
	WSTM $_{ref.T}$	NG	$8.3 * 10^{5\,a}$	$8.5 * 10^{5\,a}$	$8.2 * 10^{5\,a}$
	WSTM $_{RT}$	NG	$8.2 * 10^{5\,a}$	$8.0 * 10^{5\,a}$	$7.9 * 10^{5\,a}$
	RTM + $P_{ref.T}$	NG	$7.1 * 10^{5\,b}$	$7.0 * 10^{5\,a}$	$7.2 * 10^{5\,a}$
	RTM + P_{RT}	NG	$6.8 * 10^{5\,b}$	$6.9 * 10^{5\,a}$	$7.0 * 10^{5\,a}$
	RTM $_{ref.T}$	NG	$7.4 * 10^{5\,b}$	$8.2 * 10^{5\,a}$	$7.6 * 10^{5\,a}$
	RTM $_{RT}$	NG	$8.1 * 10^{5\,a}$	$7.9 * 10^{5\,a}$	$7.7 * 10^{5\,a}$
LSD ($P<0.05$)			**0.4214**	**0.4710**	**0.4473**

Means with the same superscript do not differ significantly ($p>0.05$) and means with different superscripts differ significantly ($p<0.05$) according to the Least Significant Difference (LSD) test.

The proliferation of these microorganisms might be attributable to lactic acid bacteria cells that have survived processing procedures. In research by Nyarko *et al*. (2011) on the microbiological safety of tiger nuts in Ghana's cape coast metropolis, it was discovered that E.*coli* and *Bacillus* spp. were the most often detected species, accounting for 18.9% of the total. *Bacillus* is a spore-forming bacteria that may be found in soil, water (due to soil-water pollution), and plants. Because the spores of some strains of these organisms are impervious to pasteurization temperature, the presence of these bacteria in food samples in our investigation may be unavoidable. Others include *Enterococcus* spp, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Streptococcus* spp. *Staphylococcus aureus* is a common environmental bacterium that might have gotten into the food through cross-contamination during preparation. The enterotoxin produced by *Staphylococcus aureus* is recognized to be important in food-borne disease (Kadariya *et al*., 2014).

Microbial development is often aided by high moisture content. The germs in the samples might have come from the handlers' noses, hands, skin, and clothes, as well as coughing, talking, and sneezing droplets that landed on the milk during storage (Haas *et al*, 2014). The presence of fungus in tiger nut beverage samples is cause for worry. The deterioration of the storage microflora has been connected to this. The development of off-flavors is the most common symptom of microbial deterioration of refrigerated tiger nut milk. According to Chukwu *et al*. (2013) several fungi (*Aspergillus niger*, *Aspergillus flavus*, and *Aspergillus terreus*) are connected with both fresh and dry tiger nuts and might perhaps withstand processing methods. In addition, the pH values of the different tiger nut beverage treatment samples declined with storage time. With time, the treatments got more acidic, which might lead to additional degradation of the milk since bacteria thrive and proliferate in an acidic environment. According to the findings of this investigation, the microbiological counts (Table 4.2 and 4.3) were over the acceptable level, indicating that the milk was unsafe for drinking after only a few days of storage. This is consistent with the findings of Abaejoh *et al*. (2011) who found that microbes impeded the manufacture of tiger nut milk drinks in Ghana.

CHAPTER FIVE

CONCLUSION, AND RECOMMENDATIONS

5.1 Conclusion

Conclusively, tiger nuts are widely consumed in Ghana and are most preferred by many of the people in Ghana. It has been found that the generation of fat during storage of tiger nut milk helps in increasing the sensation of taste in the product at room temperature where the necessary conditions for fat generation are readily available. Hence, properly storing tiger nut milk at room temperature is a requirement for better taste development in the sample. Notwithstanding, it is important to soak tiger nuts in water before processing them into milk since it helps in enhancing physical parameters such as color, flavor, and mouthfeel compared to other preliminary processing methods such as roasting.

For this reason, it can be confidently pronounced that, water-soaked tiger nuts milk (WSTM) scores better in color, taste, and flavor than tiger nut milk processed in other ways including roasting. This is sole because roasting the tiger nuts further degrade some pronounced properties of the nut and aid in the burning away of some integral parts. Reduction, in the quality of roasted tiger nuts, can be fetched from chemical reactions that resulted from the heating of the samples in an open flame. Moreover, the various processing techniques employed in this study showed a minimum effect on scent, hence, the processes employed can be clearly stated to yield volatile substances that are comparable. These substances are known to excite the olfactory receptors of the nasal cavity is known as smell. Lastly, tiger nut milk have been found to have a very short shelf life. This is mainly because the extracted milk starts going bad only after a few days. The cause has been hypothesized to be from the skin, cloth, mouth, nose, and hands of handlers of the milk. This calls for maximum attention to hygiene during milk extraction. The microbiological analysis of the samples revealed that the shelf life of tiger nut beverages was differently affected by the various treatments (the preservative and non-preservative treated samples, refrigerated and room temperature samples). Based on the above results, an acceptable Ghanaian tiger nut milk can be produced using a preservative but an effective control measure to minimize contamination during processing and higher moisture content of the tiger nut should be adopted, as the higher the moisture content, the higher the susceptibility to microbial growth.

5.2 Recommendations

The following recommendations were made based on research findings:

- It is recommended that tiger nuts meant for milk extraction should be soaked first in water to add taste to the milk.
- Milk handlers should keep their clothes neat to prevent milk contamination from clothes
- To effectively enhance the shelve life of nut milk, the handler needs to cover their mouth and nose by the use of a nose mask to prevent the overflow of microbes from saliva as well as breathed air.
- Roasting tiger nuts before milk extraction should be avoided to enhance the physicochemical parameter of extracted milk.

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