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Microbial and Sensory Properties of Canned Tigernut Milk

by

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Master of Science in Food Quality Management

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

Dairy milk is an indispensable food for the nourishment of animals and man due to its treasured nutritional content and thus remains an important part of daily meals. The purpose of this study was to evaluate the microbial and sensory properties of canned Tigernut milk. The Tigernut were sorted, washed and divided into three batches for further processing. Cans were filled with 100 mL of the Tigernut milk produced and double seams made using a metal box 1 seamer. Retorting was done at 121 °C for 15 min. Microbial assay was carried out for 8 weeks to determine the total viable count of microorganisms in the canned Tigernut milk. The assessment of the microbial load of the products over the 8-week storage period showed results exhibiting similar trend as observed for the hourly study. The microbial loads over the storage period had no significant increase in load over time for some of the product formulations. Others however recorded some microbial growth with increasing counts over time. Even though the shelf life cannot be accurately predicted from such observation, an emphatic conclusion of the shelf stability of the product being far beyond an 8-week period can be ascertained. Microwaving as a method was seen to have resulted in producing sweet-smelling compounds leading to a higher preference over the other samples. Sensory evaluation was done. The results showed that the processing methods variably affected the various sensory attributes with no significant differences recorded for smell ($p < 0.05$). The cooked and microwaved samples were the most preferred for all the given attributes over the other samples. However, consumer preference had a slight shift towards the cooked sample in terms of overall acceptability. The microbial storage profile showed no growth up to the seventh week of storage for all samples.

DEDICATION

I dedicate this thesis to God Almighty for His abundant grace and mercy.

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LIST OF ABBREVIATIONS

AFT	-	after taste
COL	-	colour
CONS	-	consistency
CTM	-	cooked then microwaved
CSIR	-	Council for Scientific and Industrial Research
ET	-	elevated temperature
FAO	-	food and agricultural organization
LDL	-	low density lipoprotein cholesterol
M	-	mouthfeel
M1	-	microwaved 1
M2	-	microwaved 2
N/A	-	none applicable
ND	-	none detected
NM1	-	non-microwaved 1
NM2	-	non- microwaved 2
RF	-	refrigeration
RT	-	room temperature
S	-	smell
T	-	taste
TM1	-	traditional method 1
TM2	-	traditional method 2
WHO	-	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 Background

Research continues to provide information on the links between dietary pattern and health. Diabetes, obesity and stroke are some conditions that have been strongly linked with diet. As a result, many consumers are shifting towards plant-based diets. A number of plant-based diets are now receiving considerable attention because of their reported health benefits. This includes plant-based milks such as soymilk, coconut milk, almond milk and Tigernut milk (Beaulieu, J. C. *et al*, 2007). Makinen *et al*. (2016) defined plant-based milk as aqueous extracts that have an appearance like that of cow's milk and result from the homogenisation of plant sources.

Consumer's choice of plant-based milk is driven mainly by the prevalence of lactose (Lomer *et al.*, 2008). Ethical considerations by animal rights' activists and vegetarians against animal products is also increasing the movement of consumers towards plant-based milks (Jeske *et al.*, 2015). Plant-based milks such as soymilk, quinoa milk, flax milk, oat milk, hazelnut milk exist on the market (Kim *et al.*, 2012). Soymilk has the biggest market share of these (Mintel Group, 2011). According to Jeske *et al*. (2015), about 14% of people who have allergic reactions to cow's milk are allergic to soy products as well. This presents a huge market base for emerging products such as Tigernut milk.

Tigernut is widespread across the world and considered as a weed in some countries (DeFelice, 2002). It is cultivated in many parts of Ghana in commercial quantities for its edible tubers and for the purposes of medication (Sanful, 2009). Tigernut are mainly composed of carbohydrate and fats, with a low protein content (Oladele and Aina 2007; Ekeanyanwu and Ononogbu,

2010; Codina-Torella *et al.*, 2014). Tigernut milk also known as '*atadwe milk*' in Ghana. It is a water extract of Tigernut and may be consumed sweetened or unsweetened.

Tigernut milk is however highly perishable and is characterized by a relatively shorter shelf life. The milk is often consumed immediately after production. Canning over the years has proven to be an effective and efficient for long time preservation of milk products. The technique has been typically defined as a method of food preservation which involves an initial sealing of the food in air-tight jars, cans or pouches, followed by subsequent heating to a temperature that destroys microorganisms that poses health risk or reserves spoilage potential (Huang *et al.*, 2016). Thus, the objective of the study is to investigate the potential canning on the shelf stability of newly developed Tigernut milk beverages.

1.2 Problem Statement and Justification

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 °C, 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

without spoilage has been a major drawback (Chukwu, et *al.*, 2013). Therefore, evaluating the Microbial and Sensory Properties of Canned Tigernut Milk are the major objectives of this research study.

1.3 Objectives

The objective of this study was to evaluate the microbial and sensory properties of canned Tigernut milk.

CHAPTER TWO

LITERATURE REVIEW

2.1 Plant-based and Organic food Products

Human health is contingent largely on the kind of little choices we take day-to-day, in other words, our lifestyle. The choices that usually affect our health have to do with the food we eat. There are different preferences available that we must always choose which food to select and how they are rightly prepared. Having a comprehensive knowledge on the existing foods makes it easier to make the best choices for our health. Significantly, many people are resorting to plant-based and organic food products. Plant-based foods encompass constituents that produce pharmacological effects similar to any other medication, but with advantages of averting and correcting the predisposition toward disease, in addition to having therapeutic properties, they have no side effects. This contemporary world comes with countless agronomic products that can be churn out to become gems which have health and pecuniary values and will solve many concerns for the poor, but have been neglected as a result of its quick perishability. Tigernut is one of such products.

There are enormous benefits of organic and plant-based foods. Prominent among them are that it is a nutrient-denser food, which implies organic food has better nutritious dominance than its non-organic counterparts, it gives stronger and more energetic body since there are no chemicals, pesticides or administered condiments impeding your system, implying a reduced threat of ailment, sickness, and maladies in your body. Organic and plant-based food tastes better and it is cheaper even though selected organic food and yields are extra expensive, you essentially will save cash in numerous ways as well as you not having to spend extra money in visiting the hospital frequently.

2.2 Plant-based Milk

The health of humans is largely dependent on the foods eaten. Diseases and conditions such as diabetes, stroke, obesity, atherosclerosis etc. have been linked to dietary habits. Consequently, many people are resorting to plant-based and organic food products. Foods such as tomatoes, broccoli, oats and yoghurt have received considerable attention because of their reported health benefits (Hasler, 1998). Makinen *et al.*, (2016) defined plant-based milk as aqueous extracts that have an appearance like that of cow's milk and result from the homogenisation of plant sources.

Many consumers go in for milk products from plant origin either for health reasons or as a choice of lifestyle (Makinen *et al.*, 2016). One major health reason dictating this choice is the prevalence of lactose intolerance, which is due to the presence of lactose in cow's milk and other milks of animal origin (Valencia-Flores *et al.*, 2013). Jeske *et al.*, (2017) added that the increasing demand for alternatives to dairy are being driven by allergy to cow's milk as well as concerns about veterinary residues in cow's milk. Lomer *et al.*, (2008) reported that lactose intolerance is widely distributed across the world. The prevalence ranges from a meagre 5% among North Americans and Europeans to more than 50% among Asians and Africans. Lactose intolerance coupled with the lower calorie level and absence of cholesterol in plant-based milk has driven up the market share of plant-based milk. Ethical considerations by animal rights' activists and vegetarians against animal products is also increasing the movement of consumers towards plant-based milks (Jeske *et al.*, 2017).

Plant-based milk is known to have anti-hypertensive, anti-diabetic, anti-tumor and antioxidant effects (Sethi *et al.*, 2016). Other health benefits include hypocholesterolemic effect and boosting of the immune system (Sethi *et al.*, 2016). Most plant-based milks are, however, low

in protein. Notwithstanding, more than two-thirds of Americans trust plant-based milks are nutritious for children (Jeske *et al.*, 2017). Makinen *et al.*, (2016) called for increased consumer education due to the tendency for children to be fed with plant-based milks as a substitute for cow's milk. The extensive usage of rice milk, a low protein milk, in feeding children resulted in cases of kwashiorkor (Katz *et al.*, 2005). Sethi *et al.*, (2016) suggested that plant-based milks should be fortified with proteins, calcium and vitamins.

A number of plant-based milk already exists. Soymilk, sikhye, quinoa milk, flax milk, oat milk, hazelnut milk and Tigernut milk are a few (Kim *et al.*, 2012). Of these, soymilk is the most consumed in the world (Makinen *et al.*, 2016). In Spain, Tigernut milk ("horchata de chufa") remains the go-to choice for consumers and is of huge economic importance. (Rubert *et al.*, 2011). According to Leatherhead Food Research (2011), dairy-free products had a market value of \$3.6 billion in 2010. Mintel Group (2011) argues that though soymilk and soy products have a bigger market share, emerging products from coconut, almond and oat are doing well on the market. According to Jeske *et al.*, (2017), about 14% of people who have allergic reactions to cow's milk are allergic to soy products as well. This presents a huge market opportunity for products from other plant sources such as almond, coconut and Tigernut.

2.3 Tigernut: Description and Cultivation

Tigernut (*Cyperus esculentus*) is also called chufa sedge, nut grass, yellow nut sedge, Tigernut sedge or earth almond in different countries (Oderinde and Tairu ,1988). Other names of the Tigernut are Zulu nut, yellow nutgrass, edible rush and rush nut (Eteshola and Oraedu, 1996). According to Consejo (2006), Tigernut as shown in (appendix A, picture 6 and 70), is a tough erect fibrous-rooted plant, ranges from 1 to 3 feet high and reproduces by seeds and by many deep-rooted slim rhizomes. It grows to a height of about 90 cm and has solitary stems that grow

from a tuber. Its stems are triangular in section and slender leaves ranging from 3 to 10 mm width. The flowers of the Tigernut plant are distinct, with a group of flat oval seeds by four leaf-like bracts positioned 90 degrees from each other. The plant is also mostly mistaken for a grass because of the very tough and fibrous foliage (Zhang *et al.*, 2012). Mason (2005) in her article about Tigernut described it as small about the size of a peanut growing at the rhizome of the plant and not a nut as people generally called it. The tubers of Tigernut are daily ingredients in the diets of many people in Spain and North Africa (Oladele *et al.*, 2009). The nuts are known for their high nutritious content in dietary fibre, starch and carbohydrates (Umerie and Enebeli, 1997). According to Omode *et al.*, (1995), the nuts are also very high in Calcium, Sodium, Potassium, Magnesium, Zinc and some traces of copper.

It is a crop of the sedge family. *Cyperus esculentus* has a good adaptability, thus can be found in many parts of the world as a weed (DeFelice, 2002). It is classified as a weed in some countries and is closely related to purple nutsedge (*Cyperus rotundus*), which is a known weed (DeFelice, 2002). It is found in Africa, Southern Europe, as well as the Middle East and the Indian subcontinent.

Tigernut has rhizomes, with their typical scales, that ends in small underground tubers. Fibrous roots protrude from these tubers. Tigernut has leaves of about 85 cm in length and 2 to 10 mm in width arising from its base. The plant produces sweet-scented yellowish-brown flowers (DeFelice, 2002), however De Vreis (1991) reported that flowers are only common among the weedy type and rare in the cultivated varieties. Cultivated varieties of *C. esculentus* have their tubers directly beneath the shoots of the plant, an occurrence that is absent in the wild or weed varieties De Vreis (1991). The tubers can be found bunched together directly beneath the soil surface. Wilen *et al.* (1996) reported that tuber initiation is inhibited by, high levels of nitrogen,

long photoperiods, and high levels of gibberellic acid. High soil moisture contents on the other hand promote tuber initiation (Stoller and Sweet, 1987). *C. esculentus* requires long photoperiods for flower initiation. The tuber epidermis contains substances that inhibit sprouting of tubers, thus preventing growth of tubers after harvest (Wilen *et al.*, 1996).

Oladele and Aina (2007) mentioned three different varieties of Tigernut based on the colour of the rhizomes: yellow, brown and black varieties. Tigernut have been categorised into three sizes; mini (6-8 mm), standard (8-12 mm) and the large (>12 mm) (Dakogre, 2008). According to Pascual *et al.* (2000), '*gegant africana*', '*llargueta alboraia*', and '*ametlla bonrepos*' are three common varieties that fall under the large-sized category. The '*ametlla bonrepos*' produces spherical tubers of about 12.4 mm in length whereas the '*llargueta alboraia*' produces oval tubers of about 15.2 mm in length. The largest variety is the '*gegant africana*', whose tubers measure about 17.3 mm in length and 1.09 g in weight.

Tigernut grows best in moist soils; it actually requires continuous irrigation throughout its growing season. According to Abano and Amoah (2011), Tigernut are able to tolerate high soil moisture; however, they do not do well under shade. Due to the use of continuous irrigation in Tigernut farming, they require a long period of drying after harvest (Abano and Amoah, 2011). This post-harvest practice ensures an extended shelf life. Zohary and Hopf (2000) contend that evidence exists for its cultivation in Egypt since the sixth millennium BC, and for some centuries in Southern Europe. The yield of Tigernut, irrespective of the variety, ranges between 0.8 to 14 tonnes/ha (Zohary and Hopf, 2000). This wide variation of yield depends on edaphic factors and the scale of cultivation.

In Ghana, Tigernut are cultivated in many parts of the country such as Bawjiase, Techiman, Chiraa, Tanoso, parts of Northern Ghana, parts of Central Region, and the Kwahu ridge. In

Ghana, a survey conducted by CSIR (1989) as cited by Sanful (2009) in the Kwahu South District, revealed a yield range of 2.3 – 11.3 tonnes/ha. Tigernut are cultivated in other parts of the African continent including Niger, Nigeria, Togo, Benin, Burkina Faso, Egypt and many more (Belewu and Belewu, 2007; Sanful, 2009; Oladele and Aina, 2007; Sebastia *et al.*, 2012).

In Spain, Tigernut are cultivated mainly for the preparation of “horchata de chufa”, a sweet, milk-like beverage (Corrales *et al.*, 2012). It is cultivated in many parts of Ghana in commercial quantities for its edible tubers and for the purposes of medication (Sanful, 2009). Tigernut can be processed into flour, oil and milk; its fibre, which is a by-product of milk extraction, can be incorporated into other food products (Arafat *et al.*, 2009; Sebastia *et al.*, 2012).

2.4 Types of Tigernut

There are many varieties of Tigernut in the world as shown in (appendix A, picture 8) . In Nigeria, there are three varieties: black, brown, yellow but only the brown, and yellow are readily available in the market. The yellow type is preferred because of its inherent properties like its bigger size, attractive colour and fleshier body. It also yields more milk, which contains lower fat and higher protein, and less anti-nutritional factors especially polyphenols (Okafor, 2003). In Ghana, Tigernut is commonly called “Atadwe”. There are two main varieties of Tigernut namely: the Fante type and the Kwahu type. The Kwahu type is yellowish brown in colour. There are four different sub-types of the Kwahu type designated as Kwahu Types 1, 2, 3 and 4. The nuts of Type 1 are small and round, those of Type 2 are fairly large and round, those of Type 3 are large and slightly elongated and those of Type 4 are slender, long and may be straight or sickle-shaped. The Fante type has a mixture of dark-brown and black nuts, which are generally round but differ in sizes (Tetteh and Ofori, 1998). They also indicated that consumers preferred the Kwahu type to the Fante type due to the sweetness and attractiveness

of the former. Tigernut are grown at places like Aduamoa in the Kwahu South District, Asukese, Odomasua, and Demso in the Afram Plains, Agona Kwanyaako, Bawjiase, and Elmina in the Central Region, and around Techiman in the Brong-Ahafo Region.

2.5 Sensory Characteristics of Tigernut

2.5.1 Colour

The Colour for Tigernut is derived from the natural pigments in fruits and vegetables, many of which change as the plant proceeds through maturation and ripening. The primary pigments imparting colour quality are the fat-soluble chlorophylls (green) and carotenoids (yellow, orange, and red) and the water-soluble anthocyanins (red, blue), flavonoids (yellow), and betalains (red). In addition, enzymatic and non-enzymatic browning reactions may result in the formation of water-soluble brown, gray, and black coloured pigments. The enzymes involved in browning reactions include polyphenol oxidase, which catalyzes the oxidation of polyphenolic compounds, and phenylalanine ammonialyase, which catalyzes the synthesis of precursors to phenolic substrates. The chlorophylls are sensitive to heat and acid, but stable to alkali whereas their counterpart carotenoids are sensitive to light and oxidation but relatively stable to heat. An enzyme called lipoxygenase, which catalyzes the oxidation of lipid compounds, may bleach carotenoids. Anthocyanins are sensitive to both pH and heat, while the flavonoids are sensitive to oxidation but relatively stable to heat. Betalains are heat sensitive as well (Clydesdale and Francis, 1976). Appearance is determined by physical factors including the size, the shape, the wholeness, the presence of defects (blemishes, bruises, spots, etc.), finish or gloss, and consistency. Cultivar, maturity, production inputs, and the growing environment may influence size and shape. It is important for fruits and vegetables to be of uniform size and characteristic shape (Mitcham *et al.*, 1996). Some consumers associate larger size with higher quality. The wholeness and absence of defects would be affected by exposure

to disease and insects during the growing period and the harvest and postharvest handling operations. Mechanical harvesting, for example, may incur more bruises and cracks in fruits and vegetables than hand harvesting. Fruit and vegetable gloss are related to the ability of a surface to reflect light and freshly harvested products are often more glossy (Mitcham *et al.*, 1996). Gloss is affected by moisture content, wax deposition on the surface, and handling practices postharvest. Consistency or smoothness may be used as an appearance term, but is typically applied to semisolid products, where it indicates the product thickness.

2.5.2 Flavour (Aroma and Taste)

Tigernut contain a type of prebiotic fibre called resistant starch, which does not break down until it reaches the large intestine, where it stimulates good bacteria. They also contain beneficial fatty acids, like those in olive oil or avocado oil, and are a source of potassium, vitamin E, and iron. In addition: low calories, low fat. Tigernut first. Flavour has been defined (Anon, 1959) as: A mingled but unitary experience, which includes sensations of taste, smell, and pressure, and often-cutaneous sensations such as warmth, colour, or mild pain. Flavour is normally described by aroma (odour) and taste. Tigernut are mild and sweet, sort of like coconut. Aroma compounds are volatile they are perceived primarily with the nose, while taste receptors exist in the mouth and are impacted when the food is chewed. While colour and appearance may be the initial quality attributes that attract us to a fruit or vegetable product, the flavour may have the largest impact on acceptability and desire to consume it again. Taste has been divided into five primary tastes sweet, sour, salty, bitter, and umami. Umami can be described as a taste associated with salts of amino acids and nucleotides (Yamaguchi and Ninomiya, 2000). Odours are much more diverse and difficult to classify, but an attempt by Henning (Gould, 1983) includes the following spicy, flowery, fruity, resinous or balsamic, burnt, and foul. Stevens (1985) stated that it is possible to classify vegetables into two major

groups, depending on their flavour characteristics. The first group of fruits and vegetables has a strong flavour that can be attributed to a single compound or group of related compounds. Bananas with isoamylacetate, onions with characteristic sulphide compounds, and celery, with distinctive phthalides are examples of this group. The second group of fruits and vegetables includes those whose flavour is determined by a number of volatiles, none of which conveys the specific characteristic aroma. Examples in this group include snap beans, muskmelons, and tomatoes. In the evaluation of fruit and vegetable flavour, it is important to consider “off-flavours” as well as desirable ones. These off-flavours may be produced through the action of enzymes such as lipoxygenase or peroxidase, which form reactive free radicals and hydroperoxides that may catalyse the oxidation of liquid compounds. When these reactions occur, the result may be the development of undesirable flavours described as rancid, cardboard, oxidized, or wet dog. However, there are instances of enzyme-catalysed reactions that result in desirable flavours. For example, hydroperoxidelyase catalyses the production of typical tomato flavours (Anthon and Barrett, 2003).

2.5.3 Texture

Textural parameters of fruits and vegetables are perceived with the sense of touch, either when the product is picked up by hand or placed in the mouth and chewed. In contrast to flavour attributes, these characteristics are easily measured using instrumental methods. Most plant materials contain a significant amount of water and other liquid-soluble materials surrounded by a semi-permeable membrane and cell wall. The texture of fruits and vegetables is derived from their turgor pressure, and the composition of individual plant cell walls and the middle lamella “glue” that holds individual cells together. Cell walls are composed of cellulose, hemicellulose, pectic substances, proteins, and in the case of vegetables, lignin. Tomatoes are an example of a fruit vegetable that is approximately 93–95% water and 5–7% total solids, the

latter comprised of roughly 80–90%soluble and 10–20% insoluble solids. The greatest contribution or to the texture of tomato products are the insoluble solids, which are derived from cell walls. The three-dimensional network of plant cell walls is still unresolved, but is a topic of great interest to scientists in that to a large degree it dictates the perception of consistency, smoothness, juiciness etc. in fruit and vegetable tissues (Waldron *et al.*, 2003). According to Bourne (1982), the textural properties of a food are the “group of physical characteristics that arise from the structural elements of the food, are sensed by the feeling of 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.” The terms texture, rheology, consistency, and viscosity are often used interchangeably, de-spite the fact that they describe properties that are somewhat different. In practice the term texture is used primarily with reference to solid or semi-solid foods; however, most fruits and vegetables are viscoelastic, implying that they exhibit combined properties of ideal liquids, which demonstrate only viscosity (flow), and ideal solids, which exhibit only elasticity (deformation).

2.6 Nutritional Composition of Tigernut

The nutritional composition of Tigernut is greatly influenced by its geographical origin (Codina-Torella *et al.*, 2015). Codina-Torella *et al.* (2015) found significant differences in the proximate composition of Tigernut from Spain, Burkina Faso and Niger. Tigernut from Valencia were significantly higher in fat, moisture, protein and fibre than the Tigernut from Burkina Faso and Niger. The Valencian Tigernut were, however, low in carbohydrates as compared to the other Tigernut. Tigernut is mainly made up of carbohydrates in the form of starch. The carbohydrate content of Tigernut has been reported to range from 41.22 % to 47.91% (Oladele and Aina 2007; Arafat *et al.*, 2009; Adekanmi *et al.*, 2009). This high carbohydrate content is typical for tubers. Ekeanyanwu and Ononogbu (2010) reported a lower carbohydrate content of about 30%.

Fat follows as the second highest component of Tigernut. Oladele and Aina (2007) determined the fat content of yellow and brown Tigernut to be 32.13% and 35.43% respectively. Adekanmi *et al.*, (2009) and Arafat *et al.*, (2009) have also reported fat contents of 27.4% and 30%. Sanchez-Zapata *et al.*, (2012) reported a range of 22.8 to 32.88 g/100g. Arafat *et al.*, (2009) compared the compositions Tigernut oil to olive oil. Findings from the study revealed that Tigernut oil had high-unsaturated fatty acid content (about 93%). Oleic acid made up 69.5% of the fatty acid content, with palmitic acid and linoleic acid at 14.5% and 8.8% respectively. These compositions compare are similar to the fatty acid profile of olive oil as determined in the study by Arafat *et al.* (2009). Tigernut oil can therefore be said to be similarly nutritious as olive oil. Hazelnut oil and avocado oil have a similar fatty acid profile as Tigernut oil (Dubois *et al.*, 2007).

Table 2.1: Proximate composition of Tigernut tubers (g/100g)

Moisture	Carbohydrate	Fat	Protein	Ash	Fibre	Total sugar
26.00	43.30	24.49	5.04	1.70	8.91	15.42

Reference: Alegria-Toran and Farre-Rovira (2003)

The protein content of Tigernut has been reported to be about 5.04% (Sanchez-Zapata *et al.*, 2012). Adekanmi *et al.*, (2009) reported a protein content of 4.27% in Tigernut from Nigeria. Arafat *et al.* (2009) who worked on Tigernut from Egypt reported a protein content of 5%. Arafat *et al.*, (2009) determined the amino acid profile of Tigernut tubers. Varying levels of 17 out of the 20 food amino acids were found. Glutamic acid, aspartic acid and methionine were the predominant amino acids found. Though called Tigernut, it is not a nut, but a tuber. Tigernut has a higher lipid, protein and carbohydrate content than tubers such as potato, cassava, yam and sweet potato (Sanchez-Zapata *et al.*, 2012). In comparison to nuts, Tigernut has a lower

protein and moisture content than hazelnuts, walnuts, pistachios, pine nuts and peanuts (Ros, 2010). Its carbohydrate and moisture content are however higher than that of the aforementioned nuts (Ros, 2010). Arafat *et al.* (2009) reported on the mineral content of Tigernut tubers. The most abundant mineral in the tuber was calcium at a level of 152 µg/g. Sodium at a level of 140 µg/g, phosphorus at 123 µg/g and magnesium at 55 µg/g. Micro minerals followed this; manganese, zinc, iron and copper were found at levels of 41 µg/g, 1 µg/g, 2 µg/g and 1.3 µg/g respectively.

Table 2.2: Mineral and Vitamin composition of Tigernut tubers

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

Reference: Ekeanyanwu *et al.*, (2010)

Tigernut contain low levels of anti-nutrients. Adekanmi *et al.* (2009) studied the anti-nutritional composition of Tigernut. Tannins content was found to be 2.37 mg/100g and phytates, 21.42 mg/100g. Oxalates and alkaloids were also present at levels of 13.12 mg/100g and 2.63 mg/100g respectively. Ekeanyanwu *et al.* (2010) reported phytates levels of 2.40 mg/100g, tannins at a level of 9.62 mg/100g and cyanogenic glycosides at 1.08 mg/100g. The levels of these anti-nutrients are significantly reduced when the raw Tigernut is processed. Ekeanyanwu *et al.*, (2010) observed a 5% reduction in phytates and a 26% in tannins after roasting of

Tigernut. A 20% reduction was observed for cyanogenic glycosides. Adekanmi *et al.*, (2009) made use of various treatment methods to reduce the anti-nutritional composition of Tigernut. Soaking of Tigernut in distilled water at room temperature for 12 h, soaking in distilled water at 60 °C for 6 – 7 h, toasting in an oven at 120 °C and toasting in an open pan for 10 to 30 minutes were all used. Open pan toasting for 30 minutes resulted in the highest reduction of tannins (71%) and oxalates (77%). Phytates (44%) and alkaloids (27%) were most reduced were most reduced by soaking in water at 60 °C for 7h and oven toasting at 120 °C for 30 min respectively.

2.7 Food Applications of Tigernut

2.7.1 Tigernut Oil

Tigernut oil as shown in (appendix A, picture 10) has been long used as a cooking oil, though among few people (Ezeh *et al.*, 2014) as well as for non-food purposes such as the lubrication of equipment and in the manufacture of soap (Negbi, 1992). According to Ezeh *et al.*, (2014), it is commonly used in the UK fishing industry.

Tigernut oil has been extracted using solvents (*n*-hexane, 2-propanol), by the use of a hydraulic press and by supercritical fluid extraction (Lasekan and Abdulkarim, 2012; Rehab and Anany, 2012; Yeboah *et al.*, 2012). Solvent extraction results in greater recovery of oil, but safety issues exist concerning the possibility of solvents to linger on in the oil (Ezeh *et al.*, 2014). Lasekan and Abdulkarim (2012) carried out a study to optimise the use of liquid carbon dioxide in extracting Tigernut oil. The highest yield of oil obtained was 36.2% using a combination of these conditions; an extraction temperature of 80 °C, an extraction time of 6 h and pressure of 40 MPa.

Fresh Tigernut oil has a golden brown colour (Ekeanyanwu *et al.*, 2010). The refractive index (at 25 °C) of the oil has been reported to be 1.47 (Arafat *et al.*, 2009; Ekeanyanwu and Ononogbu, 2010; Yeboah *et al.*, 2012). Fresh Tigernut oil has an acid value of 0.31 mg KOH/g and an iodine value of 105.8g I₂/100 g (Ezeh *et al.*, 2014). It has a good oxidative stability due to its low content of polyunsaturated fatty acids.

Yeboah *et al.*, (2012) reported the total phytosterol content of Tigernut oil as 986.49 µg/g and 120.1 µg/g as the Vitamin E content. Sitosterol, stigmasterol and campesterol were the main phytosterols found at levels of 517.25 µg/g and 161.35 µg/g respectively. Furthermore, δ^5 and δ^7 -avenasterol were found to be present at levels above 17 µg/g. According to Sanchez-Zapata *et al.*, (2012), Tigernut oil is superior to olive oil in terms of its phytosterol profile as olive contains only 100 µg of phytosterols per gram of oil.

2.7.2 Tigernut Flour and Fibre

Tigernut flour is produced by drying cleaned Tigernut in a solar dryer or oven followed by milling into flour (Oladele *et al.*, 2007). In a method employed by Adejuyitan *et al.* (2009), the Tigernut were fermented by soaking in water for 24 – 72 h before drying and subsequent milling. Ade-Omowaye *et al.*, (2008) produced flour from Tigernut by milling the nuts after they had been dried in a cabinet dryer at 60 °C for 24 h. Aguilar *et al.* (2015a) used a remarkably different method. Tigernut were washed, disinfected and dried at a low temperature of 20 °C for 30 days before milling into flour.

Tigernut flour retains a high percentage of nutrients in the raw Tigernut tubers (Oladele *et al.*, 2007; Adekanmi *et al.*, 2009). Oladele *et al.*, 2007) studied the pasting properties of Tigernut flours. Finding from the study indicate that Tigernut flour has a low breakdown and setback

viscosity. This could make Tigernut flour useful in products that require high temperature and shearing and in cold storage food products. Tigernut flour could also find application in products such as breads, ice creams and confectioneries due to its good foaming capacity and stability, gelation capacity, water absorption and oil absorption capacities.

The flour has been used together with soybean flour and maize flour in the production of cookies (Awolu *et al.*, 2016). The most preferred cookie in the study had a 5% Tigernut composition. Ade-Omowaye *et al.*, (2008) developed composite flours from wheat flour and Tigernut flour. A 90% wheat flour: 10% Tigernut flour produced dough with good visco-elastic properties. Quality attributes and sensory properties of bread baked with this composite flour were comparable to that of 100% wheat flour. Tigernut flour can be used as an emulsifier and shortening (Aguilar *et al.*, 2015b) in gluten-free bread. Aguilar *et al.*, (2015a) reported that Tigernut flour is a good substitute for soy flour in the making of gluten-free bread.

Tigernut fibre is produced as a by-product of the Tigernut milk manufacturing process. Sanchez-Zapata *et al.*, (2010) investigated the use of Tigernut fibre in the manufacture of pork burger. Tigernut fibre was used at levels of 5%, 10% and 15%. Tigernut fibre significantly improved the nutritional value, cooking yield and moisture retention of the pork burgers. However, undesirable changes were observed in colour, and texture with increasing levels of Tigernut fibre incorporation. Sensory evaluation of the pork burgers showed that the ones with Tigernut fibre were given lower scores in greasiness, juiciness and meaty flavour. This did not have any significant effect on the overall acceptability of the pork burgers. Aguilar *et al.*, (2015a) reported that use of Tigernut fibre in bread improves its loaf volume, crumb characteristics and sensory attributes.

2.7.3 Tigernut Milk

Tigernut milk as shown in (appendix A, picture 9) is known as '*atadwe milk*' in Ghana. It is a water extract of Tigernut and may be consumed sweetened or unsweetened. Tigernut milk is nutritious. The protein and fat content of Tigernut milk ranges between 2 to 7% and 17 to 25% respectively (Udeozor, 2012; Asante *et al.*, 2015; Kizzie-Hayford *et al.*, 2015). The absence of lactose in Tigernut milk makes it an ideal alternative for consumers who are lactose intolerant. It has no known allergens unlike soymilk. Cow's milk has been substituted with Tigernut milk in the production of yoghurt (Sanful, 2009; El-Shenawy *et al.*, 2012). El-Shenawy *et al.*, (2012) reported that 10% substitution of cow's milk with Tigernut resulted in yoghurt with higher apparent viscosity and lower whey syneresis than 100% cow milk yoghurt.

According to experts, it is a nutritious and nourishing drink recommended to be taken during any time of the year, but most especially during the dry season (Bamishaiye, 2011). The drink is very high in vitamins C and E, minerals like calcium, magnesium, potassium, phosphorus and iron, carbohydrates, protein and unsaturated fats (www.Tigernut.com). According to Chevallier (1996), the calcium, iron and magnesium in Tigernut, drink is higher than what is found in cow's milk. Therefore, it can be a very good substitute for cow milk. Research has revealed that Tigernut can be added to other beverages to boost its nutritional content. Belewu and Abodunrin (2006) studied the effect of Tigernut on "Kunnu", a non-alcoholic beverage prepared from cereals like millet and sorghum. Their results revealed that "Kunnu" from Tigernut was more nutritious and acceptable than "Kunnu" prepared from either millet or sorghum. This result was in line with what Abdel-Nabey (2001) found out with respect to Tigernut drink being greatly acceptable. Though nutritious, the extensive use of Tigernut milk in children is not recommended due to its low protein content (Katz *et al.*, 2005).

Another study by Sanful (2009) which investigated the production of yoghurt from cow milk, Tigernut milk and their composite revealed that the quality characteristics for the yoghurt prepared from cow milk and the composite were rated as being the same. This means that there is a possibility of the addition of Tigernut to cow milk to produce affordable and nutritious yoghurt. A study by Emmanuel-Ikpeme *et al.*, (2012) on the use of soya bean flour and Tigernut flour in producing weaning diets revealed that the formulated foods especially the mixture of 55% Tigernut and 35% soya bean with 10% of milk contained appreciable amounts of macro and micro elements and hence would be suitable for infants. Udeozor (2012) also prepared a drink from Tigernut and soymilk and found that the milk prepared from Tigernut and soybean could be used as a beverage for both the young and old due to the high nutrient contents like protein and fat.

2.7.4 Extraction of Tigernut Milk

The production of Tigernut milk follows four major stages; washing of the Tigernut, grinding, pressing and addition of other ingredients (Sebastia *et al.*, 2012). Belewu and Belewu (2007) washed and blended Tigernut, using 6 L of water to 1 kg of nuts. The resulting mass was centrifuged and the supernatant collected as Tigernut milk. Sanful, (2009) produced Tigernut milk by soaking the nuts overnight after they had been washed. The nuts were then blended several times and strained. The resulting Tigernut milk was pasteurised at 90 °C for 15 min and cooled to 43 °C for 12 h before bottling. Sanful (2009) roasted Tigernut before following with the aforementioned main stages of processing the milk. Results from the study showed that the use of roasting in the process improved the sensory appeal of the Tigernut milk. Corrales *et al.* (2012) and Sanchez-Zapata *et al.*, (2012) produced Tigernut milk following the traditional method of the Spanish “horchata de chufa”. Washed Tigernut were soaked for about 8 h and

ground using 5 L of water per kilogram of nuts. The resulting mass was then pressed to obtain an extract that was sweetened with sugar.

Bamishaiye and Bamishaiye (2011) had employed a similar method. These authors proposed 3 L of water to 1 kg of Tigernut during blending as well as adding other ingredients including cinnamon and lemon. Udeozor (2012), however omitted the soaking step in a study on Tigernut-soy milk preparation. In the study, fresh Tigernut after being washed were grinded. The extract was then pasteurised at 72 °C for 5 s and homogenised to obtain Tigernut milk. Djomdi *et al*, (2007) on the other hand varied the soaking temperature (20 – 100 °C) of Tigernut prior to milk extraction. They found out that the yield of Tigernut milk increased with increasing soaking temperature. The study however did not carry out a sensory evaluation of the milk produced, thus it cannot be seen if soaking temperature affects sensory characteristics of Tigernut milk.

Ukuwuru and Ogbodo (2011) experimented different methods in producing Tigernut milk in a bid to optimise the process. Beyond the main steps of washing, grinding and pressing, Ukuwuru and Ogbodo (2011) undertook fermentation, pasteurisation and sterilisation of the Tigernut milk. Fermented Tigernut milk was produced by boiling the extracted milk at 80 °C for 30 min. The milk was cooling and fermentation of the milk, packaging and pasteurisation. Sterilised milk was produced by soaking the Tigernut in water at 40 °C for 3 h. The Tigernut were then blended, mixed with water and the milk extract clarified. The milk was then preheated at 50 °C for 30 min, bottled and sterilised at 130 °C for 10 s. Sensory evaluation of the final products revealed that the milk which was sterilised was the most preferred product.

In another method by Kizzie-Hayford *et al.*, (2015), 50 g of Tigernut were first washed with demineralised water. Following this, the Tigernut were soaked in 400 mL of water and heated at 40 °C for 24 h. The nuts were washed a second time using demineralised water and blended between 1 to 3 min. Kizzie-Hayford *et al.*, (2015) further comminute the resulting mush using an ultra-turrax mixer. The final mush was then pressed through a filter of pore size 4 µm. Findings from the study showed milk produced through this method had good colloidal stability and that the yield of milk improved with longer duration of blending. Up scaling this method from the laboratory to an industrial scale may not be cost-effective though.

2.8 Food Applications of Tigernut Milk

Tigernut is a nourishing food together with its derivative produce, Tigernut milk with it gradually drawing extra scientific and technological receptiveness. Nonetheless, there is a greater attentiveness in the manufacture of Tigernut milk and its associated oil. The unceasing improvement of innovative goods from the tubers and using its derivative products is augmenting progressively the consciousness in this food. The high dietary fibre content in Tigernut makes it effective in the treatment and prevention of many diseases plus coronary heart disease, obesity, diabetes, gastrointestinal disorders, colon cancer, and in weight management. Tigernut contains a moderate amount of protein, which is also a source of some valuable minerals such as potassium, phosphorus, calcium and vitamins E and C. Tigernut milk is stated to be used in the treatment of diarrhea, dysentery, flatulence and indigestion. The starch content presumably provides prebiotic properties for colon bacteria. Additionally, Tigernut has been demonstrated to encompass higher essential amino acids than those recommended in a protein standard by the FAO/WHO for satiating adult needs.

Tigernut milk is establish to be good for averting arteriosclerosis, because its consumption can help prevent heart problems and thrombosis and also activate blood circulation, mainly since its unsaturated fatty acid content is equivalent to that of olive oil and its arginine is a precursor of nitric oxide that helps the veins to develop. Diabetics for its low-glycemic carbohydrates content due to its arginine, which frees hormones that produce insulin, could take Tigernut milk. The milk is also an appropriate drink for gluten intolerant celiac patients, and for the lactose-intolerant who stay away from cow milk and many dairy foods. Tigernut milk is a rich source of essential nutrients that are vital for growing children and adults (*Tigernut.com, Traders s.l*).

2.9 Non-food Applications of Tigernut Milk

(Ofoefule, 2012) reported on the use of Tigernut milk for ethanol production. By-products from Tigernut milk processing are used as animal feed (Sanchez-Zapata *et al.*, 2012. Tigernut milk and its components are also mostly used in foodstuffs in many different forms. Nevertheless, Tigernut milk constituents also find numerous alternative applications in the non-food area such as in the manufacture of plastic materials (Southward C.R., Walker N.J., (1980), textile fibres (Feretti A., 1997), glues (Tague E.L., 2006). or in the production of ethanol or methane (Kilara A., *et al.*, 1992). Some of these technical applications have been well known for a long time, such as casein-based glues which were used in ancient Egypt (Tague E.L., 2006), but novel uses are also proposed for opening new markets for the components. Most of the technical applications are specific to one given Tigernut milk component in relation to its structural and functional properties. Separation and extraction techniques may be of importance in the valorisation process of such individual components. Valuable components can be recovered by chemical and/or physical means in Tigernut milk as well as other dairy products: casein is precipitated by adjusting pH to 4.6 (Kinsella J.E., 1984), whey proteins are recovered

by ultrafiltration (Di Giacomo, *et al.*, 1996), lactose is concentrated and crystallised from whey (Hobman, 1994). Besides, some applications concern the non-food uses of fractions containing different components together, which greatly simplify separation steps.

2.10 Health Benefits of Tigernut

According to Mason (2005), Tigernut have a high content of soluble glucose and oleic acid, along with high-energy content (starch, fats, sugars and proteins). Tigernut are rich in minerals such as phosphorous, potassium, calcium, magnesium and iron. These are necessary for bones, tissue repair, muscles, and the blood stream and for body growth and development. It is also rich in vitamins E and C. Tigernut have high content of arginine and has high amounts of carbohydrates with a base of sucrose and starch (without glucose), (Chevallier, 1996; Tigernut Traders, 2005), which liberates the hormone that produces insulin and as such sugar-free Tigernut drink is suitable for diabetics and also helps to control weight (Martinez, 2003). It also provides digestive enzymes like the catalase, lipase and amylase and as such good for those who suffer from indigestion, flatulence and diarrhea. Tigernut contains an appreciable amount of vitamin B1, which assists in balancing the central nervous system and helps the body to adapt to stress. It also contains a substantial amount of oleic acid, which has positive effect on cholesterol, thereby preventing thrombosis and cholesterol and activates blood content of soluble glucose. It also prevents constipation and reduces the risk of colon cancer. (David, 2005; Tigernut Traders, 2012). The milk of Tigernut contains Vitamin E, which reduces the harmful effects of low-density lipoprotein cholesterol (LDL) (Ahmed *et al.*, 2009) and is very essential for fertility in both men and women. Research shows that 100g of Tigernut contains approximately 7% of protein, 26% fats, 31% starch and 21% carbohydrates. It is also thought to contain approximately 26% fibre of which 12% is soluble and 14% insoluble (Childers, 1982). In China, Tigernut milk is used as a liver tonic, heart stimulant, cure for serious stomach

pain, to promote normal menstruation, to heal mouth and gum ulcers, used as a powerful aphrodisiac (sexual stimulant). They are used to treat inflammations, breast lumps and cancer (Belewu and Belewu, 2007).

Tigernut are used as an antivenin by some ethnic groups in Brazil. Tigernut extracts have also been used to treat fever and measles (De Abreu Matos *et al.*, 2008). The high fibre content of Tigernut can help in the prevention of coronary heart disease, diabetes, colon cancer and gastrointestinal disorders (Adejuyitan *et al.*, 2009; Anderson *et al.*, 2009; Ekeanyanwu *et al.*, 2010). Borges *et al.* (2008) reported that Tigernut could be essential in weight management due to its high fibre content. Using Tigernut fibre as part of diet reduces the calorie intake while making consumers feel full.

Tigernut is a good source of vitamin E, vitamin C, and minerals such as phosphorus, calcium, magnesium and potassium (Yeboah *et al.*, 2012; Arafat *et al.*, 2009). Bixquert-Jimenez (2003) reported on the treatment of gastrointestinal infections using Tigernut milk. Ekeanyanwu *et al.*, (2010) reported that consumption of Tigernut milk promotes blood circulation and reduces the risk of arteriosclerosis. Alegria-Toran and Farre-Rovira (2003) suggest that Tigernut starch can serve as a prebiotic, enhancing the population of beneficial bacteria in the colon. According to Bosch *et al.*, (2005), Tigernut contains a higher amount of essential amino acids than the recommended amount by the FAO/WHO for adults.

Ekeanyanwu *et al.*, (2010) studied the biochemical effect of phytochemicals in Tigernut using Wistar rats. There was a significant reduction in the blood glucose level of the rats with increasing doses. This could find potential application for diabetics. On the other hand, serum

albumin levels increased with increasing doses. Tigernut is also used as an aphrodisiac in Ghana, Nigeria and Brazil (Bamishaiye and Bamishaiye, 2011).

2.11 Canning

Canning is a food preservation method in which the food contents are processed and sealed in an airtight container. The process has been typically defined as a method of food preservation which involves an initial sealing of the food in air-tight jars, cans or pouches, followed by subsequent heating to a temperature that destroys microorganisms that reserves health or spoilage potential. Huang *et al.*, (2016) also defined canning as a method that sterilizes food by heating in airtight containers to achieve commercial sterility. The authors maintained that this allowed the food to be stored at room temperature without compromising its safety and sensorial quality for several months and even years. The technology is most often also referred to as sterilization. This is so because the heat treatment used eliminates all microorganisms including those that are directly pathogenic to humans and those that affect humans through the production of toxins.

Attempts by several researchers to investigate how canning preserves food and warrants it with a relatively longer shelf life than other food preservation techniques have led to one of the following. Apart from preventing the growth of undesirable microorganisms, most researchers have also stated that a deactivation process occurs for almost all food enzymes thereby arresting key food deterioration processes (Pither, 2003). The effects of moisture loss leading to reduced water activity coupled with subsequent impairment of oxygen related deterioration reactions have also been emphasized.

In general, two types of canning techniques have been established as retort processing and out-of-container sterilization. Retort processing is also called in-container sterilization. In in-container sterilization, the food product is packed in containers such as metal cans and glass jars. The pack is then heated using a retort process or steam until the center of the product attains the required temperature for sterilized products. Typically retort processing can be applied to all types of food (Huang *et al.*, 2016). In out-of-container sterilization, a separate sterilization is done for both package and product. This is then followed by packing or filling and sealing under aseptic conditions. The use of out-of-container sterilization is mostly limited to liquid foods (Huang *et al.*, 2016). Generally, the process can be broken down into three key phases: heating phase, holding phase and the cooling phase. During the heating phase, water or steam is used to heat the product increasing its temperature from ambient temperature to the required temperature to achieve sterilization. This temperature is then maintained for the stipulated period-defined holding phase. In the cooling phase, air or water is introduced as the cooling medium and the temperature of the product decreases prior to storage (Huang *et al.*, 2016).

Canning is seen to produce food products with relatively longer shelf life than most food preservation techniques. Blumenthal *et al.*, (1990) states that the shelf-life of canned products typically ranges from one to five years, though some canned products has been found to have lasted over thirty (30) years. Pither, (2003) also indicated that, the reliance of heat treatment for destruction of microorganism and preservation of food seems to provide such products with an indefinite microbiological shelf-life provided the packaging remains intact.

The history of the canning process can be traced to Napoleon Bonaparte. He catalysed the search for a better method of food preservation during the late 1700s. “An army travels on its

stomach,” was his believe and therefore looked for a better way to satisfy his army’s stomach needs. Accordingly, Napoleon offered a fortune to anyone who developed a method of preserving food on a large scale. Nicholas Appert claimed the prize years later in 1810, but it still took around 50 years before his method trickled down to the average family. This occurred soon after 1858, when John Mason invented the iconic, reusable “Mason Jar”. Canning became extremely popular. It was a safe, effective, inexpensive, and relatively simple process. People were now able to use one method to preserve just about anything: fruits, vegetables, soups, sauces, fish and meats. The canning process was quite simple. First, a tin can or glass jar was filled with food and liquid (usually water). After the container had been sealed, it was heated and often put under pressure. This process killed any microorganisms that could cause illness or spoil food. When the can or jar is removed from the water, the air inside compresses and seals the contents off from the outside world. The seal then protects the food from new microorganisms entering and from oxidization from the air. After this, the food could be conveniently stored and reused later.

There are various packaging materials for canning including, metal cans, glass cans, thermostable plastic cans, multi-layered flexible pouch and many others. Canning comes with several advantages, some being its ability to physically protect the contents during storage, transportation, handling, and distribution. Canning has the advantage of making seasonal foodstuff available all year round. Prior to the advent of refrigeration, canning was the main means of prolonging the shelf life of seasonal crops.

2.12 Safety of Canned Foods

The term food safety generally encompasses processes of handling, preparation and storage that reduces the risk of foodborne illnesses. In canned foods, the safety can be pivoted on two key principles: proper canning techniques and effective and efficient sterilization procedure. The two main issues had to be with lead poisoning and microbial contamination, however with elimination of lead soldered cans in the food industry, the critical safety issue of concern has to do with the latter.

It is well known that the intention of canning is to destroy microbial contaminants to allow for safe foods, however, under processing, inadequate cooling and pre-process spoilage can result in critical microbiological safety issues (Oranusi *et al.*, 2012). It must be stated that canning also creates the right conditions for certain microorganisms to proliferate. The high heat treatment, reduced oxygen content in cans, water activity and pH of the packaged foods can allow certain microorganisms to grow when initially contaminated with their spores. In a study conducted in Nigeria, researchers were able to isolate organisms such as *B. coagulans*, *B. cereus*, *B. subtilis*, *C. sporogenes* and *C. perfringens* from various canned foods (Oranusi *et al.*, 2012). Table 3.2 gives microbial contaminants isolated from various canned foods. The researchers indicated that the microbial contamination levels were however below the acceptable microbial limit of 10^6 . The presence of the isolated organisms was however attributed to quality of the raw materials, under processing, pre-process contamination and to the level of stringency in production.

Table 2.3: Microorganisms isolated from canned foods

Canned Foods	Microorganisms isolated
Meat	<i>B. cereus</i> , <i>B. subtilis</i> , <i>C. Perfringens</i>
Milk (Plant)	<i>B. coagulans</i> , <i>Bacillus spp</i>
Mixed Vegetables	<i>B. subtilis</i> , <i>S. aureus</i> , <i>Klebsiella spp</i> , <i>B. circulans</i>
Sardine	<i>S. aureus</i> , <i>C. sporogenes</i> , <i>Klebsiella spp</i>
Tomatoes	<i>B. coagulans</i> , <i>S. aureus</i> , <i>S. epidermides</i>

Clostridium botulinum is the most implicated organisms with respect to canned foods. The organism has the following features: spore forming, grows in the absence of oxygen, heat resistant and toxin producing. These features particularly explain why most industry players relate safety of most canned foods to the absence or presence of *Clostridium botulinum*. The vegetative form of the organism under moist low acid conditions, less than 2% oxygen and a temperature range of 4 – 40 °C multiply rapidly to produce deadly toxin within 3 – 4 days. When the organism is protected inside a spore it could survive temperatures as high as 100 °C even for 5 . *Clostridium botulinum* is most often the indicator organism used in most canned products.

2.13 Canning Milk from Nuts

There are two schools of thought about canning milk from nuts. One school says the risk of salmonella is very low, but a risk, thus the USDA canning regulations do not offer a procedure to can milk from nuts. The National Center for Home Food Preservation has withdrawn it's information on how to can any milk from nut, with the exception of green peanuts (which we all know are really legumes). The risk of moisture seeping into the jars during the canning process is where the risk really lies. So while you might find some instructions on canning milk from nut from the second school of thought, do so with the understanding that the USDA considers there to be some risk. If you have a Food Saver a Rival Seal a Meal or other vacuum

sealer, you can use their canning jar attachments to vacuum ‘can’ your milk from the nut into canning jars. This helps keep them fresher than if you just kept them in a jar. Be sure to add an O2 absorber into each jar and/or a silicone gel pack (to help reduce moisture). You are not canning in the traditional sense of the word, but taking out the air, which is one of the biggest reasons things go bad.

2.14 Gaps in Literature

This chapter looked at plant-based milk and its relationship to the health of humans. It noted that the health of human beings was largely dependent on the foods eaten as diseases and conditions such as diabetes, stroke, obesity, atherosclerosis etc. had been linked to dietary habits. Due to this, it concluded that many people were diverting to the usage of plant-based and organic food products. For example, according to Hasler (1998), foods such as tomatoes, broccoli, oats and yoghurt had received considerable attention because of their reported health benefits. Again, it had been identified that many consumers go in for milk products from plant origin either for health reasons or as a choice of lifestyle (Makinen *et al.*, 2016).

In Ghana, many plant-based products including Tigernut are cultivated in many areas of the country including Bawjiase, Techiman, Chiraa, Tanoso, parts of Northern Ghana, parts of Central Region, and the Kwahu ridge making the country rich in plant based milk such as Soy milk, sikhye, quinoa milk, flax milk, oat milk, and hazelnut milk. So far, there is not enough literature on the production and preservation of Tigernut milk though studies show that it has a short shelf span after harvesting. Canning as a food preservation method enables the food contents to be processed and sealed in an airtight container to prevent the product from a potential spoilage. Studies conducted by researchers on Tigernut have concentrated on its derivatives and benefits (Bamishaiye *et al.*, 2011), the effects of moisture content on the

physical properties of Tigernut (Abano, *et al.*, 2011) and the morphological characterization and evaluation of Tigernut in Ghana (Dakogre, 2008). The closest researchers have come to, was to look at the production and sensory evaluation of Tigernut beverages (Sanful, 2009), the Physicochemical properties of flour obtained from fermentation of Tigernut (Adejuyitan, *et al.*, 2009) and the extraction of oil from Tigernut with super critical carbon dioxide (Asekan, *et al.*, 2012). The next chapter maps out the production processes in Tigernut milk production to evaluate the microbial and sensory properties of canned Tigernut milk, a gap in literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Source of Materials

The Tigernut used were procured fresh from an indigenous grower of the plant at Okorase in the Eastern region of Ghana. Metallic Cans were also obtained from Pioneer Food Cannery, Tema, Ghana. Machines and chemicals used were of standard quality and obtained at the, Food Science Laboratory, Microbiology Laboratory, Forensic Laboratory and the Product Development Laboratory all of the Kwame Nkrumah University of Science and Technology.

3.2 Tigernut milk production

Tigernut were washed three times in a 15 L bowl of water to remove bad nuts and other extraneous materials, which naturally floats on the water surface. The Tigernut were then soaked the fourth time with the same quantity of water (15 L) but with added 0.1 mL of food grade bleach for 5 min. The Tigernut are then poured into a plastic strainer to allow water to drain. 1.5 kilogram of the nuts is weighed and spread in bits on a tissue paper on a wooden chopping board. The tissue paper serves to further drain water on the nuts. Each nut is then cut into two to identify and get rid of additional bad nuts. The cutting is done until the quantity of nuts required (1.5 K) for production is attained. The milk product is dispensed into the thoroughly washed Cans for canning and retorting. Three methods were used in the extraction of the Tigernut milk, namely; traditional method, microwaved method and the cooked method.

3.2.1 Traditional method

This followed the traditional method of Tigernut milk production as outlined by Udeozor (2012). 1.5 kg wholesome nuts were milled using a Fitzpatrick hammer mill (R28902, USA) as shown in (appendix A, picture 12) and subsequently mixed with 6 L purified water to obtain a homogenous slurry. The slurry obtained was filtered with a clean cheesecloth to obtain Tigernut milk. The final product is weighed (100 mL) into the washed Cans as shown in (appendix A, picture 5) for canning and retorting.

3.2.2 Microwaved Tigernut milk

The wholesome nuts obtained were microwaved using a Home base microwave oven (EW-G205AW, China) at 900 W power rating for 1 and 2 min. The Tigernut were milled using a Fitzpatrick hammer mill (R28902, USA). The resulting pulverised mass was dissolved in water (1.5 kg: 6 L water) and filtered using a cheesecloth, to separate the milk from the fibre. The milk is weighed and canned using cans as shown in (appendix A, picture 5) for retorting.

3.2.3 Cooked Tiger nut milk

This procedure combines both the traditional and microwave methods. The healthy Tigernut (1.5 kg) were microwaved (EW-G205AW, China) and milled using a Fitzpatrick hammer mill (R28902, USA). The resulting mass was mixed with water (6 L water) to obtain a slurry. The slurry was filtered and the filtrate heated at 50 °C for 30 min using a Master Chef Free standing oven (MC-OR5080, China). It was left to cool down. This was followed by canning and retorting.

3.2.4 Canning and Retorting

Cans (appendix A, picture 5) were filled with 100 mL of the various Tigernut milk produced. The cans were sealed with Electrical Food canning machine (HHSMNS88, China) as shown in (appendice A, picture 11). The cans were then packed into a laboratory retort with Vertical Pressure Steam Sterilizer Retort and retorted at a temperature of 121 °C for 15 min.

3.3 Microbial Assay

3.3.1 Sterilisation and Media Preparation

Glassware, spreaders and Petri dishes were sterilised in a hot air oven at 200 °C for 30 min. Pipette tips were sterilised by autoclaving at 121 °C for 15 min. The media used; buffered peptone water (BioLab Inc, USA) and plate count agar (OXOID, England) were weighed into washed media bottles according to manufacturer's instruction and autoclaved at 121 °C for 15 min. About 15 – 20 mL of sterilised plate count agar was poured into each sterilised Petri dish and incubated at 37 °C for 24 h. Petri dishes were checked at the end of the incubation period for growth. Sterile Petri dishes were then used for inoculation and incubation.

3.3.2 Serial dilution

Ten gram of the respective tiger nut milk samples was weighed into 90 mL of the sterile diluent (sterilised buffered peptone water) and shook for 30 s. Subsequent dilutions were prepared by adding a 1 mL aliquot of the initial solution to 9 mL of the sterile diluent.

3.3.3 Inoculation and Incubation

The total viable count was enumerated by the spread plate method. An inoculum of 100 µL of the dilutions was dispensed onto Petri dishes and spread evenly. Inoculated plates were incubated at 37 °C for 24 h. A colony counter was used in counting colonies at the end of incubation and recorded as total viable count.

3.4 Sensory evaluation

Sensory evaluation was carried out in a sensory laboratory with partitioned booths and sufficient lighting. Forty-five (45) through a designed questionnaire as shown in(appendix B picture 1), assessed all Tigernut milk samples. The milk samples were given 3-digit codes and presented to panellists in plastic cups. Panellists were required to assess each sample using a 5-point hedonic scale, where 1 was ‘dislike strongly’, 2 ‘dislike’, 3 ‘neither like nor dislike’, 4 ‘like’ and 5 ‘like strongly’. Colour, taste, aroma, mouthfeel, consistency and aftertaste were the attributes assessed by panellists. Panellists were provided with water as a palate cleanser after assessing each sample. Overall acceptability was determined by summing the sensory scores for each sample. A distribution was fitted for the various samples using the Palisade @Risk Software. The minimum, maximum, mean, mode, median as well as 5th and 95th percentiles of the distribution were recorded.

3.5 Data Analysis

Statistical investigation was done on the sensory scores by means of ANOVA. The test was carried out at a confidence interval of 95% and Tukey’s HSD method was used for the post-hoc multiple comparison test.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Microbial profile after production

A microbial assay was conducted every two hours for eight hours to ascertain the effectiveness of the process. The results showed the absence of microbial growth in all samples up to the 6th hour (Table 4.1)

Table 4.1: Microbial profile of Tigernut milk 8 hours after production

Product	0 h	2 h	4 h	6 h	8 h
CTM	ND	ND	ND	ND	ND
M1ET	ND	ND	ND	ND	ND
M2ET	ND	ND	ND	ND	ND
TM1ET	ND	ND	ND	ND	ND
TM2ET	ND	ND	ND	ND	<30

CTM: Cooked Tigernut milk; M1: Microwaved Tigernut milk, 1 min; M2: Microwaved Tigernut milk, 2 min; TM1: Traditional Tigernut milk, soaked for 5 min; TM2: Traditional Tigernut milk, soaked for 5 min; A: Ambient condition; ET: Elevated temperature; ND: None Detected

At the 8th hour, almost all samples still indicated the absence of microbial growth with the exception of TM2 which had some amount of growth, but was insignificant (<30). These spores were then growing into vegetative forms with the establishment of favourable conditions in the cans. Similar ‘after production’ growth trends were obtained by Ukwuru *et al.* (2011). It should be noted that milk products are usually easily perishable and may be rendered unfit for human consumption even few hours after production by contaminating bacteria and mold (Ukwuru *et al.*, 2011). Hence the safety and quality of such products should as often as possible be investigated immediately after production.

4.2 Microbial quality and safety assessment

The assessment of the microbial load of the products over the 8-week storage period showed results exhibiting similar trend as observed for the hourly study. The microbial loads over the storage period had no significant increase in load over time for some of the product formulations. Others however recorded some microbial growth with increasing counts over time. The recorded counts however were within the acceptable limit as recommended by the regulation. Almost all samples stored under refrigerated and ambient conditions had no microbial growth detected after the 8 weeks of storage. This observation suggests a good quality and safe product even after the time of storage. It goes to tell the effectiveness of the sterilization process. In most instances, spores would have developed into vegetative forms by an 8-week period at favourable conditions. An emphatic conclusion of the shelf stability of the product being far beyond an 8-week period can be ascertained. This totally deviates from the known short shelf life of the natural Tigernut milk drink (Sebastia *et al.*, 2012). Perhaps this trend could be due to the strict compliance to sterilization principles during the canning process. It must be stated that the cold point principle suggested by FAO was not employed. The principle seeks to bring a compromise between food microbiological safety and food quality requirements by quantifying the amount of heat to which a particular canned product should be exposed to during sterilization prior to canning. The protocol used focused on providing high enough heat for the complete elimination of microorganisms, their spores and inactivation of their toxins. The growth recorded for the TM2 samples can be attributed to the malfunctioned autoclave and perhaps a contamination to that batch of samples. That notwithstanding it is seen that the recorded growth does not compromise the safety of the product during this 8-week storage period since the obtained values are within the acceptable limits. The shelf life however could not be seen as one extended beyond the 8-week period with critical examination of the rate of growth.

Table 4.2 Microbial quality of canned Tigernut milk during 8 weeks of storage under refrigeration and ambient temperature conditions

Weeks	CTM	CTMA	M1RF	MIRA	M2RF	M2RA	TM1RF	TM1RA	TM2RF	TM2A
0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND	<30
3	ND	ND	ND	ND	ND	ND	ND	ND	ND	<30
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	$6.6 \times 10^2 \pm 4.51$
5	ND	ND	ND	ND	ND	ND	ND	ND	ND	$3.7 \times 10^3 \pm 5.13$
6	ND	ND	ND	ND	ND	ND	ND	ND	<30	$9.8 \times 10^3 \pm 10.03$
7	ND	ND	ND	ND	ND	ND	ND	ND	<30	$1.4 \times 10^4 \pm 5.51$
8	ND	ND	ND	ND	ND	ND	ND	ND	$3.6 \times 10^3 \pm 5.57$	$8.7 \times 10^5 \pm 7.00$

CTM: Cooked Tigernut milk; M1: Microwaved Tigernut milk, 1 min; M2: Microwaved Tigernut milk, 2 min; TM1: Traditional Tigernut milk, soaked for 5 min; TM2: Traditional Tigernut milk, soaked for 5 min; A: Ambient condition; RF: Refrigeration condition; ND: Not detected

4.3 Sensory Analysis

As anticipated, changes in process methods variably influenced the sensory appeal for the final product. For the colour, it can be observed that the microwaved samples (M1 and M2) had mean scores that are significantly ($P < 0.05$) different from the soaked samples (TM1 and TM2). This is perhaps due to Maillard reaction that occurred during the microwave heating causing browning in the final product (Maillard, 1912). The cooked sample (CTM) was found not to be significantly different from the microwaved sample ($P > 0.05$). This perhaps could suggest similarities in chemical changes resulting from the microwave heating and the open gas heating done after the extraction. It must however be stated that the mean value for the consumer's preference for colour ranged from 3.18-4.05. These literally translate borders around neither like nor dislike region to the moderate likeness. (Okyere, *et al.*, 2014), (Udeozor, 2012), (Awonorin, *et al.*, 2014) in their study obtained similar scores for colour when they

extracted milk from irradiated Tigernut samples, Tigernut-Soy milk drink and chemical properties of Tigernut-Soy milk extract.

Table 4.3: Mean sensory scores of Tigernut milk samples

Sample	Colour	Smell	Taste	Aftertaste	Mouthfeel
M1	4.05 ^b	3.51 ^a	3.18 ^{ab}	3.46 ^b	3.31 ^{ab}
M2	3.72 ^{ab}	3.08 ^a	2.90 ^a	3.13 ^{ab}	3.03 ^{ab}
TM1	3.18 ^a	3.38 ^a	3.08 ^{ab}	3.08 ^{ab}	2.97 ^{ab}
TM2	3.28 ^a	3.00 ^a	2.76 ^a	2.85 ^a	2.77 ^a
CTM	3.97 ^b	3.31 ^a	3.49 ^b	3.33 ^{ab}	3.41 ^b

Values with different superscript in the same column are significantly different ($p < 0.05$)

Consumer's preference for smell of the various samples however differed from that of colour. The mean score ranged from 3.00 to 3.51 still hinging on the neither like nor dislike region. There was however no significant difference between all samples ($p > 0.05$). This implies none of the processing methods affected consumer's preference for smell of the Tigernut. Smell is generally defined as the sensation produced when volatile compounds stimulate the olfactory receptors of the nasal cavity. The results therefore imply similar volatile compounds are produced with the different processing methods. With Various sensorial studies on Tigernut milk, consumers assessment of smell or aroma is usually lowly rated (Ukwuru *et al.*, 2011; Oranusi *et al.*, 2012; Amponsah *et al.*, 2017). This perhaps reiterate the notion that certain inherent sensorial qualities of the Tigernut are not much liked by most consumers.

The 'taste' mean scores ranged from 3.49 -2.76 with the traditional method sample getting lower rating and that which was cooked after extraction highly rated in this attribute. With average acceptability scores of 3.08 and 3.08, samples TM1 and M1 were not significantly

different from the highest scoring sample, CTM ($p>0.05$). Samples M2 and TM2 although least preferred, were not significantly different. The relatively longer processing times might have impacted negatively on the taste of the samples. Taste is a 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 (Moon, *et al.*, 1999). The taste scores imply the possibility of a low impact on consumer purchasing behaviour.

The 'aftertaste' followed a similar trend as that of the taste with the processing methods invariably affecting consumers' preference for the parameter. With no significant differences for the microwaved samples (M1 and M2), the cooked sample (CTM) and sample TM2 was the least accepted in terms of aftertaste with a mean score value of 2.85.

The 'mouthfeel' refers to the attribute of a beverage to flow without any lagging, particularly of insoluble particles. The mean score of the cooked Tigernut milk sample was highest (3.41) which was not significantly different ($p>0.05$) from the 1 min microwaved sample. This intend was not different ($p>0.05$) from the 2 min microwaved sample. This could be due to the fact that moisture was lost in these heat treated samples. This moisture loss coupled with release of fat molecules into solution due to the heating could be the reason of the relatively higher mouthfeel scores for these samples. Comparative to other similar plant based milk products, Tigernut has a higher fat content and hence it was expected to record higher mouthfeel scores, reiterating the fact that fat is a good promoter of mouthfeel. The low mouthfeel scores were however comparable to that of (Udeozer, 2012). It is important to note however that the value ranges still border around the neither like nor dislike region and hence adjustments could be made to the methods to improve these sensory scores.

4.3.1 Sensory Acceptability

Table 4.4 indicates a fitted distribution of the sensorial preference of consumers for the four (4) types of Tigernut milk products. An adjusted scale with 6 being “dislike strongly” and 30 indicating the highest preference – “like strongly”. For the microwaved samples, M1 and M2 representing microwaving for 10 and 20 min respectively had a similar range of preference (12-28).

Table 4.4: Statistical distribution of sensory acceptability of Tigernut milk with different treatments.

Sample	Min	Max	Mean	Median	Mode	5 th	95 th
M1	12.00	28.00	21.02	21.00	N/A	15.00	27.00
M2	12.00	28.00	18.87	19.00	N/A	12.00	25.00
TM1	10.00	26.00	18.40	19.00	18.00	10.00	26.00
TM2	8.00	26.00	17.56	18.00	N/A	8.00	24.00
CTM	8.00	29.00	21.18	22.00	24.00	12.00	27.00

The sensory scores (Figure.4.3) revealed various significant differences in all the parameters evaluated. Although the highest taste, aroma, colour, mouth feel and overall acceptability were recorded for CTM and M1, the milks were still highly acceptable to the panellists. The higher values for CTM and M1 may be due to the microwaving that gave the biscuit taste. However, all the samples were generally acceptable to the panellists. Mouth feel values for TM1 and TM2 were notably lower than that for M2.

Data in Figure 4.4 were achieved after the raw data from the administered questionnaire was integrated into the Palisade @Risk software. This presents an uncertainty around the actual preference of the product as 12 falls in the region of “dislike” whereas the maximum, 28, is indicative of “like strongly”. Falling on the mean and median reveals a slight difference in terms of preference between samples microwaved for 10 min (M1) prior to extraction and samples microwaved for 20 min (M2). Based on the mean and mode, it was observed that sample M1 was more preferred as compared to sample M2. Preference for M2 was however more preferred than all samples. From the median scores, sample CTM was more preferred as compared to sample M1. Samples M2 and TM1 had the same score of 19, with the least preferred being sample TM2 with a score of 18. This is again emphasized with the 5th and 95th percentiles. A closer look indicates that a 5th percentile of 15 and 12 for M1 and M2 respectively. This implies the lowest 5% of assessors disliked the samples as compared to the top 5% (95th percentile) who assessed the samples as “like strongly”. The 95th percentile values also shows the same trend observed for the other metrics. Samples CTM and M1 received higher scores than samples M2 and TM1. Sample TM2, again, was the least preferred among the samples.

A similar preference of samples was observed for samples TM1 and TM2. These samples were soaked, but not microwaved, prior to milk extraction. With TM1 obtaining a minimum preference of 10 and that of TM2 being 8. The maximum values, however, are equal (26) for both. The mean values of 18.40 for TM1 and 17.56 for TM2 indicate that samples that were soaked in water for 10 min (TM1) was more preferred as compared to the samples in which the Tigernut was soaked for 20 min (TM2). Their median values of 19 and 18 respectively translates into “uncertainty”. This literally translates that 50% of the assessors neither like nor dislike the product: suggesting that samples TM1 and TM2 should be improved. Contrasting

samples TM1 and TM2, even though they both fall in the “uncertainty” region, it could be said that TM1 was slightly preferred than TM2.

For the CTM samples, they were heated prior to canning and so the final product had reduced moisture and came in the form of a condensed milk. The minimum (8) and maximum (29) preference values suggest the widest data range. Again the actual consumer preference for the product cannot be indicated as there is a wide uncertainty resulting from the data range. The mean and median marks (21.18 and 22.00 respectively) however positions the preference in the like very much region. This indicates the product is liked in a way slightly higher than M2 and M1. A look at the 95th percentile indicates 27 which is again comparable to M1. With a median of 22 and a 5th percentile of 12 the product could be seen as the most preferred.

The most preferred sample was M1 followed by CTM and then M2. Samples TM1 and TM2 then followed. The top 3 preferred samples all had microwaving as part of its processing. During production, it was observed that samples that were microwaved had a nicer aroma as compared to the samples that were not microwaved. It is suggested that microwaving must have resulted in Maillard reaction, producing aroma compounds. This could have been responsible for the higher preference among the microwaved samples. The preference of samples however decreased as the length of microwaving increased. Sample M1 which was microwaved for 1 min was more preferred than sample CTM (microwaved for 1.5 min). CTM was also more preferred than sample M2 that was microwaved for 2 min.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This was a novel Tigernut milk product stemming from the use of microwave heating in the production process. Microbiological study on the canned samples over an 8-week period showed a strong positive effect of the canning on the shelf stability of the Tigernut milk. The result revealed that canned Tigernut milk could be used as a beverage for pregnant women and the new born, the young and old persons due to the high nutritional contents. Consumption of Tigernut will increase once processed into canned milk. As a result, it is proposed that canned milk from Tigernut be heartened to solve the challenge in malnutrition in Ghana and beyond.

5.2. Recommendations

There is the need to investigate the nutritional quality of the canned Tigernut product. It is again recommended that shelf life studies on the product be conducted using all parameters that are critical to the storage of Tigernut milk.

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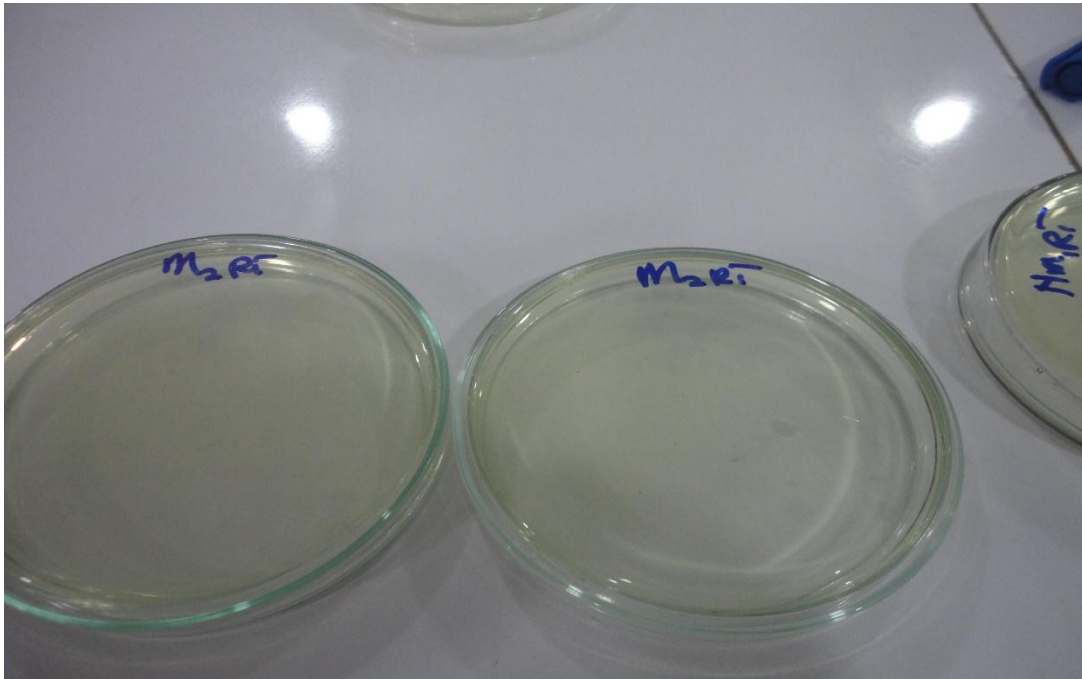
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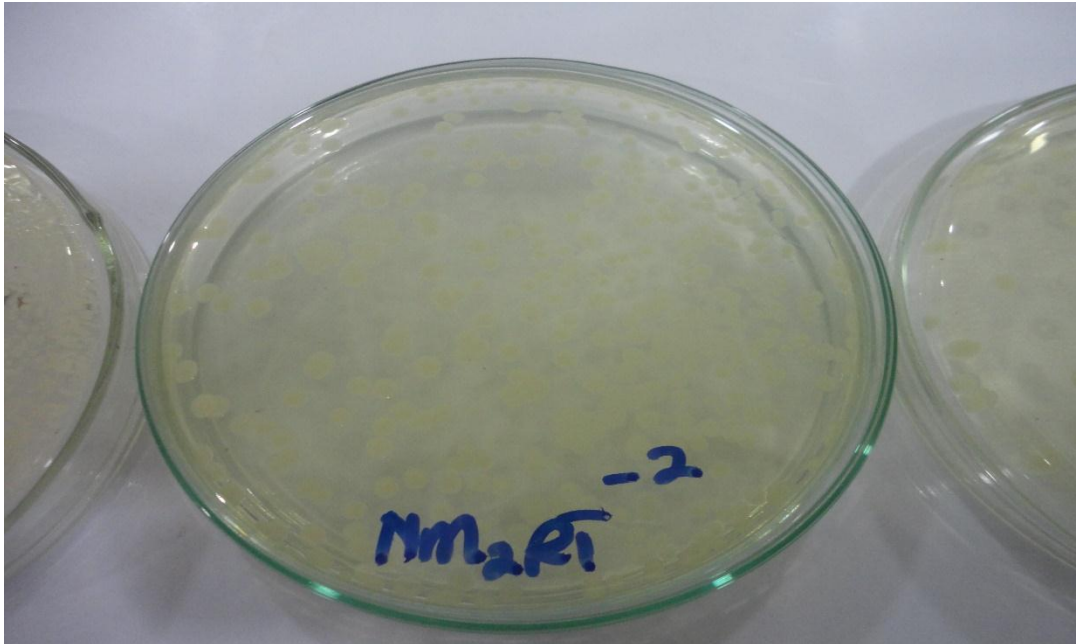
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APPENDIX A

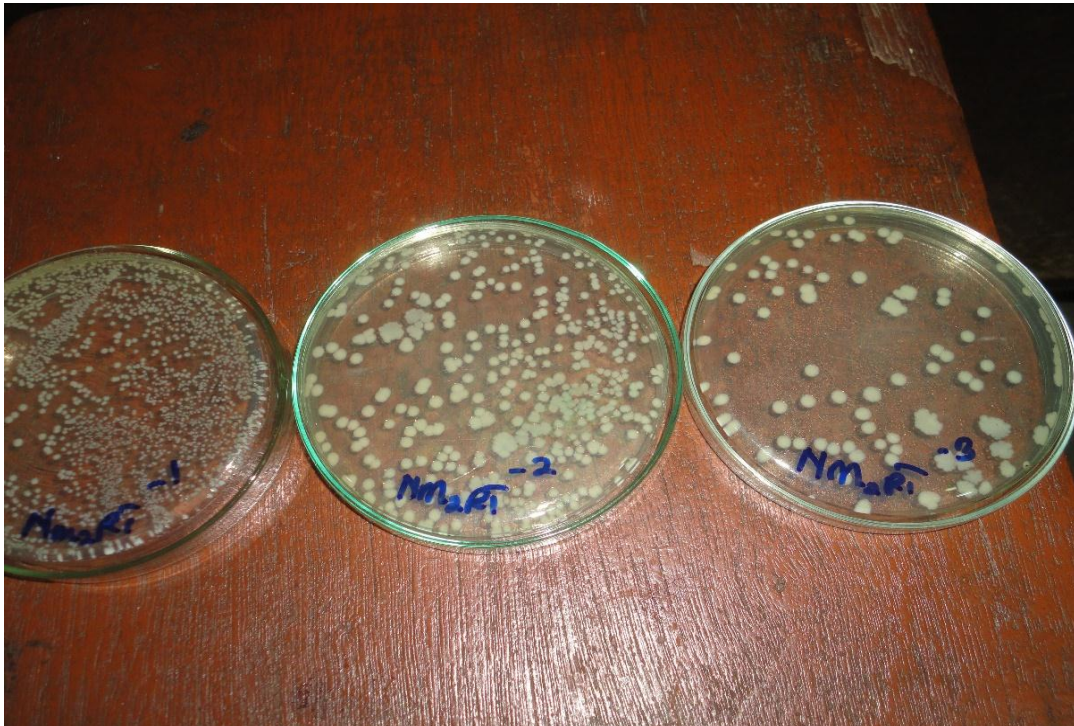
1. PICTURES OF 8 WEEKS MICROBIAL STUDY



2.



3.



4.



5. PICTURE OF CANNING MATERIAL USED



6. PICTURES OF TIGERNUT CULTIVATION



7.



8. PICTURES OF THE VARIOUS YIELDS OF TIGERNUT



9. PICTURES OF TIGERNUT MILK



10. NON-FOOD APPLICATION OF TIGERNUT



11. PICTURE OF CANNING MACHINE USED



12. PICTURE OF MILLING MACHINE USED



APPENDIX B

Date: __/__/____

PARTICIPANT NO.:

BIODATA OF PARTICIPANTS

Gender	Age Range	Marital Status	Religion	Educational Status	Occupation
Male ☐	≤ 19 yrs ☐	Single ☐	Christian ☐	Informal ☐	Not working ☐
Female ☐	20 – 29 yrs. ☐	Married ☐	Muslim ☐	Basic ☐	Student ☐
	30 – 39 yrs. ☐	Divorced ☐	Traditional ☐	JHS ☐	Farmer ☐
	40 – 49 yrs. ☐	Widowed ☐	Other ☐	SHS ☐	Trader ☐
	≥ 50 yrs. ☐			Tertiary ☐	Civil Servant ☐
					Public Servant ☐
					Others ☐

BASIC CONSUMER INFORMATION

Have you ever Consumed Tiger nut	How long have you consumed it (in years)	How do you get it	Who introduced you to it	Do you have relatives who also consume Tiger nut	How do you consume Tiger nut
Yes ☐	0 ☐	From the wild ☐	Family ☐	Yes ☐	Raw ☐
No ☐	1 ☐	Self-reared ☐	Friends ☐	No ☐	As composite for food ☐
	2 ☐	Sales persons ☐	Self- Identified ☐		As composite for medication ☐
	3 ☐	Family ☐	Sales persons ☐		
	4 ☐	Friends ☐			
	5 ☐				Other (Specify ☐
	6 ☐				below
	7 ☐				
	8 ☐				
	9 ☐				

What is your general perception on the consumption of Tiger Nut?

.....

.....

What is your perception on making food products from Tiger Nut?

.....

.....

CODES FOR SCORING				
1	2	3	4	5
Dislike Strongly	Dislike	Uncertain	Like	Like Strongly

	VARIETY				
	M1	M2	NM1	NM2	CTM
COLOUR					
SMELL					
CONSISTENCY					
TASTE					
MOUTHFEEL					
AFTER TASTE					
OVERALL					

Briefly describe the product in your own words? (Not your acceptability rather an objective description: color, smell and taste)

M1.....

.....

M2.....

.....

NM1.....

.....

NM2.....

CTM.....

MARKETABILITY AND CONSUMPTION OF THE PRODUCTS	
Indicate which of the products you prefer most?	
How much are you willing to pay for the various products	M1 = M2 = NM1 = NM2 = CTM =
How would you use the products	

Special Remarks on Products

M1.....

M2.....

NM1.....

NM2.....

CTM.....

SAMPLE	COL	PRIMARY DATA					
		S	CONS	T	M	AFT	
M1		3	4	2	2	2	2
M2		4	4	4	2	2	3
NM1		3	3	2	4	4	4
NM2		4	3	4	2	2	2
CTM		3	4	2	2	2	2
M1		3	4	2	2	2	2
M2		4	4	4	2	2	3
NM1		3	3	2	4	4	4
NM2		4	3	4	2	2	2
CTM		4	3	4	2	2	2
M1		4	3	5	4	3	5
M2		2	2	3	3	4	1
NM1		3	3	4	3	3	3
NM2		4	2	3	3	2	2
CTM		4	3	4	4	4	5
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M2		2	3	2	2	2	4
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NM2		3	4	3	2	2	2
CTM		3	3	4	3	3	3
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M2		4	2	2	2	2	3
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NM2		2	2	3	3	2	2
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NM2		2	1	2	3	3	3
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