EVALUATION OF FOOD POTENTIALS OF TIGERNUT TUBERS (*Cyperus esculentus*) AND ITS PRODUCTS (MILK, COFFEE AND WINE)

BY

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PG/M.SC/03/34134

DEPARTMENT OF HOME SCIENCE,

NUTRITION AND DIETETICS,

UNIVERSITY OF NIGERIA, NSUKKA

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TITLE PAGE

EVALUATION OF FOOD POTENTIALS OF TIGERNUTTUBERS (*Cyperus esculentus*) AND ITS PRODUCTS (MILK, COFFEE AND WINE)

A RESEARCH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF HOME SCIENCE, NUTRITION AND DIETETICS, UNIVERSITY OF NIGERIA, NSUKKA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN HUMAN NUTRITION AND DIETETICS

BY

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DEPARTMENT OF HOME SCIENCE, NUTRITION AND DIETETICS,
UNIVERSITY OF NIGERIA, NSUKKA

MAY, 2009

APPROVAL PAGE

This research project has been approved for the Department of Home Science, Nutrition and Dietetics, University of Nigeria Nsukka

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CERTIFICATION

Ndubuisi, Linda Chinenyenwa, a post graduate student in the department of Home Science, Nutrition and Dietetics with registration number PG / M.Sc / 03 / 34134 has satisfactorily completed the research project for the requirements for the award of Master of Science (M.Sc) Degree in Human Nutrition and Dietetics. The work embodied in this project is original and has not been submitted in part or in full to this or any other institution for the award of a certificate/ diploma or degree.

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Date

DEDICATION

This research project work is dedicated first and foremest to the Holy Spirit (My Inspiration) and secondly, to my late parents (Mr. Okechukwu J. Ndubuisi (O'Ndu) and Rev. Dr. (Mrs.) Irene N. Ndubuisi) for ever desiring that I should study Food and Nutriton.

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Ndubuisi, L. C.

Table of contents **Page**

List of tables and figures **Page**

ABSTRACT

The food potentials of tigernut tubers (Cyperus esculentus) locally know as “aki awusa” in Igbo, ”aya” in Hausa and “ofio” in Yoruba were evaluated. The proximate composition of 100g of raw and processed tigernuts showed that moisture content of tigernuts ranged from 4.19 – 51.93 %, crude protein 2.61 – 10.12 %, ash 0.70 – 1.77 %, crude fibre 7.48 – 13.97 %, crude fat 10.79 – 32.06 %, and carbohydrate 22.73 – 56.85 %. Energy values ranged from 232.31- 487.15 Kcal. Tigernuts contain significant amounts of Mg (95.32 -140.96 mg), K (106.44 – 427.92 mg), P (121.78 – 195.95 mg), Fe (1.60 – 4.03 mg), Cu (0.08 – 0.99 mg), Zn (0.32 - 2.46mg), vitamin C (30.90 – 84.66 mg), vitamin E (2.22 – 5.26 mg), moderate Ca (24.42 – 62.29 mg) and low Na (15.77 – 18.27 mg) content. Processing of tigernuts generally increased carbohydrate but decreased magnesium and sodium values. Malting significantly increased calcium content (85 %) and drying and roasting increased Zn and Cu by 100 %. Physico-chemical and functional properties showed that tigernuts and its products are acidic while viscosity of the products per 100 ml was between 88 – 90 cP, specific gravity 1.01 – 1.07, reducing sugar 0.30 – 0.44 g , foaming capacity 18 %. Foaming stability 5.35 %, emulsion capacity 21.88 %, and emulsion stability 49.38 %. Alcohol content of tigernut wine was between 3.17 – 7.13 %. Fresh tigernuts were utilized in the development of tigernut products (milk, coffee and wine) using household methods such as soaking, drying, roasting, malting, fermentation and freezing. Organoleptic and acceptability assessment of the developed tigernut products showed that there was no significant difference ($P > 0.05$) between tiegrnut products and their controls in most of the parameters tested. All then products were highly acceptable. Tigernuts products (milk extract and wine) evaluation per 100 ml showed high ascorbic acid (6.18 – 7.8 mg), thiamin (0.80 – 1.25 mg), riboflavin (0.35 – 0.59 mg), vitamin E (0.22 – 0.75 mg) and cyanocobalamin (0.03 – 0.05 ug) content. The result of the microbial count of tigernut products (milk and wine) showed values between 3.0 x 10^2 – 8.0 x 10^2 cfu / ml and keeping quality ranged from 6 hours to 10 months.

1. Introduction

1.1 Background study

Tigernut *(Cyperus esculentum)* is a perennial grass-like plant with spheroid tubers, pale yellow cream kernel surrounded by a fibrous sheath. It is also known as yellow nut sedge, earth or ground almonds, "*souchet"* in French, "*ermandeln"* in German and "*chufa"* in Spanish (TTSL, 2005). Grossman and Thomas (1998) reported that c*hufa* came to Spain from Africa. Tigernut is found wild and cultivated in Africa, South America, Europe and Asia. Tigernuts grow in the wild, along rivers and are cultivated on a small scale by rural farmers mostly in the northern states of Nigeria. It is locally called "*aya*" in Hausa; "*aki awusa*" in Igbo; "*ofio*" in Yoruba and "*isipaccara*" in Effik. Tigernuts are edible, sweet, nutty, flavoured tubers which contain protein, carbohydrate, sugars, and lots of oil and fiber (FAO, 1988). Grossman and Thomas (1998) showed that tigernuts have been cultivated for food and drink for men and planted for hogs for many years in Spain and that the lovely milky elixir is served in health Spas, Pubs, and Restaurants as a refreshing beverage (competing successfully with other soft drinks). Unfortunately, despite these potentials in tigernuts it has been a neglected crop in Nigeria. This probably may be due to inadequate knowledge on its production, utilization and nutritional value.

Tigernut could provide a basis for rural industries in Africa. It is an important food crop for certain tribes in Africa, often collected and eaten raw, baked as a vegetable, roasted or dried and ground to flour. The ground flour is mixed with sorghum to make porridge, ice-cream, sherbet or milky drink. It is mostly consumed raw as snack without knowledge of the food and nutritional quality (FAO, 1988). It has also been found to possess good therapeutic quality (Moore, 2004; Zimmerman, 1987; Farre, 2003; Bixquert, 2003; Valls, 2003). Moore stated that "the expansion of tigernut milky drinks will significantly help the research linking tigernut milk to healthier cholesterol levels and other non-dairy manufacturers. This could also gain a boost from an increased consumer interest in health foods".

Variety of food products can be derived from tiger nut tubers though there is little documentation at large. Various food processing techniques can be applied to tiger nut processing to modify its appearance, develop its natural flavour, stimulate the digestive juices, add variety to the menu, make it easily digestible and bio-available, destroy harmful microorganisms, improve its nutritional quality and prevent decomposition. This project work

intends to basically evaluate, promote production and utilization of tiger nuts using various processing techniques.

1.2 Statement of problems

Food insecurity continues to threaten large proportions of households in low income countries. In view of the operational definition of household food security stated by ACC / SCN (1991), a household is food secure when it has access to the food needed for a healthy life for all its members (adequate in terms of quality, quantity, safety and culturally acceptable), and when it is not at undue risk of losing such access. Adequate nutrition is essential for individual development, activity, good health, fulfillment function and success in societies and nations (ACC / SCN, 1991). Some of the factors that may affect food security as well as nutrition are as follows:

- Inadequate production and knowledge of the food use
- Poor processing, preservation and storage techniques
- Poor infrastructure, especially poor housing, sanitation and storage facilities, education, communications, and transporting systems.
- Poverty
- Extreme imbalances in food or population ratio
- War / political or civil unrest
- Rapid depletion of natural resources
- Cultural attitudes toward certain foods
- High external debt
- Seasonal factors or climatic variations
- Food prices

Tigernut has been for many years one of the underutilized food crops in Nigeria. It is mostly eaten raw as snack and un-identified as a very important food crop that has great potential in managing, preventing and eliminating malnutrition (macronutrient and micronutrient deficiencies) or food insecurity problems. It has been demonstrated by nutritionist that the major nutritional problems could be solved through exploitation of the nutrition and economic potentials of the local food resources. Tigernut is one of the under utilized tubers with great potentials for domestic and commercial purposes. There is no documentation of a successful product made from tigernuts in the Nigerian market. A

successful product offers a benefit that is perceptible and valued by the consumer (NUTRA, 2005).

There is little documentation on the nutritional quality and versatility of tigernuts in food preparation despite its availability. However, tigernut is still one of the least popular tubers in Nigeria and hence the need for this research which intends to evaluate, promote production and utilization of tiger nuts using various processing techniques.

1.3 Objectives of study

The broad objective of this study is to evaluate the food potentials of tigernut tubers (tigernuts) and its products.

Specific objectives are as follows: to

1) determine the proximate, mineral, vitamin, physico-chemical and functional properties of tigernuts.

2) develop products from tiger nuts using traditional processing techniques such as natural fermentation, malting, drying and roasting.

3) assess the organoleptic properties and general acceptability of the developed tigernut products (milk, coffee and wine beverages).

4) determine some nutritional properties and microbial load of developed tigernut products (milk, coffee and wine beverages).

1.4 Significance of study

In recent years, the need to increase the production and utilization of locally available food resources has been highlighted at different national and international fora. Tigernuts, one of the under utilized food crops locally available in Nigeria could be demonstrated to aid in solving major nutritional problems through exploitation of its nutritional and economic potentials.

The results of this study will provide a baseline data on tigernut utilization. This will go a long way to diversify its use and in turn lead to its increased production both at household and national levels ultimately to ensure food security. Furthermore, it is expected that through the knowledge of its composition, tiger nut may be exploited for use in the prevention and treatment of some non communicable diseases for example cancers, diabetes, heamorrhoids and cardiovascular diseases.

Chapter Two

2. Literature review

2.1 History of tigernuts

Tigernuts are not actually nuts but tubers found on the root of a sedge plant. It was first discovered 4000 years ago and comes in several varieties. The tubers were originally cultivated by ancient Egypt's populations at the Nile valley. Their cultivation was subsequently extended throughout other areas with temperate climate and fertile soil. Reports have shown that tigernuts came to Spain from Africa (IHS, 2005; HBR, 2005; CVNews, 2006; Deatra, 1999). Tigernuts are edible tubers with a sweet nutty flavour. Other common names for these tubers are "earth almond" and "yellow nut sedge". They are quite hard and are generally soaked in water before consumption.

In Egypt and the Mediterranean nut sedges were used as sources of food, medicine and perfumes. Tigernut tubers were routinely roasted and consumed by nursing mothers. The dried ground tubers were used in coffee and chocolate drinks. Oil extracted from the tubers was an ingredient in soap maikng as well as a lubricant for fine machinery. The leafy plant parts of the nut sedge were fed to livestock. Egyptians made very efficient use of the nut sedge. They used them in cultivation as early as 2400 BC. One such example of tigernuts is depicted in a wall painting of an Egyptain tomb in 15th century BC (Deatra, 1999). In the painting, workers are shown to be weighing the nuts while a scribe records their work. In another part of the same tomb, instructions were written for eating the tubers as sweets after grinding and adding honey. Tigernut tubers have been found in the tombs and are considered to be locally domesticated in Egypt. This gives the impression that the tubers were greatly valued by the Egyptian people as a food source (Deatra, 1999)

2.2 Botany of tigernuts

Cyperus esculentus (tigernut sedge / chufa sedge / yellow nut sedge / earth almond) is a species of sedge, native to warm temperate to subtropical regions of the Northern Hemisphere. Tigernut is a highly adaptable crop and grows well under a wide range of climatic and soil conditions. It is found throughout the tropics, subtropics and warm temperature regions. It is cultivated in Western Africa, but is a serious weed of cotton, cereals, potatoes and sisal in

Eastern Africa. It is also grown in south America, Europe and Asia. The tiuber grows 50- 250 tubers per plant and weigh 2 – 26 g per tuber (FAO, 1988).

Tigernut is an annual or perennial plant, growing to 90 cm tall, with solitary stems growing from a tuber. The stems are triangular in section, and bear slender leaves 3-10 mm wide. The flowers of the plant are distinctive, with a cluster of flat oval seeds surrounded by four hanging leaves positioned 90 degrees from each other. The plant foliage is very tough and fibrous, and is often mistaken for a grass (Deatra, 1999). Tigernut plant produces edible yellow to yellow brown spike-lets flowers, mostly only 1 cm to 1.5 cm long. The root system is by yellowish rhizome, ending in single tubers of 5-20mm in length, with a thin brown outer skin which darkens with maturity. In its non-flowering state it resembles *Cyperus rotundus* which is dark brown, slightly fragrant, unpleasant tasting tubers produced in a chain and blunt tipped leaves with no shoulders. The leaves of tigernut (*Cyperus esculentus leptostachyus*) are long, narrow, shiny, light green, arranged in 3 rows around the triangular stem often with characteristic pointed tip separated from the rest of the leaf by a distinct shoulder (FAO, 1988).

Tigernut is classified in the division: Magnoliophyta; class: Liliopsida; order: Cyperales; family: Cyperaceae. *Cyperus esculentus* is in the order Commelinales and the family Cyperaceae. *Cyperus esculentus* can be distinguished from other species of New World nut sedge by its persistent linear brown spikelets that have closely overlapping scales. The stem of yellow nut sedge is triangular and has a light green-yellow color. Rhizomes that terminate in tubers are the main means of reproduction, although it does produce viable seed (Deatra, 1999; HBR, 2005).

In West Africa the plant often grows in great concentration and is gathered from the wild. It is interesting to note that *esculentus*, means edible in latin (Negbi, 1992). Tigernut tubers are of different varieties, the notable ones are black yellow and brown with various sizes (Barminas *et al*., 2001).The most common varieties are long and round.The varieties are:

- *Cyperus esculentus var. esculentus.*
- *Cyperus esculentus var. hermannii.*
- *Cyperus esculentus var. leptostachyus.*
- *Cyperus esculentus var. macrostachyus.*
- *Cyperus esculentus var. sativus*
- *Cyperus esculentus var. rotundus*

The two varieties of interest to us are *Cyperus esculentus* var. *esculentus* (weedy) and *Cyperus esculentus* var. *sativus* (cultivated). Most literature uses the name *Cyperus esculentus* for both the weedy and the useful sedge. The weedy variety *esculentus* produces many seeds although the cultivated variety *sativus* produces few (Lapham and Drennan, 1990). *Cyperus esculentus* var. *esculentus* and *Cyperus esculentus* var. *sativus* are closely related (ONRG, 2005; Negbi, 1992). The color of the tubers appears to be one unusual character. Variety *sativus* has a grey-orange color and variety *esculentus* has a grayed brown color according to the Royal Horticultural Society Colour Chart as reported by De Vries and Femke(1991).

The cultivated variety does not have capability of the perennial yellow nut sedge grown as annual plants. They also lack the abundant seed production typical of the perennial nut sedge. Cultivated tubers are also known to be larger than perennial yellow nut sedges. These characteristics seem to indicate a possible pattern of human selection that may have separated the edible tigernut from the weedy nut sedge. The taste of the weedy tigernuts compared to the cultivated has been found to be very similar. Also, the weedy nut sedge is more fibrous to chew it is less desirable (De Vries, 1991).

The perennial yellow nut sedge is sometimes a troublesome invasive weed in planted fields (FAO, 1988). It is often regarded as a useless pest to home gardeners as well as commercial growers. Along with being a useless weed it is difficult to control. However, several commercial herbicides have been labeled for use exclusively on yellow nut sedge and are available at local retailers (Deatra, 1999).

2.3 Ecology of tigernuts

Tigernut is common in seasonally wet grassland, irrigated crops, damp grassland, and along banks, but at the same time is considered fairly drought resistant. It does not tolerate shade. Best yield are obtained with moderately high temperature throughout the growing season, and well distributed rainfall. High temperature of 27 - 30 ºC, with low nitrogen levels favors tuber formation. Light sandy loamy soils of PH 5.5 - 6.5 are preferred, but can grow in any soil provided it is well drained. Alluvial soils containing relatively high quantities of Manganese (Mn), sulfur (S), calcium (Ca), Magnesium (Mg), and boron (Bo) are particularly suitable. It is tolerant of salty soils. Short photo periods of 8-12 hours favor tuber formation and long photo periods of more than 16hrs favor vegetative growth (FAO, 1988).

Tigernut cultivation requires sandy soil and a mild climate. Tubers are soaked in water for 24 – 36 hours before being planted out, either by hand or using a drill. In United States of America, tubers which had been chilled were found to germinate better and to produce more sprouts per tuber. Tubers may be planted at 10-15cm intervals along rows 60-90cm apart, about 2.5-4cm deep. At closing spacing, 1 tuber per hole is used, with 2 per hole at wider spacing seed rates (FAO, 1988). Tigernuts are planted during March, April and May and must be irrigated every week until they are harvested in November and December. Harvest time may take 90-120 days only and at the end of dry season. Immediately after harvest, tigernuts are washed with water in order to remove any sand and small stones. Once the Tigernuts have been cleaned, they are dried out in order to preserve them. This is a natural process that requires 1-3 months. Temperature and humidity levels are carefully monitored during this period. The Tigernuts are turned over every day to ensure uniform drying. Small and damaged tigernuts are removed before packaging and utilization (TTSL, 2005; FAO, 1988).

2.4 Nutritional composition of tigernuts and its products

FAO (1988) and TTSL (2005) showed that tigernut tubers are rich in starch (20-30% of DW) and fat (20-28% DW) with small quantities of protein which is about twice of that of cassava. Table 2.1 showed the energy and nutrient content of tiegrnuts as reported by other researchers (Umerie *et al*.,1997); TTSL, 2005; Addy and Eteshola, 1984; Temple *et al*., 1990). Tigernuts have relatively higher fat content and gross energy, and in this regard compared better with nuts than that of cereals which also belong to the same other Cyperales. Research has been done on the oil extracted from the seeds of yellow nut sedge (*Cyperus esculentus* var. *esculentus*) as a non-conventional oilseed. This study was used to determine oil substitutes for more conventionally used oil types such as soybean, palm and olive oils. Non-conventional oils would be less expensive and therefore more available to poorer (developing) countries.

Tigernut oil is 80% unsaturated fatty acid, mainly oleic (64.2 – 68.8 %) and this shows that tigernut oil has a good potential as a substitute for imported olive oil (Deatra, 1999; Mc Namara, 2004; TTSL, 2005). Fat in diets provide twice much energy as carbohydrate or protein, thus low fat diets are recommended to aid weight control. Different types of fat (fatty acids) have different effects on health and the risk of diseases states such as coronary heart disease (CHD). Saturated fatty acids (SFA) increase levels of blood cholesterol and should be avoided whenever possible. There is evidence that the replacement of SFA with

monounsaturated fatty acid (MUFA) may have a favorable effect on the risk of CHD. Venho *et al.* (2000) investigated types of fat intake in relation to CHD risk in women and reported that for every increase of 5% in energy from MUFA there is a decrease in CHD relative risk of 0.81%.

Tigernut is a good source of phosphorous, potassium and iron. It also contains magnesium, calcium, zinc, copper, sodium and manganese (TTSL, 2005). Phosphorus found in plant is usually bound to a compound called phytate meaning that it is poorly absorbed from the gut into the body. Phosphorous (P)**,** together with calcium, constitutes the bulk of the mineral substance of the bones and teeth. It plays a part in the formation of ATP (an energy compound indispensable for "activating" glucose, fatty acids, etc) and in improvement of intellectual performance. Phosphate is important in the body. It helps regulate acidity/ alkalinity by acting as a buffer (Moore, 2004).

Potassium (K) is important in maintaining electrolyte and chemical balance between the tissue cells and the blood. K is the most important neural element in intracellular behaviour. It plays a part in numerous enzymatic reactions and in important physiological processes, such as cardiac rhythm, nervous conduction, and muscular contraction. Iron (Fe) in food is often in a complex form. Vitamin C aids in the absorption of iron. Vitamin C is a reducing agent and changes Fe into a more easily absorbed form. An acid medium also helps Fe absorption. Consequently, Fe helps prevent anaemia. Zinc has a wide variety of functions in the body and is found in all body tissues. It is involved in many enzyme reactions including those involved in energy generation from carbohydrate, fat and protein. It also has a role in cell division, the transport of carbon dioxide and oxygen in the blood and also in immunity. Since it has a wide range of role in the body, symptoms of zinc deficiency are also wide-ranging and include a delay in wound healing, poor appetite, a suppressed immune system and poor growth (Moore, 2004; Wardlaw and Kessel, 2002).

Magnesium is also involved in many enzyme systems and in particular those involving the currency of energy in the body, ATP. Magnesium is also required for the synthesis of proteins, the production of energy and muscle contraction (Moore, 2004). Research studies have suggested that a low intake of magnesium may increase the risk of coronary heart disease (Al-Delaimy *et al*., 2004) and type 2 diabetes (Lopez-Ridaura *et al*., 2004).

Table 2.2 showed the amino acid composition of tigernuts. Bosch *et al*. (2005) observed that the essential amino acid contents of tigernuts were greater than those proposed in the protein standard for adults by the FAO/WHO, with the exception of histidine. The arginine content (1414.0 ± 4.75 mg) is found to be very high compared to the other essential

amino acids while the Tyrosine (50.0 ± 0.13 mg / g N) and methionine content as total sulphur (58.1 ± 0.62 mg) is found to be low. Lysine content of tigernuts (307.5 ± 0.30) may supplement foods deficient in lysine such as maize. This can be useful in the development of multi-mixes in infant nutrition.

A 200 ml glass of "horchata" contains about 1.12% starch, 1.30% fat, 12.60%, protein; 0.35% carbohydrate, 0.38% fibre and 132 Cal energy value (TTSL, 2005). Tigerwhite, a brand of vegetable milk by Bottlegreen as reported by Moore (2004) contains vitamins E, thiamin, niacin, vitamin B_6 and folate. Results on the nutrient content of tigerwhite and the results of a comparative study on the nutrient content of tigerwhite with other milk beverages (cow milk and soya milk) has been shown in table 2.3 and 2.4.

2.5 Importance of tigernuts

2.5.1 Nutritional and health importance of tiger nuts

Tigernuts and its products are rich in carbohydrates, mono-, di-, and polysaccharides (TTSL, 205; Moore, 2004). They contain relatively high levels of protein, oleic acid (monounsaturated fatty acid which has a bigger resistance to chemical decomposition) and fat (TTSL, 2005). Tigernuts have excellent nutritional quality with a fat composition similar to olive oil and rich mineral content, especially phosphorus and potassium (FAO, 1988; Moore, 2004). Tigernut oil has a mild, pleasant flavour and is considered as food oil similar but superior in quality to olive oil. The polyunsaturated fatty acid content (linoleic acid & linolenic acid) is enough to cover daily minimum needs of about 10 g (TTSL, 2005), Moore (2004) oil has high content of Vitamin E (alpha-tocopherol), and thus higher oxidative stability than other oils**,** due to its content of polyunsaturated fatty acids and gamma-tocopherol.

Tiger nuts may need to rely significantly on its health benefits, promoting a rich monounsaturated fatty acid content, high vitamin E levels and prebiotic qualities (NUTRA, 2005; Moore, 2004). Vitamin E, an antioxidant which protects the body form free radical attack, is vital for the maintenance of cell membranes. It may also play an important role in delaying cells from aging thereby improving the elasticity of skin. Vitamin E is good for treatment of acne and other skin 'alterations'. It is particularly important in areas of the body exposed to oxidative stress such as the lungs and the red blood cells. Vitamin E may reduce the risk of cancer and CHD due to its role as anti oxidant, however research in this area is

currently inconclusive (Moore, 2004; Wardlaw and Kessel, 2002). In supra-nutritional doses, Vitamin E has been claimed to benefit diseases associated with oxidative stress including cardiovascular disease, cancer, Alzheimer's and Parkinson's disease (Brigelius-Flohe, 2002).

Tigernut oil has therapeutic properties as it reduces "bad" cholesterol (LDL-cholesterol) and increases the "good" one (HDL-cholesterol). It can also reduce levels of triglycerides in blood, reduce risk of formation of bloody clots, produce dilatation in veins and prevent arteriosclerosis**.** Tigernuts may play an important role in the prevention and nutritional therapy for cardiac pathologies, due to its high content of monounsaturated fatty acids (Oleic acid) to improve metabolism and health (TTSL, 2005; Moore, 2004). Tigernut oil exhibits positive effects on digestive secretions (gastric, pancreatic and bile), due to high content of oleic acid, the most powerful stimulator of production of Cholecistokinine (TTSL, 2005).

Tigernuts may prevent heart attacks, thrombosis and activate blood circulation. The high contents of soluble glucose in tigernuts prevent cancer. Recently, some investigators discovered that they reduce the risk of suffering colon cancer. Tigernuts have relative antioxidant capacity, because they contain considerable amount of water-soluble flavonoid glycoside (a phytochemical). Consumption of antioxidant could protect the immune system of malnourished populations. The intake of antioxidant containing foods may delay the progression of HIV infection to AIDS (ONRG, 2005)

The high fibre content of tigernuts combined with its delicious taste makes them ideal for healthy eating. The high content of fiber content of tigernut has a good effect on digestion (TTSL, 2005). This is because fibre stimulates digestive juices, contributes to a longer feeling of fullness and speeds up transit in the intestinal tract and so prevents constipation.

Tigernut may have prebiotic qualities, a result of the short chain carbohydrates called oligosaccharides, which feed probiotic bacteria helping to promote intestinal health (NUTRA, 2005). Moore (2004) reported that levels of oligosaccharides have not been measured in tigernut, however they were found in the milky drink "*horchata"*. The oligosaccharides, which are short chain carbohydrates and have shown the most promise as potential prebiotics. Recent research has also suggested that oligosaccharides may increase the absorption of the minerals calcium and magnesium. These effects were observed with doses in the range of 5-10 g per day (Delzenne, 2003).

The amino acid profile of tigernuts is dominated by arginine (Table 2.2). Although arginine is not an essential amino acid, it has been termed 'conditionally essential'. It is essential in the fetus and the neonate. In adults it may have a role in disease states especially where tissue is being broken down such as in sepsis or trauma (Wu *et al.*, 2000). The area of

arginine remains an exciting area of nutrition research, however it must be noted that some of the effects may require pharmacological doses, at a much higher level than that supplied by our regular diet (Moore, 2004).

Many of the postulated beneficial roles of arginine are related to the fact that it is a precursor for nitric oxide (NO). NO is a vasodilator produced by the endothelial cells of the vascular system and has an important role in the regulation of the cardiovascular system. This 'endothelium-derived relaxation' is impaired in conditions such as diabetes, high blood pressure and high plasma cholesterol (Pieper *et al*.,1996) demonstrated in animal studies that oral administration of L-arginine could normalize endothelial relaxation in diabetic rats. Guigliano *et al.* (1997) however, showed that intravenous infusion of L-arginine (3-5g) to humans could reduce blood pressure in diabetic men. In men with high blood cholesterol levels, 21g per day of intravenously administered arginine improved endothelium derived relaxation. This intravenous dose is much higher than the level of arginine consumed in a usual diet (Moore, 2004).

Tigernuts are free from gluten cholesterol. They have very low sodium content (TTSL, 2005). Scientific analysis on the "nutritional and dietetic aspects of tigernuts" (Farré, 2003), "digestive aspects of tigernuts" (Bixquert, 2003) and "effects of tigernuts on heart diseases and related aspects" (Valls, 2003) concluded that tigernuts have high content of oleic acid, have positive effects on cholesterol levels due to high content of vitamin E. Tigernuts are suitable for diabetic persons, ideal for children, older persons and sportsmen and are very healthy. For many years, tigernuts have been considered to have adequate properties to fight respiratory infections, and some stomach illnesses (CVNews, 2006). The scientific analysis by Zimmermann (1987) concluded that tigernuts reduce the risk of colon cancer and are suitable for diabetic and obese persons.

To this date, *horchata* is considered an effective remedy for diarrhea, according to popular tradition in Valencia, Spain CVNews, 2006). "*Horchata",* a natural sweet tasting vegetable milk can be extracted directly from tigernuts and used as a refreshing drink which can also serve as substitute for cow milk. The following characteristics make "horchata" a perfect substitute of vegetable milk:

- It is ideal milk for persons that don't tolerate gluten (celiacs) or that are allergic to cow milk and its derivates**.**

- It helps in reduction of LDL ("bad") cholesterol and increases HDL ("good") cholesterol because of its high contents of oleic acid and Vitamin E, which has an antioxidant effect on fats.
- The high content of oleic acid and the amino acid arginine prevents arteriosclerosis.
- It is suitable for diabetic persons.
- It is recommended for persons with digestion disorders, flatulence and diarrheas, because of the content of digestive enzymes (lipase, catalase and amylase).
- It is high phosphorus, potassium, calcium, magnesium and iron.
- It has considerable amounts of vitamins C and E (TTSL, 2005 and Moore, 2004).

2.5.2 Economic importance

In some parts of Africa, Europe and Asia, tigernut is grown for its edible tubers. Tigernuts may be regarded as an obnoxious weed that has been used historically as food and medicine by the Egyptians and Native Americans. Even today the Egyptians cultivate tigernuts in moist soils or sandy shores for their edible tubers (ONRG, 2005). Tigernut tubers may be consumed raw, roasted, or ground into flour as well as being used to produce vegetable oil, and cellulose (FAO, 1988). Tigernut is a representative crop of the Spanish Mediterranean region, where tubers are used to make *horchata*. The milky-looking aqueous extract of tiger nuts has a pleasant and characteristic flavor of vanilla and almonds and could be sold in Pubs. Unfortunately, popularity of tigernut milk extract or "horchata" has not extended to Nigeria.

In Maradi state, Eastern Niger, tigernut is cultivated for export to Nigeria. Revenues from this exceed those from the typical cash crops such as cowpea and groundnut. Nowadays, tigernut is cultivated in Northern Nigeria, Ghana and Togo where it is made into a sweet meat or used uncooked as a side dish. These countries, and some others including the Ivory Coast, export 2300 tons of tigernut tubers every year to Spain (ONRG, 2005). Tigernut could be used in seed mixes for wetland restoration, mitigation and erosion control.

In the United States, the primary use of tigernut as a crop is to attract and feed game, particularly wild turkeys. Turkeys love tigernuts; as natural scratchers, once discovering a plot of tigernuts, they will return again and again, all winter long, or until spring arrives and other food is readily available. Also, tigernuts have been planted in fields for pigs and hogs to fatten and improve the taste of pork (Wikipedia, 2005; HIS, 2005; Anne and Grossman, 1998).

Tigernuts are identified as valuable food for waterfowl and cranes. Ducks dive for them when wetland fields are flooded (ONRG, 2005).

Burden (2005), reported that tigernuts weigh about 44 pounds per bushel with oil yields from 0.5 to 1.5 tons/hectare. Tigernut is potentially a commercial source of high-oleic acid vegetable oil and high-carbohydrate tuber cakes. Some authors believe that the tuber oil could be exploited in the same way as olive oil. The iodine level of tigernut oil comes under a non drying oil which is substantially unsaturated, which could be utilized for cooking and may find application as a raw material in industries for manufacturing soap, vegetable oil-based ice cream, salad cream and other non-food application (Umerie *et al*.,1997; Zhang *et al*., 1996).

Barminas *et al*. (2001) reported that the calculated fuel value of tigernut oil is comparable to that of soybean oil. Tigernut oil has high energy density. Researchers have measured the physical and fuel properties of oil extracted from the tigernut, and concluded that the physical properties are similar to those of other vegetable oils. They have suggested that this oil may also be used as bio diesel fuel. The waste residue after oil extraction could be further modified producing syrups, flours, or livestock feeds (Zhang *et al*., 1996; Barminas *et al*., 2001). In the textile industry tigernut oil can be used in waterproofing textile fibers (TTSL, 2005).

Another specie of sedge plant called *Cyperus papyrus* has been used by Egyptians to make paper, sails, cloth, mats, ropes, or plaited into sandals. In the Peruvian Amazon, reportedly there is a native species of *Cyperus* is used widely by tribal women as a natural contraceptive. This property has been attributed to a certain mold that grows on the root of the Amazonian species that has oxytoxic (abortive) properties similar to Ergot, a fungus that grows on rye.

2.6 Anti nutrient factor

Nutritional quality of a food may be dictated mainly by its chemical composition and the presence of anti-nutritional factors, such as phytic acid, tannin and trypsin inhibitor. Phytic acid, a principal storage ubiquitously distributed in plants was reported to be about 724 mg per 100 g by Linssen (1989). However, reports have been made by researchers that fermentation, hydrothermal treatment and some other processing methods are able to nullify or reduce this antinutrient effect (Obizoba and Atti, 1992).Therefore the level of antinutrient in raw tigernuts could be reduced by processing.

There are no reported cases of tigernut toxicity. However, Ochratoxin A (OTA) has been found as a contaminant in tigernut. Ochratoxin A (OTA) is a mycotoxin produced by different species of *Aspergillus* and *Penicillium*. It is found as natural contaminants in many foodstuffs including cereals, dried fruits, cocoa, wine, poultry eggs and milk. OTA is immunosuppressive, teratogenic, genotoxic and mutagenic. The problem with mycotoxin contamination in herbal plants is that they are consumed directly, unlike other products such as maize and groundnuts, which may undergo some processing before eating (Adebajo, 1993). Besides, Adebajo (1993) reported the presence of aflatoxins in tigernut at toxicologically unsafe levels. Bankole and Eseigbe (1996) detected aflatoxins in 35% of tigernut with concentrations ranging from 10-120 g / kg collected from different parts of Nigeria, and the incidence of *Aspergillus flavus* and aflatoxin contamination was found to be correlated.

2.7 Some properties of tigernuts and its products

There is little documentation on the physico-chemical, functional and organoleptic properties of tigernuts. Physico-chemical and functional properties influence the food quality. The term "functionality "as applied to food ingredient's usefulness in food (Satin, 2005). Most functional properties play a major role in food ingredients during preparation, processing or storage. The functional properties of tigernuts can predict how tigernuts should be used in food formulations.

Tigernuts are rich in starch. Starch has two major components: amylose and amylopectin. These polymers are very different structurally with amylose being linear and amylopectin highly branched - each structure playing a critical role in the ultimate functionality of the native starch and its derivatives. Viscosity, gelatinization, texture, solubility, tackiness, gel stability, cold swelling and retrogradation are all functions of their amylase / amylopectin ratio (Satin, 2005).

Functionality is the key to marketing starches in the wide range of food applications. No other ingredient provides texture to as many foods as starch does. Whether it is a soup, stew, gravy, pie filling, sauce or custard, starch provides a consistent shelf-stable product that consumers rely upon.

Viscosity is a useful criterion of desegregation (such as is produced in the initial states of hydrolysis of proteins, starch and pectin). It is important in influencing the processing, preparation and quality attributes of foods. The extent of specific functional properties of starches required by the food industry is almost unlimited and includes the following: specific viscosity (hot and cold) freeze-thaw stability (natural / modified) clarity, opacity, processing conditions tolerance, gel formation, flow properties, emulsion stabilizing capacity, mouth feel, lubricity, palate-coating, suspension characteristics, bland taste, long shelf-life stability, colour, anti-caking, cold-water swelling or dispersibility swelling and resistance to swelling film-forming properties (Marsili, 1993).

Satin (2005) reported that starches obtained from starchy tubers and rice showed similar properties; the solutions of the starches exhibit good paste stability, clarity, and adhesive strength. Starch can be used in many starch-based foods as well as in the cosmetic industry, and for laundry, glazing and stiffening. Starch from tigernuts gelatinizes efficiently and it has low levels of tannin that could exert some inhibitory effects on the activities of the amylases (Umerie *et al*., 1997; Umerie and Uka, 1998).

The oil in tigernuts can be classified as stable, non-drying (lauric) oil, as implicated by its very low iodine value (<100), sharp melting point, and low un-saturation. Tigernut oil shares with coconut oil, an exceptional saturated oil, olive oil and groundnut oil the common feature of remaining liquid at room temperature for the same possible reason of having a preponderance of relatively short-chain saturate fatty acids. The heat of combustion of tiger nut oil (9500 g cal / g) qualifies it edible oil. Since the oil is low in solidification point (-2 to -4) it makes it a requisite for salad and cooking oil. The oil can be used as an accompaniment or for cooking food. Less fat is absorbed into food during cooking as a crust is formed on the surface, preventing the oil itself from being absorbed (TTSL, 2005). Tigernut oil has a very low viscosity making it a suitable substitute for industrial applications in petroleum and natural gas (Deatra, 1999). Tigernut oil is stable and could be used for diverse purposes and applications including polish, shampoos, soaps, and by-products, margarine, salad and cooking oils (Umerie *et al*., 1997).

Tigernuts are rich in carbohydrate reserves and they have a natural sweet vanilla. Almond flavoured taste. Sugar acids and reducing sugars (polyhydroxy-carbonyl compounds) show a browning reaction (or caramelization) when heated a relatively high temperatures. Browning reaction is accelerated by the presence of carboxylic acids and their salts, phosphates, metallic ions and nitrogenous substances present in foods (Umerie and Enebeli, 1996; Bender, 1973; Lake and Waterworth, 1983).

2.8 Handling and keeping quality of tigernuts

Handling of tigernuts is a very important step in preserving freshness. Proper/ hygienic handling is required when processing tigernuts to avoid tissue invasion which may contribute to microbial (bacteria, fungi, viruses) contamination. The number and type of microorganisms present in foods reflect the quality and safety of that food. The extent of microbial growth is influenced by the physico-chemical properties of the food, environmental conditions under which the food is stored and characteristics of the microorganisms (Frazier and Westhoff, 1991; Garbutt, 1997; Mountney and Gould, 1988).

Cooling or freezing of raw tigernuts may slow down the biological decomposition process in tigernuts. Rapid spoilage due to fungi infection, fat deterioration and rapid fermentation causes difficulties in handling and processing of tigernuts and may lead to serious losses. Fat deterioration (lipolysis) caused by different fat splitting enzymes (lipases)

is a general feature in foods with high fat content. Tigernuts will keep for a long time if well dried, shriveled and wrinkled (FAO, 1988; TTSL, 2005). Fresh tigernuts can be kept in water changed daily for up to 10 days. It can also be kept at 0 ºC – 5 ºC but under warm conditions ferments rapidly. This is due to naturally present microorganisms growing on the tubers (FAO, 1988). Eradication of such fungal infections can be by special mechanisms such as solarization and hot water treatment at high temperature (35-50°C) to kill pathogens. Besides, viability of tigernuts is affected at 55 ºC and above and also within 30 minutes high temperature treatment (Garcia *et al*., 2004).

Anaerobic conditions of bulk storage of tigernuts create a complex medium for microbes with the formation of a variety of chemical spoilage products. One predominant product is mycotoxins. Tigernuts (well dried) can be stocked before use without losing any of their unique properties for up to 2 years after purchase. It is important, however, that they should be stored in a properly ventilated area (if possible, next to a window) and during hot periods, plastic that they are wrapped in should be removed (TTSL, 2005). In addition, tigernuts may need to be fumigated every 6 weeks to protect them from any kind of damage that may be caused by bugs or insects if they are to last for 2 years (TTSL, 2005).

2.9 Utilization of tigernuts

Tigernut is an important food crop for certain tribes in Africa. It is often collected and eaten by children. It has been cultivated since early times for its small tuberous rhizomes which are eaten raw or roasted, used for hog feed or pressed for the juice to make a beverage. Products from tigernuts may include aqueous solutions (as a base for non-alcoholic beverages), milky solutions (as refreshing beverage or partial milk substitute), as well as an ingredient in cookies and ice cream. Tigernuts are often used as a substitute for almonds or as a coffee and cocoa additive (FAO, 1988; NUTRA, 2005). Fresh tigernuts have been fermented to produce a local alchoholic drink (Barminas *et al*, 2001).

Flour obtained from tigernuts has a unique sweet taste that has been found ideal for use in the baking industry. It can be used to make delicious cakes and biscuits and also used to compliment fruit flavours as well. The ground flour can be mixed with sorghum to make porridge (TTSL, 2005). Tigernuts could be used in bread, breakfast cereals and puddings. It could be used to enrich rice, cassava, custard, pap, and couscous. Tigernuts and its extract could be blended with wheat flour and local flours for baked products and gruels. Tigernuts

make tasty snacks for the farm family and can be processed into fine, powdery flour usually substituted at a rate of one-half tigernut flour to store-purchased wheat flour in bread and other recipes without affecting the baking characteristics adversely (IHS, 2005).

Oil obtained from tigernuts was first used by Egypt 4000 years ago in preference to olive oil. The oil is golden brown in colour and has a rich, nutty taste (TTSL, 2005). Tigernut oil is also a fantastic component of beauty products. It has a high oleic acid content and low acidity, and so is excellent for the skin. Industrial applications for tigernut oil include high-value applications for cosmetics (perfume carriers) and instrument lubricants. Tigernut oil has advantages over other oils. The oil is tasty and stable and has high quality due to its extraction without adding any external heat (cold pressed oil). It is highly recommended for cooking above other oils because it is more resistant to chemical decomposition at high temperatures.

Tigernuts are also used raw as snack and refreshing beverage production and can be converted to highly valued products. Tiger nuts make tasty snacks for the farm family and can be processed into fine, powdery flour usually substituted at a rate of one-half tiger nut flour to store-purchased wheat flour in bread and other recipes. Tigernut flour has digestible proteins that can complement all cereals. About 5% flour may be added to bread recipes without affecting the baking characteristics adversely.

Yogurt has been produced from milk obtained from coconut and tigernuts, singly, and in combination with fresh cow milk, by fermentation using starter cultures of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Akoma *et al*., 2000). Umerie and Enebeli (1996) produced caramel from malted tubers of tigernut which appeared as black brown syrup and is suggested that it could find applications where it will add body, flavour or colour, as in bakery products, non alcoholic beverages, dark beers and in condiments production. Tigernut could also be used as a livestock feed as reported by many researchers (Wikipedia, 2005; Bamgbose *et al*., 2003; ONRG, 2005).

2.10 Processing techniques

Processing techniques have been extensively used in the preparation of foods, beverages. The purpose of food processing may include to separate components of foods (raw material) into solids and liquid, modify its appearance, develop its natural flavour, stimulate the digestive juices, add variety to the menu, make it easily digestible and bio-available, destroy harmful microorganisms, improve its nutritional quality and prevent decomposition. Tigernuts could be processed using different techniques and methods such as selection, washing, heating (boiling and roasting), milling, blending, sieving, drying, soaking, fermentation, malting, packaging, storing and preserving.

Selection of mature, healthy tubers can be done to obtain maximum quality. Washing of tigernuts in clean changes of water is necessary for removal of sand and dirt and microbial load reduction.

Heating (boiling or roasting), coagulates protein, ruptures fat depots and gelatinizes the starch granules. The general view has been that the best results of heating could be obtained at the highest possible temperatures, which, at atmospheric pressure, would be 100 °C. However, caramelization of tigernuts occurs at temperatures above 100 °C (Umerie and Enebeli, 1996). The most common practice of roasting of tigernuts is at about 95 – 120 °C within15 to 20 minutes (Umerie and Enebeli, 1996). Roasting at 120 °C and above is basically applied during coffee production for its characteristic flavour (Hilton, 1976).The proof of a good cooking is the softening of the tubers, which leads to busting of the outer sheath coatings. Boiling for about 4-5hrs will soften tuber and make easy and longer preservation in the refrigerator (www.tigernut.com).

Milling or blending tigernuts breaks down large fraction into tiny particles (powder or flour or fine paste). Commercial milling machines may be used in flour processing in other toobtain fine powdery even products as possible about 0.02mm. In practice there is a great variation in particle sizes.

Sieving of milled or blended samples can be done using different sizes of sieve or muslin cloth). The smaller the size of particles of the flour and paste obtained, the better the quality of the product and realization of maximum aqueous extraction.

Drying is primarily done to reduce moisture content to such a level that insufficient water remains to support the growth of the microorganisms. The main feature of this process consists on lowering the water content in order to avoid or slow down spoilage by microorganism. Drying at temperatures below 70 °C may contribute to keeping quality of

tigernuts. This is sufficiently low to stop chemical degradation. Sun drying of tigernuts is best achieved in hot, dry season, on a clean mat well spread out far from motor roads and dusty area to prevent contamination (TTSL, 2005). However, nutrients in foods are generally affected when exposed to high temperatures for long periods (MAFF, 1981).

Steeping or soaking and fermentation of staples serves as a major source of nourishment for large populations in rural communities and contributes significantly to food security by increasing the range of raw materials, which can be used in the production of edible products (Satin, 2005). Length of steeping may have a significant influence on enzyme development and extract recovery. Steeping leads to the conversion of starch to reducing sugars. Reducing sugars decrease during the early part of steeping (24 hrs) and then increases towards the later phase (Brookes *et al*., 1976). Traditional small-scale food fermentation is very weak and existing information on the subject is not widely dispersed. Furthermore, "indigenous knowledge" on fruit and vegetable fermentations is being lost as technologies evolve and populations move away from traditional food preservation practices (Satin, 2005).

Fermentation creates new food flavours and odours. Besides, microorganism involved in fermentation process can be used directly as a food source or as a supplement to other food (single cell-protein).

Malting involves steeping and germination. After steeping process has been carried out for about 24 hrs, in such a way as to degrade or modify tubers with a minimal loss in grain weight, germination can then be carried out. Malting can be done on a flat sieve in a dark cool compartment for germination. The tubers are watered by spraying (using a spraying pump) until desired germination stage is attained for some days. The germinated tubers (malted tubers) may be sun dried and roasted until brown in colour (Umerie and Enebeli, 1996). Malting also ensures maximum extract release (protein and carbohydrate). Malting of tigernuts has been observed to increase the concentration of reducing sugar. This has been used to produce caramel (Umerie and Enebeli, 1996).

Packaging, storage and preservation of tigernuts could be made in air tight containers at room temperature. Tigernuts could be refrigerated or freezed in constant and mild temperatures to prevent rapid colour changes, microbial growth and / or spoilage. The addition of artificial preservatives to products may also be necessary in order to conserve the exceptional qualities intact.

Drying is one of the oldest methods of preservation available to mankind that play an important role in the food supply chain. Although the primary objective of drying is preservation, quality aspects are taken into account according to the process carried out one

may end up with very different products. It has been recognized that the important factor is not the water content but water availability for spoilage reactions. Over the last several thousand years, fermentation has been a major way of preserving food. Microbial growth, either of natural or inoculated populations, causes chemical and textural changes to form a product that can be stored for extended periods (Prescott *et al*., 2005).

Chapter Three

3. Materials and Methods

3.1 Collection of samples

Fresh raw tigernuts (about 10 kg) and all the other ingredients except palm wine were purchased from the Nsukka Urban Main Market, Enugu State, Nigeria.

3.2 Sample preparations and analyses

3.2.1 Sample preparation

Fresh tigernuts (untreated tigernuts) were used for the preparation of tigernut milky juice extract (plain tigernut milk), fermented tigernut milky juice (tigernut wine), treated tigernuts (dried, malted and roasted tigernuts) and all the developed tigernut products (milk, coffee and wine).

3.2.1.1 Fresh tigernuts (Unmalted tigernuts)

Fresh tigernuts were visually inspected. Defective tubers were manually removed and discarded. Hence, only matured healthy tigernut tubers were selected. Tigernuts were weighed out in portions washed thoroughly in two changes of clean water and drained prior to use for all the studies. A portion of tigernut (500 g) was packaged in nylon bags kept in an air tight container and stored in the freezer (fresh unmalted tigernuts). Another portion (500 g) was soaked for 12 hours in two changes of water, drained and stored as stated above. Samples were taken out from the freezer prior to analysis.

3.2.1.2 Tigernut milky juice extract (plain tigernut milk)

Fresh tigernuts (500 g) were soaked in two changes of clean water for 12 hours (figure 3.1). The soked tiegrnuts were washed in two changes of water, drained, blended into paste in electric blender and slurried. 2500 ml of distilled water was used all together during the blending and slurring process. The slurry was filtered with the aid of a clean damp muslin cloth and the filtrate obtained was transferred into sterilized plastic bottles, corked and stored in the freezer (for not more than three days) prior to analysis (samples were taken out from the stored fresh tigernut milky juice extract). Samples were discarded after a maximum of three days and new samples prepared for replicate analysis.

3.2.1.3 Fermented tigernut milky juice (tigernut wine)

Fresh tigernuts (500 g) were soaked in water (1: 3 w / v) for 12 hours (to develop acidity, activate enzymes and indigenous microbial fermentative organisms) and washed in water (figure 3.3). Tigernuts are blended into fine paste with water (2000 ml) using a mammomlex electric blender. The resultant paste was slurried with water (2500 ml) and filtered using a muslin cloth (squeezing the edges of the cloth towards the slurry for maximum liquid extraction). About 450 g of granulated sugar (as osmotic agents which will make water unavailable for spoilage changes and causes plasmolysis of pathogenic organisms) and 200 ml of juice extracted from fresh lemon (to inhibit bacterial activity by lowering the pH of the aliquot below the range tolerated for growth and metabolism for most pathogenic organisms but could allow the growth of yeast and lactic acid bacteria) was added to the filtrate. The entire mixture was homogenized by shaking vigorously for 5 minutes, poured into a sterilized fermentation gallon and corked. The medium was fermented for 24, 36 and 48 hours. Sample portions were taken out from in triplicates from the gallon at 24, 36 and 48 hours period of fermentation into sterilized plastic bottles and stored in the freezer prior to analysis. Samples were discarded after 1 week in the freezer and new samples prepared for replicate analysis.

3.2.1.4 Malted tigernuts

About 2 kg of selected fresh tigernuts were steeped (soaked) in water (1:3 w / v) at room temperature (27 °C - 30 °C for 24 hours) in for changes of water at 6 hours interval before re-soaking (figure 3.2). At the end of the steeping period, the tubers were germinated on a sterilized jute cloth. The jute cloth was treated by washing, oven drying at 60 °C and cooling. Tigernut tubers were spread out on the jute cloth and malted for 1 week in an oven compartment (about 30 °C). Tubers were water sprayed with the aid of spraying pump for at least 2 times per day. At the end of the malting period, germinated tubers were degerminated or devegetated (removal of sprouts, shoots and roots), washed to reduce microbial load and drained. The malted tigernuts were divided into three portions. The first portion was stored in the freezer in an air tight nylon pack (freshly malted tigernuts), the second portion was used for preparing malted dried tigernuts and third portion was used for preparing malted roasted tigernuts.

3.2.1.5 Dried tigernuts

1 Dried unmalted tigernuts: Abouyt 600 g fresh tigernuts (unmalted tigernuts) were oven dried at 55 °C fro 48 hours and packaged in nylon bags kept in an airtight jar and stored in the freezer and room temperature prior to analyses.

2 Dried malted tigernuts: About 600 g of freshly malted devegetated tubers were oven dried at 55 °C for 48 hours, packaged and stored as mentioned above in case of dried unmalted tigernuts.

3.2.1.6 Roasted tigernuts

1 Roasted unmalted tigernuts: About 600 g of fresh unmalted tigernuts were air dried at room temperature for 24 hours and roasted at 150 °C in an electric oven tray (40 litre, Gold star oven) for 3 hours (figure 3.2). Tigernuts were stirred from time to time to ensure even roasting until coffee brown in colour. The roasted samples were cooled for several hours and packaged in nylon bags. These were stored in an air tight jar in the freezer and at room temperature prior to analysis.

2 Roasted malted tigernuts: About 600 g of freshly malted devegetated tubers were washed and air dried at room temperature for 24 hours. They were roasted at 150 °C for 3 hours until coffee brown in colour in an electric oven (40 litre, Gold star oven). The roasted sample was cooled fro several hours, packaged and stored as mentioned above, in case of roasted unmalted tigernuts.

3.2.2 Proximate composition analyses of tigernuts (treated and untreated)

The proximate components of fresh, dried and roasted unmalted and malted tubers of tigernuts were determined by the methods described in pearson (1976), Kirk *et al*. (1991) and Association of Official Analytical Chemist (1995).

3.2.2.1 Moisture content

Dry matter was determined by oven drying at 105º C to a constant weight.

Five grammes (5g) of each sample will be weighed into pre-weighed drying dishes and kept in oven adjusted at 105 °C. After 6 hrs, the sample was withdrawn, cooled in a desiccator and reweighed. Moisture content of each sample was calculated as follows:

$$\% \text{ Moiture content (M)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100.$$

W_1 = Initial weight of crucible

W_2 = Weight of crucible + sample before drying

W_3 = Weight of crucible + sample after drying

3.2.2.2 Crude protein content (Macrokjeldahl method)

Tigernut sample (5 g) was mixed with 15 g potassium sulphate (K_2SO_4), 0.7 g mercuric oxide, copper sulphate ($CuSO_4$) as acatalyst and digested in a long necked Kjeldhal bottles with 40 ml concentrated sulphuric acid for approximately 2 hours. Distilled water (200 ml) and 25 ml sodium thiosulphate solution (80 g / L) was added.

The contents of the digestive flask was mixed and boiled until at least 150ml distills into the receiver. Five (5) drops of methyl red indicator solution (0.5 g / 100 ml ethanol) was added to the mixture before titration with 0.1 M sodium hydroxide. The percentage nitrogen obtained was multiplied by a conversion factor (6.25) to get the protein (Feeding stuff-determination of nitrogen content and calculation of crude protein).

% Nitrogen = Volume of acid required to titrate sample – volume of acid required to titrate blank multiplied by acid normality multiplied by 100 all divided by weight of sample.
% Protein = % Nitrogen x Conversion factor (6.25)

3.2.2.3 Mineral ash content

Mineral ash content was determined by heating 5 g of each ground tigernut sample in a clean dry crucible. This was charred over a Bunsen flame in a fume cupboard to destroy most of the organic matter. The heated tigernut sample was further heated in a muffle furnace at about 500 ºC for about 3 hours until white ash remains. Heated tigernut sample was cooled in a desiccator and reweighed. Ash was calculated as follows:

$$\% \text{ Ash (dry basis)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100.$$

Where: W_1 = Initial weight of empty crucible

W_2 = Weight of crucible + sample before Charring and ashing

W_3 = Weight of crucible + white ash

3.2.2.4 Crude fat content (Soxhlet method)

Five grammes (5 g) of each tigernut sample was weighed into a small porcelain bowl and heated in an oven at 105°C for one hour. After cooling, the dry tigernut samples were transferred into a soxhlet thimble. The samples in the thimble were covered with glass wool and placed into a soxhlet apparatus (fat extraction unit). Dry and clean fat extraction flask (pre-weighed) was placed into the extraction unit together with about 300 ml of petroleum ether (boiling point 40 - 60°C) and was allowed to reflux for about 6 hours. Extraction was carried out on each tigernut sample.

Finally, petroleum ether was evaporated off and the flask dried in an oven at 105°C for about 1 hour and then transferred into a dessicator to cool. The weight increase of the flask was estimated as corresponding to the fat content. Fat was calculated as follows:

$$\% \text{ Fat} = \frac{\text{Weight of fat}}{\text{Weight of Sample}} \times 100$$

3.2.2.5 Crude fiber content

Crude fibre was determined after boiling 5g defatted sample in refluxing sulphuric acid and sodium hydroxide. The 5 g sample was defatted and treated with light petroleum (boiling range 40-60 °C), 0.255 M sulphuric acid (about 200 ml H_2SO_4) and dilute sodium hydroxide (about 0.1313 N 200 ml NaOH). The sulphuric acid was used to disperse the sample. The mixture was heated to boiling point within 1 minute (the flask was heated in a liebig reflux condenser). The whole insoluble material was transferred to the filter paper by means of dilute hydrochloric acid. The final residue was filtered through with the aid of a pre-weighed filter paper used to line a buckner funnel connected to a vacumn pump. The insoluble matter transferred to the weighed filter paper was dried at 100 °C to a constant weight. The filter paper and contents were incinerated to ash. The weight of the ash was subtracted from the increase of weight on the paper and insoluble material. The difference in weight was reported as crude fibre ie:

% Crude fibre = the loss in weight after incineration x 100.

3.2.2.6 Carbohydrate content

Available carbohydrate was determined by difference (subtracting crude protein (%), moisture (%), fat (%), crude fiber (%) and ash (%) contents of the tigernut sample from 100). Carbohydrates = 100 – {protein (g %) + fat (g %) + water (g %) + fibre (g %) + ash (g %)}

3.2.2.7 Energy value

Energy value of tigernut sample was calculated using Atwater values: 4, 9, 4 as follows (4 x protein, 9 x fat, and 4 x carbohydrate) and expressing the sum of products in (4 x protein + 9 x fat + 4 x carbohydrate kilocalories. This was converted to kilo joule (KJ) using a conversion factor = 4.184 (approximately 4.2) to multiply the energy values given in Kcal (MAFF, 1981).

3.2.3 Mineral and vitamin content analyses of tigernuts (treated and untreated)

3.2.3.1 Mineral content

Five grammes (5 g) of each tigernut sample was heated gently over a Bunsen burner flame until most of the organic matter was destroyed. This was further heated strongly in a muffle furnace for several hours until white- grey ash was obtained. The ash material was cooled. About 20 ml of distilled water and 10 ml of the dilute hydrochloric acid was added to the ashed material. This mixture was boiled, filtered into a 250 ml volumetric flask, washed thoroughly with hot water, cooled and made up to volume. Minerals content of each sample was analyzed using colourimetric or spectrophotometric or titrimetric methods were applicable (AOAC, 1995; Pye Unicam, 1970; Pearson, 1976). Samples were analyzed for sodium (Na), potassium (K), calcium (Ca), iron (Fe), magnesium (Mg), zinc (Zn), copper (Cu) and phosphorus (P).

Sodium (Na)

Colourimetric method was used to determine sodium content. Sodium stock solution was prepared by dissolving 1.271 g sodium chloride in water and diluting to 1 litre (≡ 500 mg/g l Na) and a standard dilute sodium solution will be prepared by diluting 10 ml stock sodium solution to 500 ml with water (≡10 mg/l Na) and kept aside. A calibration graph was prepared from the readings obtained. About 5 ml of sample was mixed with 5 ml of uranyl

acetate, shaken and allowed to stand for 5 minutes. The sample was centrifuged and the supernatant obtained and mixed with 1 % acetic acid and 0.4 ml of potassium fericyanide. The colourimeter was set to scale 0 with distilled water and the standard dilute sodium. Absorbance was read and the sodium content was calculated using the following formula:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Potassium (K)

Potassium stock solution and standard dilute potassium solution were prepared. A calibration graph was prepared from the reading obtained. About 2 ml of sample was mixed with 2 ml of sodium cobaltonitrate and allowed to stand for 45 minutes. About 2 ml of water was added to the mixture and centrifuged for 15minutes. The supernatant was obtained and mixed with 2 ml of 70 % ethanol. The mixture was centrifuged for 5 minutes and the supernatant boiled in a water bath for 10 minutes. About 1 ml of 1 % choline hydrochloride, 1 ml potassium fericyanide and 2 ml of distilled water is added to the extract. Absorbance was determined at 620 nm using a colourimeter. The sample solution was then read and sodium content was calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Calcium (Ca)

Calcium was determined by titrimetric method after precipitation as calcium oxalate (pearson, 1976). Five mililitres (5 ml) of samples was mixed with 1 ml of ammonium oxalate solution. pH was adjusted to 8 using ammonium hydroxide solution and adjusted again to 5 using dilute acetic acid. The mixtures were allowed to stand for 4 hours, centrifuged and decanted. About 2 ml dilute sulphuric acid was added and it was heated. Titration was then carried out using 0.02 N potassium permanganate (1 ml = 0.0004 g Ca).

Iron (Fe)

Three militres (3ml) of acetate buffer, 2 ml of 2.5 % hydrochinon and 2 ml of α- α dipyridyl was added to 5 ml of the tigernut mineral ash solution. The pH of the mixture was adjusted using few drops of Ammonia and the preparation read in a photometric colourimeter at 250 nm (Pye Unicam, 1970). Iron was the calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{}$$

Absorbance of standard solution x Sample volume

Magnesium (Mg)

One mililitre (1 ml) of magnesium buffer and 2.5 ml of eriochrome blue black tea was added to 5 ml of treated ash solution from tigernut sample. This was allowed to stand for 10 minutes. Absorbance was taken at 520 nm using a colourimeter (pye Unicam, 1970). Magnesium was calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Zinc (Zn)

Dithizone method was used for zinc determination. About 2.5 ml of 0.2 M acetate buffer and 0.5 ml of 0.1 N sodium thiosulphate were added to 5 ml of mineral ash sample solution. The pH was adjusted to 4 – 5.5 and 5 ml of dithizone solution was added. The mixture was shaken for 4 minutes and allowed to stand to separate. The supernatant was decanted away and the remaining read at 535 nm (AOAC, 1995). Zinc was calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Copper (Cu)

One mililitre (1ml) of versenate citrate mixture, 2 drops of phenolpthaline indicator and few drops of concentrated ammonia (until pink) were added to mineral ash sample solution. One mililitre (1ml) of 0.1% diethyl diether carbamite and 5 ml of carbon tetrachloride was also added, agitated for 5 minutes and allowed to separate. Absorbance was taken at 440 nm (AOAC, 1995). Copper was calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Phosphorus (P)

The Vanado Molybdate method was used fro phosphorus determination. About four (4) drops of ammonia, 2.5 ml vanadyl molybdate and 2.5 ml of distilled water was added to 5

ml of mineral ash sample solution. Absorbance was taken at 470 nm using a colourimeter (Pearson, 1976; AOAC, 1995). Phosphorus was calculated as follows:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

3.2.3.2 Vitamin C and E content of tigernuts (treated and untreated)

Vitamin C or Ascorbic Acid (AA) was determined by 2, 4 dinitrophenyl hydrazine method of Roe and Kuethe described by Ball (1994) using colourimetric method. Vitamin E was determined by spectophotometric methods (AOAC, 1995).

Ascorbic Acid (Vitamin C)

One gramme (1 g) of freshly macerated tigernut sample was liquidized with 50 ml distilled water and filtered. About 1 ml of the samples filtrate was homogenized with 10 % trichloroacetic acid and 0.5 ml chloroform. The mixture was centrifuged and allowed to settle. The clear supernatant liquid was taken out and mixed with 0.4 ml freshly prepared colour reagent (5 ml 2, 4, dinitrophenyl hydrazine, 0.1 ml 5 % cupric sulphate and 0.1 ml 10 % thiourea) and incubated for 56 $^{\circ}$C in a water bath for 1 hour. This was cooled in ice bath for 3 minutes. Ice cold 85% sulphuric acid was added slowly to each tube with mixing and left at room temperature for 30 minutes. The absorbance was taken at 490 nm (Ball, 1994). Vitamin C was calculated with the formula:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Vitamin E

One gramme (1 g) of freshly macerated tigernut sample was liquidized with 50 ml distilled water and filtered prior to analyses. About 10 ml the filtrate was mixed with petroleum ether to extract the oil fraction. The supernatant was withdrawn and allowed to evaporate by adding 5 ml of 1.5 M alcoholic potash and boiling for 1 hour in a water bath. About 5 ml of petroleum ether and 5 ml of distilled water was added and the mixture centrifuged for10 minutes. The supernatant was again withdrawn and allowed to evaporate. About 3 ml of ethanol, 1 ml of 0.2 % ferric chloride and 1 ml of 0.5 % alcoholic were added.

Absorbance was taken at 520 nm (AOAC, 1995). Calculation was made using the following formula:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

3.2.4 Physico-chemical and functional properties of tigernuts

The physico-chemical and functional properties of dried and roasted tigernuts and its products were determined. Samples of fresh tigernut milk extract (plain tigernut milk), 24 hr, 36 hr and 48 hr fermented tigernut milky juice (wine), ground roasted malted and unmalted tigernuts were prepared as mentioned previously. Lemon tigernut milk was prepared using 100 g of tigernuts, 500 ml of water, 125g sugar and 1 / 5 teaspoon of fresh lemon zest as in figure 3.1. The pH, viscosity, specific gravity (in relation to relative density), foaming capacity and stability, emulsion capacity and stability, ethanol content and total reducing sugar of tigernuts and or its products (fermented or unfermented tigernut extract or roasted tigernuts) and were determined.

3.2.4.1 pH

The pH of tigernuts and its products (fermented and unfermented tigernut extract or roasted tigernuts) were determined using a Pye Unikam pH meter at room temperature. About 10ml of liquid sample or 10 g of ground dry sample (diluted with 100 ml distilled water and homogenized for 5 minutes) was placed in the measuring cup of the pH meter and then the measuring arm lowered into the cup in contact with the supernatants to determine the pH. The control device of the pH meter was turned on for 30 minutes before measurements were taken. Distilled water was used as a blank to set the meter to neutrality before taking the readings.

3.2.4.2 Specific gravity

Specific gravity of fresh tigernut milk extract, lemon tigernut milk and 24 hr, 36 hr and 48 hr fermented tigernut milky juice (wine) were determined as described by Kirk *et al*. (1981). A 10 ml pyknometer (specific gravity bottle) was weighed when clean, empty and dry. The pyknometer was be filled (so that no air is incorporated) with sample extract liquid (cooled to several degrees below 20 °C and allowed to come to 20 °C by placing in a bath). Excess liquid was wiped off by blotting paper. The capillary tube of the pyknometer was carefully wiped and its cap was placed on at 20 °C. Specific gravity (d) was calculated as follows:

$$SG = d^{t^\circ}_{20^\circ} = W_1 / W$$

Where d = specific gravity temperature (t° designate 20 °C)
W_1= weight of the volume of liquid sample
W = weight of an equal volume of distilled water.

This was related to degree Baumé by Urarov et al. stated by Umerie and Enebeli (1996).

$$^\circ Bé = \frac{144.3\ (\text{relative density} - 1)}{\text{Relative density}}$$

3.2.4.3 Viscosity

Viscosity of tigernut milky juice extract and lemon tigernut milk were determined using a Torsion Gallenhamp Viscometer with core head size 30 and a standard weight guage of 1 5 / 8 inches and read on graph number 2 at 28 $^\circ$C and the average mean taken. The control device was turned on 30 minutes before measurement. The sample was placed in the measuring cup of the viscometer and then the measuring arm was lowered into the cup. Measurement was taken following some minutes of spindle rotation. This viscosity was then extrapolated from the graph.

3.2.4.4 Foaming capacity and stability of tigernuts

Foaming capacity and stability of tigernuts were determined using a modified method of Coffman and Garcia (1977).Tigernut milky juice extract (100ml) was homogenized for 5 minutes in a blender and immediately poured into a 250 ml glass graduated measuring cylinder. The initial foam volume (foam capacity) was measured as volume increase.

$$\text{Foaming capacity} = \frac{Va - V_b}{V_b} \times 100$$

Where: Va = volume after homogenization

V_b = volume before homogenization or initial foam volume

Foaming stability was determined by allowing 100 ml of blended homogenized sample to stand for 60 minutes and reading the total volume after 15 minutes interval. The percentage foam volume decrease was calculated as foam stability.

$$\text{Foam stability} = \frac{V_t \times 100}{V_0}$$

Where V_t = foam volume at 60min

V_0 = initial foam volume

3.2.4.5 Emulsion capacity and stability

Pearce and Kinsella's (1978) method was used for emulsion capacity and stability determination. The emulsion capacity of tigernut milky juice extract sample (50 ml) was homogenized in a blender for 60 sec with the addition of 30 ml of olive oil. This was transferred into two 50 ml centrifuge tube, kept in a water bath (80 °C) for 15 minutes and then centrifuged for 30 minutes. The volume of oil separated from the emulsified layer and liquid layer was recorded and emulsion capacity calculated as:

$$\text{Emulsion capacity} = \frac{\text{Volume of oil emulsified} \times 100}{\text{Volume of sample}}$$

Emulsion stability of tigernut milky juice extract was determined by homogenizing 50 ml of sample with 30 ml of olive oil. The emulsion was transferred into two 50 ml centrifuge

tube and the total volume, emulsified layer, total oil and liquid separated during standing at room temperature was recorded at 60 minutes. Emulsion stability was calculated as:

$$\text{Emulsion stability} = \frac{\text{Height of oil emulsified layer} \times 100}{\text{Height of whole solution}}$$

3.2.4.6 Ethanol content of fermented tigernut milky juice (tigernut wine)

About 100 ml of 24 hr, 36hr and 48 hours fermented tigernut milky juice extract (wine) were determined for alcohol content. About 100 ml of sample was transferred at 20 °C into a distillation flask and 40 ml water was used in rinsing the measuring flask. The measuring flask was used to collect the distillates was determined at 30 °C with the pyknometer and used to estimate the alcohol content of the fermented sample. Spirit inication equivalent to the alcohol content was given by the expression 1000 (1 – Specific gravity) as stated in pearson (1976).

3.2.4.7 Total available reducing sugar of tigernut milk and wine

Total available reducing sugar as glucose was determined by phosphomolybdic method. The diluted sample (tigernut milk extract, tigernut lemon milk and the fermented milky juice) was mixed with cooper reagent, boiled and cooled on ice, then mixed with phosphomolybdic acid reagent and read at 420 nm. Total sugar was determined using spectrophotometric method. About 0.1 ml of product samples was made up to 1 ml with water. About 1 ml of alkaline cooper reagent was then added and the mixture boiled in a water bath for 8 minutes and cooled on ice. About 1 ml of phophomolybdic acid reagent and 7 ml of water was added and thoroughly shaken. Absorbance was read at 420 nm. Calculation was made using:

$$\frac{\text{Absorbance of sample} \times \text{Concentration of standard solution} \times \text{Dilution factor}}{\text{Absorbance of standard solution} \times \text{Sample volume}}$$

3.2.5 Development of tigernut products

Milk, coffee and wine were developed from fresh tigernuts using basic food processing and preservation techniques such as drying, roasting, malting, milling, blending, fermentation, refrigeration and or freezing. Fermented and unfermented tigernut beverages were made from fresh raw tigernuts (unmalted) while coffee beverages were made from dried ground roasted

malted and unmalted tigernuts. Flow diagrams of tigernut products (milk, coffee and wine) are shown in flow diagram 3.1, 3.2 and 3.3.

3.2.5.1 Tigernut milk (unfermented tigernut beverages)

Fresh raw tigernuts (500 g) were steeped or soaked in a bowl of clean water (about t1:3 w/v at room temperature; 27 °C – 30 °C) for about 24 hours to ensure maximum water absorption, sugar level retention, softening of tuber tissues and juice extract recovery. Odour build up was avoided by changing the steeping water every 6 hrs (however, a longer steeping period of 24 hrs without changes of water will affect the taste and quality of the milky juice extract). After 12 hours, tigernuts was drained with the aid of a sieve, washed again in two changes of clean portable water, ground into paste using an electric blender and slurried with water (2500 ml). A muslin cloth was used to filter the resultant paste to obtain the milky juice extract (plain tigernut milk). This was used in preparing tigernut beverages. Brands of tigernut milk was formulated using sweetner (sugar) and flavours such as lemon juice and its peel, ground fresh ginger and liquid vanilla flavour as follows:

1) **Unsweetened- unflavoured / plain tigernut milk / tigernut milk extract**

Ingredients: About 500 g tigernuts and 2500 ml of water

Methods: Fresh tigernut tubers were washed, soaked for 12 hours, drained, washed again twice in clean water and blended. The paste was slurried with water and sieved with a washed damp clean muslin cloth. The filtrate obtained was kept in the fridge or freezer (30 minutes and above) to chill before consumption.

2) **Ginger flavoured – sweetened tigernut milk / ginger tigernut milk**

Ingredients: About 500 g tigernuts, 2500 ml water, 125 g sugar and 1 tablespoon fresh grated ginger.

Method: Fresh tigernut tubers were washed, soaked for 12 hours, drained, washed again twice in clean water and blended. Grated fresh ginger (well washed and skinned) was added and blending continued. The resultant paste was slurried with water and sieved with a washed damp clean muslin cloth. Sugar was added to the filtrate obtained and this was kept in the fridge or freezer (30 minutes and above) to chill before consumption.

3) **Lemon flavoured – sweetened tigernut milk / lemon tigernut milk**

Ingredients: About 500 g tigernuts, 2500 ml water, 125 g sugar and 1 teaspoon lemon peel (freshly grated) and 125 ml lemon juice (about 1 small lemon fruit).

Method: Fresh tigernut tubers were washed, soaked for 12 hours, drained, washed again twice in clean water and blended. Grated lemon zest (well washed and skinned) was added and blending continued. The resultant paste was slurried with water and sieved with a washed damp clean muslin cloth. Sugar and lemon juice were added to the filtrate obtained and then poured into a gallon and vigorously shaken for few minutes. This was kept in the fridge or freezer (30 minutes and above) to chill before consumption.

4) Vanilla flavoured – sweetened tigernut milk / vanilla tigernut milk

Ingredients: About 500 g tigernuts, 2500 ml water, 125 g sugar and 1 tablespoon vanilla flavour (Rayner's liquid concentrate).

Method: Fresh tigernut tubers were washed, soaked for 12 hours, drained, washed again twice in clean water and blended.. The resultant paste was slurried with water and sieved with a washed damp clean muslin cloth. Sugar and vanilla flavour were added to the filtrate obtained and the mixture was bottled and kept in the fridge or freezer (30 minutes and above) to chill before consumption.

3.2.5.2 Tigernut coffee (coffee or cocoa substitute)

Two coffee samples were prepared (malted tigernut coffee and unmalted tigernut coffee). Fresh malted and unmalted tigernuts air dried at room temperature (24 hr) were roasted respectively in an electric oven regulated at 150 ºC until it is coffee brown in colour. The roasted tigernut coffee samples were allowed to cool for several hours and then milled into powder (using a clean hammer mill). Black and cream tigernut coffee extracts were prepared from the ground tigernut coffee samples as follows:

1) Black tigernut coffee (ground malted and unmalted roasted tigernut coffee; BMTC or BUTC)

Ingredients: Five (5) tablespoon ground tigernut coffee (malted or unmalted) and 1250 ml hot water

Method: The ground roasted tigernuts were infused in boiling water in a coffee pot and allowed to stand for 5 minutes. The supernatant liquid was decanted (black tigernut coffee extract) or strained and poured into a flask or teacup for consumption.

2) Cream tigernut coffee (ground malted and unmalted roasted tigernut coffee; CMTC or BUTC)

Ingredients: Five (5) tablespoon ground tigernut coffee (malted or unmalted tigernut coffee), 1250 ml of water, 5 tablespoon instant milk powder and 10 teaspoon granulated sugar.

Method: The ground roasted tigernuts were infused in boiling water in a coffee pot and allowed to stand for 5 minutes. The supernatant liquid was decanted (black tigernut coffee extract) or strained. Powdered milk and sugar (sweetener) was added to the tigernut coffee extract and poured into a flask or teacup for consumption.

3.2.5.3 Tigernut wine (fermented tigernut beverages)

Tigernuts were steeped in water (1:3 w/v) for 12 hours (to develop acidity, enzymes and build up indigenous microbial fermentative organisms) and washed in clean water. Tigernuts were blended into paste with water using a mammomlex electric blender. The resultant paste was slurried with water and filterated using a muslin cloth (squeezing the twisted edges of the cloth for maximum liquid extraction). The tigernut milk filterate obtained was mixed with granulated sugar (as osmotic agents which will make water unavailable for spoilage changes and causes plasmolysis of pathogenic organisms) and lemon fruit juice (to inhibit bacterial activity by lowering the pH of the aliquot below the range tolerated for growth and metabolism for most pathogenic organisms but allow the growth of yeast and lactic acid bacteria). The mixture was homogenized by shaking vigorously for about 5 minutes and poured into a plastic fermentation gallon and corked lightly (tigernut wine medium). The gallon containing the tigernut medium was swirled every 6 hours. Three brands of fermented tigernut beverages (tigernut wine) were developed from the fresh tigernut extract medium with respect to the period of fermentation.

1) **24 hours fermented tigernut wine**

   Ingredients: About 500 g tigernuts, 4500 ml water, 450 g of granulated sugar and 200 ml lemon juice

Method: Tigernut wine medium was prepared as stated earlier and kept in a cool clean place for 24 hours to ferment naturally at room temperature. This was chilled or preserved in the freezer before consumption.

2) **36 hours fermented tigernut wine-A**

Ingredients: About 500 g tigernuts, 4500 ml water, 450 g of granulated sugar and 200 ml lemon juice

Method: Tigernut wine medium was prepared as stated earlier and kept in a cool clean place for 36 hours to ferment naturally at room temperature. This was chilled or preserved in the freezer before consumption.

3) **36 hours fermented tigernut wine-B**

Ingredients: About 500 g tigernuts, 5000 ml water, 500 g of granulated sugar and 225 ml lemon juice

Method: Tigernut wine medium was prepared as stated earlier and kept in a cool clean place for 36 hours to ferment naturally at room temperature. This was chilled or preserved in the freezer before consumption.

3.2.6. Vitamin and zinc content of tigernut products (milk and wine)

Tigernut product samples (milk and wine) were analyzed for their vitamins B_1, B_2, B_{12}, C, E and zinc content. Thiamin (vitaminB_1), riboflavin (vitamin B_2), cyanocobalamin (vitamin B_{12}), and Vitamin E were determined by spectophotometric methods (AOAC, 1995; Ball, 1994; Pye Unicam, 1970). Vitamin C or Ascorbic Acid (AA) was determined by 2, 4 dinitrophenyl hydrazine method of Roe and Kuethe using colourimetric method (Ball,1994).

Thiamin (vitamin B_1)

A standard solution of thiamin and a reagent solution prepared from 1 % potassium ferricyanide and 10 % sodium hydrioxide in the ratio of 1: 9 were used to determine concentration of thiamin in serial dilutions at 367 nm. A graph was plotted to extrapolate the slope of the concentration of thiamin in the test sample.

About 2 ml of tigernut product sample solution were pipetted into 100 ml separating funnel and 2 ml of reagent solution added after 1 minute. About 15 ml isobutyl alcohol was added and the mixture slowly shaken for 2 minutes to separate the isobutyl alcohol layer. This

was then passed through anhydrous sodium sulphate. The absorbance was taken at 367 nm using isobutyl-alcohol as blank. Thiamin was calculated with the formula:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Riboflavin (vitamin B_2)

A standard solution of riboflavin and Denigees reagent solution prepared from 5 g yellow mercuric oxide, 80 ml water and 20 ml sulphuric acid was used to determine concentration of riboflavin in serial dilutions at 525 nm. A graph was plotted to extrapolate the slope of the concentration of riboflavin in the test sample.

About 1.5 ml of tigernut product sample was taken and diluted with 8.5 ml of distilled water. About 5 ml of diluted samples were mixed with 5 ml of Denegees reagent and allowed to stand for 2 minutes. Filtration was carried out and absorbance was taken at 525 nm. Calculation was made for the concentration of riboflavin using:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Cyanocobalamin (vitamin B_{12})

About 10 ml of the tigernut product sample is pipetted and mixed with 0.1 g potassium cyanide until dissolved. pH adjusted was made to 9 – 10 using 5 Normal Hydrogen chloride. The mixture was left in the dark for 24 hours. Sodium sulphate was added and the pH readjusted with sodium hydroxide to 11 – 11.5. The solution was extracted three times with benzyl alcohol, centrifuged fro 5 minutes, mixed with benzene and extracted again three times with distilled water. The extract solution obtained was made up to 25 ml with water and 10 ml of the extract solution was mixed with 2 ml potassium dihydrogen phosphate. Another 10 ml of extract solution was mixed with 2 ml potassium cyanided solution and centrifuged fro 30 minutes. Absorbance of potassium cyanide treated extract was measured at 585 nm using potassium hydrogen phosphate treated extract solution as blank (Pye Unicam, 1994. Calculation was made for the concentration of cyanocobalamin using:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Ascorbic Acid (Vitamin C)

One mililitre (1 ml) of tigernut product sample were homogenized with 10 % trichloroacetic acid and 0.5 ml chloroform. The mixture was centrifuged and allowed to settle. The clear supernatant liquid was taken out and mixed with 0.4 ml freshly prepared colour reagent (5 ml 2, 4, dinitrophenyl hydrazine, 0.1 ml 5 % cupric sulphate and 0.1 ml 10 % thiourea) and incubated for 56 $^{\circ}$C in a water bath for 1 hour. This was cooled in ice bath for 3 minutes. Ice cold 85% sulphuric acid was added slowly to each tube with mixing and left at room temperature for 30 minutes. The absorbance was taken at 490 nm (Ball, 1994). Calculations were made using:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Vitamin E

Approximately 10 ml tigernut product samples were mixed with petroleum ether to extract the oil fraction containing the vitamin by withdrawing the supernatant. This was allowed to evaporate by adding 5 ml of 1.5 M alcoholic potash and boiling for 1 hour in a water bath. About 5 ml of petroleum ether and 5 ml of distilled water was added and the mixture centrifuged for10 minutes. The supernatant was again withdrawn and allowed to evaporate. About 3 ml of ethanol, 1 ml of 0.2 % ferric chloride and 1 ml of 0.5 % alcoholic were added. Absorbance was taken at 520 nm. Calculation was made using:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

Zinc (Zn)

About 10 ml of tiegrnut product sample was ashed and 2.5 ml of 0.2 M acetate buffer and 0.5 ml of 0.1 N sodium thiosulphate were added to 5 ml of mineral ash sample solution. The pH was adjusted to 4 – 5.5 and 5 ml of dithizone solution was added. The mixture was shaken for 4 minutes and allowed to stand to separate. The supernatant was decanted away and the remaining read at 535 nm. Zinc was calculated using the formular:

$$\frac{\text{Absorbance of sample x Concentration of standard solution x Dilution factor}}{\text{Absorbance of standard solution x Sample volume}}$$

3.2.7 Organoleptic properties and acceptability

Tigernut products were prepared and compared to their controls using a standard formulation and processing method. Tigernut milk beverages (unsweetened tigernut milk, vanilla tigernut milk, ginger tigernut milk, lemon tigernut milk, unsweetened soya milk (control), soya bean milk (control), tigernut malted coffee, tigernut unmalted coffee, 24 hr fermented tigernut wine, 36 hr fermented tigernut wine and palm wine (control) were displayed for organoleptic assessment.

Soya bean milk (SMU and SMSV), a vegetable milk, was used as control during the organoleptic assessment of tigernut milk beverages. Four brands of tigernut milk were prepared from tigernuts (TMU, TMSV, TMSL and TMSG). The Soya bean milk used as control was prepared as shown in the index. The coffee used as control was bought from the commercial market and prepared according to the standard given by the producers. Thus, the commercial coffee (control) was prepared as shown in the index.

Organoleptic and acceptability quality of samples of tigernut milk beverages, tigernut coffee and tigernut wine were assessed within three days respectively. Attributes that make food appealing and satisfying such as appearance, colour, consistency, taste, flavour, aroma, fizziness (wine) were assessed using a 9-point hedonic scale where scores where:

9-Extremely desirable
8-Very much desirable
7-Moderately desirable
6-Slightly desirable
5-Neither desirable nor undesirable
4-Slightly undesirable
3-Moderately undesirable
2-Very much undesirable
1-Extremely undesirable

Pilot testing sessions were carried out on each product by 20 persons (trained panelists) from different departments and works of life at the university of Nigeria Nsukka) to enable expression of their observations and feelings, at the dietary laboratory of home science, nutrition and dietetics. Water was provided for each panelist for mouth rinsing after testing each product to avoid carry over effect. Panel listing of attributes was carried out on three different days for each tigernut product (milk, coffee and wine). Evaluation forms were

designed with respect to some suitable attributes and presented to the panelists to record their sensory assessments for each evaluation session.

3.2.8 Microbial count and keeping of quality assessment of tigernut products

The microbial load (total microbial count) in the samples from tigernut milk and tigernut wine beverages were determined by using the spread (viable) plate count method (Pelczar *et al*, 1993; Mountney and Gould, 1988; Garbutt, 1997). Dilution series (10^{-1} – 10^{-6}) were prepared from the liquid sample homogenate. 0.1 ml was taken from each dilution to an agar plate (plate count agar) and each of the innoculum on the surface spread with the aid of a loop on the agar plate. This was incubated at 37°C for 24 – 48 hours. Plates with colony growth were counted at 24 hr and 48 hr. Numbers of colony forming units were calculated as follows:

$$\text{cfu } g^{-1} = \frac{\text{count x 1/ dilution}}{\text{inoculum}}$$

Keeping quality of products (milk, coffee and wine) were determined using a graded level sensory evaluation at 6 hrs, 12 hrs, 18 hrs, 36 hours… 1 week, 2 weeks, 3 weeks… 1 month, 2 months…1 year and above… at room temperature (27 – 30 °C), refrigeration temperature (> 17 °C) and freezing temperature (<0 °C).

3.3 Statistical analyses

The mean and standard deviation of the result data from the experiment was calculated and analyzed using single factor ANOVA in the Statistical Package for Social Science (SPSS, 2003) Software (SPSS version12. 0.1 for windows). The Duncan's New Multiple Range Test was used to determine the significant difference between mean values.

Chapter Four

4. Results

4.1: Proximate composition and energy value of tigernuts

Table 4.1: presents the proximate composition of fresh, dried, roasted and malted tigernuts per 100 gramme. The moisture content of tigernuts ranged from 4.19 – 51.93%, crude protein 2.61 – 10.12%, ash 0.70 – 1.77 %, crude fibre 7.48 – 13.97 %, crude fat 10.79 – 32.06 %, carbohydrate 22.73 – 56.85 %. The energy values ranged from 232.31 – 486.26 kilo calories per 100 gramme sample (976 – 2042 Kilo joules).

The moisture values for treated and untreated unmalted tigernuts ranged from 4.62 – 51.93 %, and that of treated and untreated malted tigernuts were from 4.19-44.84 %. Dried tigernuts ranged from 4.92 – 5.47 % and roasted tigernuts were from 4.19 - 4.62 %. Protein values for treated and untreated unmalted tigernuts ranged from 2.61 – 10.12 %. The treated and untreated malted tubers had protein values ranging from 3.75 – 7.41 %. Ash values for treated and untreated unmalted tigernuts ranged from 0.70 – 1.77 % and the values for treated and untreated malted tigernuts were 0.72 % for fresh, 1.36 % for dried, and 1.54 % for roasted samples. Crude fibre values for treated and untreated unmalted tigernuts ranged from 7.48 – 12.66 % and that of malted tigernuts were between 8.80 – 13.97 %.

Crude fat values for treated and untreated unmalted tigernuts ranged from 14.55 – 32.06 % and that of malted tigernuts ranged from 10.79 – 19.80 %. Carbohydrate values for treated and untreated unmalted tigernuts ranged from 22.73 – 50.76 % and that of treated and untreated malted tubers ranged from 31.10 – 56.85 %. Energy values for treated and untreated unmalted tigernuts ranged from 232.31 – 478.15 Kcal and that of treated and untreated malted tigernuts ranged from 235.70 Kcal – 423.08 Kcal.

Table 4.1: Energy(Kcal / KJ) and proximate composition(%) of tigernuts(fresh, dried, roasted and malted)

Sample / 100 g	Moisture	Protein	Ash	Crude fibre	Crude fat	CHO	Energy
Unmalted							
Fresh (S)	51.93 ±6.44	2.61 ±1.58	0.70 ± 0.50	7.48± 1.63	14.55± 1.30	22.73± 2.29	232.31 (976 KJ)
Fresh (U)	38.86±1.78	3.94± 1.05	0.91±0.47	9.28±0.39	20.42±1.00	26.59±0.94	305.90(1285KJ)
Dried [a]	5.47±0.50	6.12±0.37	1.53±2.00	11.51±1.68	32.06±1.00	43.31±1.19	486.26(2042KJ)
Roasted [b]	4.62±1.00	10.12±0.66	1.77±2.73	12.66±1.70	20.07±1.22	50.76±1.46	478.15(2008KJ)
Malted							
Fresh (S)**	44.84±6.32	3.75±2.45	0.72±0.53	8.80±1.78	10.79±4.23	31.10±3.06	235.70(990KJ)
Dried [a]	4.92±0.73	5.92±0.54	1.36±1.84	12.70±0.19	19.80±3.43	55.30±1.35	423.08 (1777 KJ)
Roasted [b]	4.19±0.69	7.41±1.18	1.54±2.73	13.97±1.4	16.04±1.09	56.85±1.41	401.36(1686 KJ)

S= soaked U = unsoaked * = soaked for 12 hours, malted for 1 week and devegetated

a = dried at 55 °C fro 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours

4.2: Effect of processing on the proximate composition and energy value of tigernuts

Table 4.2a: presents the effect of processing on proximate composition of tigernuts per 100 g (dry weight basis). Protein values ranged from 5.43 – 10.63 %, ash 1.30 – 1.86 %, crude fibre 12.20 – 15.92 %, crude fat 16.68 – 33.98 % and carbohydrate 43.61 – 59.12 %. The energy value was between 417.46 – 515.44 Kcal (1753 - 2165 KJ).

Untreated tigernuts (fresh unmalted – unsoaked tigernuts) had lowest carbohydrate value (43.61 %). Soaked fresh tigernuts (12 hrs) had lowest protein value (5.43 %). Dried unmalted tigernuts had lowest fibre value (12.20 %), highest fat value (33.98 %) and highest energy value (515.44 Kcal). Roasted unmalted tigernuts had highest protein value (10.63 %) and highest ash value (1.86 %). Freshly malted tigernuts had lowest ash value (1.30 %), lowest energy value 426.62 Kcal and highest fibre value (15.92 %).The protein value of freshly malted tigernuts (6.79 %) was higher than that of unmalted fresh tigernuts (5.43 %). Treated and untreated malted tigernuts had lower fat values ranging from 16.68 – 20.79 % compared to that of treated and untreated unmalted tigernuts which had higher fat value ranging from 16.68 – 20.79 % compared to the treated and untreated unmalted tigernuts which had higher fat values ranging from 27.37 – 33.98 %. Roasted malted tigernuts had lowest fat value (16.68 %), lowest energy value (417.46 Kcal) and highest carbohydrate value (59.12 %). Dried (unmalted and malted) tigernuts had lower fibre vaues (12.20 % and 13.34 % respectively) than roasted (unmalted and malted) tigernuts (13.29 % and 14.53 % respectively). Drying reduces fibre values of tigernuts more than roasting. Malted tigernuts had higher carbohydrate values (56.29 % -59.12 %) compared to unmalted tigernuts (43.61 – 53.30 %).

Table 4.2a: Effect of processing on proximate composition (%) and energy value (Kcal / KJ) of tigernuts per 100 g(Dry weight basis)

Sample	Protein	Ash	Crude fibre	Crude fat	CHO	Energy
Unmalted						
Fresh (S)*	5.43	1.46	15.56	30.26	47.28	483.20 (2029 KJ)
Fresh (U)[c]	6.46	1.49	15.22	33.49	43.61	501.68(2107KJ)
Dried [a]	6.49	1.62	12.20	33.98	45.90	515.44 (2165KJ)
Roasted [b]	10.63	1.86	13.29	27.37	53.30	502.06(2109KJ)
Malted						
Fresh (S)** [c]	6.79	1.30	15.92	19.37	56.29	426.62(1792KJ)
Dried [a]	6.22	1.43	13.34	20.79	58.07	444.23 (1866 KJ)
Roasted [b]	7.71	1.60	14.53	16.68	59.12	417.46(1753 KJ)

S= soaked U = unsoaked CHO= Carbohydrate

* = soaked for 12 hours **= soaked for 24 hours, malted for 1 week and devegetated

a = dried at 55 °C for 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours c= control

4.3: Percentage changes on the proximate composition and energy value of tigernuts due to processing (soaking, drying, roasting and malting) effects

Table 4.2b: presents the percentage increases and decreases on proximate composition of tigernuts due to treatments. Soaking of fresh tigernuts (12 hours) increased carbohydrate by 8.42 % and decreased protein values by 15.94 %. There were no significant changes (< 5 %) in ash, fibre, fat and energy values. Malting of fresh tigernuts increased protein by 5.11 %, fibre 4.60 %, carbohydrate 29.08 % and decreased ash by 12.75 %, fat 36.47 % and energy values by 14.96 %.

Drying of unmalted tigernuts increased carbohydrate by 5.25 %, ash 8.72 %, fat 11.45 %, and decreased fibre by 19.84 %. There were no significant changes in protein (+0.46 %) and energy values (+2.74 %). Drying of malted tigernuts increased ash by 10.00 %, fat 31.81 %, and carbohydrate 33.16 % and decreased fibre by 16.21 % and energy values 11.45 %.

Roasting of unmalted tigernuts increased the protein by 64.55 %, ash 24.83 %, carbohydrate 22.22 % and decreased fibre by 12.68 % and fat by 10.23 %. There was no significant change in energy value (0.08 %). Roasting of malted tigernuts increased protein values by 13.55 %, ash 23.08 %, and carbohydrate 35.57 % and decreased fibre by 8.73 %, fat 45.29 % and energy values by 16.79 %.

Table 4.2b: Percentage increases / decreases on the proximate composition and energy content (per100 g) due to processing (soaking, malting, drying and roasting) effects

	Protein %	Ash %	Crude fibre %	Crude fat %	CHO %	Energy %
Soaking*	**-15.94**	**-2.01**	**+2.23**	**-0.66**	**+8.42**	**-3.68**
Malting**	**+5.11**	**-12.75**	**+4.60**	**-36.47**	**+29.08**	**-14.96**
Drying(U)a	**+0.46**	**+8.72**	**-19.84**	**+11.45**	**+5.25**	**+2.74**
Drying(M)b**	**-8.39**	**+10.00**	**-16.21**	**+31.81**	**+33.16**	**-11.45**
Roasting(U)	**+64.55**	**+24.83**	**-12.68**	**-10.23**	**+22.22**	**+0.08**
Roasting(M)b**	**+13.55**	**+23.08**	**-8.73**	**-45.29**	**+35.57**	**-16.79**

U = unmalted M= malted CHO= Carbohydrate

* = soaked for 12 hours **= soaked for 24 hours, malted for 1 week and devegetated

a = dried at 55 °C for 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours c= control

4.4 Mineral and vitamin content of tigernuts

Table 4.3 presents the micronutrient (mineral and vitamin) composition of fresh, dried and roasted and malted tigernuts per 100 g. Magnesium (Mg) vslues of tigernuts ranged from 95.32 – 140.96 mg, potassium (K) 106.44 – 427.92 mg, phophorus (p) 121.78 – 195.95mg, calcium (ca) 24.42 – 62.29 mg, sodium (Na) 15.77 – 18.27 mg, copper (Cu) 0.08 – 0.99 mg, iron (Fe) 1.60 – 4.03 mg and zinc (Zn) 0.32 – 2.46 mg. The vitamin C values ranged from 30.90 – 88.89 mg and vitamin E 2.22 – 5.26 mg per 100 g of sample. Macroelement nutrient showed that Mg values for treated and untreated unmalted tigernuts ranged from 122.79 – 140.96 mg and that of treated and untreated malted tigernuts was from 95.32 – 108.66 mg. K values of treated and untreated unmalted tigernuts ranged from 265.12 – 427.92 mg and that of treated and untreated malted tigernuts ranged from 106.44 – 197.25 mg. P values for treated and untreated unmalted tigernuts ranged from 131.51 – 195.95 mg and that of treated and untreated malted tigernuts was from121.78 – 181.86 mg. Ca values for treated and untreated unmalted tigernuts ranged from 24.42 – 35.57 mg and that of treated and untreated malted tigernuts was from 40.98 – 60.13 mg. Na values fro treated and untreated unmalted tigernuts ranged from 16.95 – 18.27 mg and that of treated and untreated malted tigernuts was from 15.77 – 17.41 mg.

The Cu values for treated and untreated unmalted tigernuts ranged from 0.10 – 0.99 mg and that of treated and untreated malted tigernuts was from 0.08 – 0.84 mg. Fe values for treated and untreated unmalted tigernuts ranged from 2.57 – 4.03 mg and that of treated and untreated malted tigernuts was from 1.60 – 2.56 mg. Zn values for treated and untreated unmalted tigernuts ranged from 0.37 – 2.46 mg and that of treated and untreated malted tigernuts was from 0.32 – 2.30 mg.

Vitamin C values for treated and untreated unmalted tigernuts was between 30.90 – 84.66 mg and that of roasted malted tigernuts was 59.94 mg. Vitamin E values for treated and untreated unmalted tigernuts was between 2.22 – 5.26 mg and that of roasted malted tigernuts was 4.16 mg.

Table 4.3: Mineral and vitamin content of tigernuts(mg/ 100g)

Sample	Mg	Cu	Fe	K	P	Zn	Ca	Na	VitC	Vit E
Unmalted										
Fresh (U)	140.96±1.59	0.10± 0.01	2.57± 0.30	265.12±2.82	131.51±5.70	0.37±0.21	24.42±1.34	18.27±3.74	30.90 ±0.51	5.26 ±0.1
Dried [a]	122.79±1.48	0.68±0.25	3.82±0.27	415.09±0.93	179.90±0.79	2.46±0.01	36.92±1.62	17.73±2.28	31.52±0.23	4.71±0.37
Roasted [b]	131.07±1.56	0.99±0.34	4.03±0.25	427.92±0.63	195.95±3.57	2.43±0.40	35.57±1.59	16.95±0.25	84.66±0.10	2.22±0.10
Malted										
Fresh (S)**	108.66±1.61	0.08±0.01	1.60±0.38	106.44±0.51	121.78±0.88	0.32±0.02	40.98±1.55	16.50±1.87	-	-
Dried [a]	95.32±1.58	0.57±0.14	2.25±0.42	185.36±3.98	166.84±1.15	2.31±0.52	62.29±1.71	17.41±2.26	-	-
Roasted [b]	100.09±1.60	0.84±0.23	2.56±0.38	197.25±0.24	181.86±1.31	2.30±0.20	60.13±1.47	15.77±3.21	59.94±0.34	4.16±0.31

S= soaked U = unsoaked * = soaked for 12 hours **= soaked for 24 hours before malting for 1 week

a = dried at 55 °C fro 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours

4.5: Effect of processing on the mineral content of tigernuts

Table 4.4a: presents the effect of processing on mineral content of tigernuts per 100 g (dry weight basis). Mg ranged from 100.09 – 231.17 mg, Cu 0.14 – 0.87 mg, Fe 2.36 – 4.23 mg, K 192.66 – 449.32 mg, P 175.18 – 215.68 mg, Zn 0.53 – 2.61 mg, Ca 37.35 – 74.17 mg and Na 16.40 – 29.96 mg.

Fresh unmalted tigernuts had highest Mg value (231.17 mg) and dried malted tigernuts had the lowest Mg value (100.09 mg). Roasted unmalted tigernuts had highest copper value while malted had the lowest value. Roasted unmalted tigernuts had highest Fe value (1.04 mg) and dried malted tigernuts had the lowest Fe value (2.36 mg). Roasted unmalted tigernuts had highest K value (449.32 mg) and freshly malted tigernuts had the lowest K value (192.66 mg). Fresh unmalted tigernuts had highest P value (215.68mg) and dried malted tigernuts had the lowest P value (175.16 mg). Unmalted dried tigernuts had highest Zn value (2.61 mg) and freshly malted tigernuts had the lowest Zn value (0.58 mg). Freshly malted tigernut had highest Ca value (74.17 mg) and roasted unmalted had the lowest Ca value (37.35mg). Fresh unmalted tigernuts had highest Na value (29.96 mg) and roasted malted tigernuts had the lowest Na value (16.40 mg).

Table 4.4a: Effect of processing on mineral content of tigernuts per 100 g(Dry weight basis)

Sample	Mg	Cu	Fe	K	P	Zn	Ca	Na
Unmalted								
Fresh U[c]	231.17	0.16	4.22	434.80	215.68	0.61	40.05	29.96
Dried [a]	130.16	0.66	4.05	440.00	190.69	2.61	39.14	18.79
Roasted [b]	137.62	1.04	4.23	449.32	205.75	2.55	37.35	17.80
Malted								
Fresh (S)**	196.67	0.14	2.90	192.66	202.42	0.58	74.17	28.96
Dried [a]	100.09	0.60	2.36	194.63	175.18	2.43	65.40	18.28
Roasted [b]	104.09	0.87	2.66	205.14	189.13	2.39	62.54	16.40

S= soaked U = unsoaked * = soaked for 12 hours **= soaked for 24 hours before malting for 1 week

a = dried at 55 °C fro 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours c=control

4.6: Percentage changes on the mineral content of tigernuts due to processing (soaking, drying, roasting and malting) effects

Table 4.4b presents the percentage increases and decreases on mineral and vitamin content of tigernuts due to treatments. Malting of fresh tigernuts increased Ca by 84.16 % and decreased Mg by 14.92 %, K 55.69 %, Cu 12.5 %, Fe 31.28 %n and 4.92 %. There were no significant changes P (+2.20 %) and Na (-3.34 %).

Drying of unmalted tigernuts increased Zn by 100 %, Cu 100 % and decreased Mg by 43.70 %, P 11.59 % and Na 37.28 %.. There were no significant changes in Fe (- 4.03 %), Ca (- 2.27 %) and K (+1.20 %). Drying of malted tigernuts increased Cu by 100 %, Zn 100 %, and decreased Mg by 49.11 %, P 20.52 %, Ca 11.82 %, Na 38.80 % and Fe 18.62 %. There were no significant changes K (+1.02 %)

Roasting of unmalted tigernuts increased Cu by 100 %, Zn 100 %, P 4.60% and decreased Mg by 40.47 %, Ca 6.74 % and Na by 40.58 %. There were no significant changes in Fe (+ 0.24 %) and K (+3.34 %). Roasting of malted tigernuts increased Cu values by 100 %, Zn 100 %, and K 6.48 % and decreased Mg by 47.07 %, Fe 8.28 %, P 14.20 %, Ca 12.88 % and Na 43.37 %.

Table 4.4b: Percentage increases / decreases on mineral content (per100 g) due to processing (drying. Roasting and malting) effects (per 100g)

	Mg	Cu	Fe	K	P	Zn	Ca	Na
	%	%	%	%	%	%	%	%
Malting**	**-14.92**	**-12.5**	**-31.28**	**-55.69**	**+2.20**	**-4.92**	**+85.19**	**-3.34**
Drying(U)a	**-34.70**	**+100**	**-4.03**	**+1.20**	**-11.59**	**+100**	**-2.27**	**-37.28**
Drying(M)b**	**-49.11**	**+100**	**-18.62**	**+1.02**	**-20.52**	**+100**	**-11.82**	**-38.80**
Roasting(U)	**+40.47**	**+100**	**+0.24**	**+3.34**	**+4.60**	**+100**	**-6.74**	**-40.58**
Roasting(M)b**	**-47.07**	**+100**	**-8.28**	**+6.48**	**-14.20**	**+100**	**-12.88**	**-43.37**

U = unmalted M= malted S= soaked U= unsoaked

* = soaked for 12 hours **= soaked for 24 hours before malting for 1 week

a = dried at 55 °C for 48 hours b= air dried at room temperature for 24 hours and roasted at 150 C for 3 hours

Values ± 5 % increases or decreases are significantly differen

4.7: Physico-chemical and functional properties of tigernuts and its products

Table 4.5 presents the physico-chemical and functional properties of tiogernuts andits products. The pH of tigernuts and its products ranged from 4.87 – 6.10. Tigernut milk extract / plain tigernut milk 6.10, lemon tigernut milk 4.87, 24 hrs fermented tigernut milk 4.59, 36 hrs fermented tigernut milk 3.79, 48 hrs fermented tigernut wine 5.00, malted tigernut coffee tubers 4.81 and unmalted tigernut coffee tubers 5.02. pH of tigernut products varied with fermentation period. Tigernut milk extract was slightly acidic in pH (6.10). Tigernut wines (fermented bevcrages) were more acidic with acidity ranging from 3.79 – 4.87. The pH of fermented wort during wine production decreased from 4.87 to 3.79 within 36 hrs and slightly increased again to 5.0 within 48 hrs of fermentation. 48 hrs fermented wine had a vinegarate flavour and strong aroma and thus poor and unacceptable for consumption as beverage.

Specific gravity of tigernut products ranged from 1.023 – 1.07. Relative density ranged 1.63 – 9.48. 48 hrs fermented wine had highest relative density (9.48 $^{\circ}$Bé) and plain tigernut milk had the lowest value (2.83 $^{\circ}$Bé). Viscosity of plain tigernut milk and lemon tigernut milk was 88 to 99 cP at 28 $^{\circ}$C respectively. Total available sugar (as glucose) of tigernut milky beverages ranged from 0.30 – 0.44 g per 100 ml.24 hrsfermented wine had lowest value in total sugar (30 %) and lemon tigernut milk and had highest value (44 %). Tigernut milk exract / plain tigernut milk had foaming capacity of 18.0 %, foaming stability 5.35 %, emulsion capacity 21.88 % and emulsion stability 49.38 %.

Alcohol content of tigernut wines ranged from 3.17 – 7.13 %. Alcohol content of tigernut wine increased with fermentation period. 48 hrs fermented wine had highest alcohol content (7.13 %) and 24 hrs fermented wine had lowest alcohol content (3.17 %).

Table 4.5: Physico-chemical and functional properties of tigernuts and its products (milk, coffee and wine)

	pH	Viscosity (cP)	SG r.d (°Bé)	FC	FS	EC	ES	Ethanol	Reducing Sugar**
	30 °C			%	%	%	%	%	g
Plain tigernut milk	6.10 ± 0.21	90	1.02(1.63)	18.0	5.35	21.88	49.36	-	0.38
Lemon tigernut milk	4.87 ±0.81	88	1.04(5.55)	-	-	-	-	-	0.44
24 hr fermented wine	4.59 ±0.76	-	1.03(4.22)	-	-	-	-	3.17	0.30
36 hr fermented wine	3.79 ±0.42	-	1.05(6.87)	-	-	-	-	5.17	0.33
48 hr fermented wine*	5.00 ±0.31	-	1.07(9.48)	-	-	-	-	7.13	-
Malted tigernut coffee	4.81 ±0.31	-	-	-	-	-	-	-	-
Unmalted tigernut coffee	5.02 ±0.29	-	-	-	-	-	-	-	-

Plain tigernut milk= tigernut milk extract Lemon tigernut milk= sweetened-lemon flavoured milk

SG= Specific gravity (r.d= relative density) FC= foaming capacity FS= foaming stability EC= emulsion capacity ES= emulsion stability

°Bé= Degree Baumé= 144.3 (r.d – 1) / r.d Baume scale (Uvarov *et al*., 1979)

cP= Centipoise

*Vinegary taste in the 48 hrs fermented wine making it undesirable for consumption (poor quality)

** Total available reducing sugar as glucose (100 ml)

- Not tested

4.8: Vitamin and zinc content of tigernut products (milk and wine)

Table 4.6 presents the vitamin and zinc content of tigernut products (milk extract and wine). Ascorbate (vitamin C) values of tigernut products ranged from 6.18 mg – 7.8 mg/ 100ml, vitamin E 0.22 mg – 0.75 mg / 100 ml, vitamin B_1 (Thiamin) 0.80mg – 1.25 mg/ 100ml, vitamin B2 (riboflavin) 0.35 mg – 0.59mg / 100 ml and vitamin B12 (cyanocobalamin) 0.03 ug – 0.05 ug / 100ml.

The 36 hrs fermented wine had highest vitamin C value (7.81 mg) and tigernut milk extract had lowest value (6.18 mg). The 24 hrs fermented wine had highest value of vitamin E (0.75 mg) and 36 hrs fermented wine was lowest value (0.22mg). The 36 hrs fermented wine had highest vitamin B_1 (1.25mg) and tigernut milk extract had lowest value (0.80 mg). Vitamin B_2 depreciated during fermentation. Tigernut milk extract had highest vitamin B_2 value (0.59 mg) and 36 hrs fermented wine had lowest value (0.35 mg). The 24 hrs fermented wine had no traces of vitamin B_{12} (0.0 ug), tigernut milk extract had 0.05 ug and 36 hrs fermented wine 0.03 ug.

Zinc values of tigernut products ranged from 0.04 mg – 0.11 mg/ 100ml. Zn values reduced within 24 hrs of fermentation and increased again within 36 hrs of fermentation. Tigernut milk extract had zinc values of 0.11mg / 100 ml, 24 hrs fermented wine 0.04 mg / 100 ml and 36 hrs fermented wine 0.07 mg/ 100ml.

Table 4.6: Vitamin and zinc content tigernut products (milk and wine) per 100ml

	Vit C	**Vit E**	**VitB$_1$**	**Vit B$_2$**	**Vit B$_{12}$**	**Zinc**
	mg	**mg**	**mg**	**mg**	**mg**	**mg**
Tigernut milk extract*	6.18 ±0.34	0.64± 0.26	0.80± 0.35	059 ±0.11	0.05± 0.02	0.11± 0.11
24 hr fermented wine	7.15 ±0.18	0.75± 0.01	1.08± 0.12	0.46 ±0.16	0.0± 0.00	0.07 ±0.21
36 hr fermented wine	7.81± 0.15	0.22± 0.13	1.25 ±0.25	0.35 ± 0.13	0.03± 0.01	0.04± 0.14

*Tigernut milk extract /. plain tigernut

4.9: Organoleptic evaluation of tigernut milk beverages (unfermented)

Table 4.7 presents the sensory scores associated with tigernut milk beverages (unfermented) and its control (soya bean milk beverages) as follows: appearance (6.81 – 8.81), colour (6.88 – 8.63), aroma (4.38 – 7.69), flavour (4.44 – 7.38), consistency (6.63 – 7.06), and acceptability (4.63 – 7.31). The control (plain soya bean milk / SMU) had highest scores in appearance (8.81) and colour (8.63). Vanilla tigernut milk (TMSV) and Ginger tigernut milk (TMSG) had the samevalues in colour (6.88), besides, 6.88 was the lowest value scored in colour. The appearance of TMSG (7.44) however, was preferred to that of TMSV (6.81).

In terms of appearance, soya bean milk had significantly higher scores of 8.31 – 8.81 ($P<0.05$) than tigernut milk beverages (6.81 – 7.44). Though there were differences in appearance and colour, tigernut milk beverages (unfermented) were not significantly different ($P>0.05$) from soyabean milk beverages ranged from 8.19 – 8.63 and that of tigernut milk beverages ranged from 6.88 – 7.25.

SMU had lowest scores in aroma (4.38), taste (4.13), flavour (4.44) and acceptability (4.63). However, vanilla soya bean milk (SMSV) had highest scores in aroma (7.69), taste (7.69), flavour (7.38) and consistency (7.06). Besides, TMSG had highest acceptability score (7.31), followed by SMSV (7.06), TMSL or lemon tigernut milk (6.94), TMSV (6.44), TMU (6.00) and SMU (4.63) which scored lowest.

Table 4.7 Organoleptic evaluation of tigernut milk beverages (unfermented)

	TMU	SMU	TMSV	SMSV*	TMSG	TMSL
Appearance	$7.38^{b}\pm 0.13$	$8.81^{a}\pm 0.10$	$6.81^{b}\pm 0.47$	$8.31^{a}\pm 0.22$	$7.44^{b}\pm 0.36$	$7.38^{b}\pm 0.18$
Colour	$7.25^{bc}\pm 0.37$	$8.63^{a}\pm 0.13$	$6.88^{c}\pm 0.46$	$8.19^{ab}\pm 0.23$	$6.88^{c}\pm 0.46$	$7.19^{bc}\pm 0.23$
Aroma	$4.75^{b}\pm 0.48$	$4.38^{b}\pm 0.48$	$6.63^{a}\pm 0.58$	$7.69^{a}\pm 0.27$	$6.50^{a}\pm 0.71$	$7.13^{a}\pm 0.29$
Taste	$6.13^{b}\pm 0.09$	$4.13^{c}\pm 0.43$	$6.88^{ab}\pm 0.49$	$7.69^{a}\pm 0.42$	$7.13^{ab}\pm 0.59$	$6.56^{ab}\pm 0.40$
Flavour	$6.00^{b}\pm 0.30$	$4.44^{c}\pm 0.38$	$7.00^{ab}\pm 0.49$	$7.38^{a}\pm 0.41$	$6.94^{ab}\pm 0.55$	$7.25^{ab}\pm 0.36$
Consistency	$6.81^{a}\pm 0.21$	$6.94^{a}\pm 0.23$	$6.63^{a}\pm 0.50$	$7.06^{a}\pm 0.37$	$6.88^{a}\pm 0.46$	$6.88^{a}\pm 0.43$
Acceptability	$6.00^{a}\pm 0.20$	$4.63^{b}\pm 0.46$	$6.44^{a}\pm 0.56$	$7.06^{a}\pm 0.51$	$7.31^{a}\pm 0.48$	$6.94^{a}\pm 0.34$

Mean ±SEM
Means not followede by same alphabetic superscripts in a row are significantly different ($P<0.05$)
TMU (Unsweetened – unflavoured/ Plain tigernut milk / tigernut milk extract)
SMU (Unsweetened – unflavoured/ Plain soya bean milk / soyabean milk extract)*
TMSV (Vanilla flavoured- sweetened tigernut milk / vanilla tigernut milk)
SMSV (Vanilla flavoured- sweetened soya bean milk / vanilla soya bean milk)*
TMSG (Ginger flavoured- sweetened tigernut milk / ginger tigernut milk)
TMSL (Lanilla flavoured- sweetened tigernut milk / lemon tigernut milk)
*= control

4.10: Organoleptic evaluation of tigernut coffee

Table 8 presents the sensory scores associated with tigernut coffee and its control (a commercial instant coffee). The coffee appearance values ranged from 6.50 – 7.94, colour 5.94 – 8.00, aroma 6.38 – 8.00, flavour 5.81 – 8.00, consistency 5.94 – 7.56 and acceptability 6.38 – 8.06.

Cream coffee samples (7.44 – 8.06) were more acceptable than the black coffeesamples (6.38 – 6.94). The cream commercial coffee (CCC) had highest scores in most attributes such as in appearance 7.94, colour 8.00, aroma 8.00, taste8.00. The cream malted tigernut coffee (CMTC) had highest acceptability score (8.06) and the black coffee BMTC had lowest score (6.38).

Tigernut coffee was not significantly different ($P<0.05$) from its control sample in all the parameters assessed. Sensory scores generally, were between 5.81 – 7.00 for black coffee beverages and 7.13 – 8.06 for the cream coffee beverages.

Table 4.8 Organoleptic evaluation of tigernut coffee (black, cream,malted and unmalted) beverages

	BMTC	BUTC	BCC*	CMTC	CUTC	CCC*
Appearance	$6.69^{bc} \pm 0.36$	$6.50^{c} \pm 0.52$	$6.63^{c} \pm 0.48$	$7.88^{ab} \pm 0.27$	$7.63^{abc} \pm 0.33$	$7.94^{a} \pm 0.42$
Colour	$5.94^{b} \pm 0.58$	$6.13^{b} \pm 0.52$	$6.44^{b} \pm 0.66$	$7.88^{a} \pm 0.24$	$7.75^{a} \pm 0.27$	$8.00^{a} \pm 0.33$
Aroma	$6.88^{ab} \pm 0.34$	$6.38^{b} \pm 0.44$	$7.00^{ab} \pm 0.51$	$7.38^{ab} \pm 0.29$	$7.13^{ab} \pm 0.31$	$8.00^{a} \pm 0.34$
Taste	$5.94^{b} \pm 0.41$	$5.69^{b} \pm 0.37$	$6.13^{b} \pm 0.60$	$7.63^{a} \pm 0.30$	$7.38^{a} \pm 0.30$	$8.00^{a} \pm 0.29$
Flavour	$5.94^{c} \pm 0.44$	$5.81^{c} \pm 0.43$	$6.50^{bc} \pm 0.61$	$7.75^{a} \pm 0.27$	$7.38^{ab} \pm 0.31$	$8.00^{a} \pm 0.27$
Consistency	$5.94^{b} \pm 0.51$	$6.06^{ab} \pm 0.51$	$6.38^{ab} \pm 0.59$	$7.56^{a} \pm 0.39$	$7.13^{ab} \pm 0.50$	$7.56^{a} \pm 0.47$
Acceptability	$6.38^{b} \pm 0.49$	$6.63^{b} \pm 0.41$	$6.94^{ab} \pm 0.50$	$8.06^{a} \pm 0.21$	$7.44^{ab} \pm 0.32$	$7.63^{ab} \pm 0.49$

Mean ±SEM

Means not followede by same alphabetic superscripts in a row are significantly different ($P<0.05$)

BMTC = Black malted tigernut coffee BUTC = Black unmalted tigernut coffee BCC= Black commercial coffee *

CMTC = Cream malted tigernut coffee CUTC= Cream unmalted tigernut coffee CCC=Cream commercial coffee*

*= control= commercial pure instant coffee (Nescafe classic prepared by Nestle Cote d'Ivoire)

4.11: Organoleptic evaluation of tigernut wine (fermented beverages)

Table 9 presents the sensory scores tigernut wine (fermented beverages) and its control (fresh palm wine). Appearance ranged from (5.93- 8.40), colour (6.53 – 7.93), aroma (5.87 – 7.67), taste (7.00 – 8.33), odour (4.93 – 8.13), flavour (6.60 – 8.20), fizziness (6.27 – 6.93) consistency (6.20 – 7.53) and acceptability (6.73 – 8.53).

Tigernut wine – 24 scored highest in appearance 8.40, colour 7.93, aroma 7.67, taste8.33, odour 8.13, flavour 8.33, consistency 7.53 and acceptability 8.53. The control (palm wine) had lowest score in appearance 5.93, colour 6.53, aroma 5.87, odour 4.93, taste 7.00, flavour 6.60, consistency 6.20 and acceptability 6.73. Tigernut wine-36b (7.80) had higher aceptability score than tigernut wine -36a (7.73). Tigernut wine- 36b had highest preference value in fizziness (6.93) and tigernut wine – 36a had lowest score (6.27). However, tigernut wine -24 hrs and the control (palm wine) had the same score in fizziness (6.80) and palmwine had the lowest score in consistency (6.20). Tigernut beverages were not significantly different ($P>0.05$) from the control in general acceptability.

Table 4.9 Organoleptic evaluation of tigernut wine / fermented beverages

	Tigernut wine-24 (24hrs fermented)	Tigernut wine-36a (36hrs fermented)	Tigernut wine-36b (36hrs fermented)	Fresh palm wine* (<15hrs old)
Appearacne	$8.40^{a}\pm 0.19$	$7.40^{b}\pm 0.31$	$7.33^{b}\pm 0.30$	$5.93^{c}\pm 0.42$
Colour	$7.93^{a}\pm 0.28$	$7.53^{ab}\pm 0.36$	$7.20^{ab}\pm 0.42$	$6.53^{b}\pm 0.35$
Aroma	$7.67^{a}\pm 0.32$	$7.00^{ab}\pm 0.35$	$7.00^{ab}\pm 0.40$	$5.87^{b}\pm 0.52$
Odour	$8.13^{a}\pm 0.32$	$7.07^{ab}\pm 0.43$	$6.60^{b}\pm 0.47$	$4.93^{c}\pm 0.47$
Taste	$8.33^{a}\pm 0.27$	$7.80^{ab}\pm 0.33$	$7.40^{ab}\pm 041$	$7.00^{b}\pm 0.38$
Flavour	$8.20^{a}\pm 0.24$	$7.47^{ab}\pm 0.31$	$7.00^{c}\pm 0.51$	$6.60^{c}\pm 0.38$
Fizziness	$6.80^{a}\pm 0.58$	$6.27^{b}\pm 0.43$	$6.93^{a}\pm 0.40$	$6.80^{a}\pm 0.44$
Consistency	$7.53^{a}\pm 0.39$	$6.33^{a}\pm 0.46$	$6.53^{a}\pm 0.42$	$6.20^{a}\pm 0.46$
Acceptability	$8.53^{a}\pm 0.24$	$7.3^{ab}\pm 0.52$	$7.80^{ab}\pm 0.34$	$6.73^{c}\pm 0.41$

Mean ±SEM
Means not followede by same alphabetic superscripts in a row are significantly different ($P<0.05$)
*= control=fresh palm wine

4.12: Microbial count / load of tigernut products (milk / wine)

Table 4.10 presents the microbial count of tigernut products (milk and wine) at 37 °C between 24 – 48 hrs. Plain tigernut milk had 8.0 x 10^2 cfu / ml, lemon tiugernut milk 5.0 x 10^2 cfu / ml, 24hr fermented tigernut wine 3.0 x 10^2 cfu / ml and 36 hr fermented tigernut wine-b 5.0 x 10^2 cfu / ml. The number of colony in the 24 hr fermented wine decreased with increase in time / length of fermentation and increased again after 36 hr of fermentation. Plain tigernut milk had highest microbial load (8.0 x 10^2 cfu / ml) and 24 hr fermented tigernut wine had lowest microbial load.

4.13: Keeping quality of tigernut products (milk, coffee and wine)

Table 4.11 presents the keeping quality of tigernut products in view of specific environmental conditions. Tigernut coffee had highest keeping quality range values (≥2 months- ≥10 months) than tigernut milk (≥ 6hrs – ≥2 weeks) and tigernut wine (≥ 6hrs – ≥1 month) at 27 - < 17 °C. Plain tigernut milk kept best for 6 hours at 27 – 30 °C, 24 hrs at <17 °C and 4 days at < 0 °C. Lemon tigernut milk kept best for 12 hours at 27 – 30 °C, 36 hrs at 17 °C and 2 weeks at < 0 °C. The 24 hrs fermented tigernut wine kept for 12 hrs at 27 – 30 °C, 36 hr at <17 °C and 1 month at 0 < °C. The 36 fermented tigernut wine kept for 6 hours at 27 – 30 °C, 24 hrs at < 17 °C and 1 month at 0 °C. Malted tigernut coffee (ground) kept for 2 months at 27 – 30 °C, 5 months < 17 °C and 10 months at < 0 °C. Unmalted tigernut coffee (ground) kept for 2 months at 27 – 30 °C, 5 months at < 17 °C and 10 months at 0 °C.

Table 4.10 Microbial count of tigernut milk and wine at the dilution of 10^{-2}

Tigernut product sample	Microbial load
37 °C, incubation for 24 -48 hours	cfu / ml
Plain tigernut milk	8.0×10^2 cfu / ml
Lemon tiugernut milk	5.0×10^2 cfu / ml
24hr fermented tigernut wine	3.0×10^2 cfu / ml
36 hr fermented tigernut wine	5.0×10^2 cfu / ml

Plain tigernut milk = tigernut milk extract (unsweetened unflavoured)
Lemon tiugernut milk = lemon flavoured – sweetened tigernut milk
24hr fermented tigernut wine = tigernut wine - 24
36 hr fermented tigernut wine = tigernut wine -36a

Table 4.11 Keeping quality of tigernut products (milk, coffee and wine)

Sample	Room temperature	Refrigerator	Freezer
	27 - 30 °C	< 17 °C	< 0°C
Plain tigernut milk*	≥ 6hours	≥ 24hours	4 days
Lemon tiugernut milk*	≥ 12hours	≥ 36hours	≥2 weeks
24hr fermented wine*	≥ 12hours	≥ 36hours	≥1 month
36 hr fermented wine*	≥ 6hours	≥ 24hours	≥1 month
Malted tigernut coffee**	≥2 months	≥5 months	≥10 months
Unmalted tigernut coffee**	≥2 months	≥5 months	≥10 months

* Sample in corked plastic bottles
** Ground coffee samples packed in nylon backs and stored in air tight containers
Note= Keeping quality values are minimum value

5. Discussion

5.1 Nutritive value of tigernuts as widely consumed raw

The results of the proximate composition and energy value of tigernuts in Table 4.1 showed that raw tigernuts, soaked or unsoaked (fresh or dried), as widely consumed in Nigeria are healthy snacks. Tigernuts are high in carbohydrate, fat and fibre content. They are also rich in magnesium, potassium, iron, copper, zinc, vitamin C. vitamin E and are low in calcium and sodium (Table 4.3).They are fairly good sources of protein. Fresh tigernuts are high in moisture content. This indicates that it could perish easily due to microbial attack. However, dried tigernuts are low in moisture with higher concentration of nutrients. Tigernuts could be eaten fresh or dried as snacks by young and old (children, adolescents, adults, pregnant and lactating mothers) for its high energy and preventive or protective nutrients. These nutrients could significantly contribute to the body's metabolic processes, refreshing the body as well. Consequenlty, if 100 g of tigernut is consumed it could significantly contribute more than 40 % of carbohydrate to a child's (4 – 9 yrs) daily carbohydrate requirement and more than 32 % of carbohydrate to an adult's daily carbohydrate need (FAO / WHO / UNU, 2002).

Tigernuts in comparison to other starchy roots and tubers have interestingly, significantly higher fat content and could contribute more than 73 % of fat to a child's daily fat need and more than 49 % of fat to an adults daily fat requirement (FAO / WHO / UNU, 2002). Fat content of tigernuts are relatively similar to that of nuts and seeds but are higher than that of cereals and compares well with that of soya beans (Achinewhu, 1989). High fat content of tigernuts may indicate high values of oil soluble vitamins such as vitamins A, D, E and K.

Fibre content of tigernuts (7.48 – 11.51 %) rank well with that of whole grains, nuts, fruits and matured leguminous seeds (Osagie and Eka, 1998). Tigernut fibre values from the findings are in line with the reports of Umerie *et al*.(1998) and Addy and Eteshola (1984). In contrast, Temple *et al*. (1990) reported a lower fibre value (5.50 %). About 100 g of tigernuts if consumed, the fibre content could pay its important role in the reduction of pressure and transit time of food through the body aiding to digestion. Fibre aids in alleviation of flatulence problem, thus, tigernut fibre could be explored in formulating diets for treating indigestion, constipation and non communicable diseases such as colon cancer, diverticulosis, coronary heart disease and obesity (Bender, 1973; Wardlaw and Kessel, 2002; Ball, 1994).

Protein content of tigernuts fell within thc range of values reported by other researchers (Umerie *et al*., 1997; Temple *et al*., 1990; Addy and Eteshola, 1984; TTSL, 2005).

Protein content of tigernuts is higher than that of most starchy roots and tuber crops (Eka, 1998; MAFF, 1981). Tigernut protein content compares well with that of cereals such as rice and sorghum (Osagie and Eka, 1998).Tigernuts can be a source of plant protein if it is bio-available. Tigernuta could contribute more than 17 % of protein to adult's daily protein need and more than 26 %to a child's daily protein requirement. About 100 g of tigernuts could provide about 15 – 22 % of the energy required for children per day (4-9 yrs) and 8 – 16 %of daily energy requirement for adolescents, adults and pregnant mothers (FAO / WHO / UNU, 2002).

The mineral ash value of 100 g tigernut (0.70 – 1.53 %) fell within the range reported for other starchy roots and tubers such as yam, cassava and potatoes (Eka, 1998). Tigernuts ash value was in line with the reports of Temple *et al*. (1990; 1998). However, values reported by Umerie *et al*. (1997) and Addy and Eteshola (1984) on tigernuts had significantly higher values (2.48 % and 6.70 % DW, respectively).

Magnesium provides bone strength, aids enzyme, nerve and heart functions. Tigernuts could contribute adequate Mg and Zn (100 %) to the daily need of children. Phosphorus enhances quick release of energy in the body and may combine with calcium for bone and teeth development. Tigernuts are relatively low in calcium and sodium. Recent studies on blood pressure showed that a diet rich in potassium and magnesium but low in sodium can lead to a decrease in blood pressure within days of beginning a specific diet (Wardlaw and Kessel, 2004). Potassium aids nerve impulse transmission and it is a major cation of intracellular fluid. High potassium to low sodium ration of tigernuts therefore, may be imperative in diet formulations for patients with high blood pressure and oedema as well.

Tigernuts contain protective nutrients because it could supply adequate zinc, copper, iron, vitamin C and E. Zinc is an integral part of hormones and more than nearly 100 different enzymes. Zinc is important in many metabolic reactions and may play an important role in immunity, alcohol metabolism, sexual development and reproduction. Copper aids in iron metabolism. It works with many antioxidants, enzymes especially those involved in protein metabolism and hormone synthesis. High iron content of tigernuts could contribute in preventing anaemia. Fe is the functional component of haemoglobin and other key compounds used in respiration, immune function and cognitive development. The Fe content in tigernuts (100 g) could be enough to cover the daily minimum needs (providing about 67 – 68 %) for children. Tigernuts could provide about 27 – 64 % of adolescents or adults daily iron need and 18 – 49 % of pregnant mother's daily iron needs (FAO / WHO / UNU, 2002).

If 100 g of tigernuts is eaten per day by children between 4 – 9 years old, the vitamin C content could be adequate, providing about 88 – 100 % of their recommended dietary intake (FAO / WHO / UNU, 2002). Vitamin C is importantin collagen synthesis, hormone and neuro transmitter synthesis. 100 g of tigernuts could also meet about 77 % daily vitamin C needs of adolescents, 69 % for adults and 52 % for pregnant mothers. Besides, high vitamin C concentration in tigernuts may help to render soluble the iron content and make it more available (Bender, 1973; Lake and Waterworth 1983; MAFF, 1981).Vitamin C and E are antioxidants which are important in the prevention of coronary diseases and cancer. 100 g of tigernuts could also meet about 75 – 88 % daily requirement needs for vitamin E for children (4- 9 yrs) and 33 – 35 % for adults. Vitamin E has also been associated to delay in the aging process and to feotal growth (Warlaw and Kessel, 2002).

5.2 Effect of processing of on nutrient composition of tigernuts

Variation in moisture content of tigenuts, seem to be the main cause of variation in protein, carbohydrate, crude fiber, crude fat, ash and vitamin content (Table 4.1). This is because nutrient content of foods containing large amounts of water are always uncertain (MAFF, 1981). Several other factors which contribute to or influence the nutritional content of tigernuts include, type and level of changes in tigernuts due to processing; structural alterations in the cell wall architecture of tigernuts may contribute greatly to the nutritional characteristics during treatment. Genetic make-up, microbial and enzyme activities of tigernuts, mineral content of the soil in which tigernuts are grown, handling, packaging and storage conditions of tigernuts are other factors which may influence the nutritional content of tigernuts (Morris *et al*., 2004). Higher moisture value of soaked fresh tigernut (51.93 %) may be attributed to water absorption by the tuber tissue cells during soaking. High moisture levels aids enzyme and microbial activities, this has an implication to the shelf life of tigernuts. However, low moisture content of dried and roasted tigernuts (4.19 – 5.47 %) was due to moisture loss during drying and roasting process. This is imperative to tigenut preservation or shelf-life.

The level of the effect of processing on nutritive value of tigernuts depends on the sensitivity of nutrient to various conditions (heat, oxygen, pH and light) prevailing during processing (Bender, 1973; Morris *et al*., 2004; MAFF, 1981). Tigernuts have a unique fibrous sheath covering tissues. This may influence the level of changes on the nutrient content of tigernuts during its processing. Biological contaminants may also attribute to the nutrient level changes in treated and untreated tigernuts.

Carbohydrate levels of tigernuts significantly increased as a result of each processing method (soaking, malting, drying and roasting). Increase in carbohydrate value due to soaking (by 8.42 %) may be attributed to starch conversion to simple sugars (glucose and fructose) by degrading enzymes such as diastatic, alpha and beta amylase (Bender, 1973; Morris *et al*., 2004). Increase in carbohydrate value as a result of malting process by (29.08 %) may be attributed to alpha-amylase activity which breaks down complex carbohydrates to simple sugars which are utilized and stored in the plant tissues during growth process and moisture loss. Carbohydrate value of tigernuts increased between 5.25 – 33.16 % due to drying and this may be attributed to moisture loss (concentration of nutrient). Increases in carbohydrate levels due to roasting (22.22 % - 35.57 %) may be attributed to starch hydrolysis due to heating.

Fat values of tigernuts increased as a result of drying. This may be attributed to concentration of fat due to moisture loss. Significant decreases in fat values were observed in malted and roasted tigernuts. Decrease in fat due to malting may be attributed to increased activities of the lipolytic enzymes such as lipase during germination which hydrolyzes fat to fatty acids and glycerol supplying energy needed for germination. These (fatty acids and glycerol) can further be used for synthesis of carbohydrate and protein for root and sprout development (Lake and Waterworth, 1983; Wardlaw and Kessel, 2002). A similar observation was made by Obizoba and Atti (1994) during the malting of millet. There was a significant decrease in fat levels of malted and unmalted tigernuts due to roasting by 45.29 % and 10.23 % respectively. This may be attributed to lipolysis which occurred during the heating process. Besides, increase in cooper value (100 %) could speed up fat degradation (Wardlaw and Kessel, 2002). Ash values of tigernuts increased as a result of drying and roasting. This may be attributed to the concentration of nutrient (mineral ash) due to moisture loss. On the other hand, malting decreased ash value of tigernuts. This may be attributed to mineral (nutrient) utilization by cell tissues for growth during germination (sprouting and root development).

Malting increases fibre value of tigernuts (4.6 %). Increase in fibre value due to soaking may be attributed to polymerization (multiple additions involving many identical molecules). In contrast, fibre values reduced due to drying and roasting. This may be attributed to loss of soluble fibre by hydrolysis, enzymatic degradation and decomposition. In addition, roasting may have decreased the pectin level in tigernuts and the degree of esterification (formation of organic products from organic acids and alcohols) leading to decreased crude fibre content (Morris *et al*., 2004).

Soaking decreased protein value by 15.94 %. This may be attributed to leaching out of soluble proteins and the length of time of soaking. Drying decreases the protein value of

malted tigernuts (by 8.39 %). This may be attributed to enzymatic degradation of free nitrogen protein released during malting (Morris *et al*., 2004).

Malting increased the protein values of tigernuts. This may be attributed to some specific amino acids which decrease and or increase due to soaking and germination process steps. Also, increase in protein may be attributed to changes in enzyme activities or net synthesis of enzymic protein by germinating tubers, degradation of storage protein and synthesis of new protein and other materials or mobilization for storage nitrogen producing the nutritionally high quality proteins which the young tubers need fro its development(FAO, 2007; Obizoba, 1998). According to Obizoba (1998), the synergistic interaction involved in protein synthesis during the malting process improves nutritional value and increases total protein. Thus, amino acids may have been produced in excess of the requirement during protein synthesis thereby accumulating in free amino acid pool (FAO, 2007; Morris *et al*., 2004). Increase in protein as a result of malting is in line with the reports of Obizoba (1998) and Nnam (2000) on cereal and legumes.

Malting process significantly decreased magnesium, copper, iron, potassium, and zinc. This may be attributed to free mineral released during hydrolysis by enzymes and were utilized for tissue growth and germination. Malting process significantly decreased iron value by 31.28 %. Decrease in iron level during malting of tigernuts is not in line with the findings of Nnam (2000), who reported a two fold increase in iron level of sprouted rice. Decrease of K by 55.69 % may be attributed to utilization of the mineral (K) during germination and growth. Slight increase in P ($P>0.05$) and significant increase in calcium (by 85.19 %) was also observed during malting. Fairly high content of calcium in malted tigernuts may contribute to bone and teeth development and normal clotting of blood. Increase in calcium due to malting may be attributed to freeing of Ca from calcium phosphate by phytase (Bender, 1973). On the contrary, Ca decreased in malted dried and malted roasted tigernuts by 2.27 and 12.88 % respectively. This may be attributed to the drying and / or roasting effect.

The most common practice of roasting of tigernuts is at about 95 – 100 degrees centigrade within 15 – 20 minutes as reported by Umerie *et al*. (1997). On the contrary, the effects of roasting tigernuts at 150 °C (Table 4.2a), showed increases in protein, ash and carbohydrate values and decreases in the fat and fibre values. Increases in protein value of tigernuts ranged from 13.55 – 64.55 % (Table 4.2b) due to raosting. This may be attributed to moisture loss (nutrient concentration) and release of bound protein during thermal hydrolysis. Morris *et al*. (2004) stated that the enzyme proteinases catalyze hydrolysis of proteins to peptides which attributes to the bitter taste in roasted foods. Roasted tigernuts had a slight

bitter coffee like taste (Table 4.8). Proteases could split proteins to peptones and polypeptides releasing free protein nitrogen. Peptidase, an enzyme, catalyzes the hydrolysis of polypeptides to simpler peptides and finally amino acids giving a desirable flavour. Thus increase in protein value may also be attributed to Maillard reaction (non enzymatic browning) which normally occurs during the roasting process releasing specific amino acids such as lysine (Bender, 1973; Lake and Waterworth, 1983, Morris *et al*., 2004) Roasting may improve digestibility of tigernuts, making nutrients such as protein, zinc and cooper more available due to inactivation of anti-nutrients such as toxins, trypsin inhibitors and phytases (Bender, 1973).

Drying and Roasting of tigernuts generally showed as significant decrease in Mg, Na, Ca, Fe and P content (Table 4.4b). In contrast, Zn, Cu and K increased during drying and roasting. The findings on the effects of roasting on Mg, Ca and Na, does not agree with the reports of Acetor and Ojo (1998) on soya beans. The increase in P (4.60 %) in roasted unmalted tigernuts may be attributed to thermal hydrolysis and moisture loss. Increase in P level (2.20%) in malted tigernuts may be due to the action of enzyme phytase which hydrolyzes phytic acid to phosphoric acid and inositol, thereby, releasing more phosphorus (Morris *et al*., 2004).This enzyme phytase hydrolyzes the bond between protein-enzyme-mineral to free more phosphorus (Nnam, 2000). Mg losses were more in dried and roasted tigernuts (47.07 – 49.11 %) than in malted tigernuts. This may be attributed to loss of chlorophyll due to Mg instability to heat, oxidation and light (Wardlaw and Kessel, 2002).

Decrease in iron may be attributed to nutrient utilization for growth during tuber germination. Interestingly, Cu and Zn generally increased by 100 % due to drying and roasting. On the contrary, Cu and Zn losses during malting were 12.5 % and 4.92 % respectively. Loses in Cu and Zn may be attributed to plant tissue mineral utilization during shoot and root development. Increases in K, Cu and Zn due to drying and roasting may be attributed to concentration of mineral due to moisture loss, freeing of bound minerals from protein, other minerals and biological contamination.

5.3 Pysico-chemical and functional properties of tigernuts and its products

Tigernuts are slightly acidic in nature (Table 4.5). tigernut milky juice extract was slightly acidic in pH (6.10). This is line with the reports on pH of tigernuts by Umerie *et al*. (1997). Tigernuts and its extract are excellent substrates and media for microbial growth. This is because most microorganisms favour conditions with a near neutral pH (7.0). However, microorganisms vary in their optimal pH requirements for growth. Certain bacteria are acid tolerant and will survive at reduced pH levels. Notable acid-tolerant bacteria such as Lactobacillus and Streptococcus species might play a role in the fermentation of dairy and vegetable products. However, moulds and yeasts are usually acid tolerant and are therefore associated with spoilage of acidic foods (FAO, 1998; Adams and Moss, 1995). Lemon tigernut milk (tigernut milky juice extract with lemon juice and sugar) had a higher acidic pH (4.87). This increase may be attributed to high acidity of lemon juice.

Fermented tigernut milky juice extract (tigernut wine) had the highest acidity range (3.79 – 4.59). This pH fell within the range of most fermented beverages (FAO, 2007). pH changes of fermented milky juice extract with lemon juice and sugar from onset to 36 hrs of fermentation may be attributed to the growth of yeasts cells which normally takes place between pH of 4.0 - 4.5 producing substances which increase acidity (Adams and Moss, 1995). The variations in the pH of tigernut products may be attributed greatly to microbiological activities and chemical reactions during fermentation process. Successions of microbes take over from each other as the pH of the environment changes making growth unfavourable for most food poisoning mesophilic microorganisms to grow (Prescott *et al*., 2005). Roasted tigernuts are acidic in pH. Variation in acidity of processed tigernuts may be attributed to steeping, malting and / or roasting effect.

Viscosity of tigernut milky juice is low. However, it fell within the range of that of most milk beverages. Viscosity is a function of degree. It is an important factor in determining the consistency of a product. Moisture content of liquid content of tigernut milk, additives and temperature may attribute to variation in viscosity and specific gravity of tigernut beverages. Variations in specific gravity of tigernut beverages may also be attributed to total microbial load and organic or chemical products or substances in products.

Tigernut milk extract is fairly low in foaming capacity and stability (18 % and 5.35 % respectively). Foaming capacity and stability are functions of a type of protein, pH, processing methods, viscosity and surface tension (Adebowale *et al*., 2005; Bera and Mukherjee, 1989). Foams are used to improve the texture, consistency and appearance of foods. Thus, fairly low levels of foaming capacity and stability of tigernut milky juice extract may contribute to the

smoothness, flavour dispersions and palatability of tigernut products. Tigernut milk extract could therefore be used as an additive in food products with high or requiring moderate foam capacity and stability.

Tigernut milk extract has a fairly high emulsion capacity (21.88 %) and stability (49.38 %). This may be due to inability of the fat globules in tigernuts to be sufficiently enveloped by the type and level of proteins which serve to stabilize the emulsion. Emulsion capacity and stability of tigernuts suggests that it could be used as ingredients in many product formulations for example in making refreshing drinks, sorbets, ice creams, yogurts, sauces and confectionaries. A food stabilizing agent such as gelatine or lecithin may also be added to the above mentioned products during preparation to achieve a more stabilized product.

Tigenut extracts (fermented and unfermented) had fairly low levels of reducing sugar (0.30 – 0.44 g / 100 ml). This makes it ideal for diabetics and in making healthy refreshing beverages. Alcohol content of fermented tigernut extract (3.17 – 7.13 %) is low compared to most wine produced from other vegetables such as potatoes and cereals (10 – 15 %) as reported by FAO (2007). Notably, alcohol content and specific gravity of fermented tigernut extract (tigernut wine) increased with fermentation period. This may be attributed to increased growth of beneficial microbes such as yeast cells and acid tolerant bacteria which has ability to release substances such as carbon dioxide, alcohol, lactic acid and acetic acid during the fermentation process (Prescott *et al*., 2005; FAO, 1998).

Tigernut and its milk extract could be combined with other tubers and starchy roots, cereals, legumes, fruits and vegetables, animal and dairy products by complimenting compatible physico-chemical and functional properties to develop successful products.

5.4: Organoleptic properties of tigernut products (milk, coffee and wine)

Organoleptic evaluation of tigernut milk, wine, and coffee products (Table 4.7, 4. 8, 4.9) showed existing differences between them and their controls (soya bean milk, palm wine and instant commercial coffee). However, they were not significantly different ($P>0.05$) from their controls for most of the parameters evaluated. Tigernut milk showed significant differences ($P<0.05$) in terms of appearance when compared to soyabean milk samples used as control (SMU and SMSV). Soya bean milk samples had higher preferential scores compared to tigernut milk samples in appearance. Besides, there was no significant difference between the tigernut samples (unsweetened- unflavoured tigernut milk / TMU, vanilla tigernut milk / TMSV, ginger tigernut milk / TMSG and lemon tigernut milk / TMSL) in appearance.

Soya bean milk (SMU) had lowest acceptability (4.63) or preference in most parameters (aroma, 4.38; taste, 4.13; flavour, 4.44). This may be attributed to the prominent beany flavour; absence of sweetener and flavour. Absence of these additives may have contributed to high preference in the colour of SMU, thus retaining the creamier natural colour of soya bean probably caused by the presence of carotene, high protein and fat content in soya bean (Lake and Waterworth, 1983). Soya bean milk (SMU) had a significant difference ($P<0.05$) in taste and flavour in comparison to the other samples (SMSV, TMU, TMSV, TMSG and TMSL) with scores ranging from 6.00 to 7.31. Vanilla soya bean milk (SMSV) had highest scores in most of the attributes than in tigernut beverages (TMU, TMSV, TMSG and TMSL) There was no significant difference ($P>0.05$) between SMSV and tigernut beverages. Flavouring and sweetening of plain soya bean milk (SMU) with sugar and vanilla essence improved its taste, flavour and aroma; camouflaging soya beans beany taste and flavour.

Plain tigernut milk (TMU) had higher preference scores than plain soya bean milk (SMU). This may be attributed to the level of sugar naturally present in tigernuts. However, preference in flavour by the judges may be attributed to preference in the unique flavouring agents (vanilla, lemon and ginger) utilized in the milk beverages. These flavours and probably healthful reasons attached to the additives influenced the general acceptability of the various branded tigernut milk beverages. Thus, ginger tigernut milk gained highest acceptability. This may be attributed to the functional and medicinal value, people and literatures ethically place on ginger. Preference in the consistency of milk samples may be attributed to the different milk temperatures which may affect the physio – chemical properties of the samples.

The results of the study of tigernut coffee showed tat there was no significant difference between tigernut coffee samples and the control (instant commercial Nescafe

coffee) sample in all the attributes assessed. Tigernut coffee samples (BMTC, BUTC, CMTC and CUTC) were similar to that of the commercial coffee (BCC and CCC). The controls had highest scores in most parameters. This may be attributed to its more refined nature (use of improved technology and techniques for its processing). In addition, differences between the control and tigernut coffee (P> 0.05) in flavour, taste and aroma may be attributed to specific amino acid levels present, treatments and roasting temperature. This is because slow drying and roasting at different temperatures impart characteristic flavour to foods. This is usually due to the reaction of particular amino acids in the presence of reducing sugar (Bender, 1973).

There was no significant difference in the colour and appearance of the coffee samples. However, malted tigernuts coffee beverages (BMTC, CMTC) had higher preference values (6.44, 7.88 respectively) than the unmalted tigernut coffee beverages (BUTC, 6.13; CUTC, 7.63). This may be attributed to the combined effect on malting and roasting in reducing the fat content of tigernuts (Table 4.2a) Fat vale of malted roasted tigernuts was lower than that of unmalted roasted tigernuts as shown in Table 4.2a. High scores of preference in colour, aroma, taste and flavour of tigernuts coffee samples may be attributed to roasting of tigernut tubers at 150 $^{\circ}$C which brought about a desirable browning reaction (Maillard reaction). This browning reaction imparted colour and a unique characteristic flavour (probably due to increase in certain amoni acids such as lysine) similar to that of roasted coffee beans or seeds (Bender, 1973; Lake and Waterworth, 1983). Malted tigenut coffee had highest acceptability score. This may be attributed to moderate unique aroma, flavour, taste and rich consistency.

The results of the study on tigernut wine (Table 4.9) showed that there was a significant difference (P < 0.05) between samples of tigernut wine or fermented tigernut beverages and the control sample (palm wine) in appearance and odour attributes. Tigernut wine beverages were more preferable and better than the palmwine. However, there was no signifant difference (P > 0.05) in aroma, taste, flavour, fizziness and consistency. Besides, tigernut wine (7.73 – 8.53) was very much desirable and had higher preference scores in most parameters assessed than palm wine (6.73). 24 hours fermented wine had highest preference score probably due to odour, better aroma and taste probably influenced by sugar content, microbial species and alcohol content of the wine (Satin, 2005; FAO, 1998). Difference in flavour (P<0.05) in tigernut wine may be attributed to increase in type of organic acid produced over time during fermentation (FAO, 1998). Palm wine had lowest acceptability due to its undesirable odour (4.93), slightly desirable appearance (5.93) and aroma (5.87).

5.5 Vitamin and zinc content of tigernut products (milk and wine)

Tigernut beverages are more than just refreshments. This is because they are nutrient dense, healthy refreshing beverages and could provide high protective nutrients (vitamin). They are excellent sources of vitamins B_1, B_2, C and a fairly good source of vitamin E. It also contains minute amounts of vitamin B_{12}. Vitamin C content in plain tigernut milk (6.18 mg / 100 ml)is significantly higher than that of other vegetable milks and non vegetable milk (<1 mg / 100 ml). Vegetable milk based on African yam bean, cowpea and corn blends had its vitamin C content to be 0.1 mg / 100 ml (Obizoba, 1998). Addy and Eteshola (1984) showed that gubdi / baobab milk contained 0.04 mg / 100 ml and the reports of Moore (2004) showed that soya bean milk contained 0.01 mg / 100 ml of vitamin C.

If 350 ml of plain tigernut milk extract is consumed (contains about 21.63 mg of vitamin C), it could provide about 62 – 72 % of vitamin C required daily by children (1- 9 yrs), 54 % of adolescents daily need, 48 % of adults and 36% of pregnant mothers daily need for vitamin C. On the other hand, 350ml of tigernut milk extract (>30 %) could provide 32 – 37 % of children's (1 -9 yrs) daily need of vitamin E and 15 % daily need of vitamin E of the adults daily requirement. Fermented tigernut beverages (tigernut wine) could provide 56 – 61 % of daily need of vitamin C and 5 – 17 % of daily need of vitamin E for adults (FAO/WHO/UNU, 2002). The thiamin (vitamin B_1) and riboflavin (vitamin B_{12}) content of 100 ml of tigernut beverages may provide at least more than 40 % of daily minimum needs fro children and adults. Thus, If 350 ml of tigernut wine is taken per day. It will provide adequate vitamins B_1 and B_2.

A major function of vitamin C is to promote the formation of collagen, an important protein found in connective tissue. Collagen is an integral component of bone, skin and blood vessels. Thus, high intake of vitamin C will improve wound healing and prevent scurvy (whose symptoms include bleeding gums and pinpoint haemorrhages on the skin). Tigernut milk beverages may play an important role in the treatment of iron deficiency anaemia because of its high vitamin C content. Vitamin C enhances iron absorption in the gastrointestinal tract. Vitamin C increases absorption of non-heme protein by donating an electron to the ferric form of iron to create the ferrous form of iron which is absorbed better, and ten chelating as well. Vitamin C being an antioxidant, will help to deter certain forms of cancer, assist carnitine production and synthesis of neurotransmitter. Vitamin C and vitamin E as antioxidants work together against free radicals. Vitamin C also helps to maintain or reactivate vitamin E levels so that it can continue its indispensable function in immunological system (vitamin C is essential for lymphatic activity within the immune system) and tissue

preservation. Hence, vitamin E is thought to have a preventive effect against ageing, cardiovascular diseases and cancer (Wardlaw and Kessel, 2002; Moore, 2004).

Vitamin B_1 is crucial for carbohydrate and amino acid metabolism. It is essential fro nerve function. Vitamin B_2 takes part in the metabolism of all energy yielding nutrients; numerous oxidation – reduction reactions. Tigernut milk has low amounts of vitamin B_{12}, a cofactor for enzymes controlling folate metabolism and homocysteine metabolism is essential for the normal maturation of the blood cells and in prevention of pernicious anaemia. Tigernut beverages could provide vitamin B_{12} for vegetarians or vegans and low income earners or countries that can not easily afford meat and dairy products as a source of vitamin B_{12}. Notably, vitamin B_{12} is found mainly in animal foods and not commonly found in plants. Its chemical structure has cobalt integrated in it. Cobalt plays its only role in human nutrition integrated in vitamin B_{12} (Wardlaw and Kessel, 2002; Moore, 2004). The presence of vitamin B_{12} in tigernut milk and 36 hrs fermented tigernut wine may be attributed to indigenous microorganisms present in tigernuts. Absence of vitamin B_{12} in 24 hrs fermentation may be attributed to utilization of nutrient (vitamin B_{12}) for microbial or yeast growth and multiplication during the fermentation process. Thus, the presence of vitamin B_{12} in 36 hrs fermented tigernut wine may be attributed to multiplication of yeasts or microorganisms containing vitamin B_{12}.

Vitamin B_1 and C content of tigernut milk extract increased with the length of fermentation period. This may be attributed probably to increase or multiplication of microbial cells. Vitamin E, B2 and Zinc values depleted during tigernut wine fermentation (Table 4.6). This may also be attributed to mineral utilization by microorganisms for growth.

5.6 Microbial count and keeping quality of tigernut beverages

The results of the study showed that the fermented and unfermented tigernut beverages had low microbial count (Table4.10). Total viable plate count of tigernut product samples did not exceed the values stipulated for safe foods consumption. Garbutt (1997) stated that microbial count less than 30 colonies or less than 2.4×10^4 colony forming units per ml for viable bacterial count in a mixed culture is negligible or insignificant in food quality and safety assessment. Low microbial count in tigernut products may be attributed to increased acidity of products, adequate hygienic measures, preservation techniques and methods used during processing. Thus, observation from the study implies that tigernut products are safe for consumption when hygienically prepared using standard methods.

Lower microbial count of tigernut wine beverages may specifically be as a result of the presence of alcohol, organic acids and increase in total acidity. Alcohol inhibits bacterial growth by plasmolyzing bacterial cell walls. In addition, low pH inhibits pathogenic and putrefactive bacterial activity, thus affecting bacterial growth and metabolism (Franzier and Westhoff, 1991; Garbutt, 1997; Mountney and Gould, 1988; Adams and Moss, 1995).

Low microbial count of tigernut lemon milk may be attributed to the acidity of the product which increased due to added lemon juice which has high acidity. Besides, high sugar concentration may act as an osmotic agent making unavailable nutrients for spoilage causing organisms. According to researchers, factors such as pH and sugar concentration influence the selection of microbes such as yeast which can thrive in acidic and high sugar concentrated environment or medium (Garbutt, 1997; Mountney and Gould, 1988; Adams and Moss, 1995). The low number of colonies in the 24 hr fermented tigernut wine may be attributed to the antimicrobial substances released by acid tolerant mesophilic bacteria which might have initiated the fermentation process. These acid tolerant microorganisms may have contributed to the increase in acidity of the 36 hr fermented wine (pH 3.79) by releasing organic acids such as lactic acid and acetic acid. In addition, alcohol produced during fermentation affects both autolytic and microbial enzymes by denaturing them (Adams and Moss, 1995; Prescott *et al*., 2005; Garbutt, 1997). The number of colonies in the 36 hours fermented wine was higher than that of 24 hours fermented wine. This may be attributed to the multiplication of selected microorganism (probably yeast) at 36 hours. The sharp vinegar -like flavour observed in the 48 hr fermented wine, makes it undesirable for consumption. This flavour could be attributed to the production and increase in acetic acid by some microorganisms over time.

Results of the study on keeping quality (Table 4.11) showed that the poor keeping quality of plain tigernut milk (tigernut milk extract) may be due to its slight acidity (6.10). This is because most microorganisms grow at pH near neutral. This makes tigernut and its milk extract an excellent substrate or media for microbial growth. Thus tigernut milky juice extract could keep longer by acidification and fermentation as well as freezing. Moisture also encouraged growth. This affects the keeping quality of the products in liquid form. Poor keeping quality of tigernut milk may also be attributed to the activity of an oxidizing enzyme, lipoxidase, which causes rancidity and liberation of free fatty acids (Mountney and Gould, 1988).

Better keeping quality of lemon tigernut milk may be attributed to its acidic pH and sugar concentration which does not support thegrowth of pathogenic bacteria. The keeping quality of tiegrnut wine was better than that of tigernut milk. This may be attributed to the

organic substances produced during the fermentation process. Fermentation process or some additives could be used in preserving plain tigernut milk, thus ensuring its safety (Garbutt, 1997; Adams and Moss, 1995).

Ground tigernut coffee powder or roasted tigernuts had highest keeping quality. This is because of the low moisture content of the tubers and low pH which inhibits microbial activity.

5.7: Conclusion.

The result of the study provides information on the nutritive value, effect of processing on nutritional composition, physico-chemical and functional properties, utilization, preservation and storage of tigernuts and its products (milk coffee and wine). Result showed that tigernuts are rich in energy giving nutrients (carbohydrate and fats), phosphorus, potassium, magnesium and preventive or protective nutrients (fiber, iron, copper, zinc, vitamins C and E). They are fairly high in protein and calcium and low in sodium. Tigernut beverages are rich in vitamins B_1, B_2, C and E.

Processing method or techniques either increased or decreased the nutrient contents of tigernuts. Generally, all the processing methods (soaking malting drying and roasting) significantly increased carbohydrate values ($P < 0.05$) and decreased magnesium and sodium. Malting of tigernuts increased protein, calcium, phosphorus and fibre but decreased ash, fat, potassium copper, iron, zinc and energy values. Drying of tigernuts increased fat, ash, copper, zinc and potassium but decreased fiber, phosphorus, calcium and iron. Roasting of tigernuts increased protein, ash, copper, zinc, and potassium but decreased fat, fibre and calcium. Soaking decreased protein, malting decreased ash, fat and energy, drying decreased fibre and roasting decreased fibre and fat contents. Significantly, tigernut processing, generally decreased Mg and Na, malting decreased K, Cu, Fe, and Zn, drying decreased P, Ca and Fe and roasting decreased Ca contents. On the other hand malting of tigernut increased Ca and P. Drying and roasting increased Cu Zn, and K.

Tigernuts were used for the production of various brands of fermented and unfermented beverages. The products developed from tigernuts (milk, coffee and wine) were all highly acceptable and not statistically different ($P > 0.05$) from their controls (soya bean milk, commercial instant coffee and palm wine as the case may be). Tigernut milk is a good

substitute for soya bean milk and is rich in thiamin, riboflavin and antioxidants, (vitamins C and E). Tigernut wine is an excellent substitute for palm wine. Tigernut coffee is an excellent substitute for commercial coffee and cocoa like beverages. Keeping quality of tigernut products depends on appropriate and standard hygienic measures, preservation techniques (additives and preservation temperature) and methods used during processing.

Tigernut and its products could bring many benefits to people (young and old) in developing countries by playing important roles in providing food security, enhancing livelihoods, improving nutritional status and social well being of vulnerable groups. Tigernuts and its products could thus, go a long way in aiding to alleviate problems of malnutrition and non communicable diseases.

5.8: Recommendation / Suggestion

Tigernuts and its product could be used in diets by young and old, pregnant and lactating mothers, for its high energy, iron and vitamins C and E content. Nutrient content of tigernuts and its products could be used in complementing or supplementing nutrients from other food sources other starchy roots and tubers such as fruits, cereals and legumes. The effect of processing on the nutrient content of tigernuts may be considerably applied in formulating diets for vulnerable groups or diets for the management of certain non-communicable diseases. High fiber content of tigernuts could be explored in formulating diets for relieving constipation problem, diabetics, weight watchers and the obese. In addition, high potassium to low sodium ratio of tigernuts may be imperative in diet formulations for patients with high blood pressure and oedema as well.

Tigernut milk could be used as a good substitute for cow milk and other vegetable milks. Tigernut wine could be used as an excellent substitute for palm wine and for healthful pleasure during drinking recreation and special occasions. Malted tigernut coffee could be used as a cheap and excellent substitute for cocoa beverages. Tigernut products (milk, coffee and wine) could be blended with different fruits such as banana, pawpaw, pear, apple etc as a refreshing food or used as a base in fruit salads. Tigernut milk extract could be used as an excellent substrate or medium in food fermentation processes and also as food additives (colouring agents, flavouring agents, sweetening agents, rising agents) in foods, confectionaries and bakery.

There is need for further development of products based on tigernuts for households and commercial purposes to ensure food security. These in turn will increase its production and utilization, thereby making it more popular. There is also need for further experimental investigation geared towards ascertaining the nutritional quality of tigernut products, identifying microbial species and enzymes found in tigernuts and its products using standard cultural, morphological and biochemical characteristics.

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Appendices

Appendix 1

Table 2.1: Energy and nutrient content of tigernuts (per 100g dry weight)

Nutrient	Composition				
		a	b	c	d
Moisture	5.47	-	5.77	4.50	3.63
Protein	6.12	6	7	3.80	2.68
Fat	32.06	26	25.7	32.8	29.67
Carbohydrate	43.31	-	86.4	47.9	52.29
Starch	-	31	-	-	-
Fibre	11.51	12	5.50	8.80	12.88
Glucose	-	21	-	-	-
Ash	1.53	-	1.86	6.70	2.48
Sodium (Na)	17.73	34	1.46	-	-
Potassium (K)	415.09	424	14.80	-	-
Calcium (Ca)	36.92	92	2.58	-	-
Magnesium (Mg)	122.79	93	0.42	-	-
Iron (Fe)	3.82	4	2.16	-	-
Cooper (Cu)	0.68	0.97	-	-	-
Zinc (Zn)	2.46	3.5	-	-	-
Manganese (Mn)	-	0.25	-	-	-
Phosphorus (P)	179.90	211	-	-	-
Energy value	486.26	386	524.6	-	486.9

Source a= extract from TTSL (2005) b= Temple *et al*(1990 ; 1998) c= addy and Eteshola (1984) d= Umerie et al. (1997)

Table 2.2 Amino acid composition of tiger nut and its extract (after hydrolysis at 24 hrs at 110°C)

Amino acid	Composition		
	Tigernuts [a] (mg / g N)	Tigernuts [a] (g / 16 g N)	Tigernut extract [b] (mg / ml)
Isoleucine	133.1 ± 0.44	1.81	0.07
Leucine	252.2 ± 0.63	3.93	0.15
Lysine	307.5 ± 0.30	4.92	0.16
Methionine	58.1 ± 0.62	0.93	0.15
Phenylalanine	152.2 ± 0.30	2.43	0.06
Threonine	170.5 ± 0.62	2.72	0.12
Tryptophan	--	1.03	--
Valine	155.3 ± 0.42	2.49	0.11
Arginine	1414.0 ± 4.75	22.63	0.62
Histidine	153.4 ± 0.20	2.46	0.10
Cystine	--	2.57	--
Tyrosine	50.0 ± 0.13	0.80	0.07
Alanine	219.4 ± 0.50	3.51	0.19
Serine	160.3 ± 0.27	2.57	0.11
Proline	126.0 ± 0.15	2.02	0.09
Glycine	188.0 ± 0.25	3.01	0.12
Glutamic acid	495.0 ± 0.92	7. 81	0.38
Aspartic acid	363.4 ± 0.90	5.82	0.23

Source a= Temple *et al*(1990 ; 1998) b= McNamara ,P (2004)

Table 2.3: Nutrient content of some milk beverages

Macronutrient (mg per 100g)	Whole cow milk*	Soya milk*	Tiger nut milk*
Fat	52	54	62
Carbohydrates	29	10	27
Protein	19	36	11
MUFA	15	11	39
PUFA	1.3	31	8
Sugars	28	10	21
Oleic acid (g per 100g)	0.9	0.4	1.4

*Extract from Moore (2004)
Note: Tiger white milk is a brand of vegetable milk developed from tigernuts
MUFA= Mono unsaturated fatty acid
PUFA= Poly unsaturated fatty acid

Table: 2.4: Mineral and vitamin content of some milk beverages (mg per 100 g)

	Whole milk	Soya milk	Tiger nut milk
Mineral			
Sodium	43	32	32
Potassium	155	120	19
Phosphorous	93	47	45
Iron	0.0	0.4	0.3
Zinc	0.4	0.2	0.2
Calcium	118	13	1.7
Vitamin			
Vit. E (mg)	0.08	0.74	0.5
Thiamin (mg)	0.03	0.06	0.01
Niacin (mg)	0.8	0.6	0.01
Vit. B_6 (mg)	0.06	0.07	0.01
Vit. B_{12} (mg)	0.9	0.8	0.0
Folate (mg)	8.00	19.0	6.00
Pantothenic acid (mg)	0.58	0.48	0.00
Biotin (mg)	2.5	2.4	0.00
Vitamin C (mg)	2	0.0	0.0

*Extract from Moore (2004)
Note: Tiger white milk is a brand of vegetable milk developed from tigernuts

Appendix 2

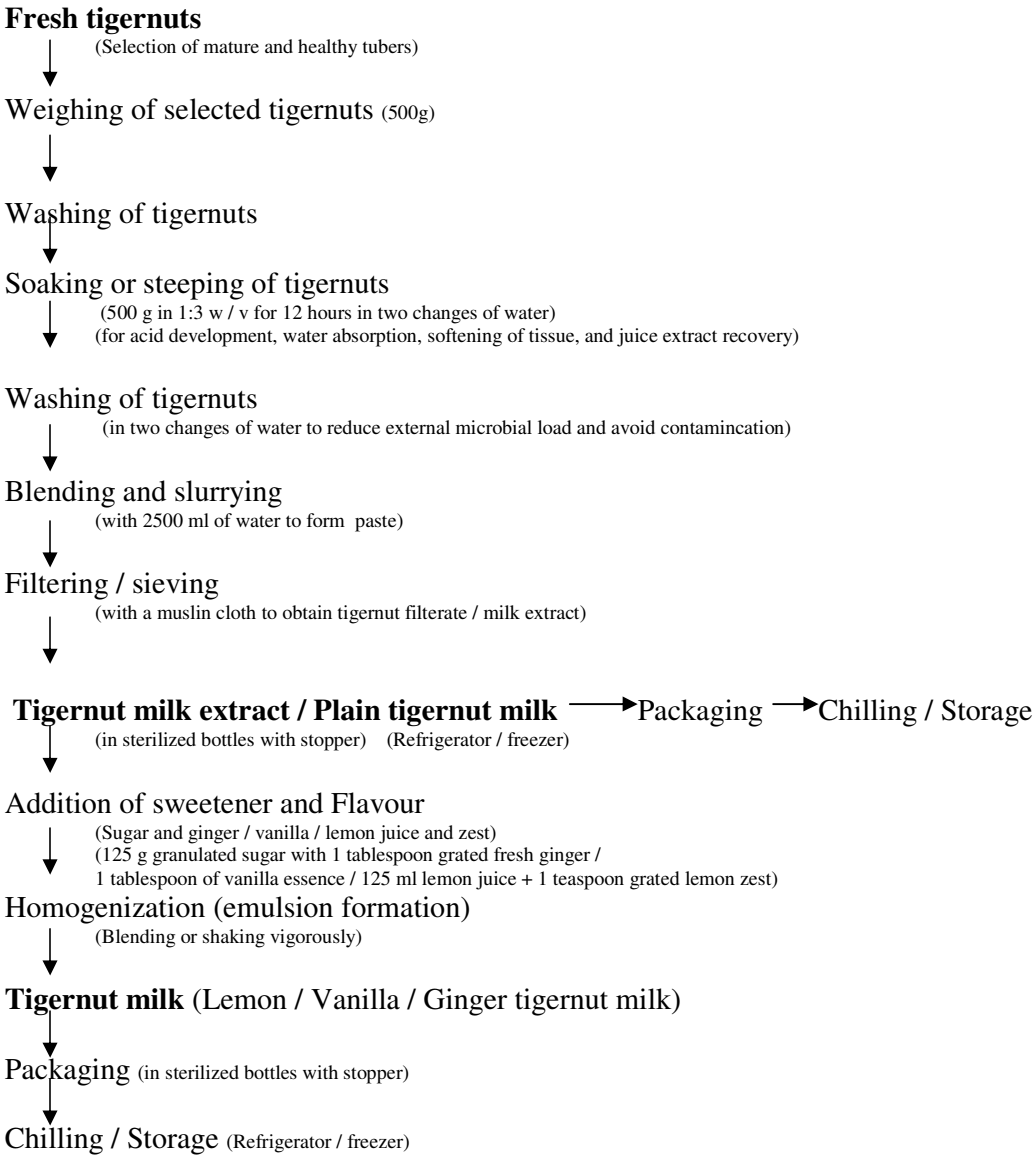

Figure 3.1: Flow diagram for the production of tigernut milky beverages


Fresh tigernuts
(Selection of mature and healthy tubers)
Weighing of selected tigernuts
Washing of tigernuts (600 g)
(in several changes of water)
Soaking or steeping of tigernuts
(600 g ; 1:3 w / v for 24 hours in 4 changes of water at 6 hrs interval)
Draining
Malting (germination for 7 days at 30 °C)
Devegetation (removal of sprouts and roots)
Air Drying of malted tigernuts
(at room temperature for 24 hours)
Roasting (roasted at 150 °C for 3 hrs)
Roasted Malted tigernuts
Cooling (several hours)
Grinding / Milling (into fine powder)
Malted tigernut coffee powder
Packaging (in nylon and plastic bags in air tight jars to prevent quick aroma and flavour depreciation)
Storage (in the refrigerator /freezer / room temperature)
Washing of tigernuts (600 g)
Air Drying of malted tigernuts
Roasting (roasted at 150 °C for 3 hrs)
Cooling (several hours)
Grinding / Milling (into fine powder)
Unmalted tigernut coffee powder
Packaging
(in nylon and plastic bags
in air tight jars to prevent quick
aroma and flavour depreciation)
Storage
(In the refrigerator /freezer / room temperature)

Figure 3.2: Flow diagram for the production of tigernut coffee powder

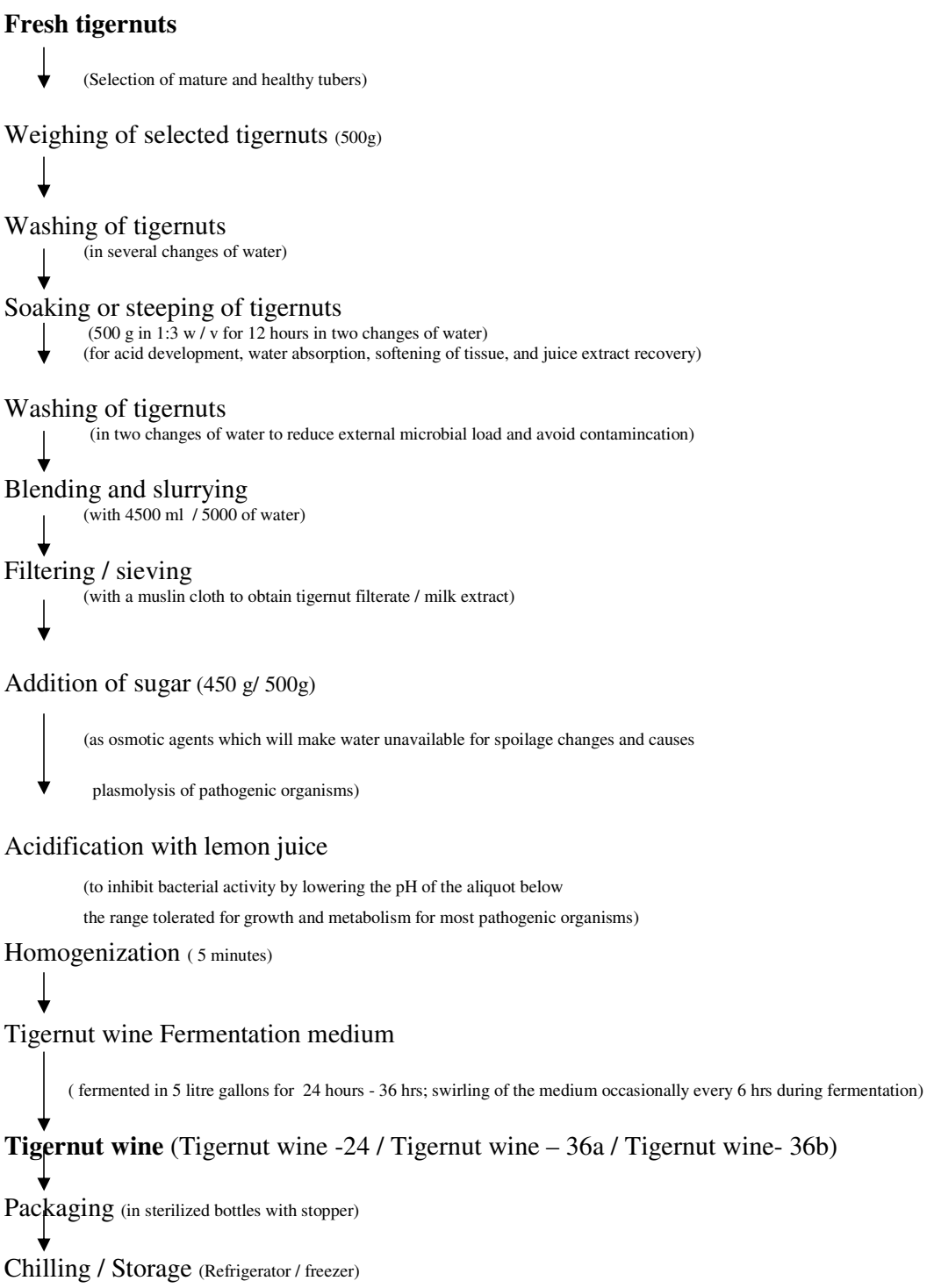

Figure 3.3: Flow diagram for production tigernut wine

Appendix 3

Sensory Evaluation /General Acceptability Form

Code number

Date

Product

Age: 20-29 ☐ 30-39 ☐ 40-49 ☐ 50 and above ☐

Instruction:

Assess the varieties of products for the listed parameters {appearance, colour, aroma taste, flavor, fizziness, viscosity, similarity to known product, generally acceptability using a nine-point scale where the degree scores are rated 9-1.

Degree scores: 9- extremely desirable, 8 – Very much desirable, 7 - Moderately desirable, 6 – Slightly desirable, 5 - Neither desirable nor undesirable, 4- Slightly undesirable, 3 – Moderately undesirable, 2 – Very much undesirable and 1 - Extremely undesirable.

Definition of parameters

Colour: Particular colour (visible quality produced by the way they reflect light)

Appearance: Noticeable and visible characteristics interesting and vivid detail / quality)

Flavour: Special characteristic / distinctive pleasant taste and smell

Taste: Soar/ bitter / sweet sensation when sample comes in contact with the tongue

Aroma: Distinctive pleasant smell

Fizziness: Capacity of having bubbles gas

Consistency: Evenness in drawing the sample over the tongue and its degree of thickness

Odour: Distinctive unpleasant smell

Sensory Evaluation / General Acceptability Form A

Please use water to rinse your mouth after assessing each sample then fill in the chosen degree score in appropriate sample columns. Fill in the degree scores of your choice in the sample columns: L M N O P and Q against their respective parameter.

Parameters	**Samples**					
	L	**M**	**N**	**O**	**P**	**Q**
Appearance						
Colour						
Aroma						
Taste						
Flavour						
Consistency						
General Acceptability						

TMU=L SMU= M TMSV=N SMSV=O TML=P TMG=Q

Comments and observations

Thank you for being a member of the panel!

Sensory Evaluation / General Acceptability Form B

Please use water to rinse your mouth after assessing each sample then fill in the chosen degree score in appropriate sample columns. Fill in the degree scores of your choice in the sample columns: E F G I J and K against their respective parameter.

Parameters	**Samples**					
	E	**F**	**G**	**I**	**J**	**K**
Appearance						
Colour						
Aroma						
Taste						
Flavour						
Consistency						
General Acceptability						

BTCU= E BTCM=F BCC=G CTCU=I CTCM=J CCC=K

Comments and observations

Thank you for being a member of the panel!

Sensory Evaluation / General Acceptability Form C

Please use water to rinse your mouth after assessing each sample then fill in the chosen degree score in appropriate sample columns. Fill in the degree scores of your choice in the sample columns: A B C and D against their respective parameter.

Parameters	**Samples**			
	A	**B**	**C**	**D**
Appearance				
Colour				
Aroma				
Odour				
Taste				
Flavour				
Fizziness				
Consistency				
General Acceptability				

TW24=A TW36a =B TW36=C PW24=D

Comments and observations

Thank you for being a member of the panel !

Appendix 4

Recipe for soya bean and instant coffee product samples used as controls

1) Tigernut milk control / Soya bean milk (SMU and SMSV)

Ingredients:

500 g Soya bean (*Glycine max*)
5000 ml Water
250 g Sugar
1 Tablespoon of Rayner's concentrated liquid vanilla flavouring essence

Method: Grit and dirt were removed from soya beans. The seeds were washed severally in clean water and then soaked for 12 hours (overnight). Seed coats were removed and te decoated seeds were soaked for 12 hours in the refrigerator, blended and slurried with water. The slurry was filtered with the aid of a muslin cloth to obtain soy milk extract. This was boiled at medium heat on a gas burner in a big pot for 1 hour stirring occasionally to avoid sticking at the base of the pot while removing the scums which appeared over time floating on the top of the boiling liquid. The boiled extract was allowed to cool. This was divided into two equal portions. One portion was bottled and refrigerated as unsweetened –unflavoured soyabean milk/ plain soy milk / soyabeanmilk extract (SMU). Sugar and flavour were added to the second portion and it was homogenized as vanilla flavoured – sweetened soy bean milk / vanilla soya bean milk (SMSV). This was bottled and stored in the freezer to chill.

2) Tigernut coffee control / Instant commercial coffee (BCC and CCC)

Black commercial coffee (BCC)

Ingredients:

5 Teaspoon pure instant coffee (25 g)
1250 ml of Water
Method: Instant commercial coffee were dissolved in boiled water in a coffee pot and poured into a flask and teacup as black commercial coffee (BCC).
Cream commercial coffee (CCC)
Ingredients
5 Teaspoon pure instant coffee
1250 ml of Water
5 Tablespoon Instant milk powder (75 g)
10 Teaspoon of granulated sugar (50g)

Method: Instant commercial coffee was dissolved in boiled water in a coffee pot and powdered milk and sugar (sweetener) were added to the dissolved coffee solution. This was poured into a flask and teacup as cream commercial coffee (CCC).