EVALUATION OF THE POTENTIAL OF ADDING TIGER NUT MILK AND SOY MILK INTO CHEESE MAKING

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BY

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DECLARATION

I, FUSEINA TIJANI hereby declare that except for the references which have been duly cited, the work in this dissertation, "EVALUATION OF THE POTENTIAL OF ADDING TIGER NUT MILK AND SOY MILK INTO CHEESE MAKING" was done entirely by me in the Department of Family and Consumer Sciences, College of Agriculture and Consumer Sciences, University of Ghana, Legon. This work has never been presented either in whole or in part for any other degree in this University or elsewhere.

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DEDICATION

First of all, I dedicate this work to the Almighty Allah for his love, provision and protection during my period of study. I also dedicate this work to my mother, Mrs. Habibatu Yusif, may Allah rest her soul, and to my family for their love and support.

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ABSTRACT

The purpose of this study was to evaluate the potential of incorporating tiger nut milk and soy milk in cheese making. In all 16 different formulations were prepared from tiger nut milk, soy milk and cow milk. Texture analysis, colour evaluation and chemical analysis were carried out on all the 16 cheese samples. Two parameters were measured (firmness and fracturability). Protein, fat, moisture content and pH were determined with respect to the chemical analysis. For the colour evaluation, L* value was determined. Microbiological analysis was carried out on 4 samples, which had the least and the most amounts of soy milk, tiger nut milk and combinations of the two. Sensory evaluation was done for 6 products. Data from the physico-chemical analysis was analysed with the statistical package Minitab version 14. A one-way anova was used to analyse data from the sensory evaluation. There were statistical differences between the samples with respect to the texture measurements. In general, firmness of the cheese samples increased as soy milk was added and decreased as the amount of added tiger nut milk was increased. The fracturability of the samples increased as soy milk was increased and decreased as tiger nut milk was increased. There were also significant differences between the colour readings of the samples ($p < 0.05$). All the counts for the microbiological quality of the four cheese products were below the maximum acceptable limit set by Ghana Standards Authority. There were significant differences in chemical composition for the 16 cheese samples ($p < 0.05$). The pH, moisture, fat and protein contents increased in the cheese samples as the amount of added tiger nut milk, soy milk or combinations of the two was increased. For the acceptance test, formulation 7 (200 ml of tiger nut milk and 50 ml of soy milk) was the cheese product accepted best by the sensory panel. Based on the findings of this work, it can be concluded that developing cheese

products from tiger nut milk and soy milk is feasible and the developed cheese product could be used as a spread on bread and other baked products. We recommend formulation 7 (200 ml of tiger nut milk and 50 ml of soy milk) because it was preferred by the sensory panel when compared with the other formulations. Adding tiger nut milk beyond the 200 ml that was used for formulation 7 produced soft cheese, while adding more soy milk beyond the 50 ml used for formulation 7 produced a hard cheese with a beany flavour.

CHAPTER ONE

1.0 INTRODUCTION

Protein deficiency is a great problem in the Ghanaian diet. As at 2001, the average diet of the Ghanaian comprised only 5% of foods of animal origin (Otchere and Okantah, 2001) and the rest comprised of starchy staples (Levin, 1997). Milk and milk products are great sources of animal protein and can be used to curb this problem. Protein-rich foods are necessary to ensure adequate nutrition.

One way of meeting the demands of the people for dairy and dairy products is to encourage the production of milk and milk products locally. Since local production of milk is low and a lot of money is used to import milk and dairy products, there is an urgent need to develop dairy products from other alternatives like tiger nuts and soya beans which we have in abundance. Cheese is a dairy product with high protein content, with a widespread consumption worldwide. Aside from containing proteins of good quality, it contributes to calcium binding and generally has fewer digestive problems than other dairy products. However, it is high in saturated fats, an important contribution of calories and in general, is an expensive product, due to the low yield (Karaman and Akalin, 2013; Mistry, 2001). It is therefore a challenge for the food industry to develop foods with ingredients that help to lower health risks, like substituting animal fats with vegetable fats and oils like tiger nuts and soy beans. Consumers are becoming more particular about food choices that have a positive effect on their health and overall wellbeing. Singh *et al.* (2008) and Devcich *et al.* (2007) reported growing consumer interest in foods that are good for their wellbeing and health. Among the sources of vegetable milk, soybean has received much attention in the research field and more research is still being designed to improve the quality of soy milk (Sun-young *et al*., 2000). However not much research has been done on tiger nut milk as a source of vegetable milk (Ukwuru *et al*., 2008). In Ghana, tiger nuts is one of the underutilized crop even though it is highly nutritious. According to Omode *et al*. (1995), the nuts are also very high in calcium, sodium, potassium, magnesium, zinc and some traces of copper. Consuming tiger nut can cure diarrhea and flatulence, control colon cancer and heart attacks among others (Bamishaiye, 2011). Soybeans are distinct among the legumes because they are concentrated sources of isoflavones and have the potential to prevent and treat cancer and osteoporosis (Messina, 1999). Research has shown that isoflavones prevent LDL oxidation in vivo (Wiseman *et al*., 2000) and inhibit DNA damage in vitro (Giles and Wei, 1997) in humans. According to Liu (1997), soya beans are excellent sources of high quality proteins. The proteins from soya beans are unique among plant proteins because of their relatively high biological value and essential amino acid content.

1.1 Statement of the problem

For a long time now, most milk products that are sold in Ghana are mostly produced from imported milk of which cheese is not an exception. High price of imported milk and milk products coupled with poor milk production in Ghana and Africa in general seem to have made consumers more ready to accept milk produced from plant sources. In view of the numerous benefits of soy beans and tiger nuts, efforts are being made to encourage increased consumption of these crops so as to solve problem of protein– energy malnutrition in Ghana and Africa in general. This study sought to evaluate the potential of incorporating soy milk and tiger nut milk into cheese making.

1.2 Aim of the study

The aim of the study was to evaluate the potential of adding tiger nut milk and soy milk into cheese making.

1.3 Objectives

The specific objectives of the study were to:

1. Prepare cheese product from tiger nut milk and soy bean milk.
2. Develop a cheese product that can be used as a spread.
3. Determine the proximate composition of the developed cheese.
4. Evaluate sensory the characteristics of the developed cheese.

1.4 Hypotheses

This study tested the following three hypotheses:

Ho_1: There is no difference between sensory attributes of cheese product made from cow milk and cheese products with added soy milk, tiger nut milk or combinations of the two.

Ho_2: The addition of tiger nut milk to cow milk does not affect the nutritional quality of the developed cheese product.

Ho_3: The addition of soy milk to cow milk does not affect the nutritional quality of the developed cheese product.

1.5 Significance of the study

If successful, the results of this study may:

1. Document a protocol for incorporating tiger nut milk and/or soy milk in cheese making.
2. Develop a cheese product that can be used as a spread.
3. Provide opportunities for entrepreneurship.
4. Provide new opportunities for utilizing tiger nuts and soy beans.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Legumes

Legumes have been cultivated for many years now, however many of the varieties of beans and peas that are common today were unknown until relatively recent times. They include peanuts, lentils, peas, beans and other podded plants used as food. Legumes are common and play a very important role in the diets of many people in the world. Legumes are low in fat, excellent sources of protein, contains dietary fiber, and a variety of micronutrients (such as folate, iron, zinc, riboflavin and calcium) and phytochemicals (Messina, 1999). Legumes usually contain 5% of energy, fat is between 20% and 30% of energy with the exceptions of chickpeas and soybeans, which contain <15% and 47% fat, respectively (Pennington, 1994). According to Remer and Manz (1994), the protein in legumes may improve calcium retention relative to animal and grain proteins. It has been estimated that for every gram of protein consumed, a loss of 1 mg Ca occurs. Folate is an essential nutrient believed to reduce the risk of neural tube defects (Daly *et al*., 1995). The dietary fibre in beans is high and high fiber, high-bean diets were shown to lower serum cholesterol in hypercholesterolemic individuals (Anderson *et al*., 1994).

2.2 Tiger Nuts

2.2.1 Description of Tiger Nuts

Tiger nut which is scientifically known as *Cyperus esculentus* belongs to the family Cyperacea. It is a cosmopolitan perennial crop which belongs to the same genus as the papyrus plant which is very common in seasonally flooded wetlands (Bamishaiye, 2011). In the temperate zone, it is grown in United States, Italy and Spain. In the tropics, it is found largely in India and West Africa (Cobley, 1962). Other names of the tiger nut plant are earth almond and yellow nut grass (Etosha and Oraedu, 1996). It is one of the most domesticated crops that was cultivated since early times and was used to preserve the bodies of Egyptian Pharoahs (Watt and Breyer, 1962). The nut has been naturalized in Ghana, Nigeria and Sierra Leon (Anon, 1992).

According to Consejo (2006), tiger nut is a tough erect fibrous-rooted plant, ranges from 1 to 3 feet high and reproduces by seeds and by many deep-rooted slim rhizomes. It grows to a height of about 90 cm and has solitary stems that grow from a tuber. Its stems are triangular in section and slender leaves ranging from 3 to 10 mm width. The flowers of the tiger nut plant are distinct, with a group of flat oval seeds by four leaf-like bracts positioned 90 degrees from each other. The plant is also mostly mistaken for a grass because of the very tough and fibrous foliage (Zhang *et al*., 2012). Mason (2005) in her article about tiger nuts described it as small about the size of a peanut growing at the rhizome of the plant and not a nut as people generally called it.

Other names of the tiger nuts are Zulu nut, yellow nutgrass, ground almond, chufa, edible rush and rush nut (Eteshola and Oraedu, 1996). The tubers of tiger nuts are daily ingredients in the diets of a lot of people in Spain and North Africa (Oladele *et al*., 2009).

The nuts are known for their high nutritious content in dietary fibre, starch and carbohydrates (Umerie and Enebeli, 1997). According to Omode *et al.* (1995), the nuts are also very high in Calcium, Sodium, Potassium, Magnesium, Zinc and some traces of copper. Consuming tiger nut can cure diarrhea and flatulence, control colon cancer and heart attacks among others (Bamishaiye, 2011).

2.2.2 Types of Tiger nuts

There are many varieties of tiger nuts in the world. In Nigeria, there are three varieties: black, brown and yellow but only the brown and yellow are readily available in the market. The yellow type is preferred because of its inherent properties like its bigger size, attractive colour and fleshier body. It also yields more milk which contains lower fat and higher protein and less anti-nutritional factors especially polyphenols (Okafor, 2003).

In Ghana, tiger nut is commonly called “Atadwe”. There are two main varieties of tiger nuts namely: the Fante type and the Kwahu type. The Kwahu type is yellowish brown in colour. There are four different sub-types of the Kwahu type designated as Kwahu Types 1, 2, 3 and 4. The nuts of Type 1 are small and round, those of Type 2 are fairly large and round, those of Type 3 are large and slightly elongated and those of Type 4 are slender, long and may be straight or sickle-shaped. The Fante type has a mixture of dark-brown and black nuts which are generally round but differ in sizes (Tetteh and Ofori, 1998). They also indicated that consumers preferred the Kwahu type to the Fante type due to the sweetness and attractiveness of the former. Tiger nuts are grown at places like Aduamoa in the Kwahu South District, Asukese, Odomasua, and Demso in the Afram Plains, Agona Kwanyaako, Bawjiase, and Elmina in the Central Region, and around Techiman in the Brong-Ahafo Region.

Figure 1 Fante Type

Figure 2 Kwahu Type

2.2.3 Nutritional and health benefits of tiger nuts

According to Mason (2005), tiger nuts have a high content of soluble glucose and oleic acid, along with high energy content (starch, fats, sugars and proteins). They are rich in minerals such as phosphorous and potassium, calcium, magnesium and iron necessary for bones, tissue repair, muscles, the blood stream and for body growth and development and rich in vitamins E and C. Tiger nuts have high content of arginine and has high amounts of carbohydrates with a base of sucrose and starch (without glucose), (Chevallier, 1996; Tiger Nut Traders, 2005),which liberates the hormone that produces insulin and as such sugar-free tiger nut drink is suitable for diabetics and also helps to control weight (Martinez, 2003). It also provides digestive enzymes like the catalase, lipase and amylase and as such good for those who suffer from indigestion, flatulence and diarrhea. Tiger nut contains an appreciable amount of vitamin B_1, which assists in balancing the central nervous system and helps the body to adapt to stress. It also contains a substantial amount of oleic acid which has positive effect on cholesterol, thereby preventing thrombosis and cholesterol and also activates blood content of soluble glucose. It also prevents constipation and reduces the risk of colon cancer. (David, 2005; Tiger Nut Traders, 2012). The milk of tiger nuts contains Vitamin E which reduces the harmful effects of low density lipoprotein cholesterol (LDL) (Ahmed *et al*., 2009) and is very essential for fertility in both men and women. Research shows that 100g of tiger nuts contains approximately 7% of protein, 26% fats, 31% starch and 21% carbohydrates. It is also thought to contain approximately 26% fibre of which 12% is soluble and 14% insoluble (Childers, 1982). In China, tiger nut milk is used as a liver tonic, heart stimulant, cure for serious stomach pain, to promote normal menstruation, to heal mouth and gum ulcers, used as a powerful aphrodisiac (sexual stimulant). They are used to treat inflammations, breast lumps and cancer (Belewu and Belewu, 2007).

Table 1: Proximate Composition of Tiger Nut Tubers per 100g

Parameter	**Dry matter (%)**
Moisture(%wet wt)	5.77
Crude protein	7.00
Ether extract	25.70
Total ash	1.86
Crude fibre	5.50
NFE	60.00
Total carbohydrate	65.50
Caloric value (kcal)	524.6

Source: Oderinde and Tahiru (1988)

2.2.4 Tiger nut utilisation

2.2.4.1 Tiger Nut Milk

Tiger nut milk refers to the milk that is extracted directly from tiger nuts. It is called "Atadwe milk" in Ghana and "Horchata" in Spain. According to experts, it is a nutritious and nourishing drink recommended to be taken during any time of the year, but most especially during the dry season (Bamishaiye, 2011). The drink is very high in vitamins C and E, minerals like calcium, magnesium, potassium, phosphorus and iron, carbohydrates, protein and unsaturated fats (www.tigernut.com). According to Chevallier (1996), the calcium, iron and magnesium in tiger nut drink is higher than what is found in cow's milk. Therefore it can be a very good substitute for cow milk. Research has revealed that tiger nut can be added to other beverages to boost its nutritional content. Belewu and Abodunrin (2006) studied the effect of tiger nut on "Kunnu", a non-alcoholic beverage prepared from cereals like millet and sorghum. Their results revealed that "Kunnu" from tiger nut was more nutritious and acceptable than "Kunnu" prepared from either millet or sorghum. This result was in line with what Abdel-Nabey (2001) found out with respect to tiger nut drink being greatly acceptable. Another study by Sanful (2009) which investigated the production of yoghurt from cow milk, tiger nut milk and their composite revealed that the quality characteristics for the yoghurt prepared from cow milk and the composite were rated as being the same. This means that there is a possibility of the addition of tiger nut to cow milk to produce affordable and nutritious yoghurt. A study by Emmanuel-Ikpeme *et al*. (2012) on the use of soya bean flour and tiger nut flour in producing weaning diets revealed that the formulated foods especially the mixture of 55% tiger nut and 35% soya bean with 10% of milk contained appreciable amounts of macro and micro elements and hence would be suitable for infants. Udeozor

(2012) also prepared a drink from tiger nut and soy milk and found that the milk prepared from tiger nut and soy bean could be used as a beverage for both the young and old due to the high nutrient contents like protein and fat.

Table 2: Proximate composition of tiger nut milk

Content (%)	**Tiger nut milk**
Dry matter	7.73
Crude protein	8.07
Total ash	0.47
Fat	26.18
Ph	6.12
Titratable acidity	0.16
Calcium	8.75
Phosphorus	10.57
Total energy (kcal. 100^{-1})	388.30

Source: Belewu and Belewu (2007)

2.2.4.2 Tiger nut flour

Tiger nut flour is gluten free and good for people who cannot take gluten in their diets and therefore good alternative to many flours like wheat flour. It is also used in baking foods (FAO/WHO, 1985; Belewu and Abodunrin, 2006). Tiger nut flour has some amount of protein, is rich in oil and can be combined with other types of flour like whole wheat flour and all-purpose flour to make biscuits, cakes, bread and other pastries (Ade-Omowaye *et al.*, 2008). It can also be used as a flavoring agent for biscuits and ice creams (Osagie and Eku, 1998). In Keta, Ghana, the sun-dried tubers are ground to a fine powder to which sugar may be added and stored till required. Roasted tubers may also be similarly ground to a powder known in Vhe (Awlan) as 'fie-dzowe'. Water may be added to make a beverage or eaten raw (Adejuyitan *et al.,* 2009). The procedure for processing tiger nuts into flour is outlined below:

1. Tiger nut is harvested from the fields/purchased.
2. Cleaned by means of specialized washing machines to eliminate the rests of soil, dust, stones or insects.
3. Natural sun- drying process is used to dehydrate the product for conservation.
4. The product is introduced in a hopper for milling.
5. All the products are milled together, skin included.
6. Allowed to cool, packaged and stored.

(Tiger Nut Traders, 2005)

2.2.4.3 Tiger nut oil

Tiger nut oil obtained from the tuber is edible, stable and said to be superior oil that compares favourably with olive oil. The oil has rich, nutty taste and is golden brown in colour (Osagie *et al*., 1986). When the oil if refridgerated, it remains in a uniform liquid state and as such is ideal for salad making. It is also low in polyunsaturated fatty acid (linoleic acid and linolenic acid) and high in oleic acid (Okladnikov *et al.,* 1977; Ezebor *et al.,* 2005). It is highly resistant to chemical decomposition at high temperatures and therefore highly recommended for cooking over other oils (Ahmed et *al.,* 2009). The procedure for processing tiger nuts into oil is outlined below:

1. The nuts are harvested from the farm, sorted and washed to remove foreign matter.

2. They are dried to safe moisture content (8%) (The drying is critical to having quality oil)

3. The nuts are milled into flour with a mechanized grinder.

4. The flour is put into a press which squeezes the flour thereby extracting the oil slowly by sweating in a first cold extraction of the oil.

5. The extracted oil is filtered to remove impurities.

6. The purified oil is collected in barrels.

(Tiger Nut Traders, 2005)

2.3 Soy beans

According to Liu (1997), soy beans have many uses in human nutrition and are excellent sources of high-quality proteins. Soybeans are distinct among the legumes because they are concentrated sources of isoflavones, according to Messina (1999). Isoflavones are a subclass of flavonoids, which belongs to a broad group of polyphenolic compounds commonly distributed in foods of plant origin. Biological effects attributed to flavonoids include antiestrogenic and proestrogenic effects, as well as antioxidant and antiproliferative actions (Ross and Kasum, 2002). Soyfoods and isoflavones have received quite a lot of attention for their potential role in preventing and treating cancer and osteoporosis (Messina, 1999). Due to the reported beneficial effects on health and nutrition, soy foods consumption and the use of soya milk in human diets are increasing (Rinaldoni *et al.,* 2014). Some of the health benefits include prevention of diabetes, cancer and osteoporosis, protection against kidney and bowel disease, relief of menopausal problems and lowering of plasma cholesterol (Anderson *et al.,* 1994; Friedman and Brandon, 2001; Shah *et al.,* 2007). Studies have shown that the consumption of soy protein is associated with a lower urinary calcium excretion compared with the consumption of similar amounts of whey protein (Anderson *et al.*, 1987) or a mixture of animal proteins (Breslau *et al.*, 1998). According to the United States Department of Agriculture (1988), soybeans are quite high in fat and the consumption of full-fat soy foods contributes significantly to a-linolenic acid intake. According to the Ghana Export Promotion Council (2002), 50,000 metric tons of soya beans are produced annually but only about 15,000 metric tons are utilized. According to Plahar (2006), soy beans were first introduced in 1910 and its cultivation is mainly in the northern region. There are various types of soy beans in the world but four main types are in Ghana. These are Anidaso, Bengbie, Salintuya and Nakpanduri. Although soy beans cannot be cooked and eaten raw, it can be processed into soya milk, soya flour and soy khebab.

Figure. 3 Soy beans

Table 3: Proximate composition of soy bean varieties

Component	Anidaso	Bengbie	Salintuya	Nakpanduri
Protein	45.8	43.9	41.2	47.9
Fat	17.6	21.5	21.1	16.6
Carbohyrate %	31.2	31.8	32.8	32.4
Energy(kcal/100g)	466.2	496.7	498.0	468.7
Moisture	12.7	9.7	10.8	9.7

Source: Annan and Plahar (1994).

Table 4: Proximate composition of soy milk

Content (%)	Soy milk
Dry matter	8.37
Crude protein	8.90
Total ash	0.66
Fat	4.30
Ph	6.20
Titratable acidity	0.17
Calcium	9.50
Phosphorus	12.65
Total energy (kcal. 100^{-1})	100.52

Source: Belewu and Belewu (2007)

2.4 Milk

According to Food and Drugs Administration (FDA) (1988), milk is defined as a lacteal secretion, free from cholesterol and which is obtained by the milking of one or more healthy cows. The final form of milk to be used as beverage should not contain less than 8.25% milk solid –not – fat and not less than 3.25% milk fat. Milk is a complex fluid which is made up of major constituents (water, lipids, sugar and proteins) and minor constituents (minerals, vitamins, hormones and enzymes). The concentration of the major and minor constituents vary among species with the major constituents being lipids (2–55%), proteins (1–20%), lactose (0–10%).The composition of milk varies among animals, between breeds, with the feed and health of animals and the stage of lactation among others (Fox, 2008). Milk is a perishable commodity and as such it is converted into other forms of products with a longer shelf life. Some of the products include butter, ice cream, yoghurt, concentrated and dried milk, cheese and fermented products. For a long time now, man has realized that milk is not only food for the young but for adults as well. Milk can be obtained from animals such as sheep, goat, buffalo, horse, camel and donkey. Cross and Overby (1988) revealed that the cow is adapted to moderate zones and in Europe and in regions like Australia, North America New Zealand are the main users of cow milk and its products.

2.4.1 World Milk Production

World milk production in 2013 is projected to grow by 1.9 percent to 780 million tonnes. Latin America, Asia and the Caribbean are presumed to account for most of the increase, with only little growth elsewhere (FAO Food Outlook, 2013).

Table 5: World Milk Production

Year	Quantity (Million tonnes)
2011	742.2
2012 (estimation)	765.6
2013 (forecast)	780.3

Source: FAO Food Outlook, 2013

2.4.2 Milk Production in Ghana

The local breeds of cattle in Ghana have very low milk production capabilities. However, the cross breeds are able to produce more milk than the local ones. Milk production has not been very well developed in Ghana and there is little statistics on the amount of milk produced. In the past, the Food and Agricultural Organization (FAO) and Government of Ghana (GOG) set up a training programme for small-scale milk producers which provided an opportunity for increased utilization of recently introduced breeds and genetic improvements of indigenous cattle breeds. The Sanga was crossed with Friesian to produce an animal that produced good levels of milk (milk produced was between 6 and 8 litres of milk per animal per day) as compared to the local breeds which produced less than 2 liters in a day (Animal Production Directorate, 2003). In Ghana, milk is extracted for home use and for commercial uses. Milking is usually done once a day and the calf is very necessary to help induce milk-letdown (Otchere 1966; Okantah *et al.*, 1995). The milk production in Ghana as at 2006 was estimated at 34,000 metric tonnes and an average of 37,195 metric tonnes of liquid milk equivalent (LME) was imported yearly into the country in the last decade (Government of Ghana (GOG)/Food and Agricultural Organisation (FAO), 2002). Milk production is very low in Ghana hence the per capita consumption of milk is low. In 2001, the annual milk production was estimated at 36.5 thousand tonnes with most of it coming from small holder agropastorial producers. Between milk production and consumption, there lies a huge gap and the loss is made up via the importation of dairy and dairy products. From 1995 to 1999 the total volume of dairy products that was imported into the country was 39,831.4 (x 103 t) (Otchere and Okantah, 2001). According to Karbo *et al.* (1998), milk producers in peri-urban

Tamale obtained a considerable daily income from selling milk during the course of the year. A study conducted by Nsiah-Ababio (1998) revealed that the potential income contribution from the sale of milk was the same as the income contribution from crop production. Also a study conducted in the Techiman District of Brong Ahafo revealed that making ‘wagashi’ (cottage cheese) from fresh local milk added a value of 54% to milk compared with sales of the fresh product (SFSP–GTZ–MoFA, 1998).

2.4.3 Constituents of Milk

Milk is a complex fluid with comprises of major constituents which are water, lipids, sugar and proteins and minor constituents being minerals, vitamins, hormones and enzymes. The concentration of the major and minor constituents vary among species with the major constituents being lipids (2–55%), proteins (1–20%), lactose (0–10%).The composition of milk varies among animals, between breeds, with the feed and health of animals and the stage of lactation among others (Fox, 2003).

2.4.3.1 Water

Water is the main constituent of milk. It serves as solvent for the salts in milk, proteins and lactose. It also controls the activity of many reactions like enzyme activity and microbial growth which goes a long way to affect the stability of milk and milk products. The amount of water can affect their quality, stability and preservation of milk products (Fox, 2003).

2.4.3.2 Protein

The protein content greatly affects the properties of milk and milk products more than any other constituent. Casein and whey proteins are the main groups of proteins which make up about 80% and 20% respectively of total milk (Fox, 2003). The acid whey contains two groups of proteins; lactalbumins and lactoglobulins. The fraction of lactoglobulin contains mainly immunoglobulins whiles the fraction of lactalbumin contains two major proteins which are β-lactoglobulin (β-Lg) and α-lactalbumin and other minor proteins like blood serum albumin and lactoferrin (Imafidon *et al.*, 1997; Fox, 2003).

2.4.3.3 Lipids

Fats or oils collectively called lipids are constituents of biological fluids, tissues and foods which are soluble in an apolar solvent (Fox, 2003).

2.4.4 Treatments of Milk

Milk is a perishable commodity and as such it is subjected to different heat treatments to prolong its shelf life.

2.4.4.1 Homogenisation

According to Pamplona- Roger (2006), homogenisation is a process whereby milk is passed through very fine sieves under high pressure between 100-150 atmospheres. This causes the fat globules present in milk to finely split into smaller globules which are uniformly distributed throughout the milk which tends not to float. This process results in the following:

a. No fat layer develops on the surface of the milk,

b. The milk coagulates more easily by heat or acids and

c. The milk is thus easier to digest.

2.4.4.2 Pasteurisation

Pasteurisation is used to destroy spoilage micro-organisms (Fox and Cogan, 2004). According to Farkye (2004), for pasteurisation to work properly, milk has to be heated at about 72^{o}C for 15 seconds. Cheese produced from unpasteurised milk contain a lot of bacteria compared with cheese produced from pasteurised milk. Various temperatures and time combinations are used in the pasteurisation process but commonly used is heating milk to 74^{o}C (165.2^{o}F) for 15 seconds (Pamplona- Roger, 2006).

2.4.4.3 Sterilisation

According to Pamplona-Roger (2006), sterilisation is a process that destroys all microorganisms in addition to their pores. Some forms of sterilisation are:

a. Classic sterilisation: This prolongs the shelf life of milk but takes away its flavour and nutritional content, particularly some essential amino acids like vitamins B_1 and B_{12}.

b. Ultra High Temperature (UHT) Sterilisation: This process is the same as classic sterilization but takes away a smaller amount of flavor and nutritional content.

2.4.4.4 Thermisation

This is a sub-pasteurisation heat treatment which is used to decrease the micro flora of milk. It is practically used for cheese milk even though it does not meet the requirements for pasteurisation from the public health point of view (Fox and Cogan, 2004).

2.4.4.5 Microfiltration

This is a very effective way of eliminating bacteria from milk. In addition to killing bacteria, it removes somatic cells which contain enzymes supposed to have a negative effect on the quality of cheese (Fox and Cogan, 2004).

2.4.4.6 Bactofugation

Bactofugation is a form of removal of spores and bacteria which are not used (Fox and Cogan, 2004). Pasteurization inactivates all activated microorganisms until technological and hygienic requirements are reached. However, the heat resistant spores are able to survive during pasteurization process. Hence bactofugation is done to remove and inactivate the spores because they can form new cells by growing under favourable conditions and can multiply quickly (Kohle *et al.*, 2009). According to Farkye (2004), in places around the world where the microbiological quality of milk is not very good, bactofugation has been used to manage the quality of milk. Kosikowski and Fox (1968) demonstrated that this method reduced microbial counts by 95.3%. According to Scott *et al.* (1998), bactofugation reduces the amount of milk by 2-3 % and the protein contents by about 7%. This results in the loss of milk solids in the sludge and finally resulting in the loss of about 6% of cheese yield (Walstra, 1999).

2.4.5 Types of Dairy Products

According to Pamplona-Roger (2006), milk products can be produced through various ways and below are some of them.

a. Products derived through separation of milk components.

i. When fresh milk is at rest, it suddenly separates into three parts namely cream, whey and curd. The cream portion contains milk's fatty material and cholesterol. Whey is the liquid portion of milk which is obtained after separating the cream and the curd. The curd is the product formed after coagulation of milk. Basically there are two types of milk curd: natural and milk curd coagulated by animal rennet.

ii. By using home and industrial methods. In the home, milk can be coagulated by using extract from specific leaves like *Calotropis procela.* After the curds have formed they are allowed to cool and then poured into baskets or sieves to drain most of the whey. In the industries, coagulants like rennet tablet or solution and/or sometimes citric acid are added for the coagulation of the milk. Then they are drained and sometimes a weight is put on it to drain properly.

b. By fermentation of milk by different microorganisms. Examples are yogurt and probiotic yoghurt

c. By a combination of both processes and an example is cheese.

2.4.5.1 Yoghurt

According to Pamplona-Roger (2006), yoghurt is a semisolid fermented milk product. Yoghurt can be made from the milks of a variety of animals but most frequently used is that of cow's milk. The process of making yoghurt is as follows.

a. Homogenization and pasteurization

b. Milk is inoculated at 2% proportion with bacteria.

c. Fermentation between 4 -8 hours.

d. Cooling and packaging.

Lactic acid bacteria present in milk aids in fermentation. Some other bacteria that are used in the fermentation of milk to obtain yoghurt are Lactobacillus bulgaricus, Streptococcus thermophiles, Lactobacillus acidophilus and Bifidobacterium bifidus.

2.4.5.2 Ice Cream

According to Pamplona-Roger (2006), ice cream is a very delicious and nutritious dairy product. The production of ice cream is described below:

a. Mixing of milk, cream and milk derivatives, egg, sugar, chocolate or other flavors.
Proteins or fats from vegetables may also be used.

b. Whipping to incorporate air into the mixed ingredients.

c. Freezing.

2.4.5.3 Milk-Based Desserts

According to Pamplona-Roger (2006), these are products produced from fat and milk protein after which vegetable flour or starch is added. They are low in vitamins but high carbohydrates, fats and protein. These products can be stored for months at room temperature.

2.4.5.4 Cheese

Cheese is a general term used to describe curdled milk. Cheese according to the National Dairy Council (2000) is defined as a fresh or matured product which is obtained after curdling of milk's major protein and draining of whey.

2.4.5.4.1 Uses of Cheese

Cheese is included in the preparation of many dishes to make them tastier. Cheese is an excellent source of calcium and proteins and the proteins makes one feel more satisfied after a meal or a snack. Cheese can be used as a pizza topping, used on sandwiches, used on salad as salad dressing and used as appetizers.

2.4.5.4.2 Nutritional and Health Benefits of Cheese

When eaten in moderation, one can reap the benefits associated with consuming cheese.

It promotes strong teeth and bones because cheese is an excellent source of calcium which is known to promote strong and healthy bones. It also enhances the flow of saliva which helps to wash away food particles in the mouth and this helps to control the development of plaque. It may prevent the development of osteoporosis and other problems associated with the bones. Cheese is good for pregnant women because it is known to enhance contractions when the baby is due and also helps the mother to produce sufficient milk for the baby. It may promote healthy skin because cheese contains B vitamins which are known for sustaining shiny and healthy skin. It may help to prevent cancer as it contains Conjugated Linoleic acid (CLA) which inhibits the development of cancer especially colon cancer. It helps to boost the immune system thus preventing the development of many diseases and illnesses (Vercillo, 2000).

2.4.5.4.3 Global Cheese Production

The cheese manufacturing industry has experienced a remarkable growth making it one of the world's traded commodities in agriculture. About a 3rd of the world's milk production is used in the production of cheese. From 1998 to 2002, the France, Germany, United States of America and United Kingdom experienced over 9% increase in the cheese market (Food and Agricultural Organisation of the United Nations, 2012).

2.4.5.4.4 Cheese Production in Ghana

Most cheese products that we have in Ghana are imported. Cheese production has not been developed very well. According to Okanta *et al.* (1995), the main processed product of milk was the cottage cheese "wagashie" which was on a small scale. Besides the "wagashie", other products like sour milk, butter, and cheese was also produced but was usually consumed by the family. Wagashie is a soft cheese which is produced by heating milk to about 80 ^{o}C, with an extract from *Calotropis procela* for the coagulation of milk. During coagulation, the temperature is maintained for about 3 to 4 hours and then to get rid of the whey, the coagulant is heated to boiling point. After the whey has separated from the curds, the heat is removed and curds are allowed to cool. The curds are then poured into small basket moulds to allow the whey to totally drain overnight. After draining, the cheese is ready (Okanta *et al*., 1995). The production of the cottage cheese was a way of preserving milk in a different form so that it can be available for a considerable amount of time. Some research has focused on substituting cheese with other ingredients equally nutritious to enrich it. Ocansey (2010) came up with significant results when he developed a cheese product by partial substitution of cow's milk with coconut milk. The preferred product was the 70% cow's milk: 30% coconut milk. Mahami *et al*. (2011) also investigated the effect of moringa extract on cheese. They found out that the extract boosted the protein content, mineral content and yield of cheese. Other studies have focused on the inclusion of starch in cheese products mainly to replace fat, act as stabilisers and to act as a bulking agent. Gampala and Brennan (2008) investigated the potential of using starch in a processed cheese system. Results from their work indicated that the starch added increased hardness of the cheese product. This could pose a problem because it could be a little difficult to cut and shred during preparation. However, the addition of starch decreased the amount of melt and this could boost the product's stability during heating and cooking. Duggan *et al*., (2007) work on the effect of starch on the water binding properties of imitation cheese revealed that the starch could help organize water molecules which would leave them entrapped within the cheese sample. The starch also helped to maintain good functionality of the cheese sample. So there is a possibility of supplementing cheese with tiger nut milk to improve the nutritional quality. Rinaldoni *et al*. (2014) also developed soft cheese-like product from soy protein concentrates. They found out that the cheese product increased in moisture, fat and protein contents as soy concentrates were increased. Chumchuere *et al*. (2000) produced a semi-hard cheese from reconstituted soy-milk rich in protein (21.8%) and low in fat (2.6%). They suggested that the cheese could be used as a protein-rich component of a meal or as a snack. Meenakshi and Verma (1994) studied the changes in organoleptic quality during ripening of cheese made from cow and soy milk blends. They found that the moisture content increased as the proportion of soy milk was increased in the blends. They also realized that the highest contents of fat and protein were found in green soy cheese made from a blend containing 95% cow milk, and the lowest fat and protein contents were found in a cheese made with a blend having 75% cow milk. So far the researcher has not come across any research that has been done on cheese with tiger nut milk incorporated in to it.

2.4.5.4.5 Classification of Cheese

According to the National Dairy Council (2000) there are over 400 varieties of cheese available and they are grouped in several ways: unripened and ripened, soft and hard, and natural and processed cheeses. Natural cheese may be ripened or unripened. The ripened types are made by coagulating the proteins in milk with rennet and culture acids. After that they are aged by either mould or bacteria. Also, natural cheeses are categorized according to their moisture content, degree of softness or hardness. The processed cheeses are produced from blending one or more cheese (natural type). Then after, it is heated and emulsifying fats are added to it. According to Magnusson (2012), different types of bacteria contribute to the varied smells, tastes and textures. She went on further to say that bacteria helps in the ripening of cheese and helps to develop the required acidity necessary for changing milk into cheese.

Table 6: Federal Standards for the Maximum Moisture and Minimum Milk Fat for Classes of Cheese Designated by Consistency

Consistency	Moisture Maximum Percent	Milk Fat Minimum in Solids Percent
Hard grating	34	32
Hard	39	50
Semi soft	50 (more than 39%)	50
Semisoft part skim	50	45 (less than 50%)
Soft	Not specified	50

United States Code of Federal Regulations, 1998.

2.5 Composition of cheese

The composition of cheese varies among the different types of cheese available. Below is a table showing the composition of some types of cheese products.

Table 7: Composition of some types of cheese

Cheese	Moisture	Fat	Protein	Ash	Ca	Salt
Camembert	50.3	26	19.8	1.2	0.68	2.5
Cheddar	37.5	32.8	24.2	1.9	0.86	1.5
Cottage	79.2	4.3	13.2	0.8	0.12	1.0
Swiss	39.0	28.0	27.0	2.0	0.9	1.2

Sivasankar, B. (2010).

2.5.1 pH

The buffer maximum around pH 5.0 is very important in cheese making because the optimum pH for most cheese ranges from 5.0 - 5.2. As the pH of cheese is reduced towards pH 5.0 by lactic acid fermentation, the buffer capacity is also increasing. The effect is to give the cheese maker substantial room for disparity in the rate and amount of acid production. Without milk's built in buffers it would be difficult to produce cheese in the optimum pH range.

The pH of cheese milk, whey and soft cheese can be measured directly. Firm and hard cheese must be broken down before any analysis is done. It is always better to measure the pH of cheese in duplicate and be extra careful in handling the electrode. The fragmented cheese is placed in a 30 ml small beaker and the electrode is gently pushed gently pushed into the cheese. If the electrode is stored in buffer it should be rinsed with distilled water before measuring another. Always keep the electrode in pH 4 buffer or as instructed by the manufacture. pH of 7 indicates neutral; pH of <7 indicates acidic condition; pH >7 indicates alkaline condition (http://www.uoguelph.ca/foodscience/cheesemaking-technology/section-b-analytical/process-and-quality-control-proceudures/ph).

2.6 Texture

According to Phadungath (2002), texture is quite difficult to define as it means different things to different people. Texture is derived from the word textura in Latin, which means a weave. Texture was formerly used to refer to the structure, feel and appearance of fabrics (Rosenthal, 1999). Food technologist attempted to define texture in terms of food because the meaning of texture did not cover the food aspect (Phadungath, 2002). International

Organization for Standardization (ISO) (1992) defines texture as a sensory characteristic perceived largely by way of the senses of touch and movement. Texture is the primary quality characteristic of cheese products. Texture analysis refers to the mechanical testing of food. Texture of products plays a very important aspect in the preference and acceptance of food products. Texture Profile Analysis (TPA) and penetration test are some types of texture analysis that can be done on cheese products. Instrumental measurement of the textural properties of cheese is frequently used to understand consumers' perception on both cheese quality and the influence of the processing technology on cheese quality (Tudoreanu and Dumitrean, 2009).

Table 8: Textural properties of foods and terms that are used to define these properties.

Mechanical characteristics		
Primary parameters	**Secondary parameters**	**Popular terms**
Hardness		Soft, Firm, Hard
Cohesiveness	Brittleness Chewiness Gumminess	Crumbly, Crunchy, Brittle Tender, Chewy, Tough Short, Mealy, Pasty, Gummy
Viscosity		Thin, Viscous
Adhesiveness		Sticky, Tacky, Gooey
Elasticity		Plastic, Elastic
Geometrical characteristics		

Class	Examples	
Particle size and shape	Gritty, Grainy, Coarse, etc.	
Particle shape and orientation	Fibrous, Cellular, Crystalline, etc.	
Other characteristics		
Primary parameters	**Secondary parameters**	**Popular terms**
Moisture content		Dry, Moist, Wet, Watery
Fat content	Oiliness Greasiness	Oily Greasy

Adapted from Bourne (2002).

Different types of machines have been developed to measure the texture of food products with specific parameters like hardness/firmness, stringiness, springiness, cohesiveness, adhesiveness, chewiness, fracturability and resilience.

According to Bourne (1982), firmness refers to the peak force of the first compression of food products. Fracturability refers to the first significant break in the first compression cycle. Not all food products fracture. A food product that breaks easily has a high fracturability (Bourne, 1982). Cohesiveness is defined as the degree to which a material can be deformed before it breaks (Civille and Szczesniak, 1973). Adhesiveness according to Civille and Szczesniak (1973) is the work required to overcome the attractive forces between the surface of the food and the surface of the other materials with which the food comes into contact.

Springiness is defined as how well a food product physically coils back after it has gone through deformation during the first compression (Bourne, 1982). Resilience according to Bourne (1982) is defined as how well a food product "fights to regain its original position".

2.6.1 Measuring Texture

Due to the complex nature of foods, it is quite difficult to measure the complete texture of food using the machine. However, it is likely to classify the main aspects determining the texture of a material and to measure them. The most common way to measure texture is to apply mechanical deformations to the sample, measure the response, and correlate the response with the sensory evaluation (Phadungath, 2002). Dobraszczyk and Vincent (1999) also identified another way of measuring texture of foods which is to predict the way food constituents respond to mechanical deformations.

2.6.2 Instruments for Measuring Texture

Force measuring instruments are the common instruments used for measuring texture. The standard unit for force is Newton (N) or gram (g). Below are some examples.

2.6.2.1 Puncture Test

This type of test measures forces from penetrating a food sample with a either a probe or a punch. The test is exemplified by a force-measuring device, penetration of the probe into the food sample resulting in irreversible breaking or flowing of the food with the depth of penetration kept constant. All the puncture testing machines are maximum-force instruments, and they may be categorized into single-probe instruments and multi-probe instruments.

They may also be grouped by the way the force is applied; a constant degree of force applied for some instruments such as fruit pressure testers and the Armour Tenderometer, and motorized testing instruments such as the TA.XT2 Texture Analyser and Instron (Phadungath, 2002)

.

2.6.2.1.1 Factors Affecting the Puncture Test

According to Phadungath (2002), the force derived from a puncture test depends on the following factors,

a. Nature of food: a soft product will give lower force.

b. Size and shape of the probe.

c. Depth of penetration.

e. The speed of the probe when testing viscoelastic food.

2.6.2.1.2 Advantages of Using a Puncture Test

According to Phadungath (2002), it is possibly the most frequently used instrumental method for measuring food texture, with several advantages such as the following;

a. Automatically simple and rapidly performed.

b. Easy and can be used in most places.

c. Can quickly distinguish between food samples.

d. Suitable for many diverse kinds of foods with almost any size or shape.

e. Suitable for mixed foods because each component can be tested independently.

f. Can be used to measure distribution of textures within particular foods.

2.6.2.2 Universal Testing Machine (UTM)

These types of machines have been generally used for the past 20 years. They are composed of three significant parts; a drive system, a test cell, and a force measuring and recording system (Phadungath, 2002). An example of the UTM is the TA.XT2 Texture Analyser.

2.6.2.2.1 Advantages of Using the UTMs

Some advantages of The UTMs as identified by Phadungath (2002) are outlined below:

a. the same machine can be used for different kind of tests.

b. the analyzing system gives a complete plotting history of the force, giving all the changes; the maximum force (peaks), the rate of change (slope), area under the curve (work), and other parameters.

2.6.2.3 TA.XT2 Texture Analyser

The standard TA.XT2 Texture Analyzer is a single screw device developed exclusively for work on food products. It has a 250 N force maximum capacity and crosshead speed of 6-6000 mm/min. Stable Micro Systems, and the US distributor, Texture Technologies Corp., have developed an extensive library of food applications for everyday texture measurements (Bourne, 2002).

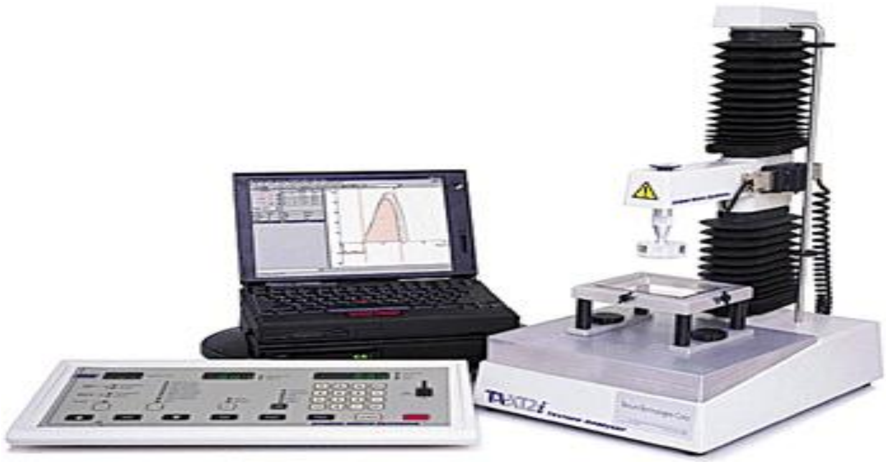

Figure 4: TA.XT2 Texture Analyser. (Source: Texture Technologies Corp, 2003).

Table 9. Some conditions for testing dairy foods using the TA.XT2 Analyser.

Commodity	Test principle	Probe	Crosshead speed (mm/s)	Parameter measured	Property measured
Cheese, cream	Penetration	5 mm diameter cylinder probe	1	Maximum force	Softness
Cheese, cream	Penetration	45° conical probe	1	Maximum force	Softness
Cheese, spread	Penetration/ extrusion	TTC spreadability rig	3	Maximum +ve force and +ve area under curve	Firmness and spreadability
Cheese, spread	Penetration	1 inch spherical probe	2	Maximum +ve force and +ve force	Firmness and stickiness
Cheese, hard	Shearing	Fracture wedge	2	Maximun	Hardness and

cubes		set		force and distance at break	brittleness
Yoghurt	Back extrusion	35 mm diameter extrusion disk	1	Maximum +ve force, +ve area, maximum –ve force and –ve area	Firmness, consistency, and cohesiveness

Adapted from Bourne (2002).

Many studies have been done using the TA.XT2 Texture Analyser to distinguish textural properties of food products especially dairy products. Gutiérrez-Méndez *et al.* (2013) used the TA.XT2 Texture Analyser to measure and compare the textural properties of fresh cheese and Chihuahua cheese using miniature cheese model by the Texture Profile Analysis method. Ferragut *et al*. (2000) used the Texture Analyzer TA.XT2 with a 25-mm diameter cylindrical probe to measure yogurt firmness made from whole ewe's milk treated by high hydrostatic pressure.

2.6.2.4 Texture Profile Analysis (TPA)

The test was first developed by the General Foods Corporation Technical Center to mimic the movements of jaw motion to a bite-size piece of food, resulting in the force-time curves with numbers of textural factors that can correlate with sensory evaluation (Phadungath, 2002). Figure 5 shows the principle of the TPA test. A 'bite-size' food sample with standard shape and size is placed on the base plate and compressed and decompressed twice by the plate attached to the drive system with a high compression to imitate the chewing action of the teeth (Bourne, 2002).

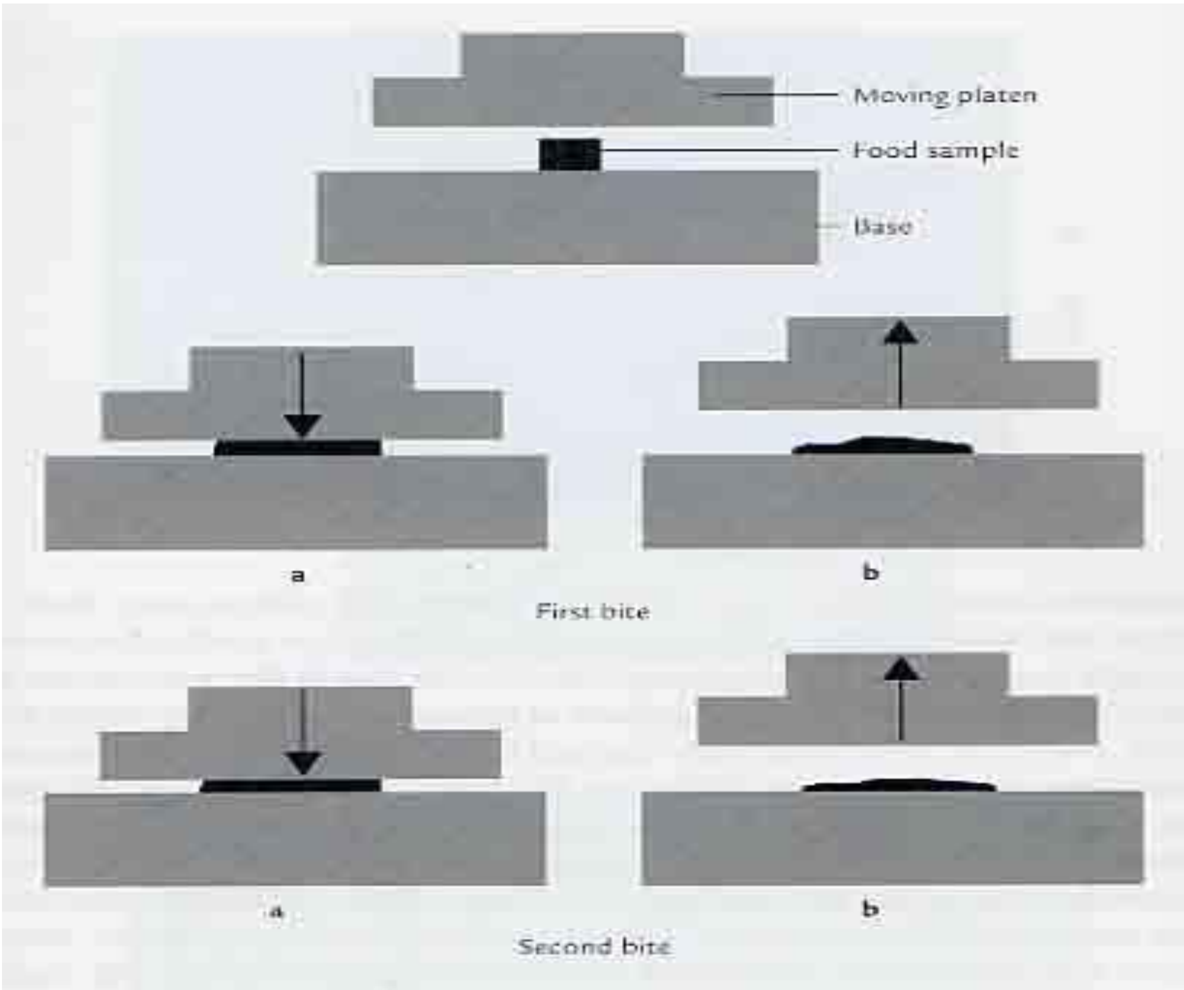

Figure 5: Schematic diagrams of the two compressions required for the TPA test; (a) Down stroke actions during the first and second bites; (b) upstroke actions during the first and second bites. (Source: Bourne, 2002).

The TA.XT2 Texture Analyser, instron, and other universal testing machines have been adapted to use for a modified TPA. Figure 6 shows a typical TPA curve from the TA.XT2.

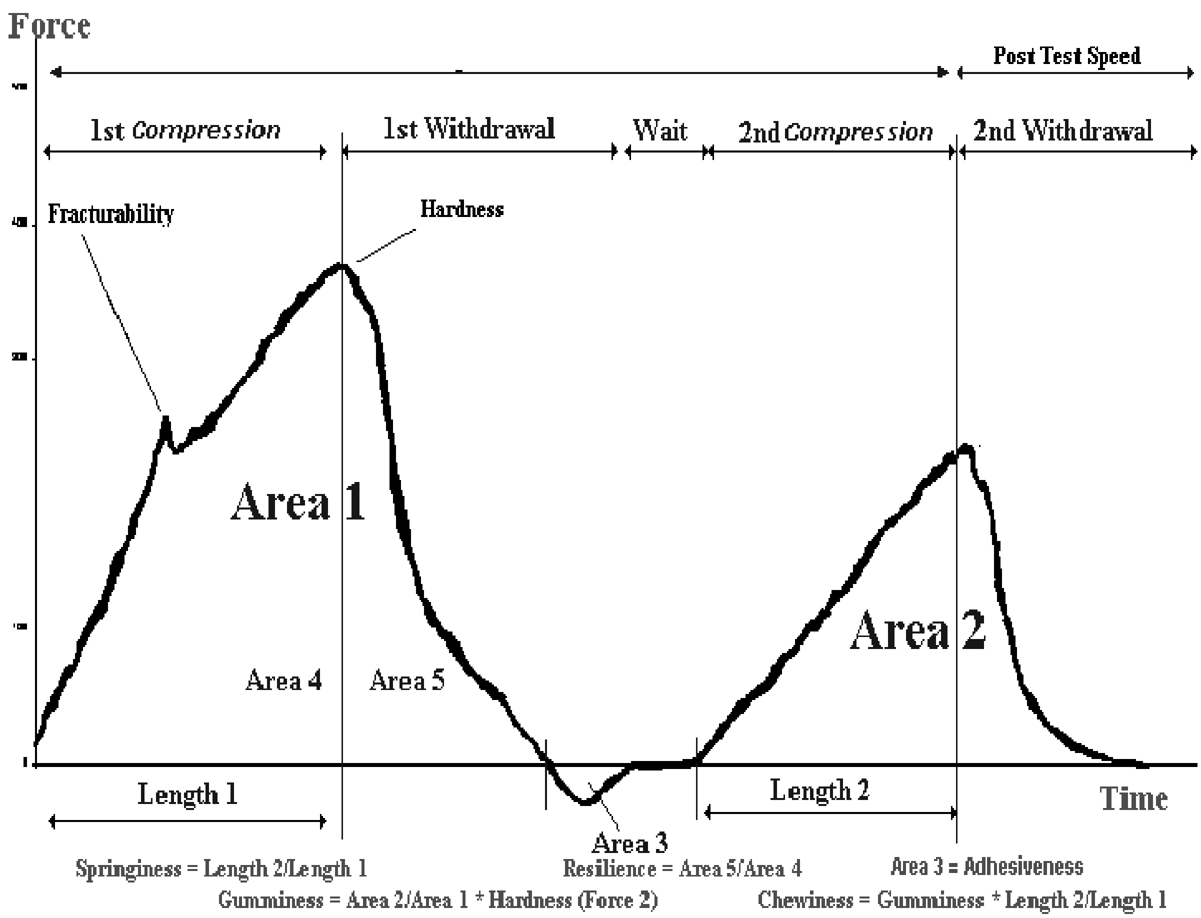

Figure 6: Representation of Texture Profile Analysis Results and Calculation of TPA terms. (Source: Annon, 2009).

Table 10: Practical definitions of standard TPA terms

Standard terms	Definition
Hardness/Firmness	This value is the peak force of the first compression of the product. It does not need to occur at the point of deepest compression, although it typically does for most products.
Fracturability	The fracturability point occurs where the plot has its first significant peak (where the force falls off) during the first compression of the product.
Cohesiveness	Cohesiveness is defined as how well a product can withstand a second deformation relative to how it behaved under the first deformation. It is measured as the area of work during the second compression divided by the area of work during the first compression (Area 1/ Area 2).
Springiness	Springiness is defined as how well a product physically springs back after it has been deformed during the first compression. It is measured at the downstroke of the second compression.
Chewiness	Chewiness only applies for solid products and is calculated as Gumminess × Springiness (Length 1/Length 2)
Gumminess	Gumminess applies only to semi-solid products and is Hardness × Cohesiveness (Area 2/Area 1).
Resilience	Resilience is defined as how well a product "fights to regain its original position". The calculation is the area during the withdrawal of the first compression, divided by the area of the first compression (Area 5/Area 4

Adapted from Texture Technologies Corp (2003).

2.7 Colour measurements in food

Instrumentation to measure colour offers a subjective and consistent method of color quality control, since judgements of visual color can be affected by a wide range of factors, from angle of observation to individual differences in color perception. Color measurement instruments are used to measure a broad variety of food products. These include fresh and processed fruits and vegetables, dairy products, meat products, formulated foods, spices and flavors, cereals and grains, oils, syrups, sugar, and beverages (http://eng.ege.edu.tr/~otles/ColorScience/cmf.htm).

2.7.1 Colour scales

A range of colour scales or schemes are used to define color. Those frequently used in the food industry include the Commission International de l'Eclariage (CIE) system, the Hunter L,a,b system, and the Munsell color solid. The CIE system is the most effective system for the explanation of colour. It is based on using a standard source of illumination and a standard observer. The system obtains CIE standard-observer curves for the visible spectrum for the tristimulus values which are converted to the unreal primaries X, Y, and Z. The HunterLab L*, a*, b* and the modified CIE system called CIELAB colour scales are opponent-type systems commonly used in the food industry. The systems measure the degree of lightness (L), the degree of redness or greenness (+/-a), and the degree of yellowness or blueness (+/-b). The Munsell color-order system is a way of identifying colours and showing the relationships among them. Every colour has three qucharacteristics: hue, value, and chroma. Munsell established numeric scales with visually even steps for each of these attributes. The colour of any surface can be identified by comparing it to the chips under proper illumination and viewing settings. The colour is then identified by its hue, value, and chroma. Spectrophotometers and colorimeters are examples of instruments used to measure colour of food (http://eng.ege.edu.tr/~otles/ColorScience/cmf.htm).

2.7.2 Colorimeters

Tristimulus filter colorimeters are intended to reproduce the "psycho-physical" sensation of the human eye's view of colour. These instruments use sensors that simulate the way the human eye sees colour and measure color differences between a standard and a production sample. While colorimeters have sensitivities consistent to the human eye, they always take measurements using the same light source and illumination method. As a result, the measurement settings will be the same, regardless of whether it's day or night, indoors or outdoors. Colorimeters usually consist of two main parts: the optical sensor, which contains the light source and the micro-processor, which automatically converts the colours to numeric equations (http://eng.ege.edu.tr/~otles/ColorScience/cmf.htm).

Figure 7: CR-400 colorimeter (Konica Minolta, Tokyo, Japan)

2.7.3 Spectrophotometers

Spectrophotometers quantify the ratio of the light reflected or transmitted from a food product to that from a known reference standard. Spectrophotometers are more precise and more costly than colorimeters. Spectrophotometers work best for liquid products and for transmission. The choice of instrument depends on the food material and type of application (http://eng.ege.edu.tr/~otles/ColorScience/cmf.htm).

2.8 Sensory evaluation

One of the most important goals of the food industry it to determine how food products affect the human senses. It is a principal concern for dieticians and nutritionist because consumers can only reap the benefits of healthy food if the senses accept it. As such, consumer reaction as perceived by the five senses (smell, sight, taste, touch and smell) is considered an important measure for food product. Human beings are used as test subjects because no device can be used as a substitute for the senses in evaluating food (Choi, 2012).

Sensory evaluation is a scientific method that evokes, measures, analyzes and interprets responses to food products as perceived by the senses of sight, smell, taste, sound and touch (Stone and Sidel, 2004). This definition is widely accepted and used by sensory evaluation committees within various organisations such as the American Society for Testing and Materials and the Institute of Food Technologists (Lawless and Heymann, 2000). The reliability of sensory evaluation depends on the skill of sensory analyst to optimize four factors: definition of the problem, test design, instrumentation and the interpretation of results (Meiselman, 1993; Pfenninger, 1979).

2.8.1 Human Senses

The physical appearance of food are observed by the five senses, that is sight, smell, taste, sound and touch (Choi, 2012).

2.8.1.2 Sight

The eyes recognize the original quality of food, thereby receiving information such as size, colour, shape, texture, consistency, and opacity. Light going into the lens of the eye is concentrated on the retina, where the cones and rods convert it to neural impulses that travel to the brain through the optic nerve (Meilgaard *et al*., 2007). Colour may precisely designate strength of dilution, ripeness and the degree to which the food has been heated. Colour is used to assess a food's appeal and acceptability. Colour may trigger certain expectations in the mind; for example, the creamy color of vanilla ice cream suggests an expectation of richness. However color can be deceptive. The quality of food can be concealed by variations in color. For instance, if yellow coloring is added to a food product without actually adding fat, the quality of low-fat food products can be upgraded. Colour variations in itself can boost a food's acceptability considerably (Choi, 2012).

2.8.1.3 Smell

According to Choi (2012), the olfactory sense or the sense of smell can also contribute to the evaluation of food products. The instability of odors is associated with temperature. It is quite easier to smell hot foods than cold ones because only volatile molecules, in the form of gas, carry odor. For example, hot tea is much easier to perceive than iced tea, and the odor of a baked products is more powerful than that of ice cream. According to Brown (2008), lighter particles that can become volatile can be perceived by the olfactory epithelium in the nasal cavity through one of two pathways:

a. Directly through the nose

   or

b. After entering the mouth and flowing retro-nasally, or toward the back of the throat and up into the cavities of the nose.

The gradual decrease in the ability to differentiate between odors over time is called adaptation. Adaptation takes place to prevent sensory overload. Dairy farmers who are exposed every day to the smell of fertilizer will slowly become unaware of it, whereas visitors to the farm may be able to detect the smell (Choi, 2012). Humans have fluctuating sensitivities to odors, depending on satiety, mood, appetite, concentration, presence or absence of respiratory infections, and gender (e.g., menstruating or pregnant women may see odors differently) (Maruniak, 1998). Due to the fact that different people perceive odor differently, detecting a new odor from a food product necessitates as large a panel as possible to get effective results (Choi, 2012).

2.8.1.4 Taste

Taste is the most prominent factor in a person’s choice of a particular food. For a food product to be tasted, it should be dissolved in oil, water or saliva. Taste is perceived by the taste buds, which are predominantly on the surface of the tongue, by the mucosa of the palate and in the areas of the throat (Choi, 2012). According to Brown (2008), in the middle of each taste bud is a pore, where saliva gathers. When food enters the mouth, pieces of it are dissolved in the saliva and come into contact with cilia, small hair-like projections, from the gustatory cells. These gustatory cells send a signal to the brain through cranial nerves. The brain then translates the nervous electrical impulses into sensations that people identify as taste.

2.8.1.4.1 Basic components of taste

Four main components of taste have been identified for several years which are sweet, sour, salty and bitter. Recently, a fifth one was added named umami. Elements that produce sweet taste include glycols, sugars, alcohols, aldehydes and alternate sweeteners (Godshall, 1997). The salty taste comes from ionized salts, such as those ions found in sodium chloride (NaCl) or other salts which are found naturally in some foods (Choi, 2012). The sour taste comes from the acids which are present in food. It is associated with the concentration of hydrogen ions (H^+) that are found in the natural acids of some vegetables, fruits and vinegar (Choi, 2012). According to Brown (2008), the bitter taste is imparted by the compounds such as theobromine, phenolic compounds and caffeine. Several bitter substances are alkaloids that are often found in poisonous plants (Choi, 2012). According to Mc Williams (2008), umami was identified from a study of seaweed broth. According to Choi (2012), umami originated from Japan which means “delicious” and is evoked by glutamate compounds, which are usually found in meats, soy sauce, mushrooms, fish sauce, and cheese products. However some taste specialists do not recognize umami as a taste.

2.8.1.4.1.2 Flavour

Flavour is the combined senses of aroma, taste and mouthfeel. Mouthfeel comprises textural and chemical sensations such as heat, spice, cooling, and metallic flavour (Choi, 2014). Among the components, aroma is especially important because it provides about 75% of the impression of flavor (De Roos, 1997).

2.8.1.4.1.3 Sound

Sound is another type of sense that is used in sensory evaluation. Sounds like bubbling, squeaking, popping, sizzling and crunching say a lot about a food (Choi, 2012). Most of these sounds are affected by the amount of water content in them; thus, their characteristics indicate a food’s ripeness and freshness (Brown, 2008). Sound is identified as vibrations in the local medium, commonly air. These vibrations are transmitted via the small bones located in the middle ear to create hydraulic motion in the cochlea. The cochlea is a spiral canal enclosed in cilia that sends neural impulses to the brain when disturbed (Meilgaard *et al*., 2007).

2.8.1.4.1.4 Touch

This sense sends impressions of a food’s texture to us through the skin or oral sensations. The perception of texture is very complex. The first input is visual; second is touch, either directly through the fingers or indirectly via eating utensils; the third is the feeling in the mouth commonly referred to as mouthfeel which is detected by the tactile nerve cells on the tongue and palate and the teeth (Choi, 2012). Texture is the sensory display of the structure or inner makeup of products with regards to their reactions to stress, which are measured as mechanical properties (like adhesiveness, hardness/firmness, cohesiveness, gumminess, resilience and springiness/resilience) by the kinesthetic sense in the muscles of the lips, jaw, hands, fingers or tongue. Texture also comprises tactile feel properties, which are measured as moisture properties (such as moistness, wetness, dryness, oiliness) by the tactile nerves in the surface of the skin of the lips, hands or tongue or geometric properties (such as grainy, gritty, crystalline, flaky) (Meilgaard, 2007).

2.8.2 Variables that are controlled during sensory evaluation

According to Choi (2012), during sensory evaluation, panelists are typically seated at cubicles, tables or booths, and the food product is presented in an even manner. To achieve valid results during sensory evaluation, the environment in which the sensory panels are to evaluate foods or beverages should be cautiously controlled, as should variables affecting the panelists. Below are some variables that should be taken into consideration when planning a sensory evaluation test.

2.8.2.1 Panel management

Two common types of panel are used in sensory evaluation; consumer panel and descriptive panel. A descriptive panel is usually used to identify differences between food samples. Descriptive panelists are experts in the type of food that is being tested and receives extensive training before the testing of the samples. A consumer panel on the otherhand is selected from the public with regards to the demographics necessary to taste test a food product (Choi, 2012).

2.8.2.2 Panel selection

When selecting a panel, it is ideal to use an equal number of men and women. The age distribution of the panel should also be considered as it may affect the test results (Brown, 2008). According to Choi (2012), the sensory analyst must train the people who knows what it required of them and who can make a reliable commitment of their time during the test. He went on further to say that test panels usually comprise of individuals who meet the following criteria:

a. Those who are free of illness related to sensory properties, such as food allergies, chronic colds or diabetes and those in good health.

b. Those who are nonsmokers (smoking can affect olfactory and gustatory sensations).

c. Those that have no strong likes or dislikes for the food(s) being tested.

d. Those that are not colour blind.

2.8.2.3 Panelist Preparation

The level of training for descriptive panels and consumer panels is rather different, due to the differences in the purpose of the evaluations (Choi, 2012).

2.8.2.3.1 Descriptive Panels

Because the investment in a descriptive panel is huge in terms of time and human resources, it is wise to conduct a comprehensive screening process rather than train unqualified panelists (Lawless and Heymann, 2000). If the ability to identify subtle differences is crucial, the sensory analyst may need to screen the sensory acuity of potential panelists on vital properties of the product(s) that will be tested (Choi, 2012). Descriptive panels can be selected through a series of tests that may include asset of acuity tests, a set of prescreening questionnaires, a set of ranking/rating tests, and a personal interview. The amount of training needed is determined by the task and the level of sensory sensitivity desired. For most descriptive panels, costly and in-depth training is necessary (Lawless and Heymann, 2000).

2.8.2.3.2 Consumer panels

Unlike descriptive panels, consumer panels usually require a larger number of panelists and may range from 200 to 500 people. Consumer panelists can be screened on a test criteria; such as demographics or potential use of product. The untrained panelists should be able to answer the questions that are asked (Choi, 2012).

2.8.2.4 Environmental controls

According to Choi (2012), physical and chemical factors that are present at the place of the sensory evaluation must be carefully organized so that any possible effects of the surroundings on the test results are reduced and each panelist experiences the food in the same atmosphere.

2.8.2.4.1 Temperature, humidity, and air circulation

The temperature should be comfortable, and the surroundings should be odor-free and quiet. The relative humidity and temperature for the sensory evaluation area should be 45–55% and 72–75°F (22–24°C) respectively. It is recommended to use replaceable active carbon filters in the ventilation system ducts. A slight positive pressure should be retained in the booth areas to prevent odor contamination (Meilgaard *et al*., 2007).

2.8.2.4.2 Colour and lighting

The lighting and color and in the sensory room should be planned to allow adequate viewing of samples while reducing distractions (Amerine *et al*., 1965; ISO, 1998).The walls of the sensory evaluation room should be off-white; the absence of shades of any color will inhibit unwanted effects on food appearance (Meilgaard *et al*.,2007). Illumination of the booths should be shadow-free, uniform and atleast 300-500 lx at the surfaces of the table (Lawless and Heymann, 2000).

2.8.2.5 Product control

According to Choi (2012), variables relating to the product samples themselves must also be controlled.

2.8.2.5.1 Sample preparation

Food samples must be of the equal sizes and from the same portion of the food. The sensory analyst should decide and control the amount of product(s) to be used in all the tests, including the preparation process, amount of each added ingredient and the minimum and maximum time after preparation that a product can be used or served for sensory testing (holding time). The person in charge of the sensory evaluation should be very cautious to standardize sample preparation techniques and all serving procedures excluding the variable under evaluation. If the appearance of the sample is not the variable under evaluation, then the samples should seem identical. Samples should be labeled with random three-digit codes, and the sample order should be randomized in order to avoid bias due to order of presentation. A reasonable number of samples, say two to four, should be tested at a time to avoid fatigue (Choi, 2012).

2.8.2.5.2 Sample temperature

Samples should be presented at the same temperature, which must be stated in the test protocol. For example, ice cream should be tempered at 5–9°F (–15°C to –13°C) for at least 12 hours before serving (Choi, 2012).

2.8.2.5.3 Presentation

Samples should be presented in containers or on plates that are of the same shape, size and color. Clear or white containers are usually preferred so as not to influence panelists' observations of the food's color. The sensory analyst should choose the container that is most suitable (Choi, 2012).

2.8.2.5.4 Carriers

Carriers refer to materials that form a base or vehicle for the food that is being tested but may generally be considered as any other food that accompanies the one being tested so they are ingested, as well (Lawless and Heymann, 2000). Examples include spaghetti sauce on a spaghetti noodle, cream fillings in pastries, butter on bread, and cheese on crackers. A carrier can mask differences or reduce the panelist's abilities to perceive the difference due to the addition of other changes and flavors to texture and mouthfeel characteristics. However, for a product that is hardly consumed alone and practically always involves a carrier, a situation where the carrier is not provided may affect test results, especially in consumer testing (Lawless and Heymann, 2000).

2.8.2.5.5 Palate cleansers

Room temperature water or plain bread is provided for panelists to eat between samples to prevent carryover tastes. A rest period of at least 30 seconds is arranged between samples. Napkins or tissue papers are provided and because swallowing the food or beverage influences the taste of subsequent samples, small containers are provided into which samples may be spit into (Choi, 2012).

2.8.3 Common types of scales used in sensory evaluation

2.8.3.1 Category Scales

Category scaling could be the oldest method of scaling which involves the choice of discrete response alternatives to suggest increasing sensation intensity in terms of degrees of liking and/or preference. The most common category scale used in sensory testing is the hedonic scale, which measures the degree of like or dislike for the sensory characteristics of food (Choi, 2012).

2.8.3.2 Line scales

Line scales may also be referred to as graphic ratings or visual analog scale. With line scale, the participant's response is recorded as the distance of the mark from one end of the scale, usually considered "lower". This type of scale differs from category scaling in the sense that the person's choices seem more continuous and less limited (Choi, 2012).

2.8.3.3 Magnitude estimation scales

Magnitude estimation scaling is a common technique in psychophysical studies. In this procedure, panelists are instructed to allot numbers to their sensations in proportion to how strong each sensation feels. In the analysis, the ratios among the numbers are supposed to reflect the ratios of sensation magnitudes that have been experienced. For example, if sample A is given the value of 15 for sweetness intensity and sample B seems three times as sweet, then B is given a magnitude of 45 (Choi, 2012).

2.8.4 Types of sensory evaluation

Sensory tests may be grouped into analytical or affective. Analytical tests are based on noticeable differences, whereas affective tests are centered on individual acceptability or preferences. Analytical tests are divided into two types of tests: difference (discriminative test) and descriptive. Affective tests are divided into two categories, depending on the key task of the test: acceptance or preference. The principal task of an acceptance test is "rating," whereas the main task of a preference task is "choice" (Meilgaard *et al*., 2007).

2.8.4.1 Analytical difference tests

The aim of a difference test is to test whether there are differences in the samples. Difference tests can be used to test the sensitivity of judges and also to perform a practical function. There are two main types of difference tests; attribute difference tests and overall difference tests (Choi, 2012).

2.8.4.2 Overall difference tests

These are the simplest types of sensory evaluation tests and they include triangle and duo-trio test. In a triangle test, three number coded samples are provided at the same time and the panelist is asked to indicate the odd one. Twenty to forty participants who are familiar with the test procedure and those who have already been screened for acuity are used. However, if the differences are large and easy to recognize, then as few as 12 panelists may be used. The duo-trio test is another test of overall difference. In this test, the reference sample is presented first and then followed by two other samples, one of which is the same as the reference. The panelists are entreated to identify which of the latter two samples is the same as or different from the reference sample (Choi, 2012).

2.8.4.3 Attribute difference tests

Attribute difference tests focus on a single sensory attribute such as bitterness or moistness. Attribute tests are usually administered to assess qualitative differences in taste, color, and texture. Examples of this type of test are paired comparison test and rating difference test.

The paired comparison test is a test of difference in which a particular characteristic is designated. The panelist is asked to test the two samples provided to detect the sample with the greater amount of the characteristic being measured. The rating difference test among multiple samples is used when a rating scale is applied (Choi, 2012).

2.8.4.4 Analytical descriptive tests

Descriptive tests enable researchers to describe their products through selective, critical scoring of specific characteristics of each product. The descriptive techniques are normally used for developing new products and for quality assurance. Descriptive tests require a well-trained panel and tend to be expensive (Choi, 2012). Descriptive tests should never be used with consumers because data and consistent are an integral part of descriptive test (Lawless and Heymann, 2000). Other types of this type of test are flavor profile analysis, texture profile analysis and quantitative descriptive analysis (Choi, 2012).

2.8.4.5 Affective tests

According to Choi (2012), for food products to be successful in the marketplace, consumers must prefer it over other food products. Therefore, consumer panels are usually used to indicate preference of one sample over another. The panelist rates his or her favourites for one of the samples on a particular quality on the score sheet. Hedonic rating scales can be used to quantity the amount of pleasure experienced with each sample. Acceptance tests involve rating the difference in acceptance between two samples. The question of importance for the preference test is, "Which sample do you prefer. The 5-point hedonic scale or the 9-point hedonic scale can be used to both acceptance and preference test.

For the 5-point hedonic scale; 1-like very much, 2-like moderately, 3- neutral, 4-dislike moderately, 5-dislike very much.

For the 9-point hedonic scale; 1-like extremely, 2-like very much, 3-like moderately, 4-like slightly, 5-neither like nor dislike, 6-dislike slightly, 7-dislike moderately, 8- dislike very much, 9-dislike extremely.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The ingredients that were used are

1. Tiger nuts (Fante type).

2. Soya beans (Nakpanduri type).

3. Citric acid: This is used to acidify the milk.

4. Rennet tablet: This was used to coagulate milk into cheese.

5. Milk powder (Nido).

3.2 Methods

3.2.1 Procedure for preparation of tiger nut milk

Fresh tiger nuts were purchased from the market and the bad nuts and other foreign materials were picked out from it. The tiger nuts was then washed and soaked in water overnight. Soaking of the tiger nuts in water helps to soften it so that it can be blended with ease. Water (500 ml) was added to 283 g of tiger nuts and blended in a blender for about 4 minutes. This was repeated three times to obtain the required amount of tiger nut milk. The blended tiger nut was then filtered to separate the filtrate from the mash. The filtrate was then stored in a container at the Family and Consumer Sciences foods laboratory at room temperature and used within 30 minutes.

3.2.2 Procedure for preparation of soy milk

Soy beans were purchased from the market and the foreign and bad seeds were removed. It was then roasted for about 3 minutes to get rid of the beany aroma (smell), washed and soaked overnight in a lot of water to cover the beans. Then the soy beans were dehulled and 500 mls of water was added to 283g of soya beans and blended for about 4 minutes to get a fine filtrate. This was done several times to achieve the required amount of the soy milk.

3.2.3 Procedure for preparation of cheese

The procedure for the preparation of the cheese is as follows: Rennet tablet (1/16 tablet) was dissolved into 1/16 cup of water. It was stirred and set aside. A quarter of 1½ teaspoons of citric acid was mixed into 1 cup of cool water until dissolved and then set aside. One litre of milk (cow milk and/or tiger nut milk and/or soy milk) was poured into a pot and both the citric acid and rennet solution was poured into it and stirred vigorously. The milk was heated to 110 ^{0}F (43.3 ^{0}C) while stirring. After about 10 minutes, the curds were completely formed and the pot was taken off the fire. It was then drained with a cheese cloth with a weight on it and left to drain further in the fridge.

Table 11: Proportions of Ingredients Used (Tiger Nut Milk, Soy Milk, Milk Powder and Water)

Formulation	Tiger Nut Milk (ml)	Soy Milk (ml)	Milk Powder (g)	Water (ml)
1	0	0	130	900
2	100	0	130	800
3	200	0	130	700
4	400	0	130	500
5	0	50	130	850
6	100	50	130	750
7	200	50	130	650
8	400	50	130	450
9	0	100	130	800
10	100	100	130	700
11	200	100	130	600
12	400	100	130	400
13	0	200	130	700
14	100	200	130	600
15	200	200	130	500
16	400	200	130	300

Rennet tablet (¼) was used to coagulate four samples, thus 1 rennet tablet was used to coagulate all 16 samples. Citric acid 1½ teaspoon was used for making four cheese samples, thus 6 teaspoons of citric acid was used in making all 16 cheese samples

Table 12: Sixteen Formulations of Cheese showing the proportions of Tiger Nut Milk and Soy Milk Used.

Amount of Tiger Nut Added (ml)	Amount of Soy Added (ml)			
	0	**50**	**100**	**200**
0	1	5	9	13
100	2	6	10	14
200	3	7	11	15
400	4	8	12	16

3.3 Data Collection

Data were collected on colour, texture, microbiological activity, physico-chemical and the sensory properties of the cheese products. The procedure for each process is described below.

3.3.1 Physical Methods

3.3.1.1 Colour

The colour of the cheese was determined using a CR-400 colorimeter (Konica Minolta, Tokyo, Japan). The L* color measurements were determined according to the CIELAB color space (CIE 1976) with reference to D65 (natural daylight, the color warmth of 6500K) and observation angle 10°. L* refers to lightness or whiteness, L* = 0 for black and L* = 100 for white color). Color measurements were made 3 times, 1 on the middle and 2 on different parts of cheese surface after removing a 0.5 cm layer of upper surface and the results represented as mean ± standard deviation.

3.3.1.2 Texture Evaluation

Texture properties of the cheese samples were determined by a Texture Analyzer TA-XT2 (Stable Micro Systems Ltd., Surrey, UK). The cheeses were carefully cut into pieces (15 x 15 mm) with a cheese slicer. At least ten measurements were performed on each cheese. TPA parameters (firmness, adhesiveness, springiness and fracturability) was measured by the software at 80 % compression with pre-test speed 1.0 mm/sec, test speed 0.5 mm/sec, post-test speed 0.5 mm/sec, crosshead speed before analysis 0.5mm/s and contact force of 3.0g. The cheese was cut into cubes with a weight of 40g, width of 4.5cm and a height of 1.5 cm. Cheeses were penetrated to 80% of their original height with a constant speed penetration of 2.0 mm/ sec. The analysis was carried out on 3 different locates of the cheese products. Samples were allowed to equilibrate (25°C) at room temperature before texture measurements were taken.

3.3.2 Chemical Methods

3.3.2.1 Microbiological Analysis

Microbiological analysis was done on the cheese samples to give an indication of the microbial load.10 g of the each of the cheese samples was homogenized in 9ml peptone water (Oxoid, Basingstoke, UK) for 1 min in an electromechanical homogenizer (Stomacher, Lab-blender 300, Seward Medical, London, UK). Serial dilutions ($10^{-1}$and 10^{-1}) of the peptone water were prepared for plating. Plate Count Agar (PCA) was used for the enumeration of total plate count. Plates were incubated at 37°C for 24 h. Yeast Extract Agar (YEA) was used for yeast and mould enumeration. Plates were incubated at 25°C for 48 hours, according to Marshall (1992). Violet Red Bile Agar was used for the enumeration of coliforms. Plates were incubated at 37°C for 24 h, according to Marshall (1992).

3.3.2.2 Proximate Analysis

Proximate analysis was carried out on 100% milk cheese as well as the cheese blends from tiger nut milk and soya milk. All analyses were done in triplicate and the results reported as mean ± standard deviation. Moisture contents and crude fat contents were determined according to the Official Methods of Analysis (AOAC, 1990) for food, crude protein contents were determined according to the macrokheldhal method (AOAC, 1990). The pH of the cheese products was also determined.

3.3.2.2.1 Moisture

The Air Oven method was used (Osborne and Voogt, 1978). The procedure is as follows:

The oven was cleaned, dried and labelled for identification. Moisture cans were conditioned to 105 °C for 30 minutes. After that the cans were cooled in the desiccator, weighed and the weight recorded. Two grams of each sample was weighed in the moisture can and the new weight was recorded. After weighing, the moisture cans containing the cheese product, were put into the oven at 105 °C overnight with the covers slightly opened. After an overnight the moisture cans were cooled and weighed.

3.3.2.2.2 Crude Fat

Two grams of each of the cheese samples was weighed into an extraction thimble and covered with cotton wool. The thimbles were placed into extraction tubes. Clean dried soxhlet flasks with fat free boiling chips were weighed. The flasks were filled to about two-thirds of the flasks with petroleum ether (B.P 40 – 60 °C). The extractors were assembled on the rack, the heater and condenser water was turned on, checked for water leaks. The extractors were refluxed for about 3 hours. The extractors were disconnected, thimbles lifted up to the top of the tube with tongs and clips to the side for draining. The thimbles were then removed, apparatus disconnected and distillation was continued using siphon to reclaim the ether. The flasks were removed to steam bath for evaporation of final few millilitres of ether. The flasks were dried in an oven at 60°C overnight. After that they were cooled in a desiccator and weighed.

3.3.2.2.3 Crude Protein

A. Digestion

Two grams of each sample was weighed and put on filter paper and pre-folded into an envelope. They were then placed into kjeldahl flasks. Similar pieces of filter papers were used as blank. Three to four boiling chips and 10 g of chiball, Reese and Williams reaction mixtures (0.1g SeO_2 + 0.25g $CuSO_4$ + 9.65g K_2SO_4) were added to the flasks and shaken carefully. Concentrated H_2SO_4 was added carefully into down sides of the flasks. The flasks were assembled for digestion, heated and turned on and the reaction was observed until first frosting ceases, heater was turned off to eliminate bumping or excessive frothing. Digestion was continued for 30 minutes after digest became clear, flask were rotated to 180°C every 10 minutes. Then flasks were allowed to cool. The solution was poured into a 100ml volumetric flak and topped up with distill water to the 100^{th} mark.

B. Distillation

One hundred ml of 2% boric acid solution and a few drops mixed indicator (0.06 bromocresol green, 0.04g methyl red in 100ml ethyl alcohol) was placed in graduated 500ml Erlenmeyer flask. The collection portion of apparatus was assembled and water was turned on to the condenser. One hundred ml of distilled water was added to digestion flask and shaken to dissolve any precipitate. Eighty ml of 50% sodium hydroxide (NaOH) solution was carefully added while holding the flask in a slanted position. The NaOH solution is required to neutralize sulphuric acid (H_2SO_4) with 13ml excess to ensure alkaline conditions. A pinch of zinc dust without and flasks were added to connecting bulb. The flasks were shaken gently but thoroughly. The metallic zinc acts as an anti-bumping agent. The heater was turned on and distilled until over 150ml distillate was collected into the boric acid. The delivery tube was disconnected, leaving the Erlenmeyer flask with distill water. The tube was rinsed into Erlenmeyer flask with distilled water.

C. Titration

The distillate was titrated with 0.1N H_2SO_4 to faint pink end point. The percentage Nitrogen was calculated and converted to crude protein using the conversion factor 6.25.

3.3.2.2.4 pH

A pH meter was used to determine the pH values of the cheese samples. 10 g of the cheese samples was put into 50 ml volumetric flask and heated on a water bath for 5 minutes with constant stirring to prevent the cheese from burning. After melting the cheese, they were put into a bowl and the probe attached to the pH meter was inserted into the flask and the pH reading were taken.

3.3.3 Sensory Evaluation

An acceptance test was carried out at the Family and Consumer Sciences foods laboratory using a 40-member untrained panel to establish sensory properties (aroma, flavor, texture, appearance, taste and overall acceptability) of the cheese product using a 9 point hedonic scale. Samples were served in plastic containers and coded with three-digit random numbers. Cheese samples were held for at least 1 hour at 20 °C to equilibrate. Crackers were provided to serve as palate cleansers between tasting. Samples of each of the six (6) products were displayed in a randomized order on separate tables in a room. Panelists were asked to score the sensory properties using the 9 point hedonic scale below:

1. Dislike extremely
2. Dislike very much
3. Dislike moderately
4. Dislike slightly
5. Neither like nor dislike
6. Like slightly
7. Like moderately
8. Like very much
9. Like extremely

3.4 Data Analysis and Presentation

Data from the physico-chemical analysis was analysed with the statistical package Minitab version 14. A one-way anova was used to analyse data from the sensory evaluation. Data was presented using charts and tables where necessary.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Microbiological Counts of Cheese Products

Table 13: Aerobic Plate Count-Total viable count

Formulation	Count(s) (cfu/g)
1 (No Tiger Nut, No Soy)	3.5×10^1
4 (400 ml Tiger Nut, 0 ml Soy)	4.5×10^1
13 (0 ml Tiger Nut, 200 ml Soy)	3.7×10^1
16 (400 ml Tiger Nut, 200 ml Soy)	5.7×10^1

Aerobic plate count is used as an indicator of bacterial populations in a food sample. The population of bacteria in the samples ranged from 3.5×10^1 to 5.7×10^1. This concentration is less than the Ghana Standards Authority (GSA) aerobic plate count limits of less than 1.0×10^6 cfu/g (Table 16), thus the cheese samples were suitable for human consumption.

Table 14: Yeast and Moulds counts

Sample code	Count(s) (cfu/g)
1 (No Tiger Nut, No Soy)	3.5×10^1
4 (400 ml Tiger Nut, 0 ml Soy)	4.5×10^1
13 (0 ml Tiger Nut, 200 ml Soy)	3.7×10^1
16 (400 ml Tiger Nut, 200 ml Soy)	5.2×10^1

The yeast and moulds counts for the samples did not exceed the GSB microbiological counts of less than 1.0×10^4 cfu/g (Table 16) indicating that they were safe to consume.

Table 15: Coliform counts

Formulation	Count(s) (cfu/g)
1 (No Tiger Nut, No Soy)	0
4 (400 ml Tiger Nut, 0 ml Soy)	0
13 (0 ml Tiger Nut, 200 ml Soy)	0
16 (400 ml Tiger Nut, 200 ml Soy)	0

No coliforms were detected in the samples, which is in accordance with the GSA microbiological standards (Table 16). This indicates that the cheese samples were within acceptable limit hence safe for consumption.

Table 16: Ghana Standards Authority Microbiological Standards for Food Samples (GSA, 1998)

Microorganism	Maximum Counts Allowed in Food (cfu/g)
Total Viable Count	$< 1.0 \times 10^6$
Yeast and Moulds	$< 1.0 \times 10^4$
Coliforms	0.0

4.2 Results of Texture Analysis

Two parameters (firmness and fracturability) were measured for the cheese products. Firmness is defined as the peak force of the first compression cycle. Figures 8 and 9 show results for the penetration test performed on the cheeses. The firmness values ranged from 60.64N to 136.26N and were significantly different from each other ($p < 0.05$). Control cheeses were firmer (110.35N) than tiger nut cheeses but not as high as soy cheeses. Firmness values decreased from the values obtained for the control cheeses (cheese from milk alone) as tiger nut milk was increased in the cheese formulation but as more soy milk was added to the cheese formulation, the cheeses became firmer. However, the values dropped with increases in tiger nut milk in the soy and liquid milk. This means that soy milk makes very firm cheese. This finding is similar to what was reported by Rinaldoni *et al.*, (2013). They found out that firmness increased as more soy protein concentrate was added to milk used in making cheese. Tiger nut milk on the other hand made very soft cheese.

Fracturability is defined as the first significant break in the first compression cycle. The fracturability values were significantly different ($p < 0.05$) ranging from 65.25N to76.24N, with soy cheeses being the highest, followed by the control and then tiger nut cheese. The tiger nut cheese values dropped from 71.68N (Formulation 1 = control) to 65.23N but increased as more soy milk was incorporated into the liquid milk. It implies that soy milk makes very brittle cheese products whiles tiger nut milk makes very smooth cheese products.

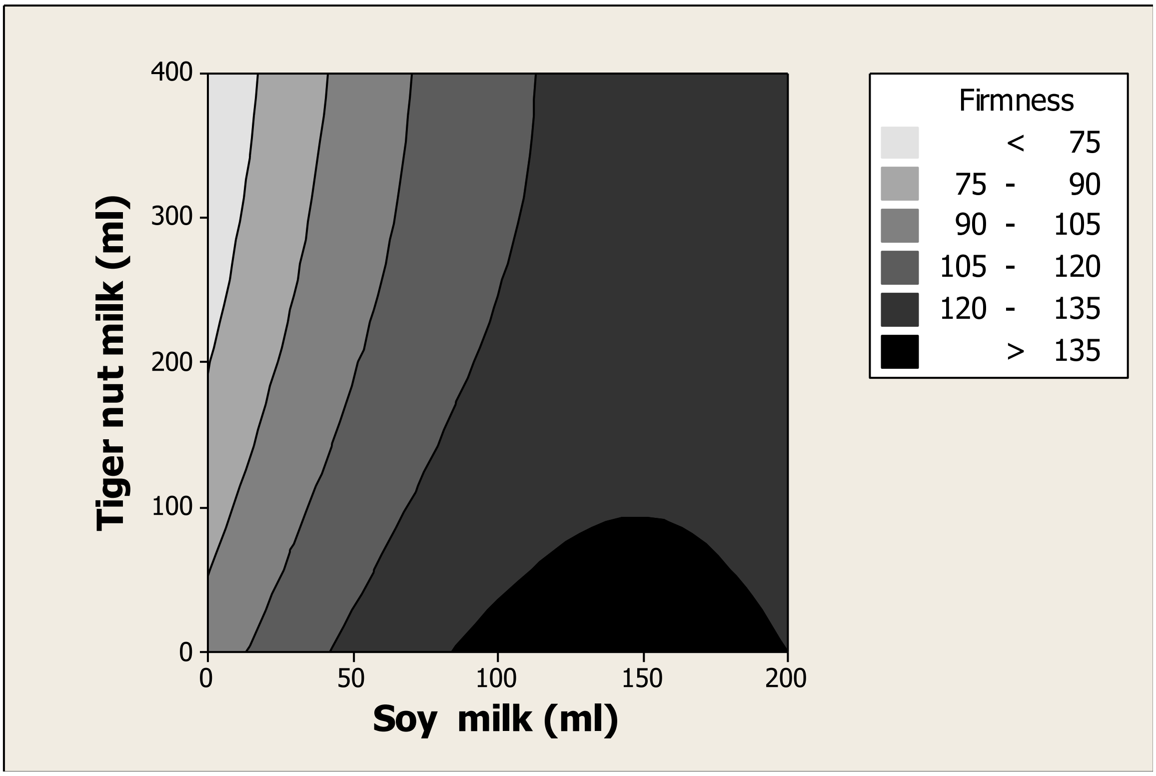

Figure 8: Contour plot showing the effect of tiger nut milk and soy milk on the firmness of cheese products.

The firmness of the cheese products ranged from 60.64N to 136.26N and was statistically significant ($p < 0.05$). As tiger nut milk was added to the raw milk, the texture of the cheese products became less firm as opposed to the soy cheeses which became more firm as soy milk was added to the liquid milk. However, the cheese gradually increased in firmness as soy milk was added to the tiger nut milk. This means that soy milk makes firmer cheese than tiger nut milk. This is largely due to the fat, protein and moisture contents of the products. An increase in moisture content as well as increase in fat content results in a softer cheese and an increase in protein content results in a firmer cheese. Tiger nut cheeses were softer because of they had high amounts of fat and moisture contents and the soy cheeses were firmer because they had higher amounts of protein content. This opposed what Rinaldoni *et al*. (2013) found out that firmness of soy cheeses increased with decreasing concentrations of soy protein concentrates.

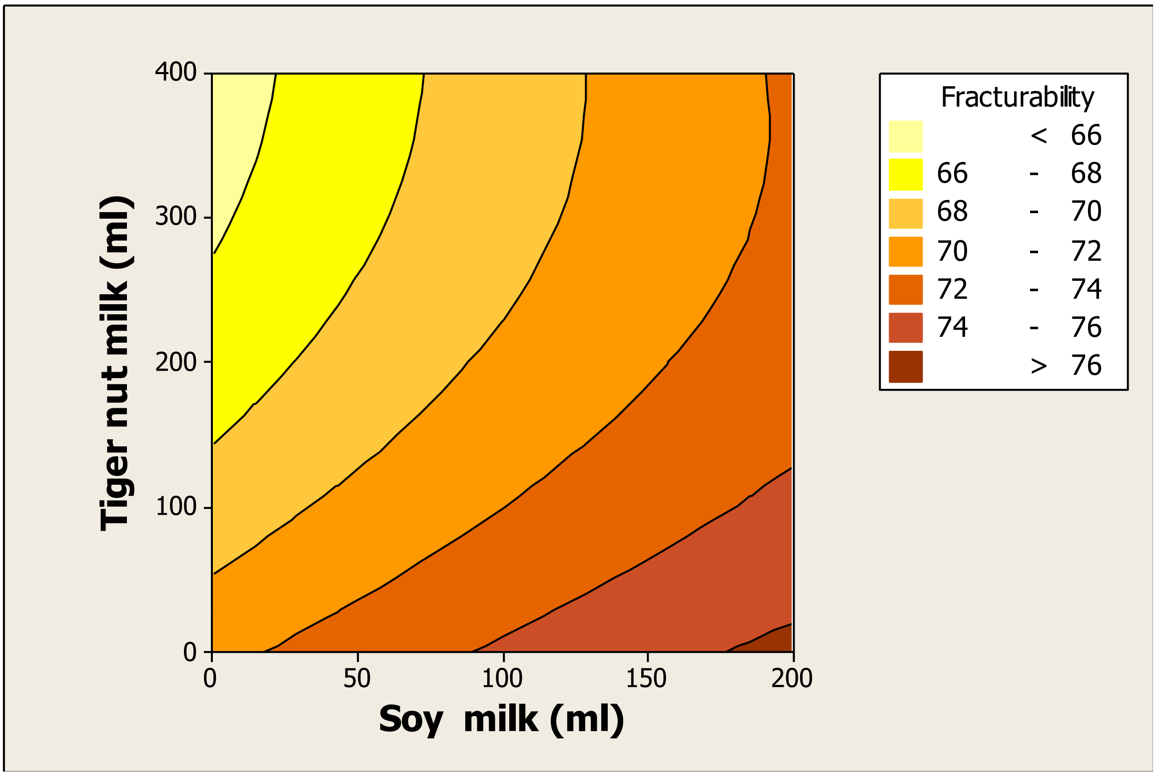

Figure 9: Contour plot showing the effect of tiger nut milk and soy milk on the fracturability of cheese products.

The fracturability of the cheese products were significant (p< 0.05). The values ranged from 65.25N to 76.24N. As tiger nut milk was increased in the raw milk, the cheeses became less brittle (the tendency to break was low) but on the other hand, an increase of soy milk in the liquid milk resulted in a more brittle (the tendency to break was high). However, there were significant increases in fracturability as more soy milk was added to the tiger nut milk making it more brittle. This implies that tiger nut milk makes less brittle cheeses unlike soy milk which makes cheeses that fractures easily. This result is in line with what Chumchuere *et al*. (2000) found out with respect to soy cheeses. They had high values for fracturability when they developed semi-hard cheese from soy milk.

4.3 Colour Readings

The colour readings ranged between 72.88 and 81.02 (Figure 10) with the control cheese (100% liquid milk) having the lightest colour (81.02). Both tiger nut cheeses and soy cheeses became darker with increasing concentrations of tiger nut milk and soy milk respectively. Rinaldoni *et al.* (2013) also reported similar increases as the colour of the soy cheese became darker with increasing concentrations of soy protein concentrates.

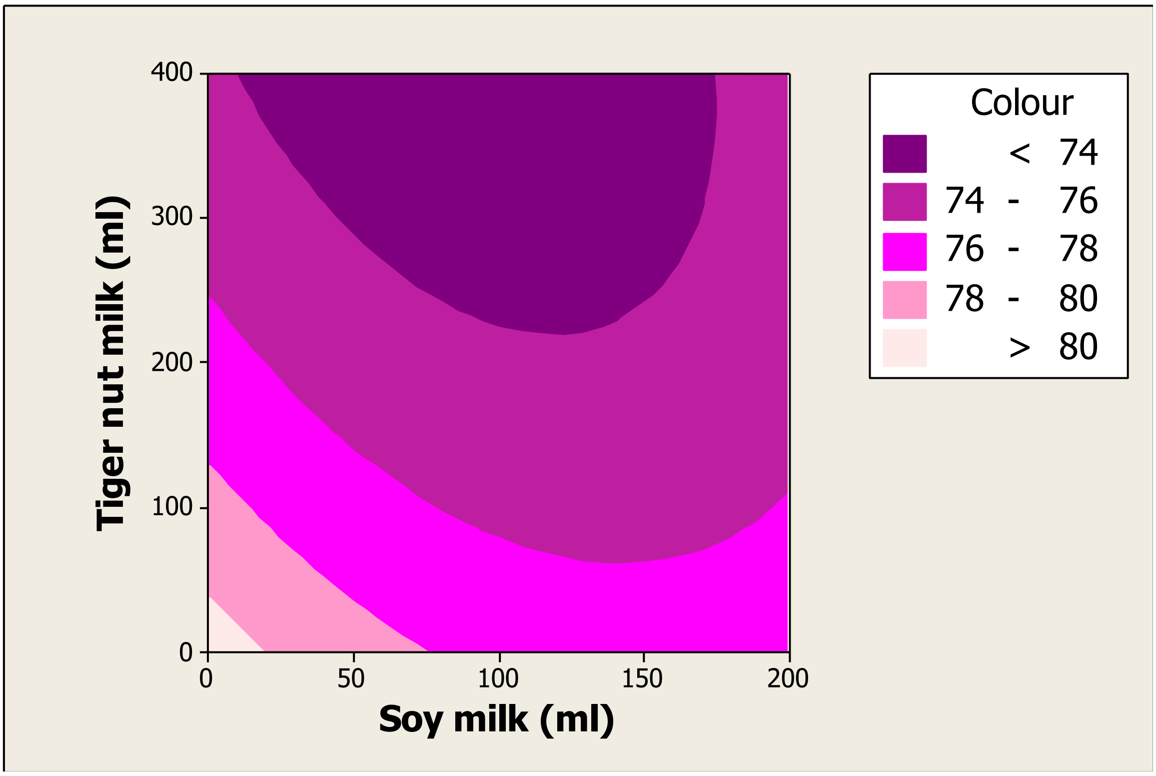

Figure 10: Contour plot showing the effect of tiger nut milk and milk on the colour of cheese products.

4.4 Results of the proximate analysis of cheese products

4.4.1 pH values of cheese products.

The pH of the samples ranged from 5.23 to 5.75 with the control cheese having a pH of 5.23 (Figure 11). The pH increased with increasing tiger nut milk in the liquid milk as well as increase in soy milk. Even though there were increases in pH as both tiger nut milk and soy milk were added in the liquid milk, there were significant increases in the pH of the tiger nut cheeses whereas those of the soy milk cheeses remained in the 5.23 zone for some time. Thus incorporating tiger nut milk into cheese making would increase the pH more than when soy milk is incorporated into cheese making. This confirms the findings of Udeozor (2012) who found that the pH of tiger nut was higher than that of soy milk. This means that cheese products developed from tiger nut milk will be more acceptable to people with ulcers and other related problems.

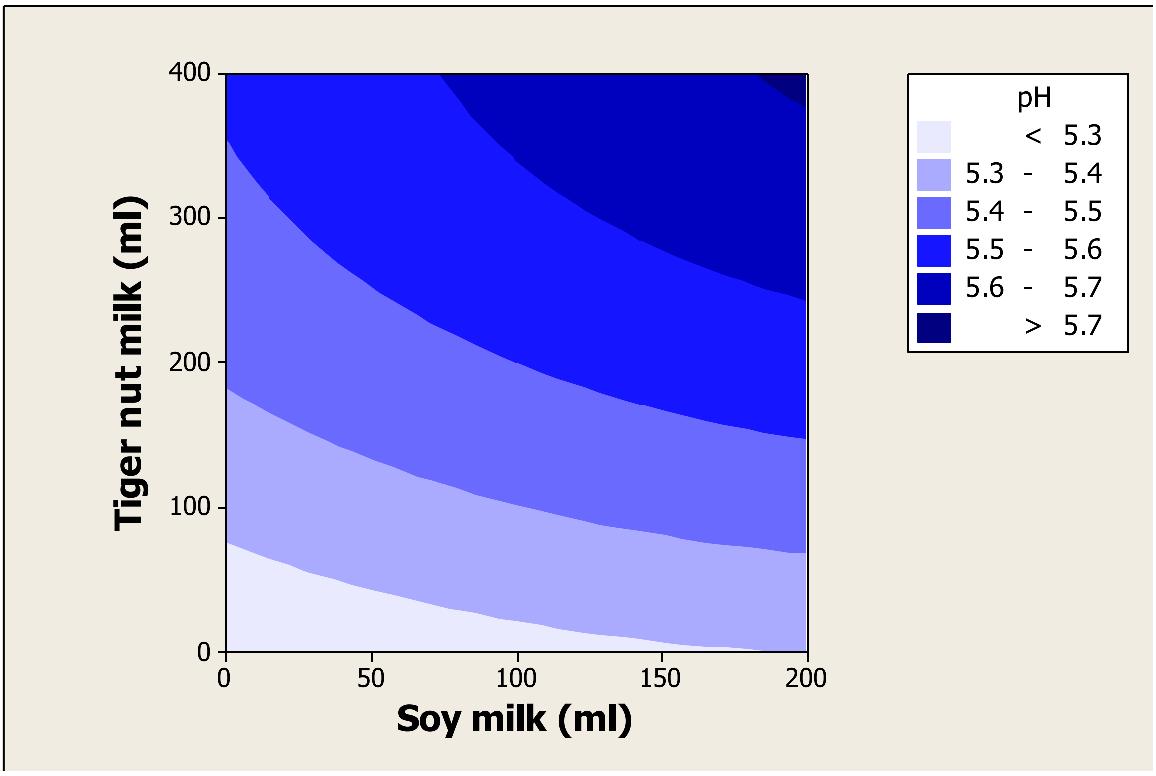

Figure 11: Contour plot showing the effect of tiger nut milk and soy milk on the pH of cheese products

4.4.2 Moisture content of the cheese products.

The moisture contents of the cheese samples ranged from 55.40% to 72.36% (Figure 12) with the control having the least moisture level (55.40%). This qualifies the cheeses as ranging from semi- soft to soft as specified by the United States Code of Federal

Regulations (1998). The moisture values increased as more tiger nut milk and soy were added to cow milk. Cheese products with tiger nut milk and soy milk blends had the highest moisture values because each of the ingredients had increasing concentrations of moisture values. The high moisture values of soy cheeses could be due to the hydrophilic nature of soy proteins (Noyes, 1969). This could affect the safety and stability of the cheese products as such it is recommended to be stored in the refridgerator and not for a very long time. The products can be stored in the refridgerator for up to 1 week after which they become unwholesome.

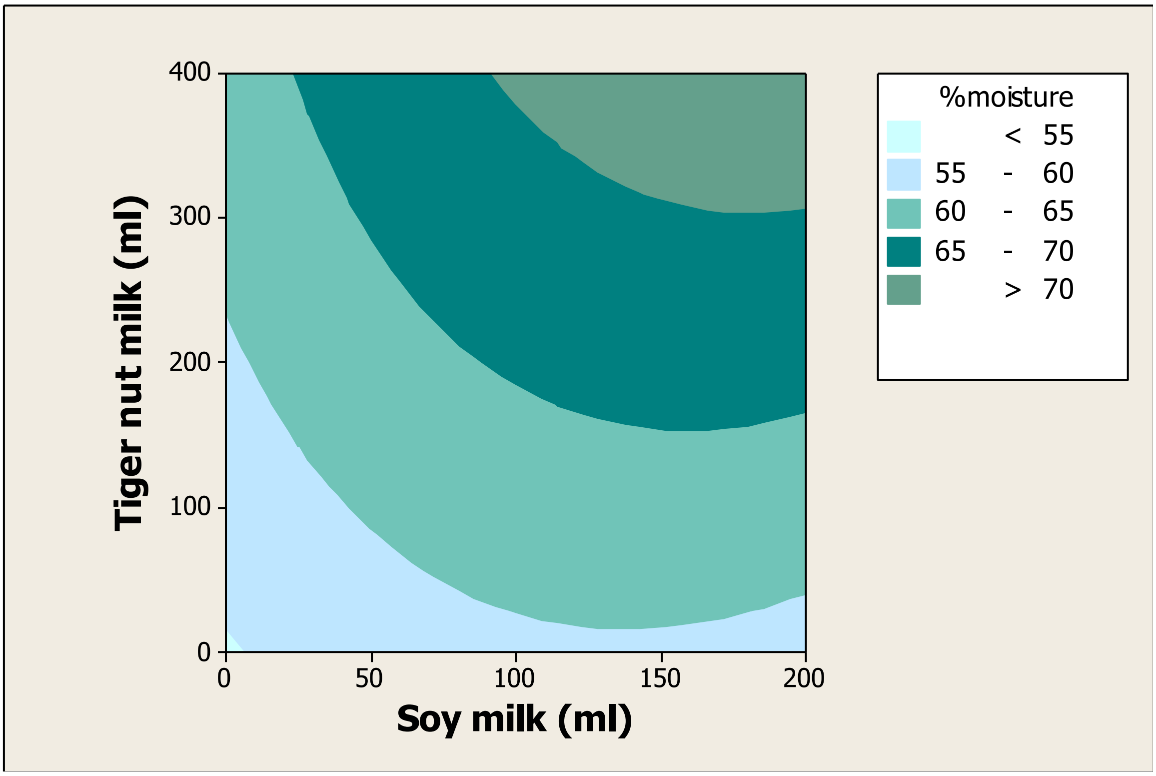

Figure 12: Contour plot showing the effect of tiger nut milk and soy milk on the moisture content of cheese products.

4.4.3 Protein content of the cheese products.

The protein contents varied among the samples, ranging from 12.24% to 14.24% (Figure 13). The control cheese was high in protein (12.24%) but again increased as more tiger nut milk was added. There were increases for all soy cheeses. Cheese products prepared from tiger nut and cow milk had the least amounts of protein in them and samples made from the three blends had the highest. As more soy milk was added to the milk, the protein content improved and this could be due to the high content of protein in soy milk. Even though protein values for tiger nut cheeses were not as high as those from soy milk, there were slight increases as more tiger nut milk were added to cow milk. The higher values of protein will be very good for children because it will help in building and maintaining their tissues and bones. Emmanuel-Ikpeme *et al*. (2012) reported progressive increase in the protein value with increase in soybean addition when they developed weaning food for infants using tiger nut flour and soy flour.

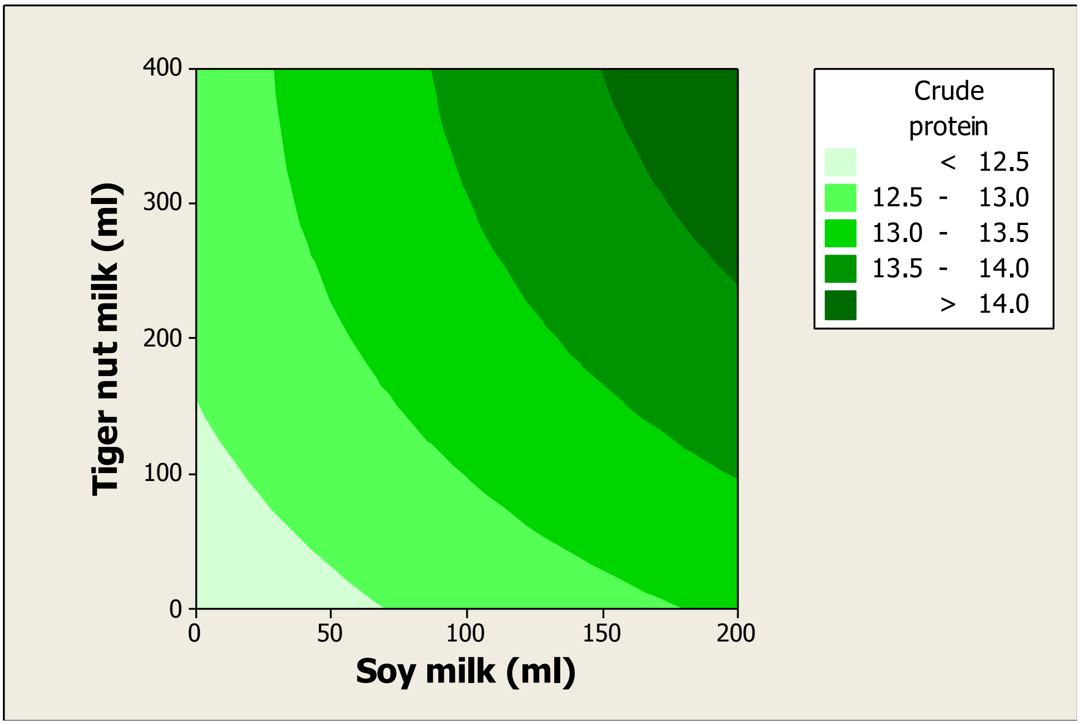

Figure 13: Contour plot showing the effect of tiger nut milk and soy milk on the protein content of cheese products.

4.4.4 Fat content of the cheese products

The fat contents of the cheese samples ranged from 11.00% to 14.51% with the control having the lowest value of fat, followed by soy cheeses and then tiger nut cheeses (Figure 14). Cheeses made from the three composites had the highest fat content and those from soy milk and cow milk had the least amount of fat. Cheeses made from tiger nut milk and cow milk were high but not as high as those from the three composites. This is because tiger nut milk is very high in fat (26.18%) and soy milk has very low levels (4.30%) as reported by Belewu and Belewu (2007). Fat contents increased as more tiger nut milk was added to soy milk and liquid milk. These products can be referred to as functional foods because some of their fat and protein are of vegetable sources. Moon *et al*., (2011) also identified the fat and protein in the soft cheese-like products they developed as being functional.

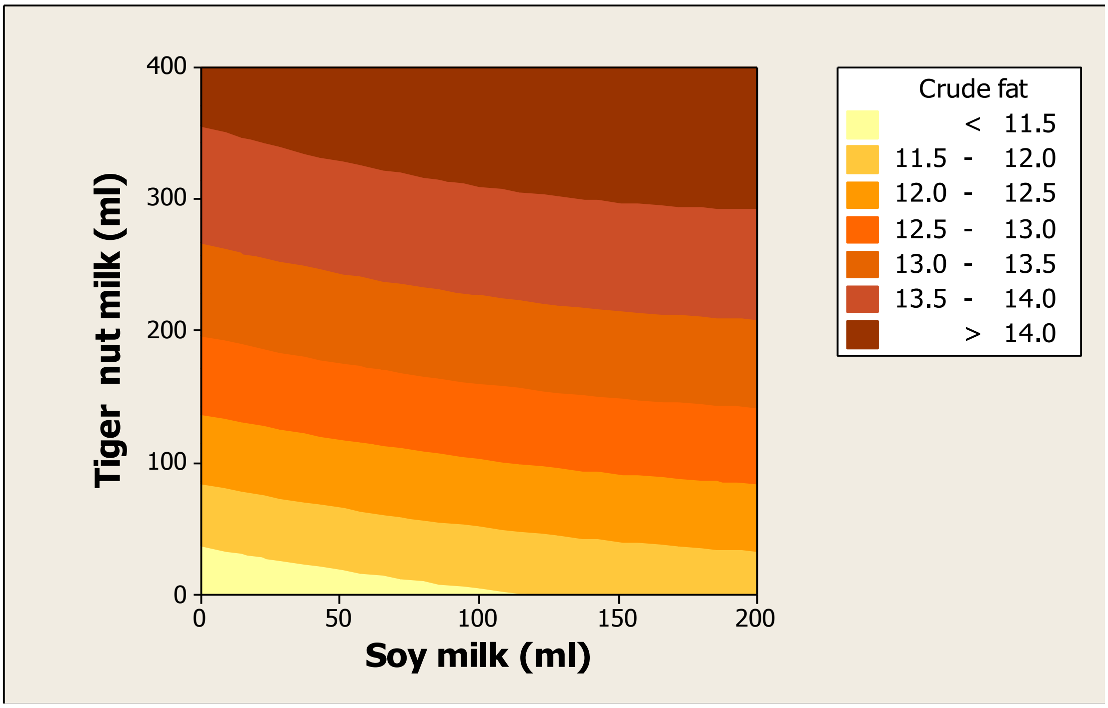

Figure 14: Contour plot showing the effect of tiger nut milk and soy milk on the fat content of cheese products.

4.5 Results of the Sensory Analysis

The panelists comprised of 60% women and 40% men and their ages ranged from 18 years to 34 years. Majority of them consumed cheese once in a month and just a few of them consumed once a fortnight. The results of the sensory evaluation conducted are shown in Table 17 as mean scores ± standard deviation.

Table 17: Mean scores for the attributes of aroma, texture (hand feel), texture (mouth feel), taste, appearance and overall liking.

Formulation	Aroma	Texture/ handfeel	Texture/ Mouth feel	Taste	Appearance /Colour	Overall Liking
1	6.55 ± 0.99	6.10 ± 1.57	6.05 ± 1.50	5.18 ± 1.87	6.15 ± 1.51	5.70 ± 1.64
2	5.90 ± 1.50	6.75 ± 1.57	6.07 ± 1.41	5.90 ± 0.96	5.80 ±1.08	4.75 ± 1.99
3	6.13 ± 1.27	5.90 ± 1.25	6.10 ± 1.50	5.65 ± 2.03	6.10 ±1.59	5.26 ± 1.43
5	5.65 ± 1.17	4.65 ± 1.96	4.30 ± 1.81	4.30 ± 1.92	5.10 ±1.60	3.90 ± 2.07
6	6.3 5± 0.97	7.20 ± 0.88	6.80 ± 0.88	6.15 ± 1.73	5.80 ±1.83	6.15 ± 1.70
7	7.40 ± 0.98	7.60 ± 0.81	7.80 ± 1.12	7.35 ± 1.12	6.70 ±1.32	7.25 ± 1.24

Means of triplicate values

With respect to the aroma all products were well accepted. Formulation 7 was accepted better than all the other products and formulation 5 was least accepted. The appearance for all cheese samples was well accepted and the acceptability was increased when tiger nut milk was increased in the soy milk. The taste for all samples was well accepted except for formulation 5 which received a mean score of 4.30. Formulation 5 contains 50ml of soy milk with no amount of tiger nut milk. For both aspects of texture, all samples were well accepted except for sample 5 (50 ml of soy milk, no tiger nut milk. For overall liking, formulation 7 (400 ml of tiger nut milk, 50 ml of soy milk) was liked more than all the other products.

For all the products, formulation 7 was the best one accepted in terms of all the attributes. Belewu and Abodunri (2006) also found similar results when they studied the effect tiger nut milk, millet and sorghum on *kunnu* (non-alcoholic beverage prepared from cereals).

Appendix 12 shows the ANOVA results for sensory evaluation. For all the 6 formulations, the various attributes which were (Aroma, texture/handfeel, texture/mouthfeel, teste, appearance/colour recorded p=0.00, which means that there were significant differences between the formulations with respect to the attributes.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The purpose of this study was to evaluate the potential of adding tiger nut milk and soy milk into cheese making. In all 16 different formulations were prepared from tiger nut milk, soy milk and cow milk. Texture analysis, colour evaluation and chemical analysis were carried out on all the 16 cheese samples. Two parameters were measured for texture (firmness and fracturability). Protein, pH, fat and moisture contents were determined with respect to the chemical analysis. For the colour evaluation, only the L* value was determined. Microbiological analysis was carried out on 4 samples, which were the outliers among the samples. Sensory evaluation was carried out on 6 products. Data from the physico-chemical analysis was analysed with the statistical package Minitab version 14. A one-way anova was used to analyse data from the sensory evaluation. Data was presented using charts and tables where necessary. There were statistical differences between the samples with respect to the texture measurements. The firmness of the cheese samples increased as more soy milk was added and decreased as tiger nut milk was increased. The fracturability of the samples increased as soy milk was increased and decreased as tiger nut milk was increased. There were significant differences between the colour readings of the samples ($p < 0.05$). All the counts for the microbiological quality of the four cheese products were less than that of the Ghana Standards Board’s limit. The chemical composition were all significant ($p < 0.05$). The pH, moisture, fat and protein contents increased as either tiger nut milk and/or soy milk was added to the raw milk. For the acceptance test, formulation 7 (400 ml of tiger nut milk and 50 ml of tiger nut milk) was the cheese product accepted best.

5.2 CONCLUSION

Based on the findings of this work, it is concluded that cheese products from tiger nut milk and soy milk is feasible and could both be used as a cheese spread on bread or cookies. The pH of all the cheese products were less than 7.00 (neutral) but those of the tiger nut cheese were less acidic which makes it ideal for individuals with ulcers and other related problems. The fat contents were somehow low and because two of the ingredients are from plant sources, consumers would not have to worry much about the fatty nature of these products. The products with high amounts of protein are those from soy milk as soy milk is rich in proteins, so it will be very ideal for children as they need proteins for growth and development. The moisture contents were quite high which makes them highly perishable. It is therefore suggested that the cheese samples should be kept in the refridgerator until they are ready to be consumed. The products can keep for at most 1 week in the refridgerator after which it becomes unwholesome. From the results of the sensory evaluation, Formulation 7 (400 ml of tiger nut milk, 50 ml of soy milk) is the best product and the formulations should not exceed Formulation 7 because the cheese products could become too soft and/or too beany.

5.3 RECOMMENDATIONS

Based on the results, the following recommendations are made:

1. Future research should be carried out to determine commercial viability of the Tiger nut milk and Soy milk products.
2. Future research should be carried out to improve the flavour of the cheese products especially the soy cheeses.

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APPENDICES

APPENDIX 1- Demographic Questionnaire

University Of Ghana

Department Of Family and Consumer Sciences

The purpose of this research is to solicit information on consumers' demographic information and knowledge on cheese. It is also purposely for student research. Any information provided will be treated with confidentiality.

Date……………………………

Respondent's code………………..

Form number…………………….

Please tick only one answer or fill in the blank spaces where applicable.

Background information

1. Age group

18-24 [ ] 24-35 [ ] 35-44 [ ] 45-54 [ ] 55-64 [ ]

65+ [ ]

2. Gender

Male [ ] Female [ ]

3. Educational level Attained

School dropout [ ] JHS [ ] SHS [ ] O-Level [ ] A-Level [ ]

HND [ ] First Degree [ ] Masters [ ] PHD [ ] Other………..

4. Occupation

Lecturer [ ] Workers [ ] Students [ ] Others……………..

5. Monthly Income

Less than GHC100 [ ] GHC100-200 [ ] GHC210-300 [ ] GHC310-400 [ ] GHC410-500 [ ] Above 500GHC

6. Religion

Islam [ ] Christianity [ ] Traditional [ ] Other……………….

7. Region of Origin……………………………………

General information on cheese

8. How often do you consume cheese?

Never [ ] Once a month [ ] Once a fortnight [ ] Once a week [ ]
Several times a week [ ]

9. Indicate the type(s) of cheese you have eaten before.

Cheddar [ ] Mozzarella [ ] Gouda [ ] Cheese spread [ ]
Feta [ ]

Other(s) specify……………………………………

10. How much will you be willing to pay for 100g of this product if available on the market?

Yes [ ] No [ ]

11. How would you like to consume this product?

i. On crackers ii. With bread iii. By itself iv. Other (s) specify

THANK YOU!!!

APPENDIX 2-SENSORY EVALUATION FORM

You are presented with …… cheese samples prepared from tiger nut and soya bean milk. Please taste the samples in the order presented to you and evaluate them on the attributes indicated.

Remember there is no right or wrong answers.

Before you taste each product, rinse your mouth with water provided. Write the sample code of each sample as they appear on your plate.

Date…………………..

Sample code…………

Panelist code…………

Taste at least half of the product before making a judgment. Please tick one answer only.

1. Overall, how much do you like or dislike this product?

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

2. What, if anything, did you like about the product?
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
………………………

3. What, if anything, did you dislike about the product?
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

4. Considering the overall appearance of this product, how much do you like or dislike it.

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Considering the overall aroma of this product ……

5. Smell the product and indicate how much you like or dislike it……

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

6. Taste the sample, breath out and describe how much you like or dislike the flavor……..

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Considering the overall texture of this product….

7. Rub a portion of the product in between your two fingers and indicate how much you like or dislike it

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

8. Taste the product and indicate how much you like or dislike the feel of the product in your mouth…..

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

Considering the overall taste of this product……

9. How much do you like the taste of the product in your mouth…..

dislike extremely	dislike very much	dislike moderately	dislike slightly	neither like nor dislike	like slightly	like moderately	like very much	like extremely
1	2	3	4	5	6	7	8	9

10. In general what do you think about this product

……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
…………………………………………………………………………...

THANK YOU

APPENDIX 3- CONSENT FORM

UNIVERSITY OF GHANA

DEPARTMENT OF FAMILY AND CONSUMER SCIENCES

I…………………………………….. confirm that

1.	I have read and understood the information about the project, as provided in the Information Sheet dated _________________.	☐
2.	I have been given the opportunity to ask questions about the project and my participation.	☐
3.	I voluntarily agree to participate in the project.	☐
4.	I understand I can withdraw at any time without giving reasons and that I will not be penalised for withdrawing nor will I be questioned on why I have withdrawn.	☐
5.	The procedures regarding confidentiality have been clearly explained (e.g. use of names, pseudonyms, anonymisation of data, etc.) to me.	☐
6.	If applicable, separate terms of consent for interviews, audio, video or other forms of data collection have been explained and provided to me.	☐
7.	The use of the data in research, publications, sharing and archiving has been explained to me.	☐
8.	I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the data and if they agree to the terms I have specified in this form.	☐
9.	I do not want my name used in this project.	☐
10.	I, along with the Researcher, agree to sign and date this informed consent form.	☐

Participant:

____________________________	______________________________	__________________
Name of Participant	Signature	Date

Researcher:

____________________________	______________________________	__________________
Name of Researcher	Signature	Date

APPENDIX 4- FORMULAS FOR PROXIMATE CALCULATIONS

MOISTURE CONTENT

$$\% \text{ Moisture} = \frac{\text{M initial} - \text{M dried}}{\text{M initial}} \times 100$$

M- Mass of sample

CRUDE FAT CONTENT

$$\% \text{ Crude fat} = \frac{\text{Average weight of extract}}{\text{Total dry matter}} \times 100$$

CRUDE PROTEIN CONTENT

$$\% \text{ Nitrogen} = \frac{(\text{Sample titre- Blank titre}) \times (\text{Normality of } H_2SO_4 \times 14)\ 100}{(\text{Weight of sample in mg})}$$

% Protein= % N × Conversion factor

APPENDIX 5- Response Surface Regression: pH versus Soy milk (ml), Tiger nut milk (ml)

Estimated Regression Coefficients for pH

Term	Coef	SE Coef	T	P
Constant	5.21163	0.012787	407.560	0.000
Soy milk (ml)	0.00073	0.000227	3.209	0.003
Tiger nut milk(ml)	0.00126	0.000114	11.108	0.000
Soy milk (ml)*Soy milk (ml)	-0.00000	0.000001	-1.430	0.160
Tiger nut milk(ml)* Tiger nut milk(ml)	-0.00000	0.000000	-5.062	0.000
Soy milk (ml)*Tiger nut milk(ml)	0.00000	0.000000	3.389	0.002

S = 0.03074   R-Sq = 95.9%   R-Sq(adj) = 95.4%

Analysis of Variance for pH

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0.928301	0.928301	0.185660	196.46	0.000
Linear	2	0.891298	0.120923	0.060462	63.98	0.000
Square	2	0.026152	0.026152	0.013076	13.84	0.000
Interaction	1	0.010851	0.010851	0.010851	11.48	0.002

Residual Error	42	0.039691	0.039691	0.000945		
Lack-of-Fit	10	0.037691	0.037691	0.003769	60.31	0.000
Pure Error	32	0.002000	0.002000	0.000063		
Total	47	0.967992				

APPENDIX 6: Response Surface Regression: %moisture versus Soy milk (ml), Tiger nut milk (ml)

Estimated Regression Coefficients for %moisture

Term	Coef	SE Coef	T	P
Constant	54.5348	0.405911	134.351	0.000
Soy milk (ml)	0.0715	0.007214	9.916	0.000
Tiger nut milk(ml)	0.0272	0.003607	7.550	0.000
Soy milk (ml)*Soy milk (ml)	-0.0003	0.000032	-8.321	0.000
Tiger nut milk(ml)* Tiger nut milk(ml)	-0.0000	0.000008	-2.160	0.037
Soy milk (ml)*Tiger nut milk(ml)	0.0001	0.000013	6.328	0.000

S = 0.9758 R-Sq = 96.6% R-Sq(adj) = 96.2%

Analysis of Variance for %moisture

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	1140.88	1140.880	228.1761	239.62	0.000
Linear	2	1032.38	135.282	67.6412	71.03	0.000
Square	2	70.37	70.374	35.1870	36.95	0.000
Interaction	1	38.13	38.128	38.1282	40.04	0.000
Residual Error	42	39.99	39.993	0.9522		
Lack-of-Fit	10	39.99	39.991	3.9991	46818.40	0.000
Pure Error	32	0.00	0.003	0.0001		
Total	47	1180.87				

APPENDIX 7: Response Surface Regression: Crude protein versus Soy milk (ml, Tiger nut milk

Estimated Regression Coefficients for Crude protein

Term	Coef	SE Coef	T	P
Constant	12.1032	0.038887	311.239	0.000
Soy milk (ml)	0.0061	0.000691	8.766	0.000
Tiger nut milk(ml)	0.0032	0.000346	9.144	0.000
Soy milk (ml)*Soy milk (ml)	-0.0000	0.000003	-1.991	0.053
Tiger nut milk(ml)* Tiger nut milk(ml)	-0.0000	0.000001	-5.220	0.000
Soy milk (ml)*Tiger nut milk(ml)	0.0000	0.000001	6.708	0.000

S = 0.09349 R-Sq = 97.8% R-Sq(adj) = 97.5%

Analysis of Variance for Crude protein

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	16.1815	16.18154	3.236308	370.31	0.000
Linear	2	15.5154	1.27777	0.638885	73.10	0.000
Square	2	0.2728	0.27281	0.136407	15.61	0.000
Interaction	1	0.3933	0.39329	0.393287	45.00	0.000
Residual Error	42	0.3671	0.36706	0.008740		
Lack-of-Fit	10	0.3519	0.35186	0.035186	74.08	0.000
Pure Error	32	0.0152	0.01520	0.000475		
Total	47	16.5486				

APPENDIX 8: Response Surface Regression: Crude fat versus Soy milk (ml), Tiger nut milk (ml)

Estimated Regression Coefficients for Crude fat

Term	Coef	SE Coef	T	P
Constant	11.0863	0.025959	427.077	0.000
Soy milk (ml)	0.0043	0.000461	9.289	0.000
Tiger nut milk(ml)	0.0116	0.000231	50.395	0.000
Soy milk (ml)*Soy milk (ml)	-0.0000	0.000002	-3.646	0.001
Tiger nut milk(ml)* Tiger nut milk(ml)	-0.0000	0.000001	-19.033	0.000
Soy milk (ml)*Tiger nut milk(ml)	-0.0000	0.000001	-4.615	0.000

S = 0.06241 R-Sq = 99.7% R-Sq(adj) = 99.7%

Analysis of Variance for Crude fat

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	58.4231	58.42313	11.68463	3000.36	0.000
Linear	2	56.8776	9.96557	4.98278	1279.47	0.000
Square	2	1.4625	1.46254	0.73127	187.77	0.000
Interaction	1	0.0830	0.08295	0.08295	21.30	0.000
Residual Error	42	0.1636	0.16357	0.00389		
Lack-of-Fit	10	0.1636	0.16357	0.01636	*	*
Pure Error	32	0.0000	0.00000	0.00000		
Total	47	58.5867				

APPENDIX 9: Response Surface Regression: Colour versus Soy milk (ml), Tiger nut milk (ml)

Estimated Regression Coefficients for Colour

Term	Coef	SE Coef	T	P
Constant	80.9107	0.317307	254.992	0.000
Soy milk (ml)	-0.0513	0.005639	-9.105	0.000
Tiger nut milk(ml)	-0.0254	0.002820	-9.024	0.000
Soy milk (ml)*Soy milk (ml)	0.0002	0.000025	6.805	0.000
Tiger nut milk(ml)* Tiger nut milk(ml)	0.0000	0.000006	3.550	0.001
Soy milk (ml)*Tiger nut milk(ml)	0.0001	0.000010	5.036	0.000

S = 0.7628 R-Sq = 89.7% R-Sq(adj) = 88.4%

Analysis of Variance for Colour

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	211.710	211.7096	42.3419	72.77	0.000
Linear	2	162.677	87.1278	43.5639	74.87	0.000
Square	2	34.278	34.2776	17.1388	29.45	0.000
Interaction	1	14.755	14.7548	14.7548	25.36	0.000
Residual Error	42	24.439	24.4391	0.5819		
Lack-of-Fit	10	24.432	24.4317	2.4432	10470.71	0.000
Pure Error	32	0.007	0.0075	0.0002		
Total	47	236.149				

APPENDIX 10: Response Surface Regression: Firmness versus Soy milk (ml), Tiger nut milk (ml)

Estimated Regression Coefficients for Firmness

Term	Coef	SE Coef	T	P
Constant	96.8615	2.83545	34.161	0.000
Soy milk (ml)	0.6448	0.05039	12.795	0.000
Tiger nut milk(ml)	-0.1382	0.02520	-5.486	0.000
Soy milk (ml)*Soy milk (ml)	-0.0023	0.00022	-10.227	0.000
Tiger nut milk(ml)* Tiger nut milk(ml)	0.0001	0.00006	2.331	0.025
Soy milk (ml)*Tiger nut milk(ml)	0.0003	0.00009	3.413	0.001

S = 6.817 R-Sq = 92.1% R-Sq(adj) = 91.2%

Analysis of Variance for Firmness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	22831.3	22831.35	4566.27	98.27	0.000
Linear	2	17178.0	9734.79	4867.40	104.75	0.000
Square	2	5112.1	5112.15	2556.07	55.01	0.000
Interaction	1	541.2	541.18	541.18	11.65	0.001
Residual Error	42	1951.5	1951.52	46.46		
Lack-of-Fit	10	1951.2	1951.24	195.12	22089.46	0.000
Pure Error	32	0.3	0.28	0.01		
Total	47	24782.9				

APPENDIX 11: Response Surface Regression: Fracturability versus Soy milk (ml, Tiger nut milk

Estimated Regression Coefficients for Fracturability

Term	Coef	SE Coef	T	P
Constant	71.4777	0.142249	502.483	0.000
Soy milk (ml)	0.0313	0.002528	12.384	0.000
Tiger nut milk(ml)	-0.0289	0.001264	-22.829	0.000
Soy milk (ml)*Soy milk (ml)	-0.0000	0.000011	-2.931	0.005
Tiger nut milk(ml)* Tiger nut milk(ml)	0.0000	0.000003	11.667	0.000
Soy milk (ml)*Tiger nut milk(ml)	0.0000	0.000005	5.937	0.000

S = 0.3420 R-Sq = 98.9% R-Sq(adj) = 98.7%

Analysis of Variance for Fracturability

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	424.327	424.3272	84.8654	725.70	0.000
Linear	2	403.281	86.1540	43.0770	368.36	0.000
Square	2	16.924	16.9242	8.4621	72.36	0.000
Interaction	1	4.122	4.1224	4.1224	35.25	0.000
Residual Error	42	4.912	4.9116	0.1169		
Lack-of-Fit	10	4.095	4.0953	0.4095	16.05	0.000
Pure Error	32	0.816	0.8163	0.0255		
Total	47	429.239				

Appendix 12: ANOVA RESULTS FOR SENSORY EVALUATION

		Sum of Squares	Df	Mean Square	F	Sig.
Overall liking	Between Groups	268.821	5	53.764	18.469	.000
	Within Groups	681.175	234	2.911		
	Total	949.996	239			
Appearance	Between Groups	55.683	5	11.137	4.885	.000
	Within Groups	533.500	234	2.280		
	Total	589.183	239			
Aroma	Between Groups	75.783	5	15.157	11.240	.000
	Within Groups	315.550	234	1.349		
	Total	391.333	239			
Texture handfeel	Between Groups	223.293	5	44.659	25.594	.000
	Within Groups	406.565	233	1.745		
	Total	629.858	238			
Texture mouthfeel	Between Groups	263.088	5	52.617	25.787	.000
	Within Groups	477.475	234	2.040		
	Total	740.562	239			
Taste	Between Groups	206.283	5	41.257	14.905	.000
	Within Groups	647.700	234	2.768		
	Total	853.983	239			