UNIVERSITY OF EDUCATION, WINNEBA

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DEVELOPMENT AND EVALUATION OF BEETROOT -ENRICHED CUPCAKES

BELINDA AGYEI-POKU

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DECLARATION

STUDENT'S DECLARATION

I, BELINDA AGYEI-POKU, declare that, this dissertation, is the outcome of my research and that except portions where references contained in published work have been duly cited, is entirely my own original work, and that it has neither been submitted nor being concurrently submitted in any other institution.

SIGNATURE………………………………………………

DATE……………………………………………………

SUPERVISOR'S DECLARATION

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

NAME OF SUPERVISOR: Dr. (Mrs) Doreen Dedo Adi

SIGNATURE: …………………………….

DATE: ……………………………………..

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DEDICATION

I dedicate this work to my beloved husband Mr Thomas Agyei-Poku for his love and care. To my children Akua, Kwasi, Ama and Kwame Agyei-Poku so that they become scholars who will not only be able to understand different aspects of the world but also to change them in an appropriate and positive ways. May Almighty God bless them all, Amen.

ABSTRACT

Beetroots are nutrient dense root vegetables available worldwide. They find use as colourants in many food products as well. The aim of this research was to incorporate beetroot in the form of powder and paste at different percentage levels (10, 20, 30, 40, and 50%) into cupcakes and evaluate the organoleptic properties, nutritional composition and shelf life of the resultant cupcakes. sensory evaluation was carried out on the various formulated cupcakes. The most acceptable product was chosen and evaluated for its proximate, nutritional, textural, antioxidant properties and shelf life. Results from the study revealed that, appearance, colour, sponginess, taste and mouthfeel the properties decreased with increased in beetroot substitution. However, consumer overall acceptability is observed to be highest (8.06±0.85: Like very much) for the control sample, followed by 7.94±0.68 for 10% beetroot powder fortified sample, 7.38±0.85 for the 20% beetroot powder fortified sample and then 7.37±0.76 and 7.37±0.90 for 20% and 10% beetroot paste fortified samples respectively. Nutritionally, beetroot powder improved the protein, ash, fibre and carbohydrate contents of the fortified cupcakes. Fat was not affected in any significant way whilst carbohydrate contents were reduced by the incorporation of beetroot. Incorporating beetroot did not improve springiness, adhesiveness and cohesiveness of the cupcakes ($p>0.05$). However, beetroot powder produced cupcakes with higher hardness ($p<0.05$) compared to beetroot paste samples. Cupcakes fortified with 20% beetroot powder obtained significantly better ($p<0.05$) nutritional, mineral, vitamin C and colour properties compared to control 100% wheat flour sample, 20% and 50% beetroot paste samples. The shelf life of the 20% beetroot powder fortified sample is 21 days when refrigerated and 4 days when stored at room temperature using a multiple regression of both microbiological and physicochemical predictors. Incorporating beetroot powder up to 20% into cupcakes maintain the consumer acceptability and considerably improves nutritional properties. The resultant product has improved mineral and fibre composition as well as Vitamin C and antioxidant properties that provides important nutrition while ensuring maximum utilization of beetroots and economic impact.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Beetroot *(Beta vulgaris L.*) is crop belonging to the Chenopodiaceae family. (Amaral *et al*., 2004)The vegetable was native to the Indian and British coastlines. The roots can be round shaped, cylindrical or tapered, and has several varieties of bulb, bright crimson colour like white, yellow or red according to the colour of the flesh. The leafy tops can also be used as a tasty spinach substitute. It is famous for its juice value and medicinal properties; and known by several common names like beet, chard, spinach beet (Yashwant, 2015). Beetroot is cultivated from June to November it is the taproot portion of the beet plant. Beetroot (*Beta vulgaris*) is very nutritious vegetables. Beetroot (*Beta vulgaris*) is an important raw material of plant origin with proven positive effects on the human body. They can be eaten raw, boiled and steamed and roasted. In Ghana, it is eaten in the form of juice and salads. It contains no fat, very few calories and is great source of folate, fiber and several antioxidants (Carotenoids and flavonoids). It also contains the significant amount of Vitamin A in the form of Beta -Carotene and it also contains small amounts of Vitamin B1, B2, B3, and Vitamin C, Calcium, Magnesium, Iron, Copper, Potassium and Sodium among others (Amnah, 2013). There are bioactive compounds present in beetroot act as antioxidant, anti-inflammatory, anticarcinogenic, hepatoprotective, antidiabetic, and cholesterol-lowering and wound-healing components (Chikara *et al.*, 2019). Beetroot is a boon to the food industry because it is predominantly used as food colourant or food additive in various food products. Beetroot has been used in different products like yoghurt (Yadav *et al.,* 2016), probiotic drink (Panghal *et al*., 2017), ice cream (Manoharan *et al.,* 2012), jelly (Chaudhari and Nikam, 2015), candy (Fatma *et al.*, 2016), multigrain snacks (Dhadage *et al.,* 2014), and cookies

(Amnah, 2013; Youssef and Mousa, 2012).

A cupcake is a small cake that has a cup like shape, they are portion-controlled, portable, easy to make, and can be inexpensive to make. Such cakes are made more attractive, flavored and tasty also consumer-appealing cakes by incorporating various additional ingredients into it like cashew, dry fruits nuts, resins, vanilla etc. Cakes are produced from wheat flour. According to Chu (2004) wheat flour is a powder made from the grinding of wheat used for human consumption. The varieties of wheat are called "soft" or "weak" if gluten content is low, and "hard" or "strong" if the gluten content high. Hard flour, or *bread flour*, is high in gluten, with 12% to 14% gluten content, and its dough has elastic toughness that holds its shape well once baked. Soft flour is comparatively low in gluten and thus results in a loaf with a finer, crumbly texture. Soft flour is usually divided into cake flour, which is the lowest in gluten, and pastry flour, which has slightly more gluten than cake flour. Cake flour is finely milled white flour made from soft wheat. It has very low protein content, between 8% and 10%, making it suitable for soft-textured cakes and cookies. The higher protein content of other flours would make the cakes tough. This research seeks to replace soft/weak or cake flour with beetroot. Cakes are the most common product because of its taste, texture and its induced appearance for all age groups. It is high in carbohydrates, fat and calories but low in fiber, vitamins and minerals, which make it unhealthy for daily consumption. Due to its high acceptability in all age groups, it is required to be improved the nutritional quality of cakes. Enriched or fortified cakes have better nutritive value and have healthy choice for consumption. The use of white flour derived from the processing of whole-wheat grain, which is aimed at improving the aesthetic value, it has also led to the drastic reduction in the nutritional density and the fibre content compared to bread made from whole grain cereals. Recently, increasing consumer awareness of the need to eat high quality and healthy foods known as functional foods. Therefore, has triggered the development of specialty bakery products like cakes made from whole grain flour and other functional ingredients known as health foods or functional foods. The development and consumption of such functional foods not only improves the nutritional status of the general population but also helps those suffering from degenerative diseases associated with today's changing lifestyle and environment (Jideani and Onwubali, 2009). Therefore, this work seeks to use beetroot as functional food to produce cupcakes to improve the nutritive value of cakes. The human body needs a good amount of fiber to provide it with minerals and vitamins like thiamine, riboflavin and niacin in order to function properly and these are largely found in fruits and vegetables like peas, corn, peppers, zucchini, onions, okra, tomatoes, millet, carrot and green beans (Troftgruben, 1977). Although consumption of fresh unprocessed plant food is widely advocated, evidence is emerging that in vivo bioavailability of many protective compounds are enhanced when vegetables are dried.

Srivastava and Singh (2016) reported the effect of beetroot powder on the physical, sensory and nutritional characteristics of biscuit. An improved nutritional profile over control biscuit was observed and proven to have many therapeutic properties. Mathangi and Balasaraswathi (2019) reported on the use of horse gram and beetroot powder in the formulation of cake and indicate that the substitution of horse gram with beetroot powder up to 10 % is possible and enhances the nutritional value of cake. Also, Ranawana *et al.,* (2018) utilized beetroot and chocolate to improve oxidative stability and functional properties of processed foods and observed that the benefits of beetroot and chocolate addition were manifested more in the food system through improving oxidative stability and shelf life, than during its digestion.

1.2 Statement of Problem

Cakes are usually made from soft wheat flour of about 72% extraction, which results in low fibre and phytochemicals. The lack of antioxidants also results in short shelf life of baked cakes. This has resulted in the use of non-wheat components such as fruits and vegetables in baking as sources of antioxidants and fibers aimed at improving nutrition and shelf life (Rodriguez *et al.,* 2006; Nagib and Zidan, 2009; Hafez, 2012). One of the emerging sources of such fibers, antioxidants and minerals in baking applications is beetroot. Kohajdova *et al.,* (2018) report that beetroot has total dietary fibre of 65.71% as well as other potent nutrients and has the capacity to increase dietary fibre (DF) in baked goods. Several studies have been carried out which focused mainly on the use of beetroot powder, extract or pomace in biscuits, cakes, noodles or extrudates and the effect on sensory, physical properties and nutritional composition of these products (Singh *et al.,* 2016; Sinha and Masih, 2014; Pinki and Awasthi, 2014)

On the other hand, Guerra *et al.,* (1998) reported that about 17% of beetroot is lost postharvest. These losses are observed in the form of weight losses, physical damage leading to rot and increase in respiration rates and microbial infestations that may also lead to rot (Sharma *et al.,* 2019). More so, Ghana does not cultivate wheat. Wheat is imported into Ghana which puts pressure on our foreign reserves. Consequently, wheat substitution with beetroot is another way of enhancing the use of other non-wheat product in baked goods. This could lead to potential reduction in wheat imports. However, literature available on the incorporation of beetroot into baked goods in Ghana is scanty.

1.3 Significance of the study

From literature, cupcake made from only beetroot powder or beetroot paste has not been reported. Neither has the effect of wheat flour substitution with beetroot paste or powder been reported in Ghana. This work therefore sought to develop and evaluate cupcakes made from beetroot powder and beetroot paste. This would help increase the nutritional content of the cake because of the high fibre, phytochemicals and minerals in beetroot and potentially increase shelf life of the cupcake. This work would also result in diversifying the use of beetroot and contribute to reducing the postharvest losses of the vegetable and bring maximum returns to farmers engaged in its cultivation.

1.4 Study Objectives

Main objective

Evaluating the suitability of producing beet root fortified cup cakes

1.4.1 Specific objectives

1. To evaluate the effect of various formulations of beetroot addition into the cake. Evaluate the addition of 10, 20, 30, 40, 50% beetroot paste and powder addition on the properties of beetroot-enriched cup cake.

2. To determine the nutritional and phytochemical properties of beetroot cupcake.

3. To determine the colour and textural properties of beetroot cupcake.

4. To evaluate and estimate the shelf life of beetroot cupcake

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A lot of research works have been done on *beetroot* in several countries including Ghana; there is more information on it as a top health food, ways of using it on menu and pharmacological area. There is however not much information on development and evaluation of beetroot cupcakes using the paste as well as powder in the catering industry; therefore, this chapter will investigate the various works that has been done on *beetroot* and also the general acceptability of beetroot cupcake in terms of the various attributes.

2.2 Origin of Beetroot

Beets are native to the Mediterranean. It was not cultivated until the 3rd century and not developed until the 19th century by German and French breeders. Beetroot is the name used by the British and some other English speaking countries including Australia and the New Zealand and the Americans call it beets a type of food. The ancient Babylonians were the first to use it for various applications. Early Greeks and Romans used the root for its medicinal properties and the leaves as vegetables. The Greek Peripatetic Theophrastus later describes the beet as similar to the radish, while Aristotle also mentions the plant (Hill and Langer, 1991). Zohary and Hopf (200) also argue that it is very probable that beetroot cultivars were also grown at the time, and some Roman recipes support this. Later English and German sources show that beetroots were commonly carried out in Medieval Europe (Hopf *et al*., 2000; Hill and Langer, 1991). They state the earliest written mention of the beet comes from 8th century Mesopotamia (Hopf *et al*., 2000). According to Amaral *et al*., 2004; Mello *et al*., 2008.Beetroot (*Beta vulgaris L.*) belongs to the

Chenopodiaceae family and is originally from temperate climate regions of Europe and North Africa.

As time went on, beetroot held an important place in medicine. In England, beetroot juice or broth was recommended as an easily digested food for the aged, weak, or infirm. Even in mythology, Aphrodite is said to have eaten beets to retain her beauty. In folk magic, if a woman and man eat from the same beet, they will fall in love. In Africa, beets are used as an antidote to cyanide poisoning.

2.3 The Beetroot plant

The **beetroot** is the taproot portion of a beet plant, usually known in North America as the beet, and also known as the table beet, garden beet, red beet, dinner beet or golden beet. The Beetroot species *Beta vulgaris L.* belongs to the Quenopodiaceae family and originated in regions of Europe and North Africa, where they are cultivated in mild to cold temperatures (10–20°C). Cultivation in climatic conditions with higher relative humidity and higher temperature favours the development of pests and diseases, altering the internal colour and taste of the plant, making it less sweet, also reducing plant productivity by about 50% (Tullio *et al.,* 2013). This plant species prefers soils rich in organic matter, with pH ranging from 5.5 to 6.2. The production cycle can range from 60 to 100 days, in summer or winter, depending on the cultivar and cultivation mode (Sediyama *et al.,* 2011; Tullio *et al.,* 2013). The plant has a root system composed of a main root and smaller roots reaching up to 60 cm in depth, with lateral branching. It also possesses a tuberous, purplish-red, part, globular in shape, with a sweet taste, which develops almost on the surface of the soil (Ravichandran *et al.,* 2013). The beetroot plant is biennial, requiring a period of intense cold to go through the reproductive stage of the cycle. The appearance of elongated leaves around the stem and the tuberous part occurs in the vegetative phase, while floral tassel emission occurs with the production of seeds comprised of glomeruli during the reproductive stage (Sediyama *et al.,* 2011).

It is famous for its juice value and medicinal properties; and known by several common names like beet, chard, spinach beet. (Kumar, 2015). Beetroot or table Beet is biennial plant that is cultivated for its thick flashy roots in early spring. Members of this family are dicotyledonous. It is an erect annual herb with tuberous root stocks. It ranks among the ten most potent vegetables with respect to antioxidant property. It makes an excellent dietary supplement being not only rich in minerals, nutrients and vitamins but also has unique phytoconstituents, which have several medicinal properties. Beetroot (*Beta vulgaris L. ssp. vulgaris*) is an traditional vegetable distributed throughout the world commercially grown for salads, juice, and natural pigments (Liu *et al.,* 2008). The colour of red beetroot is due to the presence of betalains in the cell vacuoles (Jackman and Smith, 1996). Beetroot is an excellent source of these nitrogenous pigments mainly composed of 2 red-violet betacyanins, betanin and isobetanin, and yellow betaxanthins representing only a minor fraction. Betanin is also known for its nontoxic properties and beetroot has been the subject of much experimental interest as the red pigment can be used in the pharmaceutical and food industries (Henry, 1996). As a high-nutrient vegetable, beetroot is ranked among the 10 most potent vegetables with respect to their antioxidant activity (Vinson *et al.,* 1998). In addition to carotenoids,chlorophylls, and anthocyanins ,betalains are one of the most common plant pigments yielding yellow, orange, red, purple, or blush colours of various flowers, grasses, fruits, and vegetables. Unlike anthocyanins, which take part in the colouring of virtually all members of Angiospermae, betalains are only synthesized in the Chenopodiniae suborder within the Caryophyllales and in some genera of the Basidiomycetes (Stintzing and

Carle, 2004). Interestingly, betalains and anthocyanins, the 2 most abundant red pigments, have never been detected in the same plant simultaneously (Stafford, 1994). According to Takács-Hájos (2011), the root of beetroot can store rather high amount mineral element. The core of the root has higher mineral element than the inner part, so the beetroot should be peeled thinly to avoid the loss of bioactive compounds

2.4 Varieties of beetroot

According to some authors, *Beta vulgaris L.* beetroots can be divided into three subspecies. (a) *Beta vulgaris ssp. Adanesis*, formed by a distinct group of semi-annual plants, with a great decline in auto-fertilization, with specific morphological characteristics; (b) *Beta vulgaris ssp. Maritima,* formed by a large complex of morphological types that occur in a vast geographic area; (c) Beta vulgaris ssp. vulgaris, which groups all domesticated cultivars (Lange *et al*., 1999). According to Lange *et al*. (1999), subspecies *Beta vulgaris ssp. vulgaris* cultivars can be subdivided into four other groups: (1) Leaf Beet Group, a cultivar with edible leaves and petioles and with roots with no significantly increased diameter; (2) Sugar Beet Group, a white coloured strain grown in the US and Europe for sugar production; (3) Fodder Beet Group, a cultivar intended for feeding herds and (4) Garden Beet Group, the only group cultivated in Brazil that has an edible tuberous part.

According to Takácsné Hájos *et al*., (1999), varieties with short vegetation have small or middle leaf lengths which can promote the intensive root development. The size of foliage has connection with the possibility of mechanical harvest. Between the varieties there are important differences in the lengths of leaf petiole and its colour content. Small leaf varieties have thinner petiole and deep purple colour, while the long leaf varieties have orange petiole with purple stripes. Several researchers suppose connection between the petiole and root colour intensity

The beetroot has very good colour intensity, which is determined by the ratio of red betacyanins and yellow betaxanthine content. It is influenced by genetic (variety) and environmental (growing circumstance) factors as well.

2.5 Nutritional Composition of beetroot (*Beta vulgaris L.*)

Beetroot (Beta vulgaris rubra) is an important raw material of plant origin with proven positive effects on the human body. They can be eaten raw, boiled, steamed and roasted. Red beetroot is a rich source of minerals (manganese, sodium, potassium, magnesium, iron, copper). Beetroot contains a lot of antioxidants, vitamins (A, C, B), fiber and natural dyes. Red beetroot is also rich in phenol compounds, which have antioxidant properties. These colourful root vegetables help to protect against heart disease and certain cancers (colon cancer) (Kavalcova *et al*., 2015). Beetroots are rich in other valuable compounds such as carotenoids (Dias *et al*., 2009), glycine betaine (de Zwart *et al*., 2003), saponins (Atamanova *et al*., 2005), betacyanins (Patkai *et al*., 1997), folates (Jastrebova *et al*., 2003), betanin, polyphenols and flavonoids (Vali *et al*., 2007). The beetroot species *Beta vulgaris L.* is considered a good source of dietary fiber, minerals (calcium, phosphorus and zinc), vitamins (retinol, ascorbic acid and B-complex), antioxidants, betalains and phenolic compounds, and possesses high nutritional value due to its high glucose content, in the form of sucrose (Lundberg *et al.,* 2008; van Velzen *et al.,* 2008, USDA, 2013). According to data presented by the United States Department of Agriculture (USDA) for macronutrients, 100 g of raw beetroot has an energy value of 43 kcal, 9.56 g of carbohydrates, 1.61 g of proteins, 0.17 g of total lipids, 2.8 g of total dietary fiber and 6.76 g of total sugars.

2.6 Health benefits of beetroot

Beta vulgaris var. rubra revealed significant tumor inhibitory effects in skin and lung cancer (Kapadia *et al*., 1996). These findings suggest that beetroot ingestion can be a useful means to prevent development and progression of cancer. But extracts of beetroot also showed some antimicrobial activity on Staphylococcus aureus and on Escherichia coli and also antiviral effect was observed (Rauha *et al*., 2000; Prahoveanu *et al*., 1986).

The various part of this plant are used in medicinal system such as anti-oxidant, anti-depressant, anti-microbial, antifungal, anti- inflammatory, diuretic, expectorant and carminative. It is one of the natural food which boosts the energy in athletes as it has one of the highest nitrates and sugar contents plant. (Yadav *et al*., 2016)

The juice of beetroot is also consumed as a natural remedy for sexual weakness and to expel kidney and bladder stones. The claimed therapeutic use of beetroot includes its antitumor, carminative, emmenagogue and hemostatic and renal protective properties and is a potential herb used in cardiovascular conditions. Beetroot is known to be a powerful antioxidant (Dambalkar *et al*., 2015).

According to Yao *et al*., (2004), beetroot contains high amount of phenolic components, which works in prevention against tumour and cardio vascular disease. According to Nyirády *et al*., (2010), its moderate and long-time consumption can prevent several diseases. The carotenoids and ascorbic acid content of beetroot can increase the antioxidant capacity (Wootton-Beard and Ryan, 2011).

Eating beetroot in diet reduces the chances of inflammation (an innate response including infection, erythema, edema, trauma, fever and pain that causes due to cell damage by the antigens) (Monteiro and Azevedo, 2010). Red beet provides phytochemicals that stimulate the hematopoietic, immune system, kidney and liver protection (Miraj, 2016). It reduces the bad cholesterol, oxidized LDL cholesterol and normalizes the blood pressure (Guldiken *et al*, 2016)

Phytochemicals present in beetroot are beneficial in reducing age-associated oxidative stress as well as maintain the cognitive functions like perception, learning, communication and decision making. Beetroot is a nitric oxide (NO) generator having potential to improve cerebrovascular flow (Presley *et al*, 2011). It has been reported that dietary nitrate (NO3-) supplementation affect cerebral haemodynamics (Haskell *et al*, 2011), enhance neurovascular coupling in response to visual stimuli and improve perfusion to brain areas which associated with executive function (Presley *et al*, 2011; Aamand, Dalsgaard, Ho, Moller, Roepstorff and Lund, 2013).

The consumption of beetroot enhanced the plasma nitrate level about 96% (Satyanand *et al*, 2014). Some nitrite is converted into nitric oxide when swallowed into the acidic medium of the stomach, whereas remain nitrite is absorbed to proliferate circulating plasma nitrite (Wylie *et al*, 2013). The beetroot juice is good for the skin and a mixture of little vinegar to beet juice clears dandruff, relieve running sores and ulcers. It also comprises high amounts of boron which is directly related to the production of human sex hormones. The dietary supplementation with beetroot juice, positively impact the biological responses to exercise and improves the cardiovascular health (Wylie *et al*, 2013). Beetroot juice is reported to help in purification of the blood and a great blood builder. It is rich in iron content, regenerates and reactivates the red blood cells and delivers fresh oxygen to the body (Coles and Clifton, 2012).

2.7 Uses of beetroot

Young leaves of the garden beet are sometimes used for eating. The midribs of Swiss chard are eaten boiled while the whole leaf blades are eaten as spinach beet. In some parts of Africa, the whole leaf blades are usually prepared with the major as one dish (Grubben *et al*., 2004).

The leaves and stems of young plants are steamed briefly and eaten as a vegetable, older leaves and stems are stir-fried. The usually deep-red roots of garden beet are eaten boiled either as a cooked vegetable or cold as a salad after cooking and adding oil and vinegar. A large proportion of the commercial production is processed into boiled and sterilized beets or into pickles. In Eastern Europe beet soup, such as cold soup, is a popular dish. Yellow coloured garden beets are grown on a very small scale for home consumption. Beetroot can be peeled, steamed, and then eaten warm with butter as a delicacy; cooked, pickled, and then eaten cold as a condiment; or peeled, shredded raw, and then eaten as a salad. Pickled beets are a traditional food of the South Americans.

Beetroot pigment is used commercially as a food dye. It changes colour when heated so can only be used in ice-cream, sweets and other confectionary, but it is both cheap and has no known allergic side-effects. Beetroot itself, of course, is a common salad ingredient – when cooked, vinegar is added to the water to lower the pH. Betanin, obtained from the roots, is used industrially as red food colourant, to improve the colour and flavor of tomato paste, sauces, desserts, jams and jellies, ice cream, candy, and breakfast cereals, among other applications (Grubben and Denton, 2004). The chemical adipic acid rarely occurs in nature, but happens to occur naturally in beetroot.

According to (Amaral *et al*., 2004; Mello *et al*., 2008), their leaves are cut off from the bulb to be used as organic fertilizer and animal feed or are discarded into the environment as waste. In Ghana it is used for preparing juice and salads such as Ghanaian mixed salad cucumber salad. It is also used to prepare stews such as tomato stew and at times adding to nkontomire stew" (spinach

Table 1 : Nutritional value of fresh beetroots per 100 g

Constituents	Amount	Constituents	Amount
Carbohydrates	9.96 g	Vitamin B6	0.067 mg
Sugars	7.96 g	Folate (Vit. B9)	80 µg
Dietry fiber	2.0 g	Vitamin C	3.6 mg
Fat	0.18 g	Calcium	16 mg
Protein	1.68 g	Iron	0.79 mg
Vitamin A equiv.	2 µg	Magnesium	23 mg
Thiamine (Vit. B1)	0.031 mg	Phosphorus	38 mg
Riboflavin (Vit. B2)	0.027 mg	Potassium	305 mg
Niacin (Vit. B3)	0.331 mg	Zinc	0.35 mg
Pantothemic acid (B5)	0.145 mg	Sodium	77 mg S).

Source: USDA Nutrient database

The bakery industry is one of the largest organized food industries all over the world and in particular biscuits and cookies are one of the most popular products because of their convenience, ready to eat nature, and long shelf life (Sindhuja, *et al*. 2005). Cakes are widely used up baked products which can be served as breakfast to bedtime snack. Cakes are loved for their taste, aroma, convenience, and long shelf stability due to low moisture content.

2.8 Baking

Baking is a method of preparing food that uses dry heat, normally in an oven, but can also be done in hot ashes, or on hot stones. The most common baked item is bread but many other types of foods are baked (Figoni, 2011). Heat is gradually transferred "from the surface of cakes, cookies, and breads to their center. As heat travels through, it transforms batters and doughs into baked goods and more with a firm dry crust and a softer centre" (Figoni, 2010).

According to Foskett *et al.,* (1995), baking is the cooking of food by dry heat in an oven in which the action of the dry convection heat is modified by steam.

2.8.1 Purpose of Baking

The purpose of baking is to make food digestible, palatable and safe, to create eye-appeal through colour and texture and produce an enjoyable eating quality and to lend variety to the menu.

2.8.2 Methods of Baking

All ovens must be preheated prior to baking

DRY BAKING: when baking, steam arises from the water content of the food; this steam combines with the dry heat of the oven to cook the food examples (cakes, pastry, baked jacket potatoes.

BAKING WITH UNCREASED HUMIDITY: When baking certain foods such as bread, the oven humidity is increased by placing a bowl of water or injection steam into the oven, thus increasing the water content of the food and so improving eating quality.

BAKING WITH HEAT MODIFICATION: placing food in a container of water (bain-marrie), such as baked egg custard, modifies the heat so that the food cooks more slowly, does not over-heat and lessens the possibility of the egg mixture overcooking. Foskett *et al.,* (1995),

2.8.3 Effect of Baking

According to Foskett *et al.,* (1995), chemical action caused by the effect of heat on certain ingredients, such as yeast and baking powder, changes the raw structure of many foods to an edible texture (pastry, cakes).However, different ingredients, methods of mixing and types of product required will cause many variations.

2.8.4 Advantages of Baking

A wide variety of sweet and savoury foods can be produced. Bakery products yield appetizing goods with eye-appeal and mouth-watering aromas. Also Bulk cooking can be achieved with uniformity of colour and degree of cooking. And Baking ovens have effective manual or automatic temperature controls. There is straightforward access for loading and removal of items. Foskett *et al.,* (1995),

2.8.5 Time and Temperature Control

Ovens must always be heated to the required temperature before the food is added.

In general-purpose ovens, shelves must be placed according to the food being cooked, because the hotter part of the oven is at the top with convection ovens the heat is evenly distributed.

Accurate timing and temperature control are essential to baking. The required oven temperature must be reached before each additional batch of goods is placed in the oven this is known as recovery time. Foskett *et al.,* (1995),

2.8.6 General Rules of baking

Always preheat ovens so that the required cooking temperature is immediately applied to the product, otherwise the product will be spoiled. Also accuracy is essential in weighing, measuring and controlling temperature. Trays and moulds must be correctly prepared. Minimise the opening of oven doors as draughts may affect the quality of the product, and the oven temperatures is reduced. Utilise oven space efficiently. and Avoid jarring of products (fruit cake,spongs souffle's) before and during baking as the quality may be affected. Foskett *et al.,* (1995),

2.8.7 Safety of baking

Use thick dry sound oven cloths for handling hot trays.

Jacket sleeves should be rolled down to prevent burns from hot trays and ovens. Also Trays and ovens should not be overloaded. And Extra care is needed to balance and handle loaded trays in and out of the oven. Foskett *et al.,* (1995),

2.8.9 Foods that are baked

All types of food can be baked, but some require special care and protection from direct heat. Various techniques have been developed to provide this protection. In addition to bread, baking is used to prepare cakes, pastries, pies, tarts, quiches, cookies, scones, crackers, pretzels. Baking can also be used to prepare other foods such as pizzas, baked potatoes, baked apples, baked beans, some casseroles and pasta dishes such as lasagne. Meat, including cured meats, such as ham can also be baked, but baking is usually reserved for meatloaf, smaller cuts of whole meats, or whole meats that contain stuffing or coating such as bread crumbs or buttermilk batter.

Eggs can also be used in baking to produce savoury or sweet dishes. In combination with dairy products especially cheese, they are often prepared as a dessert. For example, although a baked custard can be made using starch (in the form of flour, corn flour, arrowroot, or potato flour), the flavor of the dish is much more delicate if eggs are used as the thickening agent. Baked custards, such as crème caramel, are among the items that need protection from an oven's direct heat, and the bain Marie method serves this purpose. The cooking container is half submerged in water in another, larger one, so that the heat in the oven is more gently applied during the baking process. Baking a successful soufflé requires that the baking process be carefully controlled. The oven temperature must be absolutely even and the oven space not shared with another dish. These factors, along with the theatrical effect of an air-filled dessert, have given this baked food a reputation for being a culinary achievement. Similarly, a good baking technique (and a good oven) is also needed to create a baked Alaska because of the difficulty of baking hot meringue and cold ice cream at the same time. wikipedia.org/wiki/Baking (2020).

2.9 Cupcakes

Cupcakes are small, tasty snack cakes that are favored for their portability and portion-control. It is attractive and inexpensive to make. They are batter cakes baked in a cup-shaped foil or temperature resistant paper (Oxford Dictionaries, 2019). A cupcake (also British English: fairy cake; Hiberno-English: bun; Australian English: fairy cake or patty cake) is a small cake designed to serve one person, which may be baked in a small thin paper or aluminum cup. As with larger cakes, icing and other cake decorations such as fruit, cashew nuts, resins and candy may be applied for consumers appealing.

A cupcake is a small cake that has a cup like shape. Such cakes are made more attractive, flavored, and tasty and consumer appealing by incorporating various additional ingredients into it likes cashew nuts, resins, dry fruits, vanilla etc. They're portion-controlled, portable, easy to make, tasty and can be inexpensive to make.

2.9.1 Origin of cakes

The first official mention of the word cupcake was in the early 19th century, this dessert seems also to be referenced in 1796 as “a light cake to bake in small cups.” Today, one can find a wide variety of cupcakes, ranging from the simple to the sublime and entire businesses have emerged in the last decade focused solely on cupcakes.

The earliest extant description of what is now often called a cupcake was in 1796, when a recipe for "a light cake to bake in small cups" was written in American Cookery by Amelia Simmons (Simmons, 1996). The earliest extant documentation of the term cupcake itself was in "Seventy-five Receipts for Pastry, Cakes, and Sweetmeats" in 1828 in Eliza Leslie's Receipts cookbook (Leslie, 1836).

In the early 19th century, there were two different uses for the term cup cake or cupcake. In previous centuries, before muffin tins were widely available, the cakes were often baked in individual pottery cups, ramekins, or molds and took their name from the cups they were baked in.This is the use of the name that has remained, and the name of cupcake" is now given to any small, round cake that is about the size of a teacup. While English fairy cakes vary in size more than American cupcake, they are traditionally smaller and are rarely topped with elaborate icing.

The other kind of "cupcake" referred to a cake whose ingredients were measured by volume, using a standard-sized cup, instead of being weighed. Recipes whose ingredients were measured using a standard-sized cup could also be baked in cups; however, they were more commonly baked in tins as layers or loaves. In later years, when the use of volume measurements was firmly established in home kitchens, these recipes became known as 1234 cakes or quarter cakes, so called because they are made up of four ingredients: one cup of butter, two cups of sugar, three cups of flour, and four eggs (Olver, 2000; foodtimeline.com, 2008). They are plain yellow cakes, somewhat less rich and less expensive than pound cake, due to using about half as much butter and eggs compared to pound cake. The names of these two major classes of cakes were intended to signal the method to the baker; "cupcake" uses a volume measurement, and "pound cake" uses a weight measurement (Olver, 2000)

2.9.2 Varieties of cake

A cake in a mug is a variant that gained popularity on many Internet cooking forums and mailing lists. The technique uses a mug as its cooking vessel and can be done in a microwave oven. The recipe often takes fewer than five minutes to prepare. The cake rises by mixing vegetable oil (usually olive oil or sunflower oil) into a mixture of flour and other ingredients - as the oil in the mixture heats up, it creates air pockets in the mixture which allows the cake to quickly rise.

A cake in a jar is another way of making cupcakes. The baker uses a glass jar instead of muffin tins or cupcake liners.

A butterfly cake is a variant of cupcake also called fairy cake for its fairy-like "wings" (Farrow, 2005; Klivans, 2005). Butterfly cakes can be made from any flavor of cake. The top of the fairy cake is cut off or carved out with a spoon, and cut in half. Then, butter cream, whipped cream or other sweet filling (e.g. jam) is spread into the hole. Finally, the two cut halves are stuck into the butter cream to resemble butterfly wings. The wings of the cake are often decorated using icing to form various patterns.

Elaborately frosted cupcakes may be made for special occasions such as baby showers, graduations, or holidays (Martha, 2008).

A cake ball is an individual portion of cake, round like a chocolate truffle that is coated in chocolate (Simone, 2010). These are typically formed from crumbled cake mixed with frosting, rather than being baked as a sphere.

A gourmet cupcake is a somewhat recent variant of cupcake. Gourmet cupcakes are large and filled cupcakes, based around a variety of flavor themes, such as Tiramisu or Cappuccino. In recent years there has been an up cropping of stores that sell only gourmet cupcakes in metropolitan areas (littleviews.com, 2006). As an alternative to a plate of individual cakes, some bakers place standard cupcakes into a pattern and frost them to create a large design, such as a basket of flowers or a turtle (bettycrocker.com, 2008).

2.9.3 Pans and Liners

Originally, cupcakes were baked in heavy pottery cups. Some bakers still use individual ramekins, small coffee mugs, large tea cups, or other small ovenproof pottery-type dishes for baking cupcakes.

Cupcakes are usually baked in muffin tins. These pans are most often made from metal, with or without a non-stick surface, and generally have six or twelve depressions or "cups". They may also be made from stoneware, silicone rubber, or other materials. A standard size cup is 3 inches (76 mm) in diameter and holds about 4 ounces (110 g), although pans for both miniature and jumbo size cupcakes exist (joyofbaking.com, 1997). Specialty pans may offer many different sizes and shapes.

Individual patty cases, or cupcake liners, may be used in baking. These are typically round sheets of thin paper pressed into a round, fluted cup shape. Liners can facilitate the easy removal of the cupcake from the tin after baking, keep the cupcake moister, and reduce the effort needed to clean the pan (joyofbaking.com, 1997). The use of liners is also considered a more sanitary option when cupcakes are being passed from hand to hand. Like cupcake pans, several sizes of paper liners are available, from miniature to jumbo.

In addition to paper, cupcake liners may be made from very thin aluminum foil or, in a non-disposable version, silicone rubber. Because they can stand up on their own, foil and silicone liners can also be used on a flat baking sheet, which makes them popular among people who do not have a specialized muffin tin. Some of the largest paper liners are not fluted and are made out of thicker paper, often rolled at the top edge for additional strength, so that they can also stand independently for baking without a cupcake tin. Some bakers use two or three thin paper liners, nested together, to simulate the strength of a single foil cup.

Liners, which are also called paper cases, come in a variety of sizes. Slightly different sizes are considered "standard" in different countries. Miniature cases are commonly 27 to 30 millimetres (1.1 to 1.2 in) in diameter at the base and 20 millimetres (0.79 in) tall. Standard-size cases range from 45 to 53 millimetres (1.8 to 2.1 in) in diameter at the base and are 30 to 35 millimetres (1.2 to 1.4 in) tall. Australian and Swedish bakers are accustomed to taller paper cases with a larger diameter at the top than American and British bakers (Smith, 2010).

2.9.4 Important guidelines for producing cupcakes

Batter viscosity is important to cupcake production as it will directly affect its baking performance and final appearance. A fluid batter would cause the product to have a flatter top, while a viscous batter would have greater tolerance and result in a rounder top. Extremely thick and highly viscous batters result in cracked peaks and under baked cakes. Due to their small size, cupcakes require shorter bake time and lower temperatures than regular size layer cakes. Higher temperatures may cause the outside to set too quickly; leaving the inside under baked, or may result in cracks and leaks forming on the surface. Lower temperatures may result in at top cakes. It is important to balance baking time and temperature to create the characteristic domed top associated with cupcakes. The ratio of batter to pan size also plays an important role in determining the appearance of the product. Using a higher ratio can result in larger size cupcakes. The cupcakes are often filled and/or glazed after baking and cooling to increase variety in the product.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Sources of raw materials

The materials used in the formulation of the experimental cupcakes included wheat flour, margarine, baking powder, super sugar, vanilla and eggs which were all obtained from Shoprite, Accra. The other material being beetroot were obtained from Agbogbloshie market, Accra. All materials were transported secure in carrier bags to the sensory laboratory of Food research institute of the council for scientific and industrial research (CSIR) Accra.

3.2 Experimental Design

The study was conducted using a factorial study design approach of two (2) beetroot forms (powder and paste) in five (5) concentration formulations (10%, 20%, 30%, 40% and 50%) per form giving a 2×5 factorial design with a total sample size of ten (10).

3.3 Processing of Beetroot

The beetroot obtained from the market summed to a mass of five kilograms (5 kg) which were divided into two (2.5kg each) for the production of paste and powder.

3.3.1 Processing of Beetroot Paste

Fresh beetroot was washed, peeled and cut into small pieces using knife. The slices were blended using Panasonic mixer grinder (model mx Ac 300) without water for 10 minutes until smooth slurry was obtained. The paste was collected and stored (chilled) till further use.

3.3.2 Processing of Beetroot Powder

Fresh beetroots were washed, peeled and cut into slices of diameter ranging from 2.3-3.6mm using knife. These slices were dried on a tray in the apex dryer of model B35E for 26 hours at the temperature of 65°C. The dried beetroot slices were subjected to milling in Panasonic mixer grinder (model mx Ac 300). Then milled material were sieved to get fine powder and packed in zip lock bags, sealed and stored for future use.

3.4 Products Formulation

The ten different formulations of beetroot cakes were prepared by using refined wheat flour and beetroot in powder (BRP) and paste(BRP) in ratio of 70:30 (Type -B), 60:40 (Type - C) ,50:50 (Type - D),80:20 (Type-E) and 90:10 (Type-F). A control (Type A) was prepared with 100:0 wheat: beetroot was also prepared. The flow chart of preparation method of beetroot cakes is given in Fig 3.1.

Table 3.1: Product Formulations for beetroot cake using beetroot powder and paste

Ingredients	Control	Type B	Type C	Type D	Type E	Type F
Wheat Flour	100g	70g	60g	50g	80g	90g
Sugar	50g	50g	50g	50g	50g	50g
Margarine	100g	100g	100g	100g	100g	100g
Eggs	2	2	2	2	2	2
Vanilla essence	¼teaspoon	¼teaspoon	¼teaspoon	¼teaspoon	¼teaspoon	¼teaspoon
Baking powder	¼teaspoon	¼teaspoon	¼teaspoon	¼teaspoon	¼ teaspoon	¼ teaspoon
Beetrootpowder	0	30g	40g	50g	20g	10g
Beetroot paste	0	30g	40g	50g	20g	10g

3.4.1 Preparation of Cup-cakes

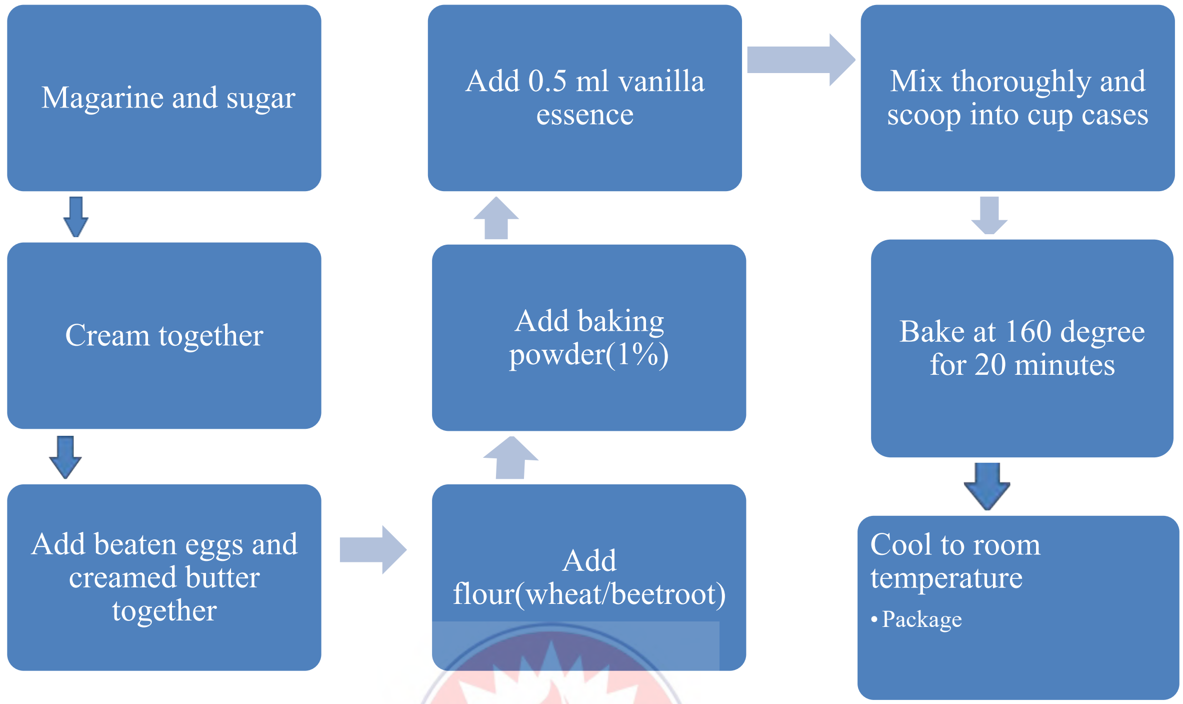


Figure 3.1: Flow chart for preparation of beetroot cupcakes.

3.5 Sensory Evaluation

A nine-point hedonic scale (9=like extremely,5=neither like nor dislike and 1=dislike extremely) was used to determine the degree of overall preference for beetroot cup cake. For this work, 15 semi trained panel were recruited from food research institute Accra. They were informed to evaluate the product for different sensory attributes which includes colour, sponginess, taste, aroma, mouth feel, and appearance and over all acceptability. Eleven samples were presented to the panelist in random. Panelists were accommodated in individual tasting booths, where they received a try containing the samples which were (randomly coded using a three-digit number), a glass of water and slices of cucumber to clean their palate before tasting each sample and an evaluation sheet were also given.

3.6 Physical properties

Physical parameters were studied after cooling of cakes at room temperature. Physical parameters of cake such as texture in terms of crust and crumbs were observed. The textural properties of cakes were measured using a texture analyzer. Texture profile analysis (TPA) of baked cupcake samples were evaluated by the method described by Agrahar-Murugkar *et al*. (2016), using the Stable Micro Systems texture analyser (TA-XT plus - 13051, Surrey, UK). A two-bite compression test was performed on samples of height 30 mm after a size 15 cork borer (22.5 mm outside diameter) was used to obtain cylindrical-shaped samples from the baked product. The analysis was done at a test speed of 5 mm/s, pre-test speed of 1 mm/s, post-test speed of 5 mm/s and a deformation of 75% using an aluminium cylindrical probe of 75 mm diameter. Data acquisition rate was at 200 pps. Using the exponent software of the measurements for hardness, adhesiveness, springiness, and cohesiveness were obtained.

Cake slices (2.5 cm thick) were placed on the platform. An acrylic cylindrical probe was used to compress the cake sample 50% of its original height at a speed of 10 mm/s.

The volume (V, cc) of the cakes was measured using the rapeseed displacement method (Rosell *et al*., 2001). Weight (W, g), length, width and height (L, Wi, H: m) of the cakes were measured. Colours of the cake were measured using Konica Minolta CR series, NJ 07446, USA). The CIE Lab colour system was used to measure the colour (MacDougall, 2010)

3.7 Nutritional Analysis

The most acceptable beetroot cake samples were nutritionally analyzed for proximate and minerals such as vitamin C, potassium, magnesium, calcium, and flavonoids by applying standard method of AOAC (2000).

3.7.1 Moisture determination

The level of moist was calculated by the Association of Official Analytical chemist (AOAC) 2000). Two grams (2 g) of fresh samples was accurately weighed in a clean (crucible) of a known weight. It was immediately put in a conventional oven at 105 °C for 6 h. The crucible was then put inside desiccator over a period of 30 minutes and allowed to cool. Afterwards, the crucible with its content was weighed. The percent moisture was then calculated using the following formula: $\% \text{ moisture} = \frac{(W2-W3)\times 100}{W2-W1}$

Where: W_1 = Weight of crucible,

W_2= Weight of crucible + slices,

W_3 = Weight of crucible + dry sample.

3.7.2 Crude protein determination

The protein content was determined by the Association of Official Analytical chemist (AOAC, 2000). A mass of two grams (2 g) of the sample were weighed into a digestion tube. Five grams (5 g) of catalyst and 1 glass bead together with 10 mL concentrated sulfuric acid will also be added. Digestion tubes were placed in the digester. Digestion commenced initially at a temperature of 400ºC in order to avoid bubbling and boiling to achieve a clearer solution. An Erlenmeyer flask of measure (250 mL) containing 50 mL of 4% boric acid was placed in distillation unit for 10 min with the condenser tip extended below the surface of the acid solution. A 100 mL water as well as 70 mL (50% sodium hydroxide) excess was added to the digests during the distillation process to ensure complete release of ammonia. Titration on the distillate with standardized 0.1 M hydrochloric acid until pinkish colourization was obtained.

Result was noted to the averaging 0.05 mL volume and calculated nitrogen and hence protein content

$$\%\text{Total Nitrogen} = 100 \times \frac{(sample\ titre\ value - Blank\ titre\ value) \times 0.1 \times 0.01401}{\text{sample weight} \times 10}$$

% Protein = %N $\times$ 6.25

3.7.3 Crude fiber

The crude fiber content was determined by the Association of Official Analytical chemist (AOAC, 2000). A mass of five (5) grams of sample was taken from the zip lock bags and defatted using the AOAC standard before subjecting to analysis. Two (2) g of beetroot cupcake samples were weighted into a flat bottom flask and 200 mL of boiling sulphuric acid (1.25%) was added for 30 min. The resulting solution will be filtered through cheese cloth using a funnel and then washed with hot water until it was free from the acid. The residue on the cloth was transferred into a flask and 200 mL of boiling sodium hydroxide solution (1.25%) was added. The flask was immediately connected to the digestion apparatus and boiled for 30 min. The flask was then removed and immediately the followed by filtration of the solution rinsed thoroughly with distilled boiling water. The residue was rinsed with 15 ml of alcohol. It was transferred into porcelain crucibles and dried at 105°C in an oven for 24 h. It was cooled to room temperature in a desiccator and weighed. The cauldron and its weight was burned in a mute heater at 550°C. It was cooled to room temperature in a desiccator and weighed. The difference between the two weights was recorded and the percentage crude fiber calculated as

$$\%\text{Crude Fibre} = \frac{(\text{weight of sample before ashing} - \text{weight of sample after ashing}) \times 100}{\text{weight of flour sample}}$$

3.7.4 Crude fat determination

The crude fat content was determined by the Association of Official Analytical chemist (AOAC, 2000). A soxhlet extractor was utilized for dissolvable extraction of the oil. The dissolvable (pet ether) was expelled from the concentrate by refining and the lingering oil part gathered and utilized for investigative work. Dried examples from the dampness examination was weighed, pressed in a Whatman channel paper and embedded into the soxhlet extractor. A 40-60ºC oil ether (BDH analar review) was utilized as the extraction dissolvable. The time of consistent extraction was 6 hours. Toward the finish of this period, the dissolvable was recouped by straightforward refiningand the lingering oil was dried in a broiler at 105ºC for 2 hours and cooled in a desiccator and permitted to cool, before being weighed. The drying, cooling and weighing was repeated until a constant dry weight was obtained. The extracted oil sample was in a well-sealed dark brown coloured glass bottle and kept for analytical test

$$\%\ \text{Fat} = \frac{(W2 - W1) \times 100}{W3}$$

Where: W_1 = Weight of empty flask

W_2 = Weight of flask + fat

W_3 = Weight of slices taken

3.7.5 Ashing

The ash content was determined by the Association of Official Analytical chemist (AOAC, 2000). Clean empty crucible will be placed in a muffle furnace at 600°C for an hour. It was cooled in a desiccator and then weighed (W_1). Sample of about 1.0 g was weighed (W_2) and transferred into the crucible. The example was lighted over a burner with the assistance of blowpipe, until scorched. At that point the cauldron was put in a suppress heater at 600°C for 6 hours to finish oxidation of all-natural tissue in the specimen. After the procedure, cauldron was cooled in the desiccator and the weight was noted W3. Percent rough fiery remains was computed and recorded as

$$\% \text{ Ash} = \frac{(W3 - W1) \times 100}{W2 - W1}$$

Where: W_1 = Weight of porcelain crucible,

W_2= Weight of porcelain crucible + slices,

W_3 = Weight of porcelain crucible + Ash.

3.7.6 Mineral analysis

Mineral analysis for Iron (Fe), Magnesium (Mg), and Calcium (Ca), Potassium(P) was done by Association of official Analytical chemist (AOAC) (2000). A mass of 1 g of the sample was weighed and 10-20 ml of nitric acid was added. The solution was digested till the volume reduced to almost half. About 10 ml sulphuric acids was added and digested until white fumes appeared and the solution cleared. About 10-20 ml of nitric acid was added and digested until the solution cleared. The arrangement was set in the instrument where it was warmed to vaporize and atomize the minerals. A light emission was gone through the atomized test, and the ingestion of radiation was measured and particular wave lengths comparing to the mineral of intrigue. The sort and convergence of the minerals introduce was acquired by measuring the area and power of the crests in the retention spectra.

3.7.7 Determination of Vitamin C

About 5g of sample was weighed and prepared. 20ml aliquot of the sample solution was pipetted into a 250 ml conical flask and about 50ml of distilled water added. 1 ml iodine solution was also added. Sample was then being titrated with 0.005M iodine solution. The endpoint of the titration was identified as the first permanent trace of a dark blue-black colour due to the starch-iodine complex using 1% starch as an indicator. Repetitions was carried out to until concordant results were obtained (titre agreeing within 0.1 ml) (AOAC, 2000).

$$\text{Ascorbic acid content (mg/100g)} = \frac{\text{titre x molarity of titrant x } 176.12 \text{ x } 100}{\text{weight of sample}}$$

3.7.8 Colour Determination

Tristimulus colour measurements (L*, a* and b* values) were performed using a chromameter CR-410 (Konica Minolta Inc. Osaka, Japan). The instrument was calibrated with a white reference tile (L*=97.52, a*=–5.06, b*=3.57) prior to measurements. The L* (0=black, 100=white), a* (+red, –green) and b* (+yellow, –blue) colour coordinates were determined according to the CIELAB coordinate colour space system.

Specimen bowl were fully filled with test samples and placed on the blank surface tile measuring unit. The Optical System was placed over the specimen bowl to start the measuring cycle by clicking on the measure button. Each sample was measured in triplicates. All samples were measure at ambient temperature. Result was displayed on the screen on the Chroma Meter.

3.8 Shelf life Determination

The shelf life of the cakes was determined using both microbiological and physicochemical index. The microbiological parameters used included total aerobic count, total Coliform count, yeast and mold counts whereas the physicochemical parameters considered includes moisture content and free fatty acid content as an index of rancidity and oxidation.

3.9 Shelf Life Using Microbiological Parameters

The shelf life using microbiological parameters lasted for a 14 days period under two storage conditions being refrigeration at 4^0C and storage at room temperature 25^0C.

3.9.1 Preparation of Malt Extract agar (MEA)

Agar powder (25 g) of MEA agar was suspended in 500ml of distilled water and brought to boil to dissolve completely. It was sterilized by autoclaving at 121°C for 15 minutes and allowed to cool to 50^0C and 50µg of Chloramphenicol added and swirled to dissolve. The resultant solution was poured into sterile Petri dishes.

3.9.2 Preparation of MacConkey agar

Agar powder (26 g) of MacConkey agar was suspended in 500ml of distilled water and brought to boil to dissolve completely. It was sterilized by autoclaving at 121°C for 15 minutes and allowed to cool to 50^0C and poured into sterile Petri dishes.

3.9.3 Preparation of Plate count agar

A known mass of 9g of Plate count agar powder was dissolved in 500ml of distilled water and heated to melt. The solution was autoclaved at 121^0C for 15 minutes and allowed to cool to 50^0C and dispensed into sterile Petri dishes. The plates were incubated overnight at 37^0C for sterility verification.

3.9.4 Serial dilution

Serial dilution was done to reduce a dense culture of cells to a more usable concentration. Each dilution done reduces the concentration by a certain amount. A mass of 5g of each sample were weighed and placed in 45ml of peptone water solution (1%). Subsequent dilutions were made by transferring 1ml from the stock dilution to 9ml of sterile diluent and mixing adequately to attain the dilution factors 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4}.

3.9.5 Determination of Yeast and Mold count

The yeast and mold count were carried out by spread plate method on malt extract agar (MEA). One milliliter aliquot from each of the dilution were inoculated into Petri dishes containing MEA. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 25 ºC for 120 hours.

3.9.6 Determination of Total Coliform Count

The Total Coliform Count (TCC) was carried out by spread plate method on MacConkey agar (MA). One milliliter aliquot from each of the dilution were inoculated into Petri dishes containing MacConkey agar. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 35 ºC for 24 hours.

3.9.7 Determination of Total Aerobic count

The total aerobic count was carried out to enumerate the total population of aerobic organisms in the water samples. Aliquots of one milliliter from each of the dilution were inoculated into already prepared Petri dishes of PCA. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 37 ºC for 24 hours.

3.10 Shelf life Determination Using Physicochemical Parameters

The physicochemical parameters used in the estimation of the shelf life included moisture content and free fatty acid content of the cakes. The methods used are same as described in 3.7.1 for moisture content.

3.11 Data Analysis

The analysis of variance (ANOVA) was used to determine significance of data. The differences in means were evaluated with Least Significant Difference (LSD) test using Statistical Package for the Social Sciences (SPSS) version 20. Statistical significance was denoted at 5%.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Acceptability of Beetroot Incorporated Cupcakes

The results from the sensory acceptability test carried out on the developed cupcake products are displayed in Table 4.1. From the results, sample WF100% had the most preferred appearance with a significantly higher ($p>0.05$) value of (8.13±0.62) and sample BRPa40% had the least (5.58±1.95) which was also significantly the lowest compared to the rest of the samples ($p<0.05$). Appearance preference was observed to have reduced with increasing substitution from 10% to 40% in both beetroot powder and beetroot paste fortified cupcake samples before increasing slightly in the 50% samples. The cupcake samples fortified up to the 30% level however showed significant similarities to the control 100% wheat flour sample. Sample BRPa40% had the least colour preference (5.16±1.54) as against samples BRPo10%, WF100% and BRPa20% with the most panelist preferences 7.94±0.77, 7.81±0.98 and 7.53±1.02 respectively. Colour preferences also reduced with increasing substitution from 10% to 50%. For the paste samples however, 20% beetroot paste fortified cupcake had a higher colour preference (7.53) compared to the 10% beetroot paste fortified sample (7.05). The colour preference then reduced to 5.16 in the 40% paste fortified sample before increasing again to 5.58 in the 50% beetroot paste fortified cupcake sample. Only the 10% and 20% beetroot paste fortified samples shared similarities with the control sample in terms of colour but the beetroot powder fortified samples share similarities with the control sample in terms of colour but the beetroot fortified samples shared similarities with the 100% wheat flour control cake up to the 40% substitution level. A similar trend was observed in the sponginess results as sponginess preference reduced with increasing substitution of wheat flour in the samples. The preference for sponginess ranged from 5.69±1.54 in 50% beetroot powder sample to 7.88±0.89 in 100% wheat flour sample. Aroma rankings ranged between 6.06 and7.63, however, there was no statistical significant difference between the panelists' preferences ($p<0.05$). The highest value however was recorded in the control 100% sample and the least in the sample substituted with 50% beetroot powder. Panelists preferred the taste of sample BRPo10% most (7.94±0.77) compared to the rest with samples BRPo50% the least preferred (5.19±2.17). Taste preference in samples containing beetroot powder decreased steadily from 7.94 in the 10% sample to 5.19 in the 50% sample. Meanwhile, taste preference reduced from 7.11 in 10% paste sample steadily to 5.84 in 30% sample before increasing again to 6.69 in 50% sample suggesting that increasing concentration of paste beyond 50% might actually improve taste of the cupcakes. The statistics reveal that adding beetroot powder up to the 20% level improves taste of the cupcakes but may be detrimental beyond the 20% level. However, the taste of the cupcakes do not show significant deteriorations with beetroot paste incorporated up to the 50% level ($p<0.05$). Mouthfeel preference was highest in 100% control sample and significantly not different from sample containing 10% beetroot powder ($p<0.05$). The least preference was recorded in sample containing 50% beetroot powder, which is also comparable to that in the 40% powder sample ($p<0.05$). The panelists' overall acceptability indicates that the most preferred sample was the control sample, which was "liked very much" (8.06±0.85). The next preferred sample that was approximately also "liked very much" was the sample with 10% wheat flour substituted with beetroot powder (7.99±0.68) and shared statistical similarities with the control sample. The least preferred sample was the 50% beetroot powder sample (5.50±1.55) ranked between "neither like nor dislike" and "like slightly". Overall acceptability also reduced when beetroot concentrations were increased. 10% and 20% beetroot samples were all ranked in the "like moderately" region and shared statistical similarities with the control 100% wheat flour sample ($p<0.05$).

Economically, to be able to reduce the use of wheat flour, there is the need to ensure maximum incorporation of beetroot powder while at the same time ensuring consumer acceptability of the product. The maximum replacement that will not affect consumer acceptability is at the level of 20% substitution as seen from the displayed attributes. In general, appearance, colour, sponginess, taste and mouthfeel preferences reduced with increase in beetroot powder and paste content. The same phenomena were recorded by Shivangi *et al*., (2019) and Singh and Hathan (2014). Alshehry (2019) reported that substituting wheat flour up to 7.5% and 10% produced acceptable cupcakes that did not differ significantly from the control. Awasthi (2014) reported that substituting up to 20% beetroot produces better physical and sensory characteristics.

Table 4.1: Consumer acceptability rankings for sample cupcake formulations with beetroot powder and paste

Sample	Appearance	Colour	Sponginess	Aroma	Taste	Mouthfeel	Overall Acceptability
BRPo50%	6.19 ± 1.76^{abcd}	5.75 ± 2.01^{abc}	5.69 ± 1.54^{a}	6.06 ± 1.69^{a}	5.19 ± 2.17^{a}	5.44 ± 1.63^{a}	5.50 ± 1.55^{a}
BRPo40%	5.75 ± 1.95^{ab}	6.19 ± 1.60^{abcd}	6.00 ± 1.37^{a}	6.13 ± 1.86^{a}	5.69 ± 1.85^{ab}	5.45 ± 2.03^{a}	5.88 ± 1.41^{ab}
BRPo30%	6.56 ± 1.36^{abcde}	6.38 ± 1.54^{abcd}	6.38 ± 1.67^{ab}	6.50 ± 1.71^{a}	6.06 ± 2.35^{abcd}	6.44 ± 1.67^{abc}	6.69 ± 1.74^{abcde}
BRPo20%	7.38 ± 0.89^{bcde}	7.38 ± 0.89^{bcd}	7.00 ± 1.26^{ab}	6.75 ± 1.77^{a}	7.63 ± 1.41^{cde}	7.25 ± 0.93^{bc}	7.38 ± 1.02^{bcde}
BRPo10%	7.69 ± 0.79^{de}	7.94 ± 0.77^{d}	7.31 ± 1.20^{ab}	7.50 ± 1.32^{a}	7.94 ± 0.77^{e}	7.38 ± 1.15^{c}	7.99 ± 0.68^{de}
WF100%	8.13 ± 0.62^{e}	7.81 ± 0.98^{d}	7.88 ± 0.89^{b}	7.63 ± 0.50^{a}	7.81 ± 1.11^{de}	7.81 ± 0.75^{c}	8.06 ± 0.85^{e}
BRPa50%	6.26 ± 2.23^{abcd}	5.58 ± 2.57^{ab}	6.16 ± 1.74^{a}	6.42 ± 1.22^{a}	6.89 ± 1.73^{abcde}	6.32 ± 1.34^{abc}	6.53 ± 1.90^{abcd}
BRPa40%	5.58 ± 1.95^{a}	5.16 ± 1.54^{a}	6.47 ± 1.74^{ab}	6.47 ± 1.78^{a}	6.79 ± 1.13^{abcde}	6.42 ± 1.17^{abc}	6.32 ± 1.89^{abc}
BRPa30%	5.95 ± 1.87^{abc}	5.63 ± 1.74^{abc}	5.89 ± 1.70^{a}	6.42 ± 1.64^{a}	5.84 ± 2.19^{abc}	5.63 ± 2.06^{ab}	6.68 ± 1.25^{abcde}
BRPa20%	7.47 ± 1.35^{cde}	7.53 ± 1.02^{d}	6.58 ± 1.57^{ab}	7.21 ± 1.18^{a}	6.74 ± 1.59^{abcde}	6.89 ± 1.52^{abc}	7.39 ± 0.76^{bcde}
BRPa10%	7.63 ± 1.01^{cde}	7.05 ± 1.51^{bcd}	6.95 ± 1.27^{ab}	6.89 ± 1.24^{a}	7.11 ± 1.45^{bcde}	6.58 ± 1.80^{abc}	7.37 ± 0.90^{bcde}

Values with the same superscripts along the columns are not significantly different ($p<0.05$).
BRPo50%-*beetroot powder,* ***BRPo40%***-*beetroot powder,* ***BRPo30%***-*beetroot powder,* ***BRPo20%***-*beetroot powder,* ***BRPo10%***-*beetroot powder,* ***WF100%***- *wheat flour,* ***BRPa50%***-*beetroot paste,* ***BRPa40%***- *beetroot paste,* ***BRPa30%***-*beetroot paste,* ***BRPa20%***-*beetroot paste,* ***BRPa10%***-*beetroot paste*

4.2 Physicochemical analysis of beetroot enriched cup cakes

The nutritional parameters considered in the assessment of the quality of the cupcakes included the moisture content, fat, protein and ash contents. The three formulations were tested for their proximate distributions and the details are discussed below.

Beetroot is a rich source of potent nutrients (Pinki and Pratima, 2014). These potent nutrients include proteins and carbohydrates. These nutrients are analyzed and reported as proximate composition of a food material. Table 4.2 shows the proximate composition of the beetroot cupcakes in this work.

4.2.1 Moisture Content of Beetroot Fortified Cupcakes

From the table, 4.2 samples with **BRPa50%** (50% beetroot paste) had the highest moisture content (30.11%) owing to the high moisture content of the paste added. The lowest moisture (11.77%) was recorded in the control sample WF100% (100% wheat flour) which is comparable to moisture content (11%) of commercial wheat flour reported by Chughtai *et al.,* (2016). It is observed that samples with beetroot flour had moderate moisture contents 16.33 and 17.62% for 20 and 50% beetroot powder respectively whilst the cakes with the paste had higher moisture contents. Nagib and Zidan (2019) however recorded the highest moisture content in their 100% wheat flour cake sample and decreasing moisture content with the addition of beetroot flour up to the 15% level.

4.2.2 Ash Content of Beetroot Fortified Cupcakes

Total ash is an indication of all minerals present in a food sample. The control sample contained 1.35% Ash. Sample **BRPa20%** was made up of only 1.04% ash as the least followed by sample

BRPa50% which contained 1.30%. Their ash contents nevertheless did not differ from that of the control. The samples BRPo50% and BRPo20% however, had 2.96 and 2.81% respectively which were significantly different from that of the control and paste incorporated samples ($p>0.05$). In a research by Nagib and Zidan (2019), recorded ash contents ranging from 3.54-4.76% in wheat flour cake control samples over a 21 day storage period. Ash contents for cake samples fortified with 15% beetroot powder ranged between 3.97% and 4.41%. These values are higher than those recorded in this work. Lucky *et al.* (2020), however recorded 1.02% ash content in their sample control wheat flour cake which was lower compared to the value recorded in this research work. They also recorded values ranging 1.72-2.84% for cakes fortified with beetroot powder from 5% to 20% level which are comparable to values recorded in this work.

4.2.3 Fat Content of Beetroot Fortified Cupcakes

The results show that there is no evident effect of the addition of beetroot on the fat content of cupcakes except for a 50% beetroot paste sample that showed a slight increase. The highest fat content (42.37%) was recorded in sample **BRPa50%** with 50% beetroot paste. The rest of the samples were not significantly different from each other with values ranging from 36.97 to 38.98%. Both wheat flour and beetroot are reported to have very low amounts of fat. This will count for a reason why the effect of the wheat flour and beetroot powder ratios is not seen on the fats.Chughtai *et al.,* (2016) reported fat of 2.5% for commercial wheat flour and 0.8% for beetroot flour. The high total fat is then more precisely being contributed by the shortening and eggs used as ingredients in the cakes (Atef *et al.*, 2011). Nagib and Zidan (2019) observed a decrease in fat content of cake samples with an increase in beetroot flour portion.

4.2.4 Crude Protein Content of Beetroot Fortified Cupcakes

The formulation **BRPa20%** again recorded the least protein content of 6.62±0.11% whereas formulation BRPo50% recorded the highest value of 11.01±0.51% thus setting the protein content of the cupcake formulations within the range of 6.62±0.11% to 11.01±0.51%. The statistics show a high significant difference ($P<0.05$: $P=0.0064$) in the protein constitution of the cupcake formulations. It is evident that the 100% wheat flour formulation maintained a moderate protein content among the samples. Substituting the wheat flour with beetroot powder increased the protein contents of the cupcake samples as observed in the increase up to 11.01±0.51% in the 50% substituted formulation. However, substituting with beetroot paste resulted in a slight decrease at 20% before increasing again to 6.93±0.35% at the 50% substitution level.

Proteins form a very important and key aspect of human diet as it is the major component of most hormones serving as functional proteins to regulate and control all life processes. Some proteins also play structural role by serving as constituents of membranes and organs to provide a solid framework and support for body stability and function.

4.2.5 Fibre Content of Beetroot Fortified Cupcakes

Beetroots are known to contain important nutrients for human health including antioxidants, vitamins, and fibre (Ingle *et al.,* 2017). Fibre recorded in this work ranged between 0.36 and 3.02%. The least fiber of 0.36% was recorded in the 100% wheat flour sample whereas the highest (3.02%) was recorded in the sample fortified with 50% beetroot powder. The fibre content was seen to be higher in the samples fortified with beetroot powder as compared with that fortified with beetroot paste. The fiber contents were significantly different for each sample. It is evident that beetroot contributes a substantial amount of fibre to the cupcakes and the concentration increased with increase in substitution percentage. Nagib and Zidan (2019) also reported the same increasing trend of fiber with increase in beetroot flour composition of cakes in their work.

4.2.6 Carbohydrate Content of Beetroot Fortified Cupcakes

Carbohydrate is one of the basic food groups that is important to a healthy diet. The results show a reducing trend with increase in beetroot paste or powder incorporation. The highest percentage of carbohydrate was recorded in the 20% powder incorporated sample with 33.06%. The lowest was observed in the sample incorporated with 50% paste (18.93%). The 20% beetroot powder and paste samples recorded similar values which significantly not different at the 95% confidence interval. Dhawan and Sharma (2019) reported a carbohydrate content of 77.74% for beetroot flour used in their work. This would be expected to make significant contributions to the carbohydrate contents of samples in which the beetroot contents are high. However, the high fat contents resulting from the high shortening ingredients used may be responsible for this decrease in carbohydrates when beetroot flours are incorporated into cakes. Nagib and Zidan (2019) on the contrary, recorded increases in carbohydrate contents with increase in beetroot flour in cake samples in their research.

Table 4.2: Proximate compositions of sample fortified beetroot cakes

Sample Code	Moisture	Total Ash	Total Fat	Crude Protein	**Fiber**	Carbohydrate
WF100%	11.77±0.5^{b}	1.35±0.30^{a}	38.98±0.73^{a}	7.27±0.10^{ab}	0.36±0.01^{a}	31.45±1.07^{bc}
BRPo20%	16.33±0.14^{a}	2.81±0.03^{b}	36.97±0.40^{a}	7.82±0.18^{b}	1.38±0.04^{d}	33.06±0.65^{c}
BRPo50%	17.62±0.23^{a}	2.96±0.23^{b}	38.65±0.49^{a}	11.01±0.51^{c}	3.02±0.04^{e}	28.89±1.48^{b}
BRPa20%	20.54±0.04^{b}	1.04±0.45^{a}	38.39±0.57^{a}	6.62±0.10^{a}	0.49±0.01^{b}	32.93±0.26^{c}
BRPa50%	30.11±0.54^{c}	1.30±0.26^{a}	42.37±1.03^{b}	6.93±0.35^{ab}	0.88±0.18^{c}	18.93±0.11^{a}

Values with the same superscripts along the columns are not significantly different (p<0.05). BRPo50%-beetroot powder, ***BRPa20%****-beetroot paste, BRPo20%-beetroot powder,* ***BRPa50%****-beetroot paste, WF100%-wheat flour (Control)*

4.3 Mineral and Vitamin C Content of Beetroot Fortified Cupcakes

4.3.1 Mineral Composition of Beetroot Fortified Cupcakes

Results of the mineral and vitamin C composition of the most preferred cupcakes from the sensory analysis are shown in Table 4.4. Sample WF100% had the highest Iron concentration of 1.80 mg/100g whilst **BRPa20%** had the lowest of 0.68 mg/100g. Samples BRPo50% and **BRPa50%** recorded 1.36 and 0.71 mg/100g, respectively. The concentration of Iron (Fe) in the samples fortified with beetroot paste at the 20% and 50% levels were however not significantly different (p<0.05).The concentrations in the beetroot powder fortified samples were higher than in the beetroot paste fortified samples. In both cases, increasing beetroot concentration from 20% to 50% increased Fe concentrations in the cupcakes. The highest Calcium concentration (59.21 mg/100g) and the lowest (24.80 mg/100g) were observed in samples BRPo50% and WF100% respectively. Sample BRPo20% recorded the second lowest Ca concentration of 29.51 mg/100g.

It is evident that beetroot significantly contributed to the Calcium concentrations in the resultant fortified cupcakes. The results show that increasing beetroot paste concentration from 20% to 50% significantly reduces the calcium concentration while increasing the beetroot powder concentration from 20% to 50% results in significant increase in calcium concentration. Potassium concentrations was highest (94.33 mg/100g) in sample BRPo50% and lowest (28.59 mg/100g) in sample WF100%. Sample BRPo20% followed BRPo50% with 56.71 mg/100g as the next highest potassium concentration. From the results, it is evident that Potassium concentrations differ at the different concentration levels significantly. Potassium is the most abundant mineral in the beetroot cupcakes among the three minerals determined and Iron the least. It can also be observed that sample BRPo50% (50% beetroot powder) had highest Calcium and Potassium concentrations as well as a substantial concentration of Iron. This can be attributed to the effect of dehydration that concentrated the minerals in the beetroot powder before consequent compositing with the wheat. It is also evident that compositing wheat flour with beetroot paste or powder significantly increases calcium and potassium contents but decreases iron contents before increasing at higher compositing percentages. A similar phenomenon was observed by Emelike *et al.*, (2015) when they sun and oven dried beetroot juice. They recorded substantial increments in Calcium and Potassium when the juices were dried. They also recorded reductions in Iron concentration after drying which explains why samples supplemented with beetroot powder had lower concentrations compared to the control. Kale *et al.,* (2018) reported values for the mineral composition of fresh beetroots. It contained 30.12 mg/100g of Potassium, 12.20 mg/100g of Calcium and 0.75 mg/100g of Iron. Calcium and Potassium recorded in this experiment are higher than as reported in the fresh beetroot due to the dehydration effect which increases the concentration of minerals in the resultant dry matter whilst Iron values are comparable to that in the fresh according to Emelike *et al*,, (2015). Dhawan and Sharma (2019) also reported Iron content of 4.14 mg/100g for beetroot flour used in their research, which is higher compared to what was recorded in this work. They however reported a Calcium content of 160.32 mg/100g, which is lower than recorded in this research work, which can be attributed to the freeze-drying method used in the research.

Beetroots are regarded as a rich source of minerals (potassium, sodium, iron, copper, magnesium, calcium, phosphorus and zinc), vitamins (retinol, ascorbic acid and B-complex) among others (Lundberg *et al*., 2008 and van Velzen *et al*., 2008). For this reason, they are being considered in the development of various health food products.

4.3.2 Vitamin C Composition of Beetroot Fortified Cupcakes

Beetroots are also known for their powerful antioxidant, anti-inflammatory and vascular protective properties. Their antioxidant properties are ascribed to their betalain and Vitamin C contents and are known to be responsible for fighting cancers (Váli *et al.*, 2007; Clifford *et al.*, 2015). Kazimierczak *et al.,* (2014) reported fresh juice extracts of conventional beetroots to contain 69.8-88.1 mg/kg and organic beetroots to contain 77.8-118.5 mg/kg of Vitamin C in their research. The extracted juices were then freeze dried and reported to contain 153.6-160.1 mg/kg and 207.4-209.1 mg/kg of fresh weight for the conventional and organic samples respectively. Substantial increase in values were realized after freeze drying of the fruit juice and there doesn't seem to be any loss of Vitamin C during the freeze drying. Dhawan and Sharma (2019) also recorded 4.2 mg/100g of Vitamin C in beetroot flour used in their work. This value is low and can be due to loss of vitamin C as they used sun drying and oven drying as dehydration methods.

However, is evident that the values recorded for Vitamin C in this work are higher than recorded for the raw beetroot flours. The control sample WF100% contained 94.92 mgAAE/100g which was higher than samples **BRPa20%** (20% beetroot paste) 92.49 mgAAE/100g and **BRPa50%** (50% beetroot paste) 90.22 mgAAE/100g. The highest Vitamin C content was recorded in sample BRPo50% (50% beetroot powder) 216 mgAAE/100g and the second highest in sample BRPo20% (20% beetroot powder) 105.48 mgAAE/100g. This shows that the addition of beetroot paste did not improve Vitamin C content of the cakes. Sample with 50% paste had the least suggesting a decrease further down as paste percentage increased. This could also suggest that Vitamin C in paste or soluble forms are more susceptible to heat degradation.

Table 4.3: Mineral (mg/100g) and Vitamin C (mgAAE/100g) composition of cake samples

Sample Code	Fe	Ca	K	Vitamin C
BRPo50%	1.36 ± 0.11^{c}	59.21 ± 1.74^{e}	94.33 ± 1.27^{e}	216.49 ± 0.64^{d}
BRPa20%	0.68 ± 0.04^{a}	35.34 ± 1.15^{d}	36.14 ± 0.94^{c}	92.49 ± 0.85^{ab}
BRPo20%	0.79 ± 0.01^{b}	29.51 ± 4.09^{b}	56.71 ± 2.84^{d}	105.48 ± 1.44^{c}
BRPa50%	0.71 ± 0.05^{a}	33.65 ± 3.76^{c}	34.60 ± 0.40^{b}	90.22 ± 0.87^{a}
WF100%	1.80 ± 0.44^{d}	24.80 ± 1.00^{a}	28.59 ± 2.10^{a}	94.92 ± 0.27^{b}

Values with the same superscripts along the columns are not significantly different (p<0.05). BRPo50%-beetroot powder, ***BRPa20%****-beetroot paste, BRPo20%-beetroot powder,* ***BRPa50%****-beetroot paste, WF100%-wheat flour (Control)*

4.4 Texture Properties of Beetroot Fortified Cupcakes

The hardness of a food substance is related to the strength of the food material under compression and is the peak force during the first compression cycle (Chandra & Shamasundar, 2015). Table 4.5 shows results of the Texture Profile Analysis of the cupcake samples. The results show that the hardest cake sample is the sample made from 100% wheat flour (0.38±0.14 N). The softest is the that containing 50% beetroot paste (0.11±0.01 N). The hardness of the beetroot powder incorporated samples and the 20% paste incorporated samples were however significantly not different. The softness of the 50% paste incorporated sample can be attributed to the high moisture content of the paste incorporated samples as seen from the proximate results.

The hardness in the samples with beetroot powder can be attributed to the hardness of beetroot fibers during baking and the low moisture contents evident from the proximate compositions. Accordimg to Szczesniak (2002), hardness in sensory terms is the maximum force required to chew or compress a food substance between the molar teeth. This can also be interpreted as the resistance to chewing. This means that, 100% wheat flour sample will require more force when chewing or eating.

Cohesiveness or consistency indicates the strength of the internal bonds holding the food particles together and the extent to which the food material can be deformed before it raptures or breaks (Radocaj *et al*., 2011). According to Chandra and Shamasundar (2015), cohesiveness expresses how strong the product can hold together. From Table 4.4, the sample made from 20% beetroot paste had the highest cohesiveness (1.40±0.35), and sample made of 20% beetroot powder had the least cohesiveness (1.00±0.13). The samples with beetroot powder incorporated have lower cohesiveness compared to those incorporated with beetroot paste. Cohesiveness may be related to how starchy a product is and the highest cohesiveness in the paste-incorporated cakes can be attributed to the effect of the high moisture contents helping to bind the food molecules together. The fresh fibers in the paste may also contribute to this effect. There is however no statistical significant difference between the cohesiveness of the samples at the 95% confidence interval.

Springiness is simply how elastic a product is. Springiness is related to the height that a food substance recovers between the time the first bite ends and the second bite starts when the food material is being eaten. In effect, if springiness is high, it requires more mastication energy as the food material quickly recovers its height during biting or eating (Rahman and Al-Mahrouqi, 2009).

From the results, there is no statistically significant difference between the springiness of the samples at the 95% confidence interval. However, the springiness is highest in the 50% beetroot powder sample (10.62±1.34 mm) followed by the sample with 20% paste incorporated as second highest (10.20±1.24 mm). Beetroot paste 50% sample was found to have the least springiness of 7.19±2.60 mm. This shows that substitution of beetroot paste and powder into cupcakes makes them easier to bite or chew or eat but have no influence on the springiness of cupcakes.

Adhesiveness relates to texture in food materials and high values correspond to softness. It is deemed to be a representation of the work required to overcome the attractive forces between the surface of a food and the surface of other materials with which the food comes into contact with (Kasapis, 2009). In a similar work carried out by Gupta *et al*. (2009), where they incorporated barley flour into sponge cakes, they found out that the flour had no effect on the adhesiveness of the products. However, springiness values decreased slightly with increasing percentage of substitution whilst cohesiveness increased. In this research also, substituting beetroot paste and powder into cupcakes did not affect the adhesiveness of the cupcake samples. The results show that the highest adhesiveness is observed in the 100% wheat flour cupcake (0.98±0.37 mJ). Samples fortified with beetroot paste recorded the least values of 0.61 mJ and the samples fortified with beetroot powder recorded higher values compared to the beetroot paste samples. This shows that incorporating beetroot paste into cupcakes makes them softer and reduces the work required to break the forces of attraction between the food particles and surfaces with which they are in contact. Hence, these products will not stick to surfaces or containers.

Table 4.4: Texture properties of beetroot fortified cupcakes

Code	Hardness (N)	Cohesiveness	Springiness (mm)	Adhesiveness (mJ)
BRPa50%	0.11 ± 0.01^{a}	1.39 ± 0.50^{a}	7.19 ± 2.60^{a}	0.61 ± 0.08^{a}
BRPo20%	0.27 ± 0.03^{ab}	1.00 ± 0.13^{a}	9.74 ± 0.45^{a}	0.80 ± 0.06^{a}
BRPo50%	0.21 ± 0.02^{ab}	1.08 ± 0.38^{a}	10.62 ± 1.34^{a}	0.72 ± 0.04^{a}
WF100%	0.38 ± 0.14^{b}	1.19 ± 0.81^{a}	10.01 ± 0.74^{a}	0.98 ± 0.37^{a}
BRPa20%	0.16 ± 0.01^{ab}	1.40 ± 0.35^{a}	10.20 ± 1.24^{a}	0.61 ± 1.27^{a}

Values with the same superscripts along the columns are not significantly different (p<0.05). ***BRPo50%****-beetroot powder,* ***BRPa20%****-beetroot paste,* ***BRPo20%****-beetroot powder,* ***BRPa50%****-beetroot paste,* ***WF100%****-wheat flour (Control*)

4.5 Colour Properties of Beetroot Fortified Cupcakes

Colour is one of the main properties of food that acts as an indicator of quality and acceptability. It is also one of the main attributes that drive consumer attraction (Alshehry, 2019). The colour of the crust and crumb of the cupcakes were analysed using the Hunter **L a b** system. According to Song *et al*. (2016), the Hunter **L a b** system is based on the concept of a colour space with the colour space defined by three (3) coordinates. The vertical coordinate (L) runs from L=0 (Black) through Grey to L=100 (White). The horizontal coordinate (a) runs from -a (Green) through Grey to +a (Red) whiles the second horizontal coordinate (b) runs from -b (Blue) to +b (Yellow). Other colours are thought to be intersections under these coordinates. The results for the colour analysis of the cupcakes is shown as in Table 4.5.

From the results, the L values indicate that the cake samples have a little dark (black) colour. However, samples made from 100% wheat flour notably have some whiteness (light colour). In general, it is observed that samples with 100% wheat flour and 20% beetroot powder or paste had darker crusts compared to crumbs. For a sample with 20% paste, the L value for crust colour is 33.09±0.23 which increases (becomes lighter or whiter) to 38.65±0.23 in the crust. The sample with 20% powder had a crust L value of 33.68±0.23 which increased (became whiter) in the crumb to 36.16±0.19. The opposite is observed in samples with 50% beetroot powder where the L value decreased from 29.79±0.30 to 23.35±0.51 meaning the crumb is blacker or darker than the crust. The L value for 50% beetroot paste sample decreased from 29.39±0.17 in the crust to 27.48±0.90 in the crumb. There is no statistical difference between the means of the crust colours of the samples made from 20% beetroot paste and powder. The same is observed for 50% beetroot paste and powder incorporated samples. It is evident that increasing beetroot component darkens cupcake crumb colours.

From the table, the highest **a** value (12.22±0.01) was recorded for the sample made of 100% wheat flour on its crust. The same sample recorded the least (-0.83±0.04) in the crumb. This means that the cake crust has red colour hues whilst the crumb has green colour hues. It can be noted that the red colour hue is higher in the crusts for the control 100% wheat flour sample, and 20% beetroot paste and powder incorporated samples compared to their crumbs. Also, the red value is higher in the 20% samples compared to the 50% samples. **b** value for the samples range from 1.05-26.26. The highest value was recorded in the crust of the 100% wheat flour cake. The least was recorded in the crust of the 50% beetroot powder cake. It is observed that with the exception of the control cake, the crumb of all samples have higher yellowness than the crusts. This can be attributed to darkness observed in the crusts based on the L values. Also, the crust serves as the surface for the heat related Maillard and caramelization reactions that lead to browning of the crust hence masking the yellowness (Aydogdu *et al*., 2017). The samples with beetroot paste have higher **b** values in the crumbs compared to that of the samples with the powder incorporated. The incorporation of beetroot into the samples reduces the white, the red and the yellow colours of the cupcake samples. A further increase reduces the colour properties further. A similar trend was recorded by Alshehry (2019) in the utilization of beetroot as a natural pigment in cakes. A gradual decrease in brightness and yellowness was recorded with increased substitution. According to Ayadi *et al*. (2009), brown index, yellowness and brightness all increase proportionally with the dominance of commercial flour in the mixture.

Browning is a general term used to describe colour formation in bakery products due to non-enzymatic chemical reactions known as Caramelization and Maillard reaction. These reactions are also thought to contribute flavor developments in baked products (Purlis, 2010). According to Buera *et al.,* (1986), browning index (BI) is one of the most common indicators of browning in sugar containing foods and it is used as a measure of brown colour purity in such foods. The browning indices of the cupcake samples are shown in Table 4.5. The results show that sample without beetroot paste or powder has the highest BI of 78.78% in the crust. The crumb however has a BI of 36.58%. The lowest BI (11.13) was recorded in the crust of sample made from wheat flour substituted with 50% beetroot powder (BRPo50%) which was significantly not different from sample substituted with 50% beetroot paste (BRPa50%) which recorded 12.23%). It is evident from the results that the crust of the cakes presented lower BI values compared to the crumbs except in the control 100% sample where the BI in the crumb was lower. According to Purlis (2010), the products of Maillard reaction and Caramelization that are responsible for browning in the cakes are chiefly, hydroxymethyl furfurals and melanoidins. Also, these chemicals are more pronounced in the crust because the reaction is temperature dependent and the surface is where there is maximum temperature impact. Hence, the high BI in the cake crust of control sample. In the substituted samples however, the lower values in the crust can be attributed to the disintegration of beetroot pigments chiefly anthocyanins that may result in darker colours instead of brown. This also accounts for the higher BI values in the crumbs of the substituted cupcakes as the impact of temperature in the inner cores of the products is less compared to the surface. In general, increasing the substitution of beetroot in the products reduces the BI meaning that side colours are produced that contaminates the brown colour of the products.

Table 4.5: Colour properties and browning index (%) of beetroot fortified cupcakes

Sample	Part of cake	L	a	b	Browning Index (%)
BRPa20%	Crust	33.09±0.23^{d}	6.55±0.07^{d}	5.48±0.04^{c}	32.07±0.54^{d}
	Crumb	38.65±0.23^{f}	2.70±0.01^{bc}	13.80±0.13^{e}	48.39±0.18^{f}
BRPo50%	Crust	29.79±0.30^{c}	3.19±0.03^{c}	1.05±0.00^{a}	11.13±0.18^{a}
	Crumb	23.35±0.51^{a}	8.60±0.40^{e}	6.50±0.35^{d}	58.42±1.87^{g}
BRPa50%	Crust	29.39±0.17^{c}	2.62±0.01^{b}	1.71±0.01^{a}	12.23±0.08^{a}
	Crumb	27.48±0.90^{b}	2.57±0.05^{b}	6.92±0.35^{d}	35.39±0.52^{e}
WF100%	Crust	55.43±0.67^{g}	12.22±0.01^{f}	26.26±0.35^{g}	78.78±0.13^{h}
	Crumb	65.58±0.15^{h}	-0.83±0.04^{a}	21.00±0.02^{f}	36.58±0.12^{e}
BRPo20%	Crust	33.68±0.23^{d}	6.42±0.08^{d}	3.00±0.01^{b}	22.68±0.05^{b}
	Crumb	36.16±0.19^{e}	6.16±0.01^{d}	4.75±0.03^{c}	26.08±0.08^{c}

Values with the same superscripts along the columns are not significantly different ($p<0.05$). BRPo50%-beetroot powder, ***BRPa20%****-beetroot paste, BRPo20%-beetroot powder,* ***BRPa50%****-beetroot paste, WF100%-wheat flour (Control)*

4.6 Antioxidant Activity of Beetroot Fortified Cupcakes

In the human body, reactive oxygen species and free radicals are produced due to oxidative stress and may lead to peroxidation of biomolecules such as lipids and proteins. Consequently, these may lead to DNA damage and cause memory impairments because the brain tissue is the most sensitive to the effect of free radicals. (Vincent *et al*, 2004; Rasoolijazi *et al*, 2015; Sulakhiya *et al*, 2016). The use of medicinal plants with high levels of antioxidant components is one of the most efficient ways to minimize the adverse effects of free radicals and treat diseases. One of such potent sources of extracts is thought to be beetroot because of its high antioxidant components (Zaidi *et al*, 2014). The DPPH method was chosen because the testing is simple, easy, fast and requires only a small sample. The antioxidant activity of the cupcake extract was expressed in percent (%) inhibition of DPPH radicals with gallic acid as standard. Table (4.6) shows the results of the antioxidant activity of the prepared cake sample extracts.

The highest antioxidant activity was observed in the sample with 50% beetroot powder with 14.98% inhibition of DPPH free radicals. This was followed by the 100% wheat flour sample with inhibition of 10.55%. The least activity was observed in the 20% beetroot powder sample. No regular patterns are visible in the results of the antioxidant activities of the samples. Sample with 20% paste had a higher antioxidant activity of 7.96% compared to 50% paste sample with 5.06%. However, the sample with 50% beetroot powder had a higher activity (14.98%) compared to 4.05% for the sample with 20% beetroot powder. It is evident that substitution with beetroot paste and powder up to the 50% level has no significant effect on the antioxidant activity or potency of cupcake samples. According to Canadanovic-Brunet *et al*. (2011), the reducing power of all beetroot pomace extracts increases with increasing concentration. Olumese and Oboh (2016) also reported that heat treatment increased the flavonoids present in their beetroot samples with a corresponding increase in ABTS and FRAP scavenging activities. However, beetroot incorporated into cupcakes did not improve the antioxidant power of the cakes in this work.

Table 4.6: Antioxidant activity of beetroot fortified cupcakes

Sample	Antioxidant activity (%Inhibition)
BRPa50%	5.06±0.31^{a}
BRPo20%	4.05±0.50^{a}
BRPo50%	14.98±0.62^{d}
WH100%	10.55±0.69^{c}
BRPa20%	7.96±0.38^{b}

Values with the same superscripts along the columns are not significantly different ($p<0.05$). BRPo50%-beetroot powder, ***BRPa20%****-beetroot paste, BRPo20%-beetroot powder,* ***BRPa50%****-beetroot paste, WF100%-wheat flour (Control*)

4.7 Shelf life Determination

The shelf life of the most preferred product formulations (BRPo20% and **BRPa20%**) which are formulations with 80:20 flour to beetroot composition, was estimated using both microbiological (Total Aerobic Count, Total Coliform Count, yeast and mold counts) as well as (moisture) determinants.

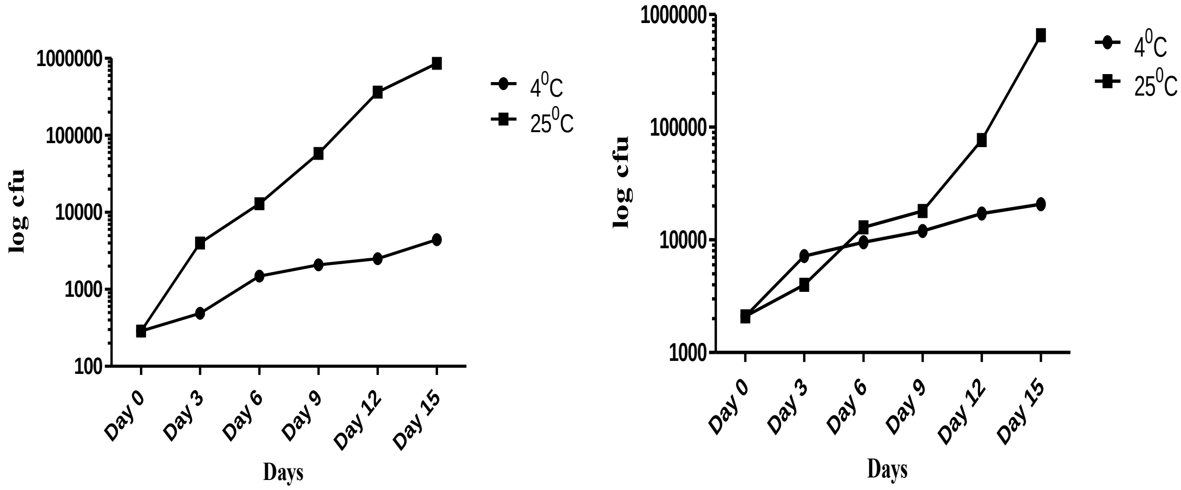
4.7.1 Shelf life Determination Using Microbiological Determinants

The findings of the microbial quality and safety of the cupcakes showed a positive and good quality index with no food pathogens (*Escherichia coli* and *Staphylococcus aureus*) detected in the products. The fungi assay also indicated no yeast and molds to have been present in the cupcakes as at day 0 of preparation. The quantitative assays however indicated some aerobes and Coliforms to be present in the samples though within the acceptable limits with a total aerobic count of $2.6\times10^{2}\pm6.02$ cfu/g and a total Coliform count of $5.6\times10^{1}\pm2.02$ cfu/g for the product formulation with code **BRPa20%**. The formulation BRPo20% recorded relatively higher microbial loads with an aerobic count of $2.1\times10^3\pm1.23$ cfu/g and a Coliform count of $6.0\times10^2\pm7.01$cfu/g.

Table 4.7: Microbial quality and safety of beetroot fortified cupcakes

Test	**Cupcake with beetroot paste (BRPa20%)**	**Cupcake with beetroot powder (BRPo20%)**
Total aerobic count	$2.6\times10^2\pm6.02$	$2.1\times10^3\pm1.23$
Total coliform count	$5.6\times10^1\pm2.02$	$6.0\times10^2\pm7.01$
Yeast	0.00	0.00
Mold	0.00	0.00
E. coli	Not detected	Not detected
S. aureus	Not detected	Not detected

The data obtained from the preliminary quality assessment highlighted the TAC as the microbial indicator to be used for the shelf life determination.



A **B**

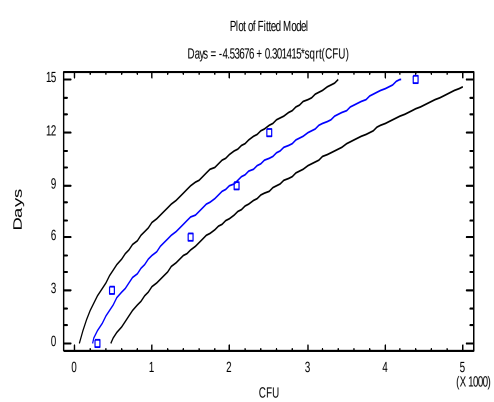
Figure 4.1: TAC of cupcakes fortified with beetroot paste (A) and beetroot powder (B) at 4ºC and 25ºC over time

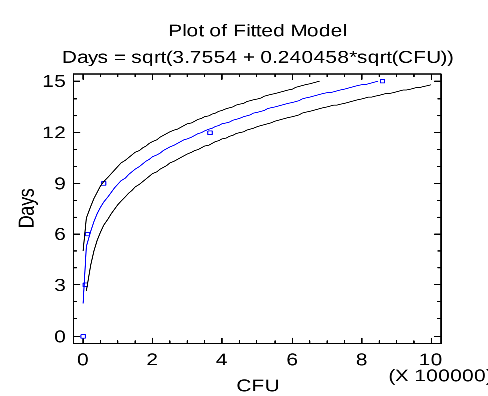
The trend observed in the progress across days showed an increasing microbial load over time as can be seen in Figure 4.2. The pattern shows that of higher increase in the products stored at room temperature as compared to the refrigerated samples for both beetroot powder and paste fortified cakes.

The statistical computation of the data showed significant difference ($P<0.05$: $P=0.0001$) in the aerobic counts of the cupcakes stored under refrigeration and room temperature. A further Post Hoc analysis using the Bonferroni tool showed the differences to have varied significantly after day 9 of storage.

The shelf life of the cupcake fortified with beetroot paste was estimated to be 26 days when refrigerated and 5 days when stored at room temperature.

Conditions	**Model**	**Equation**	**Shelf life**
4^0C	Square root-X model: Y = a + b*sqrt(X)	Days = -4.53676 + 0.301415*sqrt(CFU)	26 days
25^0C	Squared-Y square root-X: Y = sqrt(a + b*sqrt(X))	Days = sqrt(3.7554 + 0.240458*sqrt(CFU))	5 days





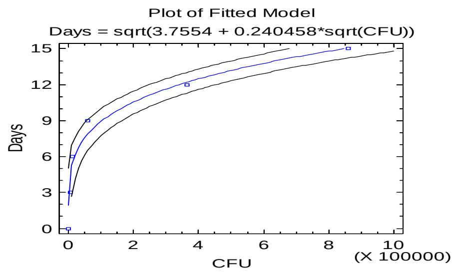


Figure 4.2: Shelf life of cupcakes fortified with beetroot paste

The cupcakes fortified with beetroot powder however recorded relatively shorter shelf lives with an estimated storage period of 7 days when refrigerated and 5 days when stored at room temperature.

Conditions	Model	Equation	Shelf life
4⁰C	Double-squared: Y = sqrt(a + b*X^2)	Days = sqrt(-8.82337 + 5.41279E-7*CFU^2)	7 days
25⁰C	Linear model: Y = a + b*X	Days = 5.51047 + 0.0000154888*CFU	5 days

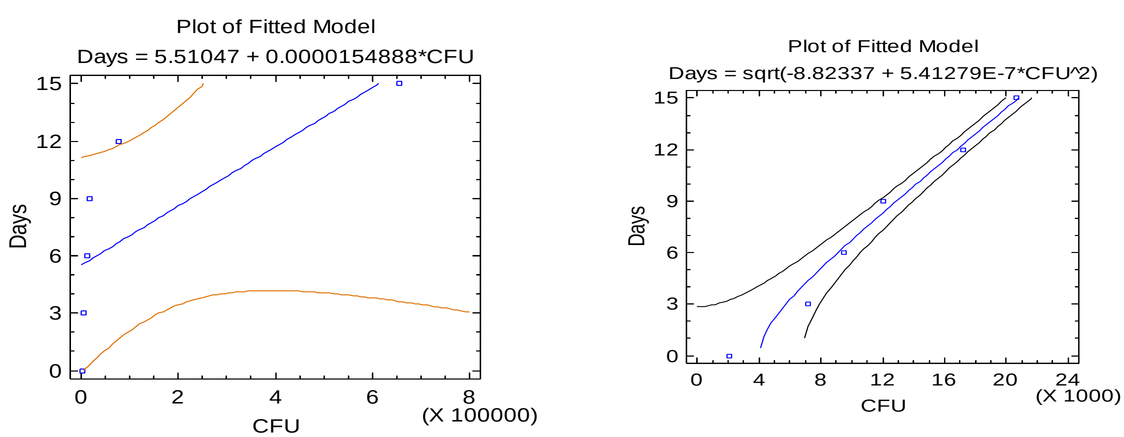


Figure 4.3: Shelf life of cupcakes fortified with beetroot powder

4.7.2 Shelf life determination using Physicochemical determinants

The study also considered using the moisture content as determinant of the shelf life considering the contribution of moisture to the activity of spoilage organisms.

The data obtained after the storage period indicated a trend of increasing moisture content values with increasing time.

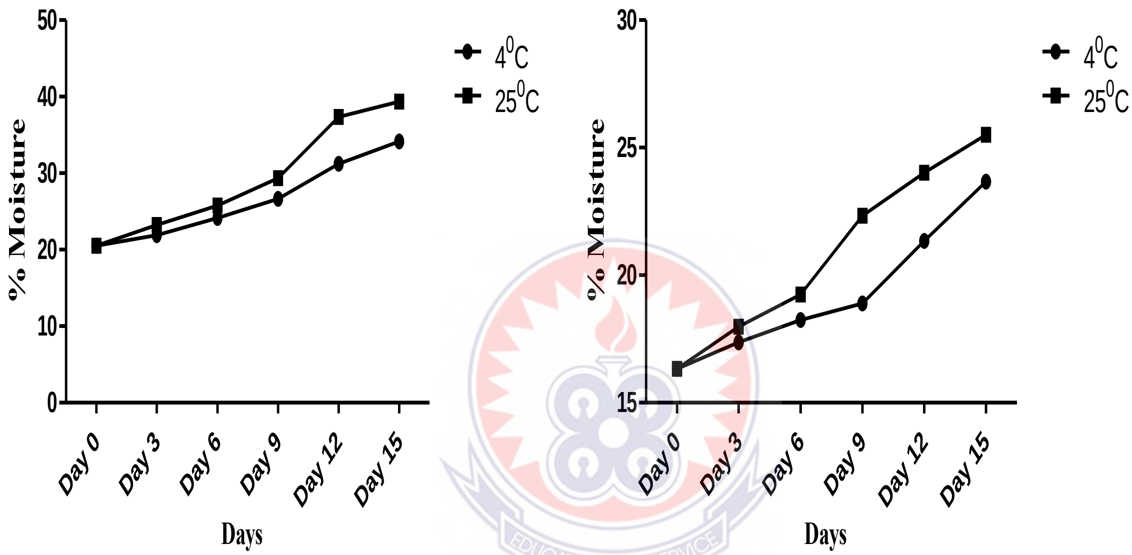


Figure 4.4: Moisture content of beetroot fortified cupcakes over time during storage

The data indicates the cupcakes fortified with beetroot paste (**BRPa20%**) have relatively higher moisture contents (20.539%) as opposed to those fortified with beetroot paste (BRPo20%) with moisture content of 16.329. The statistical computation of the data gathered showed significant difference ($P<0.05$:$P=0.0301$) in the moisture contents of the cupcakes stored at the different temperatures over time. The trend shows the samples stored at room temperature to have relatively higher moisture contents over time as opposed to those stored refrigerated.

The shelf life of the cupcakes fortified with beetroot paste was estimated to be 12 days when refrigerated and 9 days when kept at room temperature using the moisture content as predictor.

Conditions	Model	Equation	Shelf life
4^0C	Reciprocal-X model: Y = a + b/X	Days = 36.2232 - 734.358/Moisture	12 days
25^0C	Reciprocal-X model: Y = a + b/X	Days = 29.4563 - 607.545/Moisture	9 days

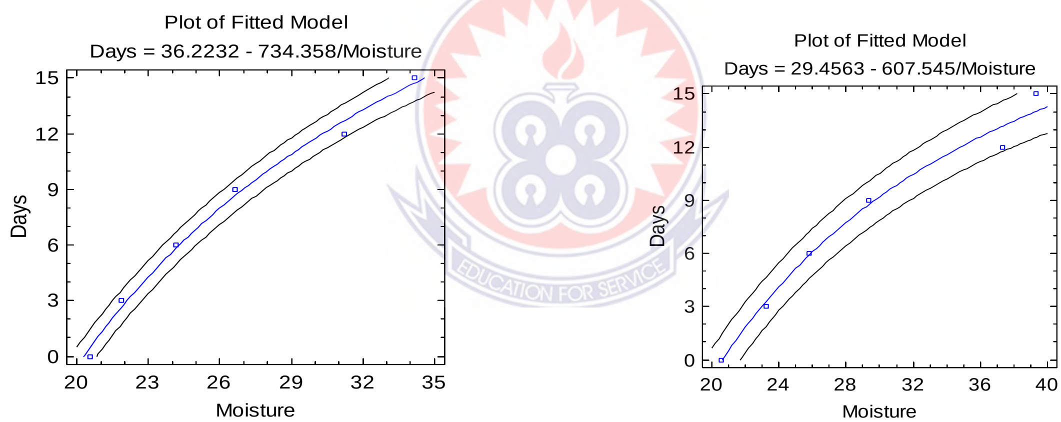


Figure 4.5: Shelf life of cupcakes fortified with beetroot paste using moisture content

The shelf life of the cakes fortified with beetroot powder was estimated to be 22 days when stored refrigerated and 20 days when stored at room temperature.

Conditions	Model	Equation	Shelf life
4^0C	Double-squared: Y = sqrt(a + b*X^2)	Days = sqrt(-218.8 + 0.794848*Moisture^2)	12 days
25^0C	Square root-X model: Y = a + b*sqrt(X)	Days = -56.6078 + 14.066*sqrt(Moisture)	9 days

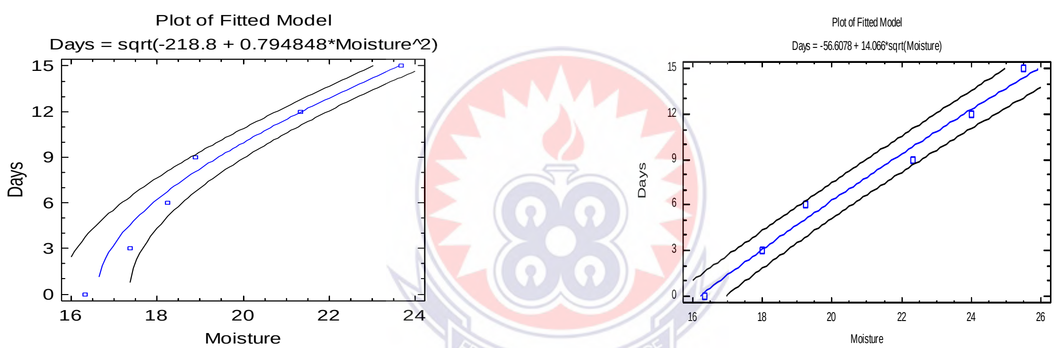


Figure 4.6: Shelf life of cupcakes fortified with beetroot powder using moisture content

4.7.3 Overall Shelf Life Determination

The ultimate shelf life of the products was estimated using a multiple regression of microbiological and physicochemical predictors. The shelf life of the cupcake fortified with beetroot paste was estimated to be 16 days when stored refrigerated and 8 days when stored at room temperature.

Conditions	Equation	Shelf life
4^0C	Days = -16.4336 + 0.00062534*TAC + 0.86126*Moisture	16 days
25^0C	Days = -14.7489 - 0.00000127791*TAC + 0.769804*Moisture	8 days

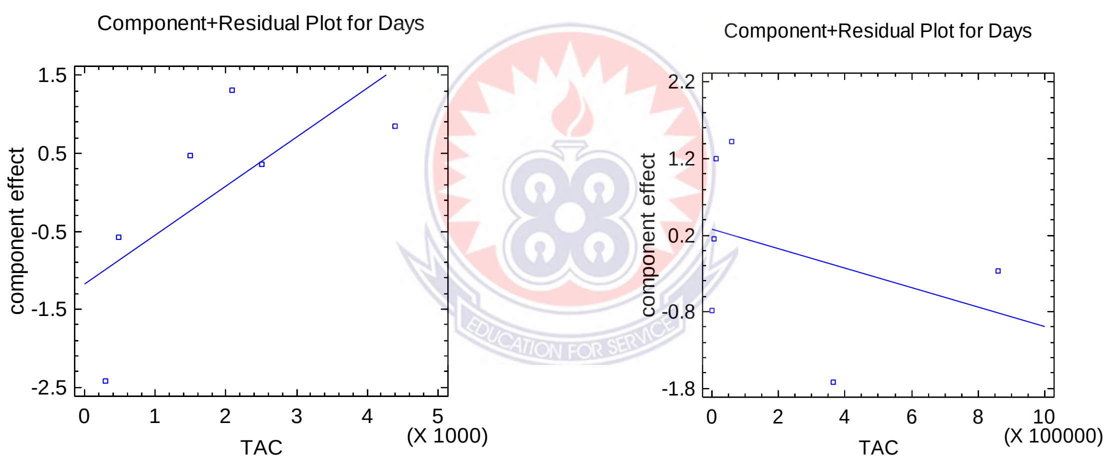


Figure 4.7: Shelf life of beetroot paste fortified cupcakes

The shelf life of the cakes fortified with beetroot powder was estimated to be 21 days when stored refrigerated and 4 days when stored at room temperature using a multiple regression of both microbiological and physicochemical predictors.

Conditions	**Equation**	**Shelf life**
4^0C	Days = 0.866831 + 0.000902232*TAC - 0.190956*Moisture	21 days
25^0C	Days = -23.6095 + 0.00000128485*TAC + 1.48038*Moisture	4 days

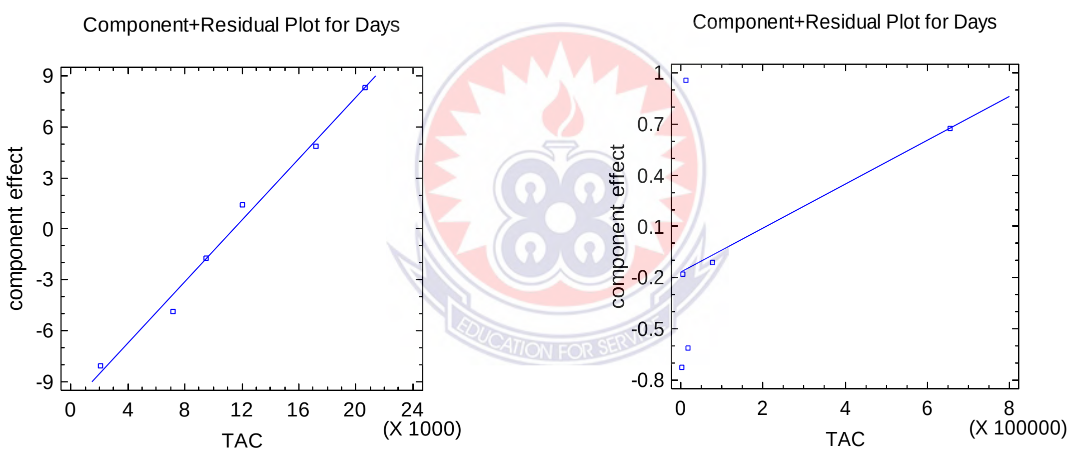


Figure 4.8: Shelf Life of cupcakes fortified with beetroot powder

Table 4.8: Shelf life of beetroot fortified cupcakes

Product	**Storage Condition**	**Shelf life**
Beetroot paste fortified cake	Refrigerated 4^0C	16 days
Beetroot paste fortified cake	Room temperature 25^0C	8 days
Beetroot powder fortified cake	Refrigerated 4^0C	21 days
Beetroot powder fortified cake	Room temperature 25^0C	4 days

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Substitution of beetroot in the form of powdered flour and paste into cupcakes aimed at improving nutritional and sensory properties of the cupcakes. The results show that sample WF100% which is the control 100% wheat flour cupcake had the most preferred sensory attributes across except for taste where sample BRPo10% (10% beetroot powder) was most preferred. It was ranked in the "like very much" region. Based on the acceptability rankings, sample BRPo10% is the next preferred sample after WF100%. The sample fortified with 20% beetroot powder however, shares similar acceptability with samples fortified with 10% powder as well as 10% and 20% paste statistically. The overall acceptability is observed to be highest (8.06±0.85: Like very much) for the control sample, followed by 7.94±0.68 for 10% beetroot powder fortified sample, 7.38±0.85 for the 20% beetroot powder fortified sample and then 7.37±0.76 and 7.37±0.90 for 20% and 10% beetroot paste fortified samples respectively all in the "like moderately" region. In general, it is evident that the overall acceptability reduced with increasing beetroot powder or paste incorporation. The maximum replacement that will not affect consumer acceptability is at the level of 20% substitution as seen from the displayed attributes. In general, appearance, colour, sponginess, taste and mouthfeel preference are reduced with increase in beetroot content.

Cupcake samples in this work had very low moisture contents demonstrated in the moisture of the 20% beetroot powder sample (16.33%). The moisture was higher in the paste-incorporated samples compared to the powder incorporated samples. Moisture tends to influence shelf-stability of food materials; hence, cakes with the powder incorporated should be more shelf stable. Ash contents were higher in the beetroot powder fortified samples compared to that of the paste fortified samples which did not have significantly higher contents with respect to the control sample. The 50% and 20% samples had 2.96 and 2.81% as the highest and next highest respectively ash contents respectively which also suggests they will have higher mineral contents. Beetroot did not contribute significant amounts of fat to the samples as well because no significant increases were observed in the fat contents of the fortified samples. The samples fortified with beetroot powder maintained higher protein contents compared to the samples fortified with beetroot paste. Sample containing 50% beetroot powder had 11.01±0.51% and sample containing 20% beetroot powder 7.82±0.18%. Substituting the wheat flour with beetroot powder increases the protein contents of the cupcake samples. The fiber content of the powder-incorporated samples was higher (1.38% and 3.02%) than in the control and the paste incorporated samples. Beetroot powder improved the fiber content of the cupcake samples. The highest percentage of carbohydrate was recorded in the 20% beetroot powder sample. The carbohydrate content decreased with increasing beetroot substitution.

The most dominant mineral in the fortified cupcakes is potassium. Samples with 50% and 20% beetroot powder which had the highest ash contents also had substantial amounts of the analyzed minerals. The fortification improved potassium and calcium contents of the cake samples did not show any significant improvements in Iron contents.

The control sample WF100% contained 94.92 mgAAE/100g and was higher than in the samples fortified with beetroot paste. The samples fortified with beetroot powder retained higher Vitamin C contents. The 50% beetroot powder sample contained 216 mgAAE/100g and the 20% beetroot powder contained 105.48 mgAAE/100g. Fortifying cupcakes with beetroot paste did not improve the Vitamin C content.

The texture properties of the cake samples did not differ in many ways. The main difference was seen in the hardness of the cake samples. The hardest cake sample was the control sample with a peak resistance of 0.38 N during the first compression cycle. Hardness is the resistance to chewing hence, the sample that will require more energy to chew will be the control sample. The cohesiveness, springiness and sponginess of the samples did not differ significantly. This suggests that substitution of wheat flour in cupcakes with beetroot paste and powder up to the 50% level does not affect sponginess, cohesiveness and springiness.

The colour properties of the cupcakes were significantly affected by the incorporation of beetroot paste and powder. In general, cupcake samples had darker crusts compared to crumbs. The crusts darkened with increasing percentage of substitution with beetroot. The sample with 20% powder for example, had a crust L value of 33.68±0.23 which increased (became whiter) in the crumb to 36.16±0.19. The same is observed for the cupcake crumbs. Increasing beetroot component darkens cupcake crumb colours. On the other hand, the crumbs of all the samples have higher yellowness than the crusts. This can be attributed to darkness observed in the crusts based on the L values. The darkness observed in the crusts mask the yellowness. The samples with beetroot paste have higher **b** values in the crumbs compared to that of the samples with the powder incorporated. The incorporation of beetroot into the samples reduces the white, the red and the yellow colours of the cupcake samples.

Browning index was highest in the crust of the control sample indicating a 78.78% purity of its brown colour. The purity however reduced drastically to 36.58% in the crumb. For the fortified samples, browning index was lowest in the crusts where temperature impact was highest and indicates the possibility of other by-products affecting the observed brown colour.

Antioxidant activity of the cupcake samples was observed in the sample with 50% beetroot powder with 14.98% inhibition of DPPH free radicals. The results however did not show any significant trend with the effect of fortification with beetroot. Substitution with beetroot paste and powder up to the 50% level did not show any significant effect on the antioxidant activity or potency of cupcake samples.

The shelf life of the cupcakes using biological determinants revealed that the sample fortified with 20% beetroot powder contained a higher microbial load transferring to a relatively shorter shelf life with an estimated storage period of 7 days when refrigerated and 5 days when stored at room temperature. However, the physicochemical determinants as predictors of shelf life revealed that the shelf life of the cakes fortified with beetroot powder increased to 22 days when stored refrigerated and 20 days when stored at room temperature. Ultimately, a multiple regression of microbiological and physicochemical predictors show a higher shelf life of 21 days when stored refrigerated but 4 days when stored at room temperature.

5.2 Recommendation

This work focused on the consumer acceptability of the formulated samples right after production. It is therefore recommended that future work focus on consumer acceptability of formulated samples over time (in hours or days). Also a baseline analysis should be performed on both paste and powder beetroot before incorporated in the cake. Also as beetroot is considered a functional food, future research could investigate the glycaemic response associated with the consumption of the beetroot-enriched cake compared with control cake. Another area of health beetroot has been found to be effective is in improving cardiovascular outcomes due to its rich nitrate content. Consequently, a clinical trial investigating the consumption of the beetroot–enriched cakes on cardiovascular function outcomes is worth considering.

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Appendix 2:

Statistical analysis of moisture content of cupcakes fortified with beetroot

Table Analyzed	Moisture
One-way analysis of variance	
P value	0.0093
P value summary	**
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	32.46
R square	0.9558

ANOVA Table	SS	Df	MS
Treatment (between columns)	77.55	2	38.77
Residual (within columns)	3.583	3	1.194
Total	81.13	5	

Appendix 2: Statistical analysis of ash content of cupcakes fortified with beetroot

Table Analyzed	Ash

One-way analysis of variance	
P value	0.0220
P value summary	*
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	17.58
R square	0.9214

ANOVA Table	SS	Df	MS
Treatment (between columns)	3.607	2	1.803
Residual (within columns)	0.3077	3	0.1026
Total	3.914	5	

Appendix 3: Statistical analysis of fat content of cupcakes fortified with beetroot

Table Analyzed	Fat

One-way analysis of variance	
P value	0.0835
P value summary	Ns
Are means signif. different? (P < 0.05)	No

Number of groups	3
F	6.350
R square	0.8089

ANOVA Table	SS	Df	MS
Treatment (between columns)	4.290	2	2.145
Residual (within columns)	1.013	3	0.3378
Total	5.304	5	

Appendix 4: Statistical analysis of protein content of cupcakes fortified with beetroot

Table Analyzed	Protein
One-way analysis of variance	
P value	0.0064
P value summary	**
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	41.80
R square	0.9654

ANOVA Table	SS	Df	MS
Treatment (between columns)	1.445	2	0.7227

Residual (within columns)	0.05187	3	0.01729
Total	1.497	5	