Sudan University of Science and Technology

College of Graduate Studies

Development of Gluten Free Cake From Beans (*Phaseolus vulgaris* L.)and Maize (*Zea mays* L.) Flours

تطوير كيك خالي من الجلوتين من دقيق الفاصوليا البيضاء والذرة الشامية

A Dissertation Submitted to Sudan University of Science and Technology in Partial Fulfilment for the Requirements of Master Degree in Food Science and Technology

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الآية

قال تعالى:

(أَفَرَأَيْتُمْ مَا تَحْرُثُونَ * أَأَنْتُمْ تَزْرَعُونَهُ أَمْ نَحْنُ الزَّارِعُونَ)

صدق الله العظيم

سورة الواقعة الآيات (63-64)

Dedication

To my wonderful father

To my lovely mother

To my beautiful grandmother

To my husband

To my brothers

To my sweety sisters

To my dear friends

To my family

To celiac disease patients

With deeply love and respect....

Esra

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First of all my great thanks shall be to **ALLAH** for enabling me to perform this work.

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Abstract

The aim of this work was to produce nutritious gluten free cake from legumes and cereal blends. Cake product was prepared from beans (*Phaseolus vulgaris* L) and maize(*Zea mays*) flours with different ratios (100% bean), (50:50% bean and maize) and control (100%wheat). Raw materials and final products were analyzed. Sensory evaluation was assessed and statistical analysis was done. Results on dry basis showed that the moisture content of bean and maize flour was 7.57 % and 7.01 %, respectively. Protein was 18.54 % and 7.56 %, respectively. Fat was found 2.39 % and 5.36 %, respectively. Fiber was 3.36 % and 1.30 %, respectively. Ash was 4.54 % and 2.13 %, respectively. Carbohydrate was 63.60 % and 76.64%, respectively. Energy value was 380.36 k.cal/100g and 413.05 k.cal/100g, respectively. Mineral content (mg/100g) of bean and maize flour on dry basis showed that Na, k, Fe, Ca and Mg was 57.65 and 16.56, 467.85 and 254.46, 1.23 and 1.80, 36.33 and 7.99, 142.05 and 97.38, respectively. The proximate chemical composition of bean cake (100%) on dry basis has moisture , protein, fat, fiber , ash, carbohydrate and energy value 56.88 %, 21.04 %, 24.25 %, 3.5 %, 5.16 %, 46.07 % and 480.48 K.cal /100g, respectively. The proximate chemical composition of bean + maize cake (50:50%) on dry basis has moisture , protein, fat, fiber , ash, carbohydrate and energy value was 54.73%, 17.94 %, 21.26%, 1.59 %, 4.76 %, 54.46 % and 480.89 K.cal /100g, respectively. The proximate chemical composition of control cake (100% wheat) on dry basis has moisture , protein, fat, fiber , ash, carbohydrate and energy value 38.18 %,14.83 %,21.62 %,0.14 %,3.05 %,60.36 % and 495.36 K.cal /100g , respectively.

The minerals content of bean cake (100%) on dry basis from sodium, potassium, iron, calcium and magnesium were 194.13, 296.05, 1.8750 , 23.26 and 95.00 mg/100g, respectively. The minerals content of bean + maize cake (50:50%) on dry basis from sodium, potassium, iron ,calcium and magnesium were 270.84 , 218.70, 1.87, 16.00 and 80.00 mg/100g, respectively. The minerals content of control cake (100% wheat) on dry basis from sodium, potassium, iron, calcium and magnesium were 294.05,117.35,1.35,10.42 and 48.00 mg/100g, respectively. Sensory evaluation showed that all samples of bean with maize cake were acceptable and the sample of 100% bean cake was highly accepted by the panelists. More over the bean + maize cake (50:50%) was found to be higher in protein, fiber, ash, k, Fe, Ca and Mg compared to wheat cake (control). Finally, bean and maize flour and their blend were found suitable for gluten free cake production and enhanced its protein, fiber and minerals content.

الملخص

الهدف من إجراء هذه الدراسة هو إنتاج كيك مغذي خالي من الجلوتين من حبوب البقوليات والغلال . تم تحضير الكيك المنتج من دقيق الفاصوليا والذرة الشامية بنسب مختلفة (100٪ فاصوليا)، (50: 50٪ فاصوليا وذرة شامية) و (100٪ قمح). تم تحليل المنتجات النهائية, تم إجراء التقييم الحسي وتم إجراء التحليل الإحصائي . أظهرت النتائج علي أساس الوزن الجاف أن محتوى الرطوبة في دقيق الفاصوليا والذرة الشامية كان 7.57٪ و 7.01 على التوالي، كان البروتين 18.54 ٪ و 7.56 ٪ على التوالي, كان الدهن 2.39٪ و 5.36 ٪ على التوالي, كانت الألياف 3.36 ٪ و 1.30٪ على التوالي, كان الرماد 4.54 ٪ و 2.13 ٪ على التوالي, كان الكربوهيدرات 63.6 ٪ و 76.64 ٪ على التوالي, كانت قيمة الطاقة 380.36 كالوري/100 جرام و 413.05 كالوري/100 جرام على التوالي. أظهر محتوى المعادن (ملجرام/100جرام) من دقيق الفاصوليا والذرة الشامية علي أساس الوزن الجاف أن الصوديوم، البوتاسيوم، الحديد، الكالسيوم، والمغنسيوم كان (57.65 و 16.56 , 467.85 و 254.46 , 1.23 و 1.80 , 36.33 و 7.99 , 142.05 و 97.38) على التوالي. التركيب الكيميائي التقريبي للكيك المصنع من الفاصوليا (100٪) علي اساس الوزن الجاف يحتوي على الرطوبة ,البروتين ,الدهون ,الألياف ,الرماد ,الكربوهيدرات وقيمة الطاقة 56.88 ٪ ، 21.04 ٪ ، 24.25٪ ، 3.5 ٪ ، 5.16 ٪ ، 46.07٪ و 480.48 كالوري/100 جرام على التوالي. التركيب الكيميائي التقريبي للكيك المصنع من الفاصوليا + الذرة الشامي (50: 50٪) علي أساس الوزن الجاف يحتوي على رطوبة ، بروتين ، دهون ، ألياف، رماد، كربوهيدرات وقيمة الطاقة 54.73٪ ، 17.94٪ ، 21.26 ٪ ، 1.59 ٪ ، 4.76 ٪ ، 54.46٪ و 480.89 كالوري/100 جرام على التوالي . والتركيب الكيميائي التقريبي للكيك المصنع من القمح (100٪) علي اساس الوزن الجاف يحتوي على الرطوبة ,البروتين ,الدهون ,الألياف ,الرماد ,الكربوهيدرات وقيمة الطاقة 38.18 ٪ ، 14.83 ٪ ، 21.62 ٪ , 0.14 ٪ , 3.05 ، 60.36 ٪ و495.36 كالوري/100 جرام علي التوالي . كان محتوى المعادن (ملجرام/100جرام) لكيك الفاصوليا (100 ٪) علي أساس الوزن الجاف من الصوديوم، البوتاسيوم، الحديد، الكالسيوم والمغنيسيوم 194.13، 296.05، 1.8750، 23.26 و95.00 على التوالي. اظهر تحليل المعادن (ملجرام/100جرام) لكيك الفاصوليا + الذرة الشامية (50: 50 ٪) على اساس الوزن الجاف من الصوديوم، البوتاسيوم، الحديد، الكالسيوم والمغنيسيوم 270.84، 218.70، 1.87، 16.00 و 80.00 على التوالي. كذلك كان محتوى المعادن (ملجرام/100جرام) لكيك القمح (100 ٪) على أساس الوزن الجاف من الصوديوم، البوتاسيوم، الحديد، الكالسيوم والمغنيسيوم 294.05، 117.35، 1.35، 10.42 و48.00 علي التوالي . وكذلك أظهر التقييم الحسي أن جميع عينات كيك الفاصوليا + الذرة الشامية مقبولة وأن عينة كيك الفاصوليا

100٪ كانت أكثر قبولا من قبل المقيمين .إضافة إلى ذلك الكيك المصنع من الفاصوليا + الذرة الشامي (50: 50٪) يحتوي علي نسبة عالية من البروتين، الألياف، الرماد،البوتاسيوم، الحديد، الكالسيوم والمغنيسيوم مقارنة مع الكيك المصنع من القمح (100 ٪) . وأخيرا، دقيق الفاصوليا البيضاء والذرة الشامية وجد انه مناسب لإنتاج الكيك الخالي من الجلوتين ويحسن من نسبة البروتين والألياف والمعادن.

CHAPTER ONE

INTRODUCTION

Celiac disease (CD) is a syndrome characterized by damage to the mucosa of the small intestine caused by ingestion of certain wheat proteins and related proteins in rye and barley (Fasano and Catassi, 2001). Celiac disease is an autoimmune disorder of the small intestine, occurring in genetically predisposed people of all ages from middle infancy onward, that might cause severe malnutrition (Windt *et al*., 2010).

Celiac disease is caused by a reaction to gliadin, a prolamin (i.e., gluten protein) found in wheat. Upon exposure to gliadin, and specifically to peptides found in prolamin, the enzyme tissue transglutaminase modifies the protein, and the immune system cross-reacts with the small- bowel tissue, causing an inflammatory reaction (Heel and West, 2006).

Legumes belong to the family Leguminosae and consist of oilseeds such as soybeans, peanuts, alfafa, clover, mesquite, and pulses, including the dry grains of peas, chickpeas, lentils, peas, beans, and lupins. Production and use of legumes date back to ancient cultures in Asia, Middle East, South America, and North Africa. They are cultivated throughout the world for their seeds, harvested and marketed as primary products. Grain legumes are grouped into pulses and oilseeds. The pulses are different from the leguminous oilseeds, which are primarily utilized for oil (Schneider, 2002). There are about 1300 species of legumes, with only about 20 commonly consumed by humans (Reyes-Moreno and Paredes-Lopz, 1993).

Legumes are also a good source of vitamins (thiamine, riboflavin, niacin, vitamin B6, and folic acid) and certain minerals (Ca, Fe, Cu, Zn, P, K, and Mg), and are an excellent source of polyunsaturated fatty acids (linoleic and linolenic acids) (Augustin and Klein,1989).

Dry beans (*Phaseolus vulgaris* L.) or common beans, have been characterized as a nearly perfect food because of their high protein, fiber, prebiotic, vitamin B, and chemically diverse micronutrient composition. Dry beans can also be grown in a variety of eco-agricultural regions and distributed in multiple forms, such as whole unprocessed seeds, as part of mixes, canned products, or as a gluten free for wheat flour substitute. As a result, dry beans are used throughout the world representing 50% of the grain legumes consumed as a human food source. Alternatively, overall US intake of dry beans is low despite links to reduced disease risks or states prevalent in western cultures, such as oxidative stress, inflammation, cancer, heart disease, and metabolic syndrome (Cristiane *et al.*, 2013)

Cereal grains are the fruits of cultivated grasses, they provide humankind with more nourishment than any other food class and nearly half of the total caloric requirement.

Maize (*Zea Mays*), also called corn, is believed to have originated in central Mexico 7000 years ago from a wild grass and Native Americans transformed maize into a better source of food. Maize contains approximately 72% starch, 10% protein, and 4% fat, supplying an energy density of 365 Kcal/100g and is grown throughout the world, with the United States, China, and Brazil being the top three maize-producing countries in the world, producing approximately 563 of the 717 million metric tons/year. Maize can be processed into a variety of food and industrial products, including starch, sweeteners, oil, beverages, glue, industrial alcohol, and fuel ethanol (Ranum *et al.*, 2014).

Objectives

General objective

To produce nutritious gluten free cake from beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) for controlling celiac disease.

Specific objectives

1- To study the quality characteristics of beans and maize flours.
2- To develop gluten free cakes from different blends from beans and maize flours
3- To determine the quality of cake and study the consumer acceptability of the cake produced.

CHAPTER TWO

LITERATURE REVIEW

2.1 Celiac disease

Celiac disease CD is a syndrome characterized by damage to the mucosa of the small intestine caused by ingestion of certain wheat proteins and related proteins in rye and barley . The gliadins of wheat gluten contain protein sequences toxic to persons with celiac disease. Recent work has also shown that glutenins of wheat contain toxic sequences .Modern screening studies showed that celiac disease is much more prevalent than previously thought; the average worldwide prevalence is estimated as high as 1:266 (Fasano and Catassi, 2001).

The cornerstone treatment for celiac disease remains the total lifelong avoidance of gluten ingestion, which means that wheat, rye, and barley have to be avoided, including durum wheat, spelt wheat, kamut, einkorn, and triticale. In CD patients, ingestion of gluten leads to inflammation and mucosal damage of the small intestine. The typical lesion in the small intestinal epithelium is villous atrophy with crypt hyperplasia, leading to malabsorption of most nutrients including iron, folic acid, calcium, and fat-soluble vitamins. This can lead to associated diseases such as osteoporosis, anaemia and type I diabetes and skin disorders (Catassi and Fasano, 2008).

Historically, nutrition counseling for celiac disease has focused on the foods to avoid in a gluten free GF diet but they should be advised on the nutritional quality of gluten- free. There are growing concerns over the nutritional adequacy of the GF dietary pattern because it is often characterized by an excessive consumption of proteins, and fats, and a reduced intake of complex carbohydrates, dietary fibre, vitamins and minerals. As a consequence, the long life adherence to gluten free products has been associated to undernourished and also minerals deficiencies that could conduct to anemia, osteopenia or osteoporosis. Breads made from sorghum without added wheat, as all gluten-free breads, require a different technology. Glutenfree doughs are more fluid than wheat doughs and closer in viscosity to cake batters due to the lack of a gluten network. These batter-type doughs have to be handled similarly to cake batters rather than typical wheat doughs. (Thompson *et al*., 2005).

2.2 Legumes

Legumes belong to the family *Leguminosae*. They are the next important food crop after cereals (Uzoechina, 2009). They are sources of low-cost dietary vegetable proteins and minerals when compared with animal products such as meat, fish and egg. Indigenous legumes therefore are an important source of affordable alternative protein to poor resource people in many tropical countries especially in Africa and Asia where they are predominantly consumed. In the developing countries, research attention is being paid to better utilization of legumes in addressing protein malnutrition and food security issues. Legumes can be classified as:

1. Pulses or grain legumes which are various peas and seeds that are low in fat content.
2. Oil seeds such as soybean and groundnut
3. Forage leguminous crops such as winged bean (*Mucuna pruriens*, *Psopocarpur tetragonolobus*).
4. Swollen root or tuberous root consumed as vegetable or fresh salad such as Yam bean(*Pachyrrhisus erosus*, *P. tuberosus*). Yam bean in Indonesia is widely planted by farmers for cash crop with better income (Fasoyiro *et al.*, 2006).

The other species such as *Flemingia grahamiana, F. procumbent, Psoralea esculenta and Pueraria lobata* are still under-utilized. The highlight of this chapter is on the pulses and the leguminous oilseeds. Different types of legumes grown are consumed in different tropical regions in the world. Legume growing areas in Tropical Africa include Nigeria, Senegal, Togo, Cameroun and Cote d'Ivoire and in Tropical Asia include Indonesia and India. Some legumes are commonly used as commercial food crops such as cowpea in West Africa while some are lesser known, neglected or underutilized outside their indigenous areas (Fasoyiro *et al*., 2006).

2.2.1 Nutritional, health and economic importance of legumes

Legumes are rich in protein and their chemical composition varies depending on variety, species and region. The protein content of legumes is twice or triples that of cereals depending on the type of the legume. The protein of legumes though adequate in essential amino acid lysine is however deficient in sulphur containing amino acids methionine and cystine (Friedman, 1996). Legumes, however, form good supplements for cereals which are lacking in essential amino acid lysine. Improved nutritional quality can therefore be achieved by combining legumes with cereals. Most legumes are low sources of fat with the exception of soybean and groundnut. Legumes are also good sources of different minerals such as calcium and phosphorus (Liu, 1997). The bioavailability of these minerals can be improved through processing. Legumes contain anti-nutritional factors such as lectins, saponin, haemagglutin, protease inhibitor, oxalate, goitrogen, phytates, trypsin inhibitor and tannin (Apata and Ologhobo, 1997). These compounds reduce protein digestibility and availability. Some anti-nutritional factors in legumes have been reported to have health benefits. Tannin, a polyphenolic compound is reported to possess antioxidative activity (Amarowicz and Pegg, 2008). Raw legumes have higher content of anti-nutritional factors but can be eliminated or reduced by processing. Legumes are also good sources of carbohydrates, minerals, dietary fibres and water soluble vitamins which are important in human health. Dietary fibre consists of indigestible polymers which are made up of cellulose, hemicellulose, pectin and lignin. They provide bulk in natural food and are resistant to hydrolysis by enzymes in the alimentary tract (Fennema, 1996). Dietary fibre is important in aiding absorption of water from the digestive track. It also has health benefits such as lowering of blood pressure and serum cholesterol, protection against cardiovascular diseases, diabetes, obesity and colon cancer (Ubom, 2007). Legumes also have complex sugars such as raffinose and starchyose which are responsible for flatulence. Legumes are important both in human and animal nutrition especially in tropical Africa where they are more consumed. Legumes are processed into various semi- finished and finished products. Retailed legume products serve as a means of economic empowerment for individuals which also help to boost the national economy of some countries. Generally minerals content of legumes were found as 3-4% of their dry matter (Bravo *et al*, 1999) and mean values minerals were found for phosphorus 0.46 g, sodium 10.3mg, potassium 1.5 g, calcium 0.2 g, magnesium 0.2 g, zinc 3.2 mg, manganese 1.4 mg, copper 0.9 mg, and iron 5.84 mg. Retention of minerals during cooking ranged from a low of 38.5% for sodium to total retention for calcium (Augustin *et al*., 1981).

2.2.2 Health benefits of legumes

Legume proteins contribute energy and amino acids, which are essential for growth and maintenance. According to Liao *et al*. (2007)**,** consumption of legumes proteins could reduce plasma low density lipoproteins and help in reducing weight. Singh *et al*. (2008) have reviewed that soy protein lowers blood cholesterol. Apart from being a valuable source of protein, consumption of legumes has also been linked to reduced risk of diabetes and obesity, coronary heart disease, colon cancer, and gastrointestinal disorders. Consumption of legumes may also have a protective effect against prostate cancer in humans. Soybean is an alternative source of protein for people who are allergic to milk protein and also highly digestible (92 to 100%). It contains all essential amino acids. Although relatively low in methionine, it is a good source of lysine. Since health and nutrition is the most demanding and challenging field, legumes can play an important role, not only to the dietary pattern of low-income groups of people in developing countries, but also for the people in rest of the world as it has lot of health benefits. The contribution of legumes towards a global healthy population therefore cannot be underscored (Bazzano *et al*., 2001).

2.2.3 Legume processing

One major way of utilizing legumes is through food processing. Food processing involves techniques of converting raw materials into semi-finished and finished products that can be consumed or stored. Food can be processed at different levels including home-based food processing and at industrial level. Industrial food processing could be at the cottage level or on a large scale. The advantages of legume processing include:

- Transformation of raw produce into edible forms
- Improving digestibility of foods
- Improving the nutritional quality of foods
- Reducing and eliminating anti-nutritional factors
- Improving consumer appeal and acceptability of foods
- Destruction of food enzymes causing food spoilage thus extending shelf-life
- Deactivation of spoilage and pathogenic microorganisms in the food products
- Serving as a mean of income generation (Potter and Hotchkiss ,1998).

2.2.3.1 Primary unit operations in the processing of legumes

2.2.3.1.1 Sun drying

Raw mature grains at harvest are at about 20% moisture content and are subject to spoilage unless dried. They come in long husk or pods which are removed by hands or mechanically. In some areas, grain legumes are steeped in water for hours (2-8 hours) before sun-drying. Seeds are dried on raised platform. In some other cases, grains are treated with oil before drying. The purpose of steeping and oil treatment is to aid dehusking process (Potter and Hotchkiss ,1998).

2.2.3.1.2 Husking

This process is also called hulling. Husking can be done by dry method or the wet method. Traditionally in African and Asian countries, the dry method involves pounding of the dried grains in mortar with pestles or in hand- operated wooden or stone sheller. Improved power-operated shellers have been designed and abrasive hulling machines have also been developed to improve the hulling process. Wet grinding process for husking involves soaking of the grains before drying. Improvement in husking process has been done through conditioning techniques through moisture adjustment to allow easy husking (Potter and Hotchkiss ,1998).

2.2.3.1.3 Winnowing

The separated husks are removed from the cotyledons by winnowing. Winnowing can done manually which is time consuming and laborious. Improved abrasive hulling machines which separate husk form cotyledons have been developed (Potter and Hotchkiss ,1998).

2.2.3.1.4 Separation

This process is used to remove or separate whole grains from split, broken and powdery ones. It is done manually using sieves or mechanically with machines designed with a sieving device. Sieving manually is laborious and time consuming (Potter and Hotchkiss ,1998).

2.2.3.1.5 Storage

Proper post-harvest handling of legumes will prevent both qualitative and quantitative losses. It is important that legumes should be dried to safe moisture level of 12-14% to ensure good storage. Dried seeds with high moisture content have increased the rate of mold attack and infestation. Dehulled seeds are often dried to a safe moisture level. Milled seeds are packaged and stored under dried conditions that will not allow absorption of moisture thereby leading to spoilage (Potter and Hotchkiss ,1998).

2.2.3.2 Secondary processing of legumes

2.2.3.2.1 Sorting and cleaning before use

Legumes are sorted and cleaned to remove dirt's, stones, chaff, broken and spoilt seeds and other foreign materials. Sorting is done by hand which is laborious and time consuming or through mechanical or electronic sorting device. Cleaning can be done by dry or wet methods. Dry cleaning is intended for grain legumes meant for storage purpose. Wet cleaning is usually done by washing with water (Taiwo, 1998).

2.2.3.2.2 Soaking

Different seeds are soaked in water for different periods of time. Soaking in water allows the seeds to absorb water, to decrease and eliminate anti-nutritional factors in legumes. However, soaking for long periods of time has been found to reduce nutritional quality of legumes through leaching of nutrients into the soak water (Taiwo, 1998).

2.2.3.2.2 .1 Effect of soaking in distilled water

Soaking in water for 16 h is recommended for improvement of nutritive value of peas, chickpeas, faba and kidney beans. This enhances the utilization by human and animals. In some cases decrease of protein levels was noted when soaking in distilled water and it could be due to leaching of some of the water soluble proteins into the soaking medium (Abd el-hady and Habiba, 2003). Since polyphenolic compounds are water-soluble in nature and mostly located in the seed coat, the decrease in the level of phenolics and tannins during soaking may be attributed to leaching into the soaking medium. Even though the soaking of seeds for 6 h in distilled water is effective in reducing significant levels of tannins and phytic acid content, it does not cause any improvement in the protein digestibility of *B. purpurea* seeds, which is in agreement with an earlier study of *Vigna aconitifolia*. In some cases like *Prosopis chilensis* and *Dolichos lablab* var. *vulgaris,* an improvement in the IVPD (3%) was recorded. Although oligosaccharides are water-soluble, soaking the seeds in distilled water resulted in a limited reduction in the flatulence factors, regardless of the soaking time (Vijayakumari *et al.,* 2007).

2.2.3.2.3 Blanching

Blanching is a mild heat treatment of seeds. Legumes are usually blanched by soaking in hot water or boiled in water for few minutes. This process destroys food enzymes and some anti-nutritional factors in the legumes. Blanching can also aid the dehulling process (Subuola *et al*., 2012)

2.2.3.2.4 Boiling / cooking

This process improves the appeal and sensory properties of legume. Boiling is usually at 100 C for some minutes. It tenderizes the seeds through water absorption. Traditionally, cooking of beans can be done using firewood. Pressure cooking pots allows legumes to be cooked under pressure and it reduces cooking time. This process eliminates heat labile antinutritional factors such as trypsin inhibitors (Bishoi and Khetarpaul ,1993).

2.2.3.2.5 Roasting

Legumes are roasted on the open frying pan in the presence or absence of salts or ash. Roasting improves the taste and edibility of legumes. It is important also in reducing and eliminating anti-nutritional factors. Roasted legumes are characterized by unique flavours which can increase their sensory appeal (Bishoi and Khetarpaul ,1993).

2.2.3.2.6 Fermention

The process increases the digestibility of plant proteins and also reduces the anti-nutritional factors. Fermentation enhances flavour, colour and texture of legumes. Changes in these attributes are major stimuli in development of legume fermented products. It reduces heat stable anti-nutritional factors such as phytate. Fermented legumes are consumed as condiments e.g fermented locust bean (Bishoi and Khetarpaul ,1993).

2.2.3.2.7 Germination

Germination enhances desired qualities such as improved digestibility, reduced antinutrients like trypsin inhibitors .It improves nutritional quality of the proteins by hydrolyzing them into absorbable polypeptides and essential amino acids. Germinated or malted legumes are eaten in form of sprouts and are better than ungerminated ones. Sprouting improves the availability of vitamins B and C. It also reduces polyphenols content. Chick pea and broad beans are commonly germinated before eating, cooking or use in salad dressing (Bishoi and Khetarpaul ,1993).

2.2.3.2.8 Milling

Dehulled legumes may be wet-milled or dry-milled. Milling is a size reduction process of the seeds into smaller particle forms. Wet-milling of seeds will produce a paste while dry– milling results in flour production. Different types of equipment have been designed for milling for household or industrial purpose. Wet milled legume may be mixed with other ingredients and steamed in leaves to produce pudding (moinmoin) or fried in hot oil to obtain bean cake (okara). The rehydrated flour maybe used to obtain these products (Subola *et al*., 2012).

2.2.3.2.9 Sieving

Sieving removes unwanted materials from whole ground legume seeds (dry or wet). Example of wet sieving is in the filtration of ground soybean paste in the production of soymilk. The sieving process removes the unwanted residue called okara. For the dry-milled legume flour, sieving helps to achieve different ranges of particle sizes. Wet sieving can be done using cheese-cloth or muslin cloth while dry sieving can be done with different kinds of local or standard sieves. Some milling equipment have sieving devices incorporated into the design (Subola *et al*., 2012).

2.2.3.2.10 Frying

Several legumes are wet milled, mixed with other ingredients in preparing different local or oriental dishes. Frying improves the appeal and eating quality of legumes. It also improves digestibility and reduces anti-nutritional factors (Abd El-Moniem *et al*., 2000).

2.2.3.2.11Canning

This is a sophisticated technology of packaging cooked beans in cans. The packaged beans are usually in brine, sugar or tomato purees. This technology allows for all year round availability of the product and for food preservation. Legumes processed in this form are however expensive (Abd El-Moniem *et al*., 2000).

2.2.4 Beans (*Phaseolus vulgaris* L.)

Phaseolus vulgaris is the best known species of the genus Phaseolus in the family *Fabaceae* of about fifty plant species, all native to America.

2.2.4.1 Taxonomy

Divisions: Magnoliophyta

Class: Magnoliopsida

Order: Fabales

Family: *Fabaceae*

Genus: *Phaseolus*

Specie: *Vulgaris*

The bean is an annual herbaceous plant, climber or erect, their leaves are composed of three oval-shaped leaflets or rhomboid, sometimes covered of villi, the habit of climbing plants have stems and fickle tendrils formed by the modification of terminal leaflets, has asymmetric flowers of white or purple and its fruit is a legume of variable color, with 3-12 seeds in its interior (Arenas *et al*., 2013).

2.2.4.2 Agricultural development of beans

The dry bean is truly a "new world crop" originating 7000 years ago in two different parts of the North and South American continents. The clear separation of the two domestication centers, *i.e.*, Mesoamerica (southern Mexico and Guatemala) and regions along the Andes mountain range (principally Peru and Columbia), resulted in the small seeded Mesoamerican beans and the large seeded Andean gene pools. The Mesoamerican beans spread northward during the next several millennia to what is now the US, Canada, and the Caribbean Islands whereas the Andes migrated throughout South America to the eastern coast. In the US, dry beans can be traced to 1300 AD, specifically in the northeast where they played an important role in the "three sisters" farming practices of the Native American Indians. As the middle sister to corn and squash, dry beans fixed nitrogen in the soil supplying fertilizer to its two sisters. Corn provided a trellis for the beans to grow while squash served as a cover crop preventing moisture. Evaporation and weed pressure. The three sisters in combination provided most of the daily nutrients needed for a balanced diet (Cristiane *et al.*, 2013).

The beans (*Phaseolus vulgaris L.*) is an important legume food crop and constitutes an essential part of the diet for over 700 million people in the world (FAO, 2004). It is most widely produced legume in Africa and 28 is grown almost exclusively by poor farmers (Gridley, 1992) in Uganda. Beans are among the most important crops in the agricultural sector and house hold economy (Opio and Male-Kayiwa, 1994). Common bean is among major food crops, it is considered as one of the highest levels of variation in growth habit, seed characteristic (size, shape, color) maturity and adaptation (Srisuma *et al*.,1991).

Bean species and cultivars grow in a wide range of area extending from round 52 north_ latitude to 32 south latitude and from sea level 3000 above sea level, implying great variation in plant habits and length of vegetation. Vegetation period of beans ranges from 70 days to more than 200 days. Bean rank third after chick pea and lentils in terms of acreage 175.000ha and production 225.000 ton in Turkey (FAO, 2005).

2.2.4.3 Nutritional value of beans

Nutritionally beans is a nearly "perfect" and rich food. It is an excellent source of carbohydrates and fairly good sources of minerals, vitamins, folic acid and dietary fibers (Rehman *et al*., 2001). Nutritional quality is related to the composition of the bean. According to Arvanitoyannis *et al*. (2007), beans can be a source of proteins, vitamins (thiamine, riboflvin, niacin, vitamin B6 and folic acid), dietary fiber (14-19%) (particularly soluble fiber), minerals (Ca, Fe, Cu, Zn, P, K and Mg) and unsaturated fatty acids. Recent studies show that dietary fiber can protect against cardiovascular diseases, diabetes, obesity, colon cancer and other degenerative diseases. (Barros and Prudensio, 2016).

The protein content of the bean ranged from 17.72 to 20.27%, indicating a high amount of protein in this legume and its potential as a dietary protein source. Similar results were found by Saha *et al*. (2009), where thirty-five different genotypes of *Phaseolus vulgaris* L. were studied and the protein content ranged from 18.66 to 26.17%. The values found for moisture, ash and lipids of the bean were close to those found by Ramírez-Cárdenasi *et al*. (2008) who studied five varieties of beans, and the results ranged from 10.69 to 15.38%, 3.36 to 4.22% and 1.27 to 1.94%, respectively.

2.2.4.4 Chemical composition of beans

2.2.4.4.1 Proteins

Grain legumes are good source of protein. The protein content in the seeds is high, ranging from 17- 40% (Lauren *et al.*, 2001). The crude protein content of beans ranges from 18-22% as reported by Wolzak *et al*. (1981) but in cereals, the protein content is sensationally lower than in legumes. Also, there is difference in the protein quality between cereals and legumes. Wheat is deficient in the amino acid lysine, while rice has in adequate levels of lysine and theronin. On the contrary, grain legumes are deficient in the sulfur containing amino acids methonine and cystine. Combined consumption of cereals and grain legumes is common in South Asia to over come the amino acids deficiencies, there by achieving almost complete protein balance and nutritional improvement in cereals –base diets maximum protein is obtained when the grain legume content is about 10% in wheat- legume diet- and about 20% in diet with rice, maize or barley and legume (Lauren *et al.,* 2001). The traditional food recipes (blends of beans and cereals) have profound influence with in lesser- developed countries and among native cultures where beans are used as vital dietary stable. Legume protein is generally less digestible than protein in grains and animal products as stated by Pastuszewska *et al.* (2004).

2.2.4.4. 2 Minerals

Legumes seeds contain significant concentration of minerals, calcium, zinc, iron. Contents of iron and zinc in wheat are at par with legumes, but calcium content is lower than legumes. Rice contains lower concentrations of minerals and vitamins when compared with legumes and wheat. Additional losses of minerals and vitamins in the grain occur during the rice milling process (Lauren *et al*., 2001). beans is often a main source of protein, dietary fiber and minerals in diet, occupying a very important worldwide place in human alimentation, offering benefits for human health. Nowadays, loss of crop diversity and extinction of genetic resources lead to a simultaneous deterioration of nutritional quality, with the majority of the crop genetic diversity and desirable traits remaining underutilized in elite varieties. Kigel reviewed available information on biochemical composition of bean seeds and documented that their nutritional and culinary quality depends of genetic, environmental and origin (location) factors(Gouveia *et al*., 2014). The Ca content of white bean (Serage, Gezaa-3 and R021) was 377, 346 and 321mg/100g, respectively. Also the P content of white bean (Serage, Geza-3 and R021) was 204mg/100g, 210mg/100g and 185mg/100g (Abdelrahman *et al*., 2005).

2.2.4.4. 3 Fibers

Dietary fiber is comprised of indigestible compounds of food fermented by microorganism in the colon. Beans are high in total dietary fiber comprised of soluble and insoluble fractions. Values for total dietary fiber in the raw legumes were 13.6% (Chick peas) and 28% (White beans). In 32 processed beans, values varied from 16.1% (Yellow peas) and 27% (Balk beans). Insoluble dietary fiber was consistently greater than soluble dietary fiber, total dietary fiber ranged from 10.2% for garbanzo beans to 34% for green beans. The soluble fiber content as a percentage of total dietary fiber ranged from 10.4% for raw lentils to 49.1% for "pork and beans". Srisuma *et al.* (1991) studied cell wall materials of selected navy bean cultivars. Seed coat is rich in cellulosic structural polysaccharides range 58.7- 65.0% and lignin rang 1.4-1.9%, whereas cotyledon cell wall was composed principally of matrix poly saccharides and was especially rich in a hot water soluble polymer range 25.7-32.5% and hemi cellulose 14.6-19.2. Cotyledon contained 11.14% protein which was resistant to proteolysis and\or in accessible to proteolytic enzymes. Gonzalez (2000) studied the effect of thermal treatment modifications on the content of total dietetic fiber, soluble and in soluble dietetic fiber in beans. Bourdon *et al.* (2001) studied the effect of a test meal that contained dry beans as a source of dietary fiber on the acute hormone and lipid responses in men. It was concluded that adding beans to meal to increase fiber content prolongs the post prandial presence of intestinally derived lipoproteins. Dietary fiber from chick pea and mung bean seed reduces cholesterol, while chick pea and common beans reduce blood sugars in human (Abdelrahman *et al.*, 2005).

2.3 Cereals

Cereals can be defined as a grain or edible seed of the grass family, Gramineae (Bender and Bender, 1999). Cereals are grown for their highly nutritious edible seeds, which are often referred to as grains. Some cereals have been staple foods both directly for human consumption and indirectly via livestock feed since the beginning of civilisation (BNF, 1994). Cereals are the most important sources of food (FAO, 2002), and cereal-based foods are a major source of energy, protein, B vitamins and minerals for the world population. Generally, cereals are cheap to produce, are easily stored and transported, and do not deteriorate readily if kept dry (Brigid, 2004).

Cereal grains are the fruits of cultivated grasses, they provide humankind with more nourishment than any other food class and nearly half of the total caloric requirement. While there are about a dozen cereal crops used for food, only wheat, maize, and rice are important human food sources, accounting for 94% of all cereal consumption. The consumption of these cereals varies widely by region; wheat is the preferred cereal in Central Asia, the Middle East, South and North America, and Europe. Rice is the major cereal in Asia, while maize (also referred to as corn) is preferred in Southern and Eastern Africa, Central America, and Mexico (Ranum *et al.*, 2014).

2.3.1 Types of cereal

Wheat is a major cereal crop in many parts of the world. It belongs to the Triticum family, of which there are many thousands of species (Kent and Evers, 1994), with *T. aestivum* subspecies Vulgare and the hard wheat *T. durum* being the most important commercially (Macrae *et al.,* 1993).

Maize - originated from South America, but is now grown everywhere that is hot and sunny enough, ie from Southern Europe southwards. It is one of the three main world cereal crops (the others being wheat and rice). (Graham , 2002).

Sorghum - Sorghum *(Sorghum bicolor L.* Moench) has been consumed as a major food staple in Asia and Africa for centuries. However, in the United States, sorghum has been used mainly for livestock feed with only a small percentage used for food and industrial purposes (Rooney and Waniska 2000)

Rice - only grows well in hot and humid conditions and so it is not grown in the United Kingdom. More than 80% of the world's rice is grown in Asia, in flooded fields called 'paddies'. For many years it has been the Eastern equivalent to wheat and potatoes.

Barley - can easily be distinguished from wheat because the ear has long spikes known as 'awns'. When the crop is ripe the ear, containing an average of 30 grains, points towards the ground (necks). Malting is the process where the barley grain is germinated thus producing enzymes which convert its starch reserves to sugars, mainly maltose (Graham , 2002).

Oats Oats can grow well on poor soil and in cool, moist climates and have mainly been grown for animal feed. A small proportion is produced for human consumption oatmeal for porridge and oatcakes, rolled oats for porridge and oat flour for baby foods and for ready-to-eat (RTE) breakfast cereals (Kent and Evers, 1994). Oats are also used in a range of non-food uses, including cosmetics and adhesives (Macrae *et al.*, 1993).

Rye Rye is a hardy plant and is generally grown in cool temperature zones, where other cereals can not be grown. Rye can also grow at high altitudes and in semi-arid areas. It is grown as a winter crop, being sown in early autumn and harvested in early summer. (Kent and Evers, 1994).

Millet refers to a number of different species. The most important type is pearl millet. A number of minor millets exist, including finger (or ragi), proso and foxtail but as these account for less than one percent of the grains produced for human consumption, they are less important in terms of world food production. (FAO, 1995).

Triticale - is a new crop, being a cross between rye and wheat. Although a relatively new crop it shows good potential as an all-round cereal. It has a high yield of between 5 and 8 tonnes per hectare, principally used as a high protein animal feed (Graham Boatfiel , 2002).

2.3.2 Maize (*Zea mays* L.)

Maize (*Zea mays* L.), also referred to as corn, originated in the Western Hemisphere (Fast and Caldwell, 2000). It is a cheap form of starch and is a major energy source for animal feed (Macrae *et al.* 1993). Although there are hundreds of different varieties, the 4 main categories of commercial importance are: (1) dent maize (identified by the dent in the crown of the kernel); (2) flint maize (hard, round kernels); (3) sweet corn (a dent-type maize); (4) popcorn (flint-type maize which expands when heated). (Fast and Caldwell, 2000).

That is only known in the cultivated state, and is be-lieved to have originated in Mexico in prehistoric times. It has currently worldwide distributed and is grown wherever summers are reasonably warm. Africa, Asia, and America are mentioned as the most likely countries of origin of maize production areas (Agriculture - Forestry and Fisheries, 2008).

Maize or corn, and both words are used as synonyms in this review, depending on the source of data or references consulted, maize was spread across the world shortly after the European discovery of the Americas. Regardless of origin, corn has proven to be one of the most adaptable crops.

Its evolution apparently occurred mainly under domestication and resulted in biotypes with adaptation ranging from the tropics to the north temperate zone, from sea level to 12,000 feet altitude, and growing periods (planting to maturity) extending from 6 weeks to 13 months, currently, the United States, Brazil, Mexico, Argentina, India, France, Indonesia, South Africa, and Italy produce 79% of the world's maize production (Gwirtz and Garcia-Casal, 2013).

2.3.2.1 Maize kernel anatomy

The maize kernel is composed of four primary structures from a processing perspective. They are endosperm, germ, pericarp, and tip cap, making up 83%, 11%, 5%, and 1% of the maize kernel, respectively (Gwirtz and Garcia-Casal,2013).

The germ or embryo of the maize kernel is high in fat (33.3%) in addition to enzymes and nutrients for new maize plant growth and development, the germ also contains vitamins from B complex and antioxidants such as vitamin E. Maize germ oil is particularly high in polyunsaturated fatty acids (54.7%), which are subject to oxidative and other forms of rancidity resulting in off or objectionable flavors from full-fat maize products.

Pericarp is high-fiber (8.8%crude) semi permeable barrier surrounding the endosperm and germ, covering all but the tip cap. The tip cap is the structure through which all moisture and nutrients pass through during development and kernel dry down. The black or hilar layer on the tip cap acts as a seal.

The term bran is also used to refer to the fiber-rich outer layer (pericarp) that contains B vitamins and minerals (Gwirtz and Garcia-Casal, 2013).

In addition to chemical composition, physical characteristics of maize in the commercial market place influnece the value of the grain or the final product. Often, countries will have grading standards for maize entering the supply chain to assist buyers and sellers assessing maize value (Gwirtz and Garcia-Casal, 2013)

2.3.2.2 Important uses

According to Agriculture, Forestry and Fisheries (2008):

- Human uses: White maize is a staple food in the country. It is utilized in the form of grain, meal and green mealiest, Processed maize is consumed as a snack and cereal.
- Industrial uses: Millers, livestock industry, probably even some snack industries rely on the planting and production of maize.
- Livestock uses:
  Both white and yellow maize can be fed to livestock as hay or silage. Yellow maize contributes significantly to the production of white and red meats and dairy products.

2.3.2.3 Chemical composition and caloric value of maize

2.3.2.3.1 Protein content

The protein content of untreated maize and lentil was found to be 10.90 and 26.10 %, respectively (Alonos *et al*., 1998). Ijabadeniyi and Adebolu,

(2005) found the protein content of three maize varieties grown in Nigeria in the range of 10.67 – 11.27% for the maize grains. Ikram *et al*. (2010) stated that the protein content was found in the range of 7.71 – 14.60%. Corn contains 8 to 11% of protein with lower lysine content (usually less than 30 mg/100g protein) than other cereal grains such as rice or wheat (Shewry, 2007).

While most corn protein (75%) comes from the endosperm, it is in the germ that the proteins with the best amino acid profile are concentrated. Those proteins present about three times more albumin, twice as much globulin, and ten times less zein than the whole kernel. In the industrial processing of corn, the kernel is degermed and the amylaceous endosperm, which is of the greatest interest to the food industry, is separated from the other fractions. The most important fraction is made up of the germ with pericarp, generally used for oil extraction and animal feed due to its high density of nutrients, particularly lipids, proteins, and fibers (Shewry, 2007).

Sheorain *et al*. (2000) reported that sorghum composition starch ranged from 60 – 64%, moisture 8 – 11%, protein 9 -11 %, fat 3 -5%, crude fiber 1.5 – 2%, ash 1 -2%, and others organics 7 – 9%.

2.3.2.3.2 Fats content

Ijabadeniyi and Adebolu (2005) determined the fat content of three maize varieties grown in Nigeria to be in the range of 4.77 - 5.00 % for the maize grains.

2.3.2.3.3 Carbohydrates content

Carbohydrates are the major chemical component of the maize grains. It was found to be in the range of 69.659 – 74.549%. Ijabadeniyi and Adebolu (2005) reported slightly lower values (65.63 – 70.23%) of the carbohydrate content for the maize varieties grown in Nigeria.

2.3.2.3.4 Crude fiber content

Ikram *et al*. (2010) reported that the percent of crude fiber in the maize grains was found in the range of 0.80 to 2.32%. Ijabadeniyi and Adebolu, (2005) reported slightly higher values (2.07 to 2.77%) of the fiber content for the maize varieties grown in Nigeria.

2.3.2.3.5 Caloric value (Energy) content

Calculated energy values of maize varieties grown in Pakistan varied from 307.047 (Kcal/100g) to 394.066 (Kcal/100g) in dry matter basis (Ikram *et al*., 2010). Kouakou *et al*. (2008) showed the energy level of maize grains as 387.7 (Kcal/100g). In another study Ejigue *et al*. (2005) found the energy value of 447 (Kcal/100g) for yellow maize.

2.3.2.3.6 Minerals content

Hassan *et al*. (2009) determined the mineral contents of two maize varieties grown in Sudan and showed the level of Na in the range of 15-18 ppm, K 93- 108ppm, Ca 212 -162 ppm, Fe 18 ppm and Zn 5ppm. Hussaini *et al*. (2008), determined minerals content of dry season maize and found that K content in the range of 3400-3600 ppm, Ca 350- 360 ppm and Mg 1060-1120 ppm, and also Feil *et al*. (2005) showed the concentration of K in the range 3930-3710ppm, Mg 1120-1130 ppm, Ca 82-137 ppm, Zn 23.1 -25 ppm and Cu 2.21 -2.36 ppm.

2.4 Cakes

2.4.1 Cake technology

The popularity of the fifth edition 1973 of The Technology of Cake Making has continued in many of the English-speaking countries throughout the world. Thes sixth edition has been comprehensively revised and brought up to date with new chapters on cream, butter and milkfat products, lactose, yeast aeration, emulsions and emulsifiers, water activity and reduced sugar and lower fat goods. The chapters on eggs and egg products, baking fats, sugars, chemical aeration, nuts in confectionery, chocolate, pastries, nutritional value and packaging have been completely rewritten (Bent, 1997).

The increased need for the continuous development of new products does not of necessity mean that new technology has to be constantly introduced. Many of the good old avourites may continue to be produced for many years and they form suitable 'bench marks' for new product development.

The sixth edition introduces the use of relative density to replace specific volume as a measure of the amount of aeration in a cake batter (the use of relative density is in line with international agreement). Specific volume is kept as a measurement of baked product volume since the industry is comfortable with the concept that, subject to an upper limit, an increase in specific volume coincides with improvement in cake quality (Bent, 1997).

2.4.2 Types of cake

2.4.2 .1 Pound cakes

The pound cake's origin can be traced back to England. Pound cakes contain a pound each of butter, flour, sugar, and eggs. They are flavored to taste using vanilla, almond, or lemon. The butter pound cake is a familiar example, and is considered to be the basis for all layer cakes. A pound cake can be frozen for up to two months, or kept refrigerated for a week. Many other variations on the basic pound cake have been developed, such as lemon poppy seed or chocolate pound cake (DAAF, 1962).

2.4.2 .2 Sponge or foam cakes

Sponge cakes, which are also called foam cakes, have an airy, light texture because of large amounts of air whipped into the eggs. This type of cake does not rely on butter or modern types of fat such as all-purpose shortening or emulsified shortening-a type of fat that helps create a smooth consistency throughout the mixture. Instead, sponge or foam cakes have a base of whipped, whole eggs. European sponge cake, which is called genoise (Zhen-WAHZ), is the most common example. Genoise can be the basis for special desserts with layers of jam, chocolate, or fruit filling. Because whole eggs are used in the batter, sponge cakes are richer than angel food cakes (DAAF, 1962).

2.4.2 .3 Angel food cakes

Angel food cakes are a type of foam cake that is made with egg whites-not egg yolks. The air whipped into the egg whites leavens the cake. Once the egg whites have been whipped, the cake batter must be finished quickly, or it will collapse when the air beaten into the egg whites. Usually angel food cakes are baked in tube pans. The pans are left ungreased so that as the batter rises it can attach to the sides of the pan. To prevent the cake from collapsing as it cools, the pan is turned upside down, and the cake left to cool inside the pan. Angel food cake may be served plain, frosted, topped with a chocolate or fruit-flavored glaze, or served with whipped cream or fresh fruit. Because angel food cakes contain no egg yolks or other fat, they are a healthier alternative to other cakes (DAAF, 1962).

2.4.2.4 Chiffon cake

Chiffon cakes are a variation of genoise cakes. They are made by using whipped egg whites, or meringue, to lighten a mixture. The egg yolks and part of the sugar are whipped to full volume and then the flour is added to the yolk and sugar mixture. Fainally, the egg whites and the remaining sugar are whipped to form the meringue, and then folded in. Chiffon cakes have less saturated fat and cholesterol than any cake except angel food, and about half the fat of a pound cake. Like angel food cakes, chiffon cakes are cooled upside down. Chiffon cakes can be stored in the freezer for up to two months or refrigerated for up to three days (DAAF, 1962).

2.4.3 Cake ingredients

2.4.3.1 Flour

Most cakes and cookies have flour as a major ingredient. All-purpose flour or cake flour may be used in cakes. In some recipes up to half of the flour can be whole wheat flour. The purpose of flour in a cake or cookie recipe is to give structure, the same as in breads. Because cakes or cookie are much more delicate than breads, just a little too much or too little flour can make a big difference. Too much flour makes a cake or cookie tough and results in a coarse texture. Too little flour causes the cake to collapse or fall. Most schools use all-purpose flour and USDA recipes require all-purpose flour. However, cake flour can be used since it gives a more tender product with a finer crumb. Cakes made with cake flour have a better volume and finer texture than ones made with regular, all-purpose flour. Because flour in a bin packs down, weighing flour is more accurate than measuring it. When flour has to be measured, because there is no scale, stir the flour well before it is measured. Never measure more than 1 quart of flour at a time. Scrape the top of the dry measure to level flour for more accurate measuring (Power, 2009).

2.4.3.2 Sugar

Sugar provides the sweet flavor and helps to make the cake tender. Also, sugar has an important effect on the structure of a cake and cookies. It is very important to follow the recipe for a cake or cookie because changing the amount of any ingredient, especially sugar, affects many other factors. Too little sugar can make a cake or cookie tough. Too much sugar causes the surface to be rough and brown too much and the cake will fall. Sugar should be weighed. The sugar crystals help to incorporate air when sugar is creamed with fat in some cake recipes (Power, 2009).

2.4.3.3 Fat

Most cake and cookie recipes include some kind of fat. The fat may be margarine, butter, oil, or shortening. Fat in a cake or cookie has several important jobs. The most important job of a fat is to make the cake tender and soft. Fat also helps to improve the keeping qualities of a cake or cookie. Different fats change the texture and tenderness of a cake or cookie. For example, cakes and cookies made with butter are the tenderest and have a velvet-like crumb. Cakes and cookies made with hydrogenated shortening have a more even grain and will rise more than butter cakes or cookies. The hydrogenated shortening helps a cake to rise because it can trap more air bubbles in the batter or dough. Low fat margarine, light margarine, whipped margarine, or whipped butter cannot be substituted for the fat in cake and cookie recipes because the amount of fat in the product has been reduced. They will not give a satisfactory product. Some cake and cookie recipes have reduced the amount of fat and substituted pureed fruit or beans for some of the fat. Applesauce can be used to substitute for some of the fat in a cake or cookie recipe. This can give an excellent product. Cakes and cookies with reduced amounts of fat or no fat should be served immediately after baking since they do not keep well. If the cake or cookies are baked ahead, cool, then wrap securely and freeze until needed. Try cake or cookie recipes that have fruits or yogurt to replace some of the fat. Prepare the cake or cookies in a 25-portion amount before it is placed on the menu. It can be served as a choice. Take the time to get feedback from students about their taste preferences (Power, 2009).

2.4.3.4 Eggs

Eggs in a cake provide some moisture and help to give the cake structure. The recipe may call for whole eggs or yolks or egg whites. When a recipe calls for whole shell eggs, USDA frozen eggs can be substituted.

• 5 pounds of frozen whole eggs = 45 large eggs

• 4 pounds of frozen whole eggs = 36 large eggs

• 3 tablespoons of frozen whole eggs = 1 large egg

Frozen eggs should be thawed in the refrigerator. After thawing, the amount needed for the cake or cookies should be measured and then allowed to come to room temperature before adding to the other ingredients in the recipe.

Remember, most cake and cookie recipes suggest that all ingredients should be at room temperature when the batter or dough is mixed (Power, 2009).

2.4.3.5 Baking Powder

Baking powder causes a cake to rise because it produces a gas (carbon dioxide) when combined with a liquid and also when the batter is heated. Be careful to measure the exact amount called for in the recipe. Too much baking powder gives a cake a coarse texture, a gummy crumb, and can make the cake fall. Too little baking powder results in a heavy, compact cake. Be sure to check the expiration date of baking powder. If uncertain, add a small amount of water to some baking powder. If it doesn’t bubble, the baking powder may be inactive and should be discarded (Power, 2009).

2.4.3.6 Flavorings

Cake and cookie recipes include a variety of flavorings. Some common flavorings are salt, vanilla, chocolate, spices, lemon extract, almond extract, butter flavoring, and many others. Although these flavorings are used only in small amounts, they have a big impact on flavor. Measure the falvorings accurately, according to the recipe. Some cake and cookie recipes call for nuts. Since nuts are high in fat, dried fruits, such as raisins or dates, can be substituted for nuts in the recipe. Substitute equal amounts (Power, 2009).

2.4.4 Cake mixes

Cake mixes are prepared using carefully tested formulas. Since these formulas are balanced, no changes should be made in the few ingredients that are added. For example, if the directions call for water to be added, do not add milk instead. Substituting ingredients or adding other ingredients will make the formula out of balance and can ruin the finished product. Follow the directions for a cake mix to get a good product (Power, 2009).

The various flour formulations used in the production of cake. Other ingredients used along with the flour blends were fat, sugar, baking powder, salt, eggs, milk powder, nutmeg and water. The method of cake preparation was adapted with little modification. Mixing of ingredients was done using a manually operated hand mixer (Philip Sc. 450,UK) while baking took place in a preset oven at 181 °C for about 1 h and 15 min (Olaoye *et al.*,2015).

2.4.4.1 Cake mixing methods

Mixing cake batter is an important step when making a cake. A properly mixed cake has the desired texture and grain. Air is blended into the batter and all ingredients are mixed completely. Each mixing method produces a certain kind of cake. Bakers use the following five standard methods (DAAF,1962).

2.4.4.1.1 Creaming method

The creaming method was once the standard method for mixing a cake. To begin with, all ingredients should be at room temperature and accurately scaled (DAAF,1962).

2.4.4.1.2 Blending method

The blending method is often called the two stage method, because the liquids are added in two stages. This method produces a smooth batter that makes a moist, tight, and firm-grained cake (DAAF,1962).

2.4.5 Baking cakes

Baking the cake completes the chemical reactions begun when the batter was mixed. Preheat the oven to the correct temperature. If the oven is too hot, the cake may set before it has risen fully, or it may set unevenly, causing the crusts to be too dark. A temperature that is too low creates poor texture and volume, since the cake won't set fast enough. Cakes also may collapse when oven temperatures are too low. Ovens and the shelves in them should be level. When pans are placed in the oven, they should not touch each other. The air needs to flow between the pans for the cakes to bake evenly. It is important to keep the oven door closed in order not to disturb cakes while they bake. Cakes may fall if they are disturbed before they finish rising or become partially browned (DAAF, 1962).

2.4.6 Cooling cakes

Cakes may break if turned out of the pan too early. Always cool cakes at least 15 minutes before removing them from the pan. When turning out sheet cakes, lightly sprinkle the top with granulated sugar. Place an empty sheet pan with the bottom side down on top of the cake. 'fum both pans upside down and remove the top pan from the cake. If parchment paper has been used to line the pan, peel it off the cake. To remove a chiffon or angel food cake from the pan, loosen the cooled cake using a spatula or knife. Put a cooling rack or tray on top of the cake pan. 'Iurn the cake pan and rack over carefully holding on to both. Carefully remove the pan from the cake (DAAF, 1962).

2.4.7 Icing and butter creams

Icing improves a cake by forming a protective layer around the cake that seals in moisture. Icing also adds richness and flavor. Fudge-type icings hold up well on cakes and last longer in storage. To use after storage, simply heat the icing in a double boiler until the icing can be spread (DAAF,1962).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Food materials

Bean (*Phaseolus vulgaris* L.**)** and maize (*Zea mays*) grains were purchased from local market in Khartoum State . Other ingredients of cake like eggs, vanilla, salt, oil, sugar and baking powder were also obtained from the local market.

3.1.2 Chemicals and reagents

Chemicals and reagents were obtained from a local company in Khartoum State.

3.2 Methods

3.2.1 Samples preparation

3.2.1.1 Preparation of bean (*Phaseolus vulgaris* L.) flour

The grains were carefully cleaned and freed from any foreign materials and broken grains, then soaked in distilled water about 16 hours. After that grains rised, drained and dried at room temperature The dried soaked seeds milled into fine flour (0.4 mm) by the grinder, and kept in cleaned container for chemical analysis and cake making.

3.2.1.2 Preparation of maize (*Zea mays* L.) flour

The grains were cleaned from extraneous material and freed from broken grains, then was milled into fine flour (0.4 mm) by the grinder, and kept in cleaned container for chemical analysis and cake making.

3.2.1.3 Flour blending

Flour blending was based on (bean: maize) with different ratios: (10:90), (20:80), (30:70), (40:60), (50:50), respectively, 100% bean (*Phaseolus vulgaris* L.), 100% maize (*Zea mays*) and 100% wheat (control).

3.2.1.4 Cake samples preparation

3.2.1.4.1 The recipe of cake

Cake flour 250 g, 6 Large eggs, 4 g Vanilla, 3 g Salt, 75 g Sugar, 12 g Baking powder ,75 ml Oil ,100 ml Water, Orange peel.

3.2.1.4.2 The procedure

The ingredients of cake samples were weighed and prepared according to the recipe. Firstly the eggs, flavouring material, salt, sugar ,oil, and water were well mixed by hand mixer for 3min till homogenous cream formed. Secondly flour and baking powder was added and blended for 2min. Finally little of oil swept into pan smoothly, then the dough was sheeted into pan well. The cakes baked in electric oven maintained at 250 C for 25 min ,the cakes were cooled for about 15 min after that packed into plastic bags for chemical analysis and sensory evaluation.

3.2.2 Sensory evaluation

Sensory evaluation of cakes including colour, flavor, taste, texture, and general acceptability were assessed by twenty panellists from the Sudan University of Science and Technology and Food Research Center in Shambat. They carried the test as prescribed in the Appendices .

Nine point hedonic scale describe by Ihekoronye and Ngoddy (1985). With 1 representing the least score (poor) and 9 the highest score (excellent) was used.

3.2. 3 Proximate chemical analysis

3.2.3.1. Moisture content

Two gram of the flour or cake sample was weighed into a pre-heated, cooled and weighed silica dish, it was dried in the oven for 24 h at a regulated temperature of 105°C to a constant weight. (The dish and the content was allowed to cool in a desiccators before weighing) , the moisture was determined as percentage moisture given by:

$$\text{Moisture\%} = \frac{\text{Wt of sample before drying (g)} - \text{Wt after drying (g)}}{\text{Weight of flour taken (g)}} \times 100$$

3.2.3.2 Ash content

This measures the minerals content of samples, crucibles were thoroughly cleaned and placed in a hot oven for 2 h and allowed to cool to room temperature in a desiccators. the empty crucibles were transferred to the muffle furnace to burn off all organic matter and also, to stabilize the weight of the crucible (AOAC, 1990). Five grams of defatted sample was accurately weighed into the labeled crucibles, placed in the muffle furnace and ashed at 600°C, for 5 h. After the ashing period, the ashed samples were removed into a desiccator to cool to room temperature and then reweighed.

$$\text{Ash\%(DB)} = \frac{Weight\ of\ crucible\ and\ ash\ (g) - Weight\ of\ crucible(g)}{\text{Weight of sample (g)}} \times 100$$

3.2.3.3 Crude protein content

0.2 gm was weighed in micro-Kjeldahl flask; 0.4 gm catalyst (Cupric Sulfate or Sodium Sulfate) and 3.5 ml of concentrated Sulfuric acid were added. Samples in Kjeldahl flask were digested on an electrical heater for 2 hours; the digested material was cooled and then placed in a distillation apparatus. Twenty milliliters of 40% Sodium hydroxide were added, the mixture was distilled. The Ammonia evolved was received in 10 ml 2% Boric acid solution until 50 ml were collected, the trapped ammonia was titrated with

0.02N hydrochloric acid using indicator (Bromocresol green plus Methyl-red in alcohol). The percentage of the protein content on dry basis was calculated according to the following equation:

$$\text{Protein content \% (DB)} = \frac{(T-B) \text{ x N x } 14.0 \text{ x F x } 100 \text{ x } 100}{\text{W x } 1000\ (100-M)}$$

Where:

T = HCl titration volume in ml

B = Blank.

N = Normality of HCl = 0.02N.

1000 = to convert from mg to g.

14.0 = each ml of HCl is equivalent to 14 mg nitrogen.

F = Factor (5.7 for wheat and wheat products, 6.25 for other grains).

W = Weight of sample.

M = Moisture content of the sample.

3.2.3.4 Fat content

Three grams of sample were weighed and placed in an extraction thimble. The sample was extracted with hexane for 7 hours in Soxhlet apparatus. Then the solvent was evaporated to dryness in an air-oven at 105°C for 2 hr. The flask with oil was cooled and weighed. The percentage of fat content was calculated on dry basis according the following equation:

$$\text{Fat content \% (DB)} = \frac{\text{Weight of residue x } 100\text{x}100}{\text{Weight of sample } (100-M)}$$

Where:

M = Moisture content of the sample.

3.2.3.5 Crude fiber content

Fiber content was carried out on the samples according to the AACC (2000) methods. The steps were as follows:

Two grams of an air dried fat-free sample were transferred to a dry 600 ml beaker. The sample was digested with 200 ml of 1.25% (0.26N) H_2SO_4 for 30 minutes, and the beaker was periodically swirled.

The contents were removed and filtered through Buchner funnel, and washed with boiling water. The digestion was repeated using 200 ml of 1.25% (0.23N) NaOH for 30 minutes, and treated similarly as above. After the last washing the residue was transferred to ashing dish, and dried in an oven at 105°C over night then cooled and weighed. The dried residue was ignited in a muffle furnace at 550°C to constant weight, and allowed to cool, then weighed. The fibre percentage was calculated as follows:

$$\text{Crude fibre \%} = \frac{Wt_1 - Wt_2 \text{ x } 100 \text{ x } 100}{\text{Wt.sample x } (100 - \text{\% moisture})}$$

Where:

Wt_1 = Weight of sample and dish.

Wt_2 = Weight of dish with ashed sample.

3.2.3.6 Available carbohydrates

The available carbohydrates were calculated by difference. The sum of moisture, fat, protein, fiber and ash contents were subtracted from 100 as it was described by West *et al.* (1988).

3.2.4 Caloric value (Energy)

The caloric value content was calculated using Atwater calorie conversion factors, based on assumptions that each gram of carbohydrate, fat and protein will yield 17 kJ (4.0 kcal), 37 kJ (9.0 kcal) and 17 kJ (4.0 kcal), respectively (FAO 2003). The values were expressed in kJ. 1 kcal = 4.184 (kJ).

3.2.5 Minerals content

One-gram sample was weighted in a muffle furnace at 450°C in porcelain dish used for ashing the ash was dissolved in 5 ml of 20% hydrochloric acid and completed the volume to 50 with distilled water.

The elemental analysis of the samples were, performed using Atomic Absorption Spectrometer for Ca, Mg and Fe, while Flame photometer was used to determine the K and Na content (Tandon,1993).

3.2.6 Statistical analysis

Duplicate determinations were carried out on each sample (N = 2) and results are quoted as mean + standard deviation (SD).

The data were assessed by variance analysis (ANOVA) at ($P \leq 0.05$) confidence limit and two samples test using Minitab, version 14.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Sensory characteristics of cakes

The organoleptic evaluation of cakes including colour, flavor , taste, texture, and general acceptability were assessed by twenty panellists, nine point hedonic scale with 1 representing the least score (poor) and 9 the highest score (excellent), analysis of variance (ANOVA) was performed on the data to determine differences. The organoleptic properties of cakes from bean and maize with different ratios (A, B, C, D, E, F, G, and H) are presented in Table 1. Color of F (100% bean) gained the highest score (7.95) followed by H (100% wheat) which gained 6.90. The lowest score (5.40) was obtained by A (10% bean +90% maize). There was significant difference ($P \leq 0.05$) in color cake from mixture (bean and maize) and pure wheat cake. Flavor showed that cake from 100% beans (F) and 100% wheat (H) obtained higher scores 7.05 and 6.65, respectively compared to the other blends . There was no significant difference ($P \leq 0.05$) noticed among them, and also no significant difference ($P \leq 0.05$) were observed between A,B,C,D,E and G. Taste scores showed that Fand H represented the higher scores 6.7 and 6.55, respectively. While the lowest score (4.40) gained by A and there was no significant difference ($P \leq 0.05$) between A, B, C, D, E, and G. Texture showed higher value (7.5 and 7.2) obtained by F followed by H, respectively. On the other hand the lowest value of texture was 4.9 observed in (D). The result showed no significant difference ($P \leq 0.05$) between A, B, C, D, E and G. General acceptability of cakes showed highest value (7.45) gained by F, while the lowest value was 4.3 gained by A. The result showed no significant difference ($P \leq 0.05$) among A, B and D. More over Table 1 shows the results obtained from the panalists for the evaluation of cakes prepared from different ratios of bean and maize blends (10:90, 20:80, 30:70, 40:60, 50:50).

Table 1: Sensory characteristics of gluten free cakes

Sample	Colour	Flavor	taste	Texture	General Acceptability
A	5.400± 2.234^{c}	4.750^{c}± 2.314	4.400^{c}± 2.137	4.950^{b}± 2.064	4.300^{d} ± 1.780
B	5.550± 1.986^{c}	4.850^{c}± 2.033	4.750^{c}± 1.943	5.150^{b}± 1.814	4.700^{d}± 1.922
C	5.450± 2.188^{c}	4.850^{c}± 2.110	5.100^{c}± 2.174	5.250^{b}± 2.049	5.050^{c}± 2.038
D	5.700± 1.809^{c}	4.900^{c}± 2.125	4.300^{c}± 1.658	4.900$_{b}$± 1.889	4.550^{d}± 1.820
E	6.350± 1.954^{c}	5.300^{c}± 2.179	5.650^{c}± 1.496	5.700^{b}± 1.490	6.100^{b}± 1.651
F	7.950 ±0.999^{a}	7.050^{a}± 1.146	6.700^{a}± 1.218	7.500^{a}± 1.192	7.450^{a}± 1.191
G	4.550± 2.259^{d}	4.900^{c}± 2.315	4.700^{c}± 1.976	5.000^{b}± 1.919	5.300^{c} ± 1.809
H	6.900± 1.774^{b}	6.650^{a}± 1.843	6.550^{a}± 1.820	7.200^{a}± 1.704	6.800^{b} ± 1.795

Mean values(±SD) sharing same superscript(s) in a column are not significantly different ($P\leq0.05$).

Key:-

A: Sample of cake (10%bean + 90%maize)

B: Sample of cake (20%bean + 80%maize)

C: Sample of cake (30%bean + 70%maize)

D: Sample of cake (40%bean + 60%maize)

E: Sample of cake (50%bean + 50%maize)

F: Sample of cake (100%bean)

G: Sample of cake (100%maize)

H: Control cake (100%wheat)

According to the panelists and their evaluation, only two samples (100% bean and 50:50%) were chosen and further studies were carried on compared to 100% wheat cake (as control).

4.2 Proximate composition and energy values of bean and maize flours

The Proximate chemical composition of beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) flours is shown in Table 2. The results are expressed on wet weight and dry weight.

4.2.1 Proximate composition and energy values of bean flour

4.2.1.1 Moisture content

Moisture content of beans flour was found to be 7.04 % on wet basis and 7.57 % on dry basis, this result slightly lower than Marquezi *et al*.(2016) and Mubarak (2005) who reported that the moisture contents were 8.21% and 9.75% on dry basis, respectively.

4.2.1.2 Protein content

Protein content of bean flour was 17.23 ± 0.49% on wet basis and 18.54 ± 0.54% on dry basis; this result was found to be within the range of 17-40% on dry basis reported by Lauren *et al*. (2001). On the other hand this result is lower than Arenas *et al*. (2013) who reported that the protein content was 21.8% on dry basis.

4.2.1.3 Fat content

The fat value of bean flour obtained was 2.22 % on wet basis and 2.39 % on dry basis, this result similar to Arenas *et al*.(2013) who reported that the fat content 2.5% on dry basis. While Mubarak (2005) reported slightly higher value 1.85% on dry basis.

Table 2: Proximate composition and energy value of bean and maize flours

Parameter	Wet weight (%) ± SD		Dry weight (%) ± SD	
	BF	MF	BF	MF
Moisture	7.04 ± 0.05	6.55 ± 0.00	7.57 ± 0.06	7.01 ± 0.00
Protein	17.23 ± 0.49	7.07 ± 0.58	18.54 ± 0.54	7.56 ± 0.62
Fat	2.22 ± 0.68	5.00 ±0.19	2.39 ± 0.74	5.36 ± 0.20
Fiber	3.12 ± 0.16	1.22 ±0.14	3.36 ± 0.17	1.30 ± 0.15
Ash	4.22 ± 0.06	1.99 ±0.00	4.54 ± 0.06	2.13 ± 0.00
Carbohydrate	66.17 ± 1.01	78.17 ±0.26	63.6 ± 1.04	76.64 ± 0.27
Energy value: K.cal/100g	353.58 ±4.08	385.99±0.42	380.36 ± 4.61	413.05 ±0.44

Values are means± SD (standard deviation)

BF = Bean flour.

MF= Maize flour.

4.2.1.4 Fiber content

Fiber content of bean flour represented average 3.12 % on wet basis and 3.36 % on dry basis, this result disagreed with Mubarak (2005) and Mendoza *et al*. (1988) who reported that the fiber content of bean flour was 4.63% and 5.07% on dry basis, respectively .

4.2.1.5 Ash content

Ash content of bean flour was 4.22 % on wet basis and 4.54 % on dry basis. This result was nearly in agreement with Mendoza *et al*. (1988) who reported that the ash content was 4.12% on dry basis, however this result is higher than Mubarak (2005) who reported that the ash content 3.76% on dry basis.

4.2.1.6 Carbohydrates content

Carbohydrate value of bean flour was found 66.17 % on wet basis and 63.6 % on dry basis, this result similar to USDA (2012) who reported that the carbohydrate value was 62.55% on dry basis, but at the same times this result disagrees with Arenas *et al*. (2013) who reported lower value (55.4%) on dry basis.

4.2.1.7 Energy value

The energy value of bean flour was 353.58 Kcal /100g on wet basis and 380.36Kcal /100g on dry basis, this result slightly higher than USDA (2012) and Arenas *et al*. (2013) who reported that the energy value was 347 Kcal /100g and 322Kcal /100g on dry basis, respectively.

4.2.2 Proximate composition and energy value of maize flour

4.2.2.1 Moisture content

As shown in Table 2 moisture content of maize flour was 6.55 % on wet basis and 7.01 % on dry basis ,this result in agreement with Aisha and El-Tinay (2004) who reported that the moisture value was in the range of 4.3 - 6.7% on dry basis . On the other hand lower than the value 10.23% reported by Shah *et al*. (2015) on dry basis.

4.2.2.2 Protein content

Protein content of maize flour was 7.07 ± 0.58% on wet basis and 7.56 ± 0.62 % on dry basis. This result found is similar to that obtained by Enyisi *et al*. (2014) and Shah *et al*. (2015) who reported that the protein content of maize flour was in the range of 4.50-9.87% and 8.84% on dry basis, respectively.

4.2.2.3 Fat content

Fat content of maize flour represented average of 5.00 % on wet basis and 5.36 % on dry basis. This result is found to be within the range of 3.21-7.71% on dry basis reported by Ikram *et al*. (2010), but at the same time higher than the value 4.57% reported by Shah *et al*.(2015) on dry basis.

4.2.2.4 Fiber content

Fiber content of maize flour was 1.22 % on wet basis and 1.30 % on dry basis. This result slightly lower than Shah *et al*. (2015) and Ijabadeniyi and Adebolu (2005) who reported that the fiber content of maize flour was 2.15% and 2.07-2.77% on dry basis, respectively.

4.2.2.5 Ash content

Ash content of maize flour was found 1.99 % on wet basis and 2.13 % on dry basis .This result was in agreement with Enyisi *et al*. (2014) and Shah *et al*. (2015) who reported value of ash of maize flour 1.10 – 2.95% and 2.33% on dry basis, respectively.

4.2.2.6 Carbohydrates content

Carbohydrate content of maize flour was 78.17 % on wet basis and 76.64 % on dry basis. This result disagreed with Shah *et al*. (2015) and Ijabadeniyi and

Adebolu (2005) who reported slightly lower value 71.88% and 65.63 – 70.23% on dry basis, respectively.

4.2.2.7 Energy value

The Energy value of maize flour was 385.99 kcal /100g on wet basis and 413.05 kcal /100g on dry basis. The result obtained was similar to that reported by Kouakou *et al.* (2008) for the energy value of maize flour (405.535 kcal /100g) on dry basis.

4.3 Minerals content of bean and maize flour

The minerals content of beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) flours were shown in Table 3. The results are expressed based on its wet weight and dry weight.

4.3.1 Sodium content

The sodium contents of beans and maize flours were 53.57 and 15.47 mg/100g on wet basis and 57.65 and 16.56 mg/100g on dry basis, respectively. The result obtained for bean disagreed with USDA (2012) who reported value of the sodium content 12 mg/100g on dry basis. While the result of maize was nearly in agreement with Shah *et al*. (2015) who reported that the sodium content was 15.9 mg/100g on dry basis.

Table 3: Minerals content (mg/100g) of beans and maize flours based on wet weight and dry weight

Parameter	Wet weight		Dry weight	
	BF	MF	BF	MF
Sodium	53.57 ± 0.00	15.47 ± 0.00	57.65 ± 0.00	16.56 ± 0.00
Potassium	434.75 ± 0.00	229.38 ± 0.00	467.85 ± 0.00	254.46 ± 0.00
Iron	1.14 ± 0.00	1.68 ± 0.00	1.23 ± 0.00	1.80 ± 0.00
Calcium	33.76 ± 0.00	7.47 ± 0.00	36.33 ± 0.00	7.99 ± 0.00
Magnesium	132 ± 0.00	91 ± 0.00	142.05 ± 0.00	97.38 ± 0.00

Values are mean ± SD

SD standard deviation

Key:

BF: Bean flour.

MF: Maize flour.

4.3.2 Potassium content

The Potassium content of bean and maize flour was 434.75 and 229.38 mg/100g on wet basis and 467.85 and 254.46 mg/100g on dry basis, respectively. The bean result was found lower than that of USDA (2012) who reported that value of 1393 mg/100g for potassium (on dry basis) but on the other hand the result of maize is similar to that reported Shah *et al*. (2015) for the potassium content (286 mg/100g) on dry basis.

4.3.3 Iron content

The Iron contents of beans and maize flours obtained found to be 1.14 and 1.68 mg/100g on wet basis and 1.23 and 1.80 mg/100g on dry basis, respectively. The result of bean flour was lower than the result obtained byArenas *et al*. (2013) who reported higher value (4.7 mg/100g) on dry basis, however maize result nearly agrees with Shah *et al*. (2015) who reported that the iron content was 2.3 mg/100g on dry basis.

4.3.4 Calcium content

Calcium content of bean and maize flour was 33.76 and 7.47 mg/100g on wet basis and 36.33 and 7.99 mg/100g on dry basis, respectively. The result of bean disagrees with USDA (2012) who reported higher value of calcium (113mg/100g) on dry basis, while the maize result was less than 10 mg/100g on dry basis as reported by Shah *et al*. (2015).

4.3.5 Magnesium content

The values of magnesium of beans and maize flours were found 132 and 91 mg/100g on wet basis and 142.05 and 97.38 mg/100g on dry basis, respectively. Beans result value was lower than 176 mg/100g on dry basis that the result obtained USDA (2012). Also maize result was found lower than the value reported by Shah *et al*. (2015) for the magnesium content (139 mg/100g) on dry basis.

4.4 Proximate composition and energy value of cakes product

Table 4 shows proximate chemical composition of cakes product prepared from beans, maize and wheat flours in different ratios (bean 100%, bean 50% +Maize 50% and wheat 100%). The results are expressed based on wet weight and dry weight.

4.4.1 Moisture content

Moisture content of cakes was found in the range between 27.63 to 36.26 % on wet basis and 38.18 to 56.88 % on dry basis. These results are significantly ($P \leq 0.05$) higher than the value 21.97% on dry basis reported by Eke-Ejiofor (2013) Bean cake represented higher value of moisture content, this maybe attributed to the high protein content that might contribute to higher water absorption according to Barros and Prudencio (2016).

4.4.2 Protein content

Protein content of cakes represented range between 10.73 to 13.41 % on wet basis and 14.83 to 21.04 % on dry basis. These results are significantly ($P \leq 0.05$) higher than the value 7.34% on dry basis reported by Eke-Ejiofor (2013). Bean cake obtained higher value of protein content, that because the bean are rich in protein content, according to Barros and Prudencio (2016).

4.4.3 Fat content

Fat content of cakes was in the range between 13.74± 0.45 to 15.65 ± 0.23% on wet basis and 21.26 ± 0.79 to 24.25 ± 0.52% on dry basis. The result of dry basis are significantly ($P \leq 0.05$) higher than the value 18.93% on dry basis reported by Eke-Ejiofor (2013).

Table 4: Proximate composition and energy value of gluten free cake products

Parameter	Wet weight (%)			Dry weight (%)		
	CONC	BMC	BC	CONC	BMC	BC
Moisture	27.63 ± 0.08[c]	35.37 ± 0.25[b]	36.26 ± 0.08[a]	38.18 ± 0.16[c]	54.73 ± 0.60[b]	56.88 ± 0.19[a]
Protein	10.73 ± 0.36[b]	11.59 ±0.34[b]	13.41 ± 0.35[a]	14.83 ± 0.48[c]	17.94 ± 0.45[b]	21.04 ± 0.58[a]
Fat	15.65 ± 0.23[a]	13.74± 0.45[b]	15.44 ± 0.31[a]	21.62 ± 0.30[b]	21.26 ± 0.79[b]	24.25 ± 0.52[a]
Fiber	0.10 ± 0.00[c]	1.03 ±0.00[b]	2.23 ±0.00[a]	0.14 ± 0.00[c]	1.59 ± 0.00[b]	3.5 ± 0.00[a]
Ash	2.20 ± 0.00[c]	3.08 ±0.03[b]	3.29 ±0.00[a]	3.05 ± 0.00[c]	4.76 ± 0.06[b]	5.16 ±0.01[a]
Carbohydrate	43.68 ± 0.51[a]	35.20±0.39[b]	29.37 ±0.75[c]	60.36 ±0.77[a]	54.46 ± 0.40[b]	46.07 ± 1.11[c]
Energy value: k.cal/100g	385.99 0.42[a]	310.80 ± 1.17[b]	310.09 ±1.26[b]	495.36 ± 1.49[a]	480.89 ±3.69[b]	480.48 ± 2.57[b]

Values are mean ± SD
Mean value(s) having different superscript(s) are significantly different ($P \leq 0.05$)
Key: CONC = Control Cake (100% Wheat) /BMC= Bean and Maize Cake (50%)/ BC= Bean Cake (100%).

4.4.4 Fiber content

Fiber content of cakes obtained was found to be in the range between 0.10 to 2.23 % on wet basis and 0.14 to 3.5 % on dry basis. These results are significantly ($P \leq 0.05$) higher than the value 0.75% on dry basis reported by Eke-Ejiofor (2013). Bean cake obtained higher value of fiber content, that because the dry beans are categorized with the vegetable group due inpart to their high fiber content, according to USDA (2012).

4.4.5 Ash content

Ash content of cakes represented range between 2.20 to 3.29 % on wet basis and 3.05 to 5.16 % on dry basis. These results are significantly ($P \leq 0.05$) higher than the value 2.25% on dry basis reported by Eke-Ejiofor (2013). Bean cake obtained higher value of ash content that may be because common bean is often a main source of protein, dietary fiber and minerals in diet, occupying a very important worldwide place in human alimentation, offering benefits for human health, according to Pujolà *et al*. (2007).

4.4.6 Carbohydrates

Carbohydrate content of cakes was in the range between 29.37 to 43.68 % on wet basis and 46.07 to 60.36 % on dry basis. These results are significantly ($P \leq 0.05$) near to the value 47.76% on dry basis reported by Eke-Ejiofor (2013). Wheat cake obtained higher value of carbohydrates, that because cereals are considered a major source of carbohydrates and also classed as carbohydrate-rich foods, according to Brigid (2004).

4.4.7 Energy value

Energy value of cakes was obtained in the range between 310.09 to 385.99 kcal /100g on wet basis and 480.48 to 495.36 kcal /100g on dry basis. wheat cake got higher value of energy that because of cereals and cereal products are an important source of energy, according to Brigid (2004).

4.5 Minerals content of cake products

Table 5 shows Minerals content of cake products

4.5.1 Sodium content

Sodium content of cakes was found in the range between 123.74 to 212.79 mg/100g on wet basis and 194.13 to 294.05 mg/100g on dry basis. There was significant difference ($P \leq 0.05$) in sodium content among them. Wheat cake obtained higher value of Sodium content comber to others. Sodium has multiple uses as a food ingredient, such as for curing meat, baking, thickening, retaining moisture, enhancing flavour (including the flavor of other ingredients), and as a preservative. Some common food additives – like monosodium glutamate (MSG), sodium bicarbonate (baking soda), sodium nitrite, and sodium benzoate, according to FDA (2018).

4.5.2 Potassium content

Potassium content of cakes was in the range between 84.93 to 188.71 mg/100g on wet basis and 117.35 ± 0.00 to 296.05 ± 0.00 mg/100g on dry basis. There was significant difference ($P \leq 0.05$) in potassium content among them. Bean cake represented higher value of potassium content. Potassium is a mineral that necessary to keep the heart and other muscles functioning normally, it is also important for the nervous system and cellular enzymes, according to Standford (2009)

4.5.3 Iron content

Iron content of cakes was found in the range between 0.97 to 1.20 mg/100g on wet basis and 1.35 to 1.8750 mg/100g on dry basis. There was significant difference ($P \leq 0.05$) in iron content among them. Bean cake represented higher value of iron content. Iron and zinc are two of

Table 5: Minerals content (mg/100g) of cake products

Parameter	Wet weight			Dry weight		
	CONC	BMC	BC	CONC	BMC	BC
Sodium	212.79 ± 0.25^{a}	175.04 ± 0.68^{b}	123.74 ± 0.76^{c}	294.05 ± 0.00^{a}	270.84 ± 0.00^{b}	194.13 ± 0.95^{c}
Potassium	84.93 ± 0.10^{c}	141.35 ± 0.55^{b}	188.71 ± 0.23^{a}	117.35 ± 0.00^{c}	218.70 ± 0.00^{b}	296.05 ± 0.00^{a}
Iron	0.97 ± 0.00^{c}	1.21 ± 0.00^{a}	1.20 ± 0.00^{b}	1.35 ± 0.00^{c}	1.87 ± 0.00^{b}	1.8750 ± 0.00^{a}
Calcium	7.54 ± 0.01^{c}	10.34 ± 0.04^{b}	14.83 ± 0.09^{a}	10.42 ± 0.00^{c}	16.00 ± 0.00^{b}	23.26 ± 0.00^{a}
Magnesium	34.74 ±0.04^{c}	51.70 ± 0.20^{b}	60.56 ± 0.07^{a}	48.00 ± 0.00^{c}	80.00 ± 0.00^{b}	95.00 ± 0.00^{a}

Mean value (± SD) having different superscript(s) are significantly different (P≤0.05)

Key:

CONC = Control Cake (100% Wheat)

BMC= Bean and Maize Cake (50%).

BC= Bean Cake (100%).

the micronutrients, i.e. essential elements needed in small amounts for proper human nutrition. Both of these minerals are crucial to human well-being and an adequate supply of iron and zinc helps to prevent iron deficiency anaemia and zinc deficiency, according to Blair *et al*. (2009)

4.5.4 Calcium content

Calcium content of different cakes produced was in the range between 7.54 to 14.83 mg/100g on wet basis and 10.42 to 23.26 mg/100g on dry basis. There was significant difference ($P \leq 0.05$) in calcium content among them. Bean cake represented higher value of calcium content. Calcium is an element that is a fundamental part of the body and its importance is related to the functions it performs in bone mineralization, primarily related to bone health, which include formation and maintenance of the structure and rigidity of the skeleton, according to, Bueno and Czepielewski (2008).

4.5.5 Magnesium content

Magnesium content of cakes was found in range the between 34.74 to 60.56 mg/100g on wet basis and 48.00 to 95.00 mg/100g on dry basis. There was significant difference ($P \leq 0.05$) in magnesium content between the different cakes. Bean cake represented higher value of magnesium content. Magnesium is the fourth most abundant mineral in the body. It has been recognized as a cofactor for more than 300 enzymatic reactions, where it is crucial for adenosine triphosphate (ATP) metabolism. Magnesium is required for DNA and RNA synthesis, reproduction, and protein synthesis, according to Gröber *et al*. (2015)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1- From the results obtained in this study, it can be concluded that beans and maize flours and their blends were found to be of good nutritional value and suitable for gluten free cake production.
2- Sensory evaluation showed that all samples of bean and maize cake were acceptable and the sample of 100% bean cake was highly accepted by the panelists.
3- Addition of bean flour to the cake product formulation enhanced its protein, fiber and minerals content.

5.2 Recommendations

1- Utilization of local grains bean and maize flour in the production of bakery with good quality and nutritional value.
2- The products will help celiac disease patients to utilize gluten free cake.
3- It is recommended to add flavouring components for the bean cake to increase its acceptability by the consumer.
4- Further study is needed to investigate microbial characteristics of cakes to determine the safety and shelf life of the product.

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APPENDICES

Appendix 1: Cakes Products from different blends

A: Sample of cake (10%bean + 90%maize)

B: Sample of cake (20%bean + 80%maize)

C: Sample of cake (30%bean + 70%maize)

D: Sample of cake (40%bean + 60%maize)

E: Sample of cake (50%bean + 50%maize)

F: Sample of cake (100%bean)

G: Sample of cake (100%maize)

H: Control cake (100%wheat)

Appendix 2: Sensory evaluation of cake

Please examine the following samples of cake bread presented in front of you, and give values to attributes on the form sheet, taking: (8-9) as excellent, (6-7) as very good, (4-5) as good, (2-3) as fair and (1) as poor:

Evaluation

Sample	Color	Flavor	Taste	texture	General acceptability