UNIVERSITY OF GHANA

EVALUATION OF SOME NUTRACEUTICAL PROPERTIES OF LESSER KNOWN FUNCTIONAL FOODS IN GHANA

BY

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DECLARATION

This is to certify that this thesis is the result of research undertaken by Rose Yaa Amoah Mante towards the award of the Master of Philosophy degree in Food Science from the Department of Nutrition and Food Science, University of Ghana, under the supervision of Prof. Agnes S. Budu and Prof. Firibu K. Saalia. All references made to other people's work have been duly acknowledged.

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ABSTRACT

Functional foods are foods that possess other health benefits apart from their regular nutritional benefits. A functional food may contain nutraceutical properties, which have components, responsible for curing or preventing a disease or disorder. There are several indigenous foods in Ghana that have been purported to possess functional properties.

The claim to functionality of some of these indigenous foods are based on folklore but the scientific backing to these claims may not be known. It is therefore important to find out foods that Ghanaians consider to be functional. Some of these may have their properties reported in literature. However, some may not be popular and so may not have been well studied. The aim of this study was to identify some of these lesser known foods and determine their nutraceutical properties. It also sought to find out, if there were correlations between the health claims of such foods with their nutraceutical properties. Since most of the local Ghanaian foods are cooked before eating, it is also necessary to know the effect of heat on their nutraceutical contents.

A consumer survey was carried out in two major market centres in Accra to determine and select some indigenous functional foods. Analysis were carried out on selected samples to determine their total phenolic content, phytochemical profile (flavonoids, alkaloids, saponins) and antioxidant scavenging capacity. The samples were then blanched at different time regimes to determine the effect of heat on the physicochemical properties.

The results revealed that foods such as turkey berries, cocoyam leaves, and fruit of *Tetrapleura tetraptera*, calabash nutmegs, bissap, water leaf, fermented African locust beans, cassava leaves, anise, orange leaves, soursop leaves, pawpaw leaves, and melon seeds were considered as functional foods. These foods were easily accessible in their communities. From those interviewed, 18% reported as having consumed some of these functional foods on a daily basis. Another 18% reported that they consumed some of them occasionally. About

16% consumed them on a monthly basis, 15% twice a week, and 9% three or more times a week.

Seven indigenous food samples selected for nutraceutical analysis were bitter kola, Calabash nutmeg, alligator pepper, cloves, fruit of *Tetrapleura tetraptera*, anise and Ashanti black pepper. For antioxidant scavenging capacity, cloves recorded 0.933%, Ashanti black pepper, 0.798%, bitter kola, 0.877%, anise, 0.789%, fruit of *tetrapleura tetraptera*, 0.867%, alligator pepper, 0.928% with calabash nutmeg having 0.709%. Bitter kola had a total phenolic content of 45.223mgGAE/g but Alligator pepper recorded levels of total phenolic content at 2.236 mg GAE/g. Total phenolic content and antioxidant scavenging capacity of the food samples were directly proportional to each other such that food samples that recorded high levels of phenolics also recorded a high level of free radical scavenging capacity. For phytochemicals, bitter kola recorded levels of alkaloids at 0.670. Cloves had on the other hand had alkaloid levels of 0.236. Ashanti black pepper had high flavonoid levels (8.250). Bitter kola recorded very high saponin content of 12.470, but low flavonoid levels of 2.040. Cloves recorded low flavonoid contents (1.886).

It can be concluded that the above indigenous foods have appreciable amounts of phenolic compounds, phytochemicals (alkaloids, saponins and flavonoids) and antioxidants which are bioactive compounds responsible for the functionality of foods. The bioactive compounds identified are to be responsible for the various medicinal and pharmacological properties of the selected food samples. This supported the claim by those interviewed that those foods have medicinal or curative properties.

There was a general decline in the levels of phytochemicals with respect to blanching time. The reduction occurred gradually but there was no significant difference in the values with heating time. Heating therefore had no effect on the levels of bioactive compounds present in the food.

DEDICATION

This work is dedicated to the God, He who was, and is to come. Without him I couldn’t have possibly completed this work. I also dedicate this work to my parents for being strong pillars in my life, both financially and spiritually.

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CHAPTER 1

INTRODUCTION

1.1 Background information

Functional foods can be defined simply as 'Foods that are capable of providing additional health benefits beyond their basic nutrition' or 'Foods that bear a resemblance to mainstream food meant to be eaten as part of everyday diet, but has been changed to function in other biological roles aside the provision of basic nutritional requirements' (Roberfroid, 2000). Diplock et al. (1999) also characterizes functional foods, to be foods that have been sufficiently shown to have a positive effect on some target functions of the body, beyond satisfactory nutritional benefits, in a manner that may enhance health and well-being and/or reduce risk of disease occurrence. Another definition of functional foods by the International Food Information Council (IFIC) (2007), is foods or dietary components that may provide a health benefit beyond basic nutrition.

Functional foods have become one of the most fascinating fields of scientific study and innovation in the food industry. In Europe alone, the sale of functional foods have been raised significantly, with France, Germany, the United Kingdom, and the Netherlands representing the most important countries in the functional foods market (Jago, 2009). An annual growth rate of between 15% to 20% was recorded at the end of the 1990's in the functional food market and continued to increase exponentially at the end of 2009 (Hilliam, 2000; Bernal *et al*., 2011). Due to an increase in awareness of the benefit of functional foods to human health today, foods are eaten not only to satisfy hunger and to provide necessary nutrients for the body but also to prevent nutrition-related diseases and improve physical and mental well-being (Menrad, 2003; Roberfroid, 2000). The growing excitement in the field of functional foods can be attributed to growing concerns regarding the diet's impact on health and diet-related diseases such as diabetes, cardiovascular diseases, and cancer. Today, extensive studies into the curative abilities of a horde of bioactive compounds present in plant based edible and non-edible plant materials have resulted in a growth in medical and nutritional based research. According to Young, (2000); Mollet and Rowland, (2002), the benefits of functional foods have become so widely spread through research that, consumers now become knowledgeable in their benefits to their health. Research that has been carried out however, has not been focused much on indigenous African and for that matter Ghanaian foods.

According to Mbhenyane, (2017), indigenous foods have a major role to play when it comes to enhancing the quality of diets and improving food and nutritional security. There is however little or no research carried out on indigenous foods due to the decline in usage as a result of its non-availability in commercialised and industrialised markets. Meanwhile, diverse avenues for the creation of never before seen dietary products have been made available. With all new fields of study come new terms. The terms "nutraceuticals" and "functional foods" are references given to foods that promote well-being in the human body, or their isolated components. Functional foods products are ingested as foods and not in regulated form (Hasler, 1998).

Nutraceuticals are defined as foods or part of foods that provides health benefits including the intervention and treatment of a disease. The term "nutraceutical" was coined from "nutrition" and "pharmaceutical" in 1989 by Stephen De Felice, MD, founder and chairman of Foundation for Innovation in Medicine (De Felice, 2002). From the definition therefore, a functional food for instance, can play the role of a nutraceutical for a consumer. Nutraceuticals are also sometimes isolated or purified from foods and generally sold in medicinal forms such as pills and capsules which are not usually associated with foods. According to Swaroopa and Srinath (2017), a wide variety of nutraceutical foods are available in the market which falls in the category of traditional foods and non-traditional foods. Traditional nutraceuticals are food in which no changes are made so it the natural, whereas non-traditional nutraceuticals are the outcome from agricultural breeding or added nutrients or ingredients like calcium, vitamins or minerals to boost the nutritional content of the food.

Since the 1990s, functional foods have become very popular around the world. Its popularity amongst consumers has been identified as a deciding factor in the success of this industry, although little research has been conducted in this field. According to Menrad (2003), the functional foods market is increasingly growing worldwide, with new products being launched continuously, and competition becoming more intense.

The therapeutic properties of these medicinal foods can be attributed to their phytochemical components especially the flavonoids, alkaloids, sterols, phenolic acids among others. Phytochemicals are not essential nutrients and are not required by the human body for sustaining life, but have important properties to prevent or fight some diseases. Because of this property, many studies have been undertaken to determine the health benefits of these phytochemicals.

There has been considerable evidence gathered to implicate cellular damage as a result of the work of reactive oxygen species (ROS). The aetiology and pathophysiology of certain diseases such as Parkinson’s disease, Alzheimer’s, multiple sclerosis etc., can in part be attributed to the presence of reactive oxygen species (ROS) in the body. Free radicals are generated in living systems as part of the body’s normal metabolic processes. Antioxidants are vital substances, which possess the ability to protect the body from damages resulting from free radical induced stress. They are inhibitors of the process of oxidation, even at relatively small concentration and thus have diverse physiological role in the body. Antioxidant constituents of the plant material act as radical scavengers, and helps in converting the radicals to less reactive species. A variety of free radical scavenging antioxidants is found in dietary sources like fruits, vegetables, tea, spices and herbs etc. (Hall, 2001).

1.2 Rationale

Many Ghanaians consume indigenous foods which are purported to bear functional properties. The claim to functionality of some of these indigenous foods are based on folklore but the scientific backing to these claims may not be known. It is therefore important to find out foods that Ghanaians consider to be functional to the body and select the ones that may not be popular (lesser known food) so may not have been well studied or reported in literature. The nutraceutical properties of these foods will need to be identified so as to link them to the claimed health benefits. Since most of local Ghanaian foods are cooked before eating, it is also necessary to know the effect of heat on their nutraceutical contents.

1.3 Main objective

The main objective of this study was to identify some lesser known functional foods in Ghana, determine some nutraceutical properties to link to their claimed health benefits and to find the effect of cooking on such health benefits.

1.4 Specific Objectives

1. Determine what foods Ghanaian consumers perceive to be functional foods
2. Determine the level of consumption of such foods.
3. Determine some nutraceutical properties (the total phenolic contents, phytochemical profile; flavonoids, alkaloids and saponins and antioxidant potential) of identified functional foods
4. Determine the effect of processing on the identified nutraceutical profiles of these foods.

CHAPTER 2

LITERATURE REVIEW

2.1 The era of Functional foods

The statement "Let food be thy medicine and medicine be thy food," stated by Hippocrates some two and a half millennia ago is being given a lot of attention today as it has dawned on food scientists and consumers alike that certain foods possess many overlooked health benefits. These foods contain certain components that aid and improve our general wellness. Food can be described in various ways. In the most basic sense, food is a fuel, thereby, a source of energy needed for the performance of day to day activities and the preservation of normal metabolic processes in the body. However, we are all aware that the function of food is much more than a substance that is responsible for the production of energy to the body since food also contains certain important nutrients needed in disease prevention. These key nutrients necessary for the prevention of particular ailments is one of the main concerns of nutritional studies over the last 100 years (Beecher, 1999). According to Wildman (2001), early civilizations including the Egyptians, Chinese and Sumerians, have provided evidence that suggests that, food can be effectively used as medicine, in the treatment and prevention of various diseases. These medicinal benefits have been explored for thousands of years. Novel research in Food industry has shown that, there is a lot more information out there concerning the science of food than what was known a few decades ago. Not too long ago, most food analysis was narrowed to sensory and nutritional tests. However, there is supporting proof that there are other compounds of food, which may be involved in a pivotal role in the association between food and health (Takayuki et al., 2008). Compounds that are of a biological nature and are present in or isolated from a plant, animal or marine source and impart beneficial health or wellness are known as bioactive compounds. According to Hasler (1998), and Dixon et al. (1999), functional ingredients are the fractions or isolated parts of a food that bear bioactive compounds of that food in different degrees of purity**.**

2.2 Bioactive compounds and phytochemicals in food

Bioactive compounds are compounds found in foods that are capable of modulating mechanic processes and hence have exhibited potential beneficial impacts on human health. Examples include probiotics, prebiotics, proteins, peptides, carbohydrates, fibres, lipids and fatty acids Vijaya Kumar et al. (2015).

Phytochemicals are the bioactive compounds found in plant foods like vegetables, fruits, cereal grains, tea and wine. They provide health benefits for humans as medicinal ingredients and nutrients as well as protect plant cells from environmental hazards such as pollution stress, drought, UV exposure and pathogenic attack (Ali and Alqurainy, 2006). Samrot et al. (2009) and Koche et al. (2010) have reported that a significant intake of phytochemicals play a role when it comes to protection of human health. Due to their medicinal properties, they can also be said to function as nutraceuticals. Examples of phytochemicals include polyphenols, carotenoids, glucosinolates, phytates, saponins, amines and alkaloids.

Phytochemicals are grouped based on the foundation that they have different chemical constituents. They are mostly, naturally occurring foods which people have been eating for years. Table 2.1 outlines some phytochemicals (used as nutraceuticals), the foods in which they can be found, and the benefit they provide to the human body. Currently, about 8000 phytochemicals have been identified; varying from simple phenolic acids to very complex polymerized compounds like tannins (Ibrić and Ćavar, 2014).

Table 2.1: Various nutraceuticals found in plants and their benefits

Chemical constitute	Source	Potential benefit
1. Carotenoids (Isoprenoids)		
a. lycopene	Tomatoes, pink grapefruit, guava, pawpaw, watermelon	Its antioxidative potential protects the body from cancer formation. Mainly prostate, cervical, leukemia.
b. lutin	maize, avocado, egg yolk, spinach	Anti-cancerous properties(i.e. colon cancer), protects the eyes against cataracts and development muscle degeneration due to ageing
β-carotene α-carotene α-cryptoxanthin zeaxanthin	Carrots, various fruits and vegetables Carrots Oranges and tangerines Corn, avocado	Antioxidative properties and protection of the cornea against UV light, anticarcinogenic properties
2. Dietary fibres		
a. Soluble fibre	Black eyed peas, oats, barley, certain fruits	Anticarcinogenic, preserves the GIT
b. Insoluble fibre	Whole grain foods, wheat corn bran and nuts	Prevention of colon cancer, maintenance of the digestive tract
3. Polyphenolic Compounds		
a. flavonones	Citrus fruits	Antioxidative and anticarcinogenic properties
b. flavones	Fruits, vegetables, soyabean	Antioxidative and anticarcinogenic properties
c. flavonols	Onions, apples broccoli, tea	Antioxidative properties
d. anthocyanins	Blueberries, blackberries, black raspberries	Antioxidative, offsets inflammation in the body, lowers blood sugar levels in diabetic patients
e. phenolic acids	Berries, legumes	Reduces the oxidation of LDL cholesterol , reduces cancer formation

f. resveratrol	Dark grapes, raisins, berries, peanuts	reduces total serum cholesterol and elevates HDL cholesterol
g. curcumin	Turmeric root	Strongly anti-inflammatory and strongly antioxidant , effective anti-clotting agent
4. Fatty Acids		
a. Omega 3- fatty acids (PUFA)	Salmon, flaxseed	Controls inflammations and maintains the regular functioning of the brain
b. MUFA	Tree nuts	Alleviates the occurrence of coronary heart disease
5. Isothiocyanates		
a. sulporaphane	Cauliflower, broccoli, cabbage, kale, horseradish	May increase the rate of removal of toxins from the body and enhance antioxidative defences
6. Phenols		
a. Caffeic acid b. Ferulic acid	Apples, pears, citrus fruits, some vegetables	May bolster cellular antioxidative defenses and may contribute to the preservation of vision and general health
7. Plant stanols/sterols		
Stanol/sterol esters	Fortified table spreads	May lessen the occurrence of coronary heart disease occurrence
8. Tocotrienol (isoprenoids)	Rice, palm oil	promotes cardiovascular health and prevents breast cancer occurrence
9. Saponins	Chick peas and soya beans	Lowers cholesterol level and has anticarcinogenic properties
10. Probiotics/prebiotics	Yoghurt, cheese, milk	May improve gastrointestinal health and systematic immunity
11. Minerals (calcium, selenium, potassium, zinc, copper**)**	Food	Essential component of a balanced diet
12. Polyols sugar alcohols (xylitol, sorbitol**)**	Fruits	Reduces the occurrence of dental caries

13. Sulphides/thiols Dithiothiones	Cruciferous vegetables	Anticarcinogenic
14. Glucosinolates	Cruciferous vegetables, cauliflower	Anticarcinogenic
15. phytoestrogens		
a. isoflavanes (genistein, daidzein)	Soy beans, cauliflower	Reduces LDL cholesterol levels. antioxidative and anticarcinogenic properties
b. lignans	Flaxseed, rye, vegetables	Inhibit the occurrence of breast cancer as well as colon cancer
16. Alkaloids		
a. quinine	Cinchona	Fights malaria
b. tropane alkaloids	Deadly night shade, datura	Alleviates cardiovascular conditions
c. morphine	Opium poppy	Antidepressant and pain reliever
d. ergot alkaloids	Fungus: *claviceps purpurea*	Abortifacients
e. vincristine	periwinkle	Antineoplastic
f. vinblastine	periwinkle	Antineoplastic
g. coumarin	fenugreek	Hypoglaceamic
h. scopoletin	fenugreek	Hypoglaceamic
i. fenugreekine	fenugreek	Hypoglaceamic
j. trigonelliine	fenugreek	Hypoglaceamic
17. non- carotenoid terpenoids		
a. perillyl alcohol	Cherries and mint	Anticancer
b. saponins	Legumes (chicks, peas, fenugreek)	Reduces cholesterol levels
c. terpenol	carrots	Anticancer
d. terpene limonoids	Peels and membranes of citrus fruits	Anticarcinogenic
18. anthraquinones		
a. senna	Legumes and pulses	Purgative
b. barbaloin	Aloe	Laxative anti-helminthic
c. hypericin	St. john's wort	Analgesic
d. capsaicin	Capsicum (hot peppers)	Anticancer, anti-inflammatory, anti-apoptotic
e. piperine	Black peppers (jalapeno peppers)	Helps in digestion
19. Terpenes		
a. Menthol (monoterpene)	Plants of mint family	Topical pain reliever and anti-pyretic

b. Borneol (monoterpene)	Pine oil	Disinfectant
c. Santonin (sesquiterpene)	wormwood	Photosensitizer
d. Gossypol (sesquiterpene)	Cotton	contraceptive

Source: Sarin Rajat et al. (2012)

2.2.1 Probiotics and Prebiotics

Probiotics and prebiotics restore a balance in the digestive tract of humans O'Bryan et al., (2013). Probiotics are advantageous bacteria that are present in several foods. Common strains include the *Lactobacillus and Bifidobacterium* strains. Probiotics such as *Lactobacilli* are naturally found in fermented foods like yoghurt (Keswani and Cohen, 2005, Collins and Gibson, 1999). Probiotics were originally used to improve the health of both animals and humans through the modulation of the intestinal microbiota. At present, several well-characterized strains of Lactobacilli and Bifidobacteria are available for human use to reduce the risk of gastrointestinal (GI) infections or treat such infections (Salminen et al., 2005). Some of the beneficial effects of probiotic consumption include improvement of intestinal health by the regulation of microbiota, and stimulation and development of the immune system, synthesizing and enhancing the bioavailability of nutrients, reducing symptoms of lactose intolerance, and reducing the risk of certain other diseases. The ability of probiotics to establish in the GI tract is enhanced by their ability to eliminate competitors. In different studies on humans and animals, beneficial microorganisms are used to improve the colonization resistance on body surfaces, such as GI, the urogenital, and the respiratory tract. Lactobacillus acidophilus and Lactobacillus casei produce lactic acid as the main end product of fermentation. In addition to lactic and acetic acids, probiotic organisms produce other acids, such as hippuric and citric acid. Lactic acid bacteria also produce hydrogen peroxide, diacetyl, and bacteriocin as antimicrobial sub-stances. These inhibitory substances create antagonistic environments for foodborne pathogens and spoilage organisms. Yoghurt bacteria are reported to produce bacteriocin against probiotic bacteria and vice versa (Dave &Shah, 1997).

Goldin & Gorbach (1980) reported that the introduction of L. acidophilus into the diet lowers the incidence of chemically induced colon tumors in rats. Later, the same authors also suggested that diet and antibiotics can lower the generation of carcinogens in the colon and reduce chemically induced tumors (Goldin & Gorbach, 1984).These effects appear to be mediated through the intestinal microbial communities. A possible mechanism for these anticancer effects relies on inhibiting intestinal bacterial enzymes that convert pro-carcinogens to more proximal carcinogens (Kumar et al., 2015).

Prebiotics on the other hand, are non-digestible foods such as fibre, which make their way through the digestive tract, and help good bacteria grow and thrive. Dietary fiber consists of non-digestible carbohydrates and lignin that are intrinsic and intact in plants. Functional fiber consists of isolated, non-digestible carbohydrates that have beneficial physiological effects in humans. Alternatively, Prebiotics are a source of food to the bacteria that reside in our gastrointestinal tract (GIT), and usually are in the form of carbohydrate fibres known as oligosaccharides. Sources of oligosaccharides include legumes, fruits and whole grains. An important mechanism of action for dietary fiber and prebiotics is fermentation in the colon and changes in gut micro-flora. The human large intestine is one of the most diversely colonized and metabolically active organs in the human body. The presence of prebiotics in the diet may lead to numerous health benefits. Studies on colorectal carcinoma demonstrated that the disease occurs less commonly in people who often eat vegetables and fruit. This effect is attributed mostly to inulin and oligofructose. Among the advantages of those prebiotics, one may also mention the reduction of the blood LDL (low-density lipoprotein) level, stimulation of the immunological system, increased absorbability of calcium, maintenance of correct intestinal pH value, low caloric value, and alleviation of symptoms of peptic ulcers and vaginal mycosis (Mojka, 2014). Other effects of inulin and oligofructose on human health are: the prevention of carcinogenesis, as well as the support of lactose intolerance or dental caries treatment (Jakubczyk and Kosikowska, 2000). Rat studies demonstrated that administration of inulin for five weeks caused a significant reduction of blood triacylglycerol levels (Socha et al., 2002). Epidemiologic studies suggest that adequate fiber intake consistently lowers the risk of CVD and coronary heart disease (CHD), primarily through a reduction in low density lipoprotein (LDL) levels. The results of randomized clinical trials are inconsistent, but suggest that fiber may play a beneficial role in reducing C-reactive protein levels, apolipoprotein levels, and blood pressure, all of which are biomarkers for heart disease. Water-soluble fibres (specifically, beta-glucan, psyllium, pectin, and guar gum) were most effective for lowering serum LDL cholesterol concentrations, without affecting high density lipoprotein (HDL) concentrations. In the U.S., there are accepted health claims for the ability of oats and barley to lower blood lipids. Other soluble fibres, glucans and pectins, have recognized ability to lower blood lipids and the regulations in individual countries determine labelling and claims.

2.2.2 Proteins and Peptides

Proteins are made up of amino acids joined together in a long chain. Peptides refer to the much shorter forms of these amino acid chains. The proteins present in our diet can act as health promoters in two ways. Firstly, they can remain in our digestive tracts as indigestible substances, responsible for trapping and expelling through stool, toxins and bile. This results in a reduction of the possibility of cholesterol being taken up from the large intestine into the blood stream. Wheat and soybean proteins are recognized as foods that possess huge amounts of insoluble proteins and their continuous ingestion is needed for the maintenance of a clean and healthy gastrointestinal tract (GIT).

Secondly, proteins have the ability to be converted into peptides during digestion from which it is absorbed into the circulatory system. Some of these bioactive peptides, especially those found in soybean, have exhibited a competence in the prevention of the production of cholesterol by cells of the liver, thereby lowering levels of cholesterol in the blood (Brannback et al., 2002). Most bioactive peptides derived from food have so far been isolated from dairy products. According to Walther and Sieber (2011), bioactive peptides have been reported to be involved in a large number of functions, consisting of antimicrobial and antifungal activities, reducing high blood pressures, reducing cholesterol levels, antithrombotic effects, and increment of mineral uptake, immunomodulatory effects and localized effects on the gastrointestinal tract. Even though much work is yet to be done in the field of peptides found in foods, it is evident that the production of bioactive peptides from proteins during the normal digestive process is of great importance. It will therefore be of importance when assessing the quality of dietary protein to take into consideration the potential effects of dormant bioactive peptides that are produced during of the protein breakdown in the gut (Inaba et al., 2002, Okamoto et al., 2003).

2.2.3 Carbohydrates and Fibers

Carbohydrates are grouped into sugars, oligosaccharides, starches and fibers and are one of the three major macro-nutrients, responsible for supplying the body with energy Slavin and Carlson (2014). There is now satisfactory proof that almost half of the energy we obtain from the foods we eat must be obtained from carbohydrates. Whereas it is crucial to preserve an appropriate equilibrium between the impact of carbohydrates on either blood glucose or adrenaline levels, and calorie intake and expenditure, research has indicated that a diet containing an optimum level of carbohydrates may help to prevent the accumulation of fat in the body.

Starch and sugars provide readily available fuel for physical activity and dietary fibers help keep the bowel functioning correctly (Currell and Jeukendrup, 2008). Other than the direct benefits of carbohydrates for the body, they are found in a wide variety of foods which themselves contribute a large range of other important nutrients to the diet. For this reason it is recommended that carbohydrates be supplied from different food sources to ensure that the overall diet contains adequate nutrients WHO, (2002). Fructose oligosaccharide and galactose oligosaccharide fortified infant formulas are currently on the market; these are intended to support the developing immune systems of neonates (De Vrese and Schrezenmeir, 2008). According to Newell-McGloughlin, 2008, Fructans are an important ingredient in functional foods because evidence suggests that they promote a healthy colon (as a prebiotic agent) and help reduce the incidence of colon cancer.

Fibre obtained from plant foods such as fruit, vegetables and whole grains is referred to as dietary fibre. They play a key role in the preservation of a fully functional digestive system. Fiber which is impossible to completely digest is commonly referred to as bulk or roughage. The fiber present in foods are of two different types. These consist of soluble and insoluble fibres (Sivam et al., 2011). Soluble fiber, which are the type of fibre with the ability to solubilize in water, is mostly present in foods like cowpea, fruits and wheat products and have the ability to decrease cholesterol in the circulatory system and regulate blood sugar. Insoluble fiber cannot dissolve in water, it therefore moves through the gut without being digested. Fiber rich foods take longer to digest, and this slow rate of digestion and its movement through the gastrointestinal tract regulates blood sugar and provides the feeling of prolonged fullness allowing people with obesity problems to control the rate at which they eat, ultimately helping them in weight loss and control.

Fiber is important in the regulation of bowel movement. It also helps keep the gastrointestinal tract (GIT) clean and lowers the incidence of diverticulosis and constipation. A high fiber diet may reduce the incidence of the development of diabetes and cancers such as those that affect the colon and rectum (Dobbing, 1989). It is important to eat plant fibers due to their importance in the preservation of a healthy gastro intestinal tract and the reduction in the absorption of sugars mainly glucose into the blood, which can be of importance to diabetic patients. Foods containing insoluble fibers such as cellulose and hemicelluloses, include wheat, kale, orange fibre peaches and tangerines. They are a source of roughage which aids in the reduction of the caloric value of diets. This is very important in obese and diabetic patients (Mircea et al., 2009). Soluble fiber such as gums and pectin are abundant in whole grain wheat and oats, as well as in fruits such pineapples and lemons; this type of fiber forms a viscous insoluble mass in the gastro intestinal tract and helps trap digestive enzymes, cholesterol, starch, glucose and toxins that are then expelled through the stool. Because of their indigestibility, soluble fiber helps patients suffering from obesity, regulate the total amounts of calories they absorb from their food and help diabetics by reducing the rate of starch digestion and glucose absorption (F.A.C.S., 2006). Fibers and phytochemicals have for a very long time been recognized as the active nutrients responsible for health benefits of fruits and vegetables to humans.

2.2.4 Lipids and Fatty Acids

Oils obtained from fish have from time in memorial been accepted as a food with functional properties due to its capacity to lower high blood pressure and reduce the occurrence of other heart related disorders such as irregular heart beat and the obstruction of blood vessels by cholesterol. The health-promoting factors found in fish oil has been attributed to the family of omega-fatty acids, specifically omega 3 and omega 6 fatty acids. The predominant omega 3 fatty acids found in fish oil are docosahexaenoic (DHA) and eicosapentaenoic acids (EPA) (Shearer et al., 2009). Studies have revealed that, DHA in particular is an important structural component of the brain and plays an important role in increased memory functions. Recently, increased incorporation of DHA into products such as margarines and baby foods has been encouraged to enhance brain memory development; a role in reducing the intensity of

Alzheimer's disease. (Brenna, 2002). Linoleic and linolenic acids are other fatty acids which have the ability to provide elevated amounts of cardiovascular benefits. They are found in large quantities in products such as fish oils, vegetable oils and nuts such as groundnuts and cashew nuts. Nut consumption is highly encouraged because, they are loaded with elevated amounts of antioxidants that help preserve integrity of organs, blood vessels and genes (Eyres et al., 2001).

2.2.5 Isoprenoids

Isoprenoids form the largest single family of compounds found in nature with over 24000 known examples and contain industrially useful compounds such as rubber, flavours, antibiotics and plant hormones. They are a large group of natural products, which contain tens of thousands of chemicals with diverse functional groups (Cuellar and van der Wielen, 2015). Most of these compounds have been isolated from eukaryotes such as plants and fungi. In plants, isoprenoids range from essential and relatively universal primary metabolites, such as sterols, carotenoids, quinones, and hormones, to more unique and sometimes species-specific secondary metabolites that may serve roles such as plant defense and communication (Lange et al., 2000). Isoprenoids are classified according to the number of carbon atoms they contain. Major groups of interest include monoterpenes containing 10 carbon atoms, sesquiterpenes with 5 carbon atoms, diterpenes with 20 carbon atoms and triterpenes with 30 carbon atoms. Many isoprenoids can be found on the global market as pharmaceuticals, nutrients, fragrances, flavouring substances, bulk chemicals, and fuels (Ajikumar et al., 2008). Several isoprenoids are vitally important in metabolic processes in animals. Tetraterpene carotenoid pigments are the source of vitamin A, which is essential for vision and is involved in growth, reproductive function, and neural development in animals. Other vitamins that are wholly or partly isoprenoid include vitamin E, important in reproduction, and vitamin K, necessary for blood- clotting process. The ubiquinones (coenzyme Q), which are involved in the derivation of energy by the oxidation of food, are also formed from isoprenoids.

2.2.6 Phenolic compounds

There are approximately 300,000 documented species of higher plants on the planet, which synthesize an enormous number of chemicals of diverse structure and class. These compounds can be further divided into primary and secondary metabolites. Primary metabolites include metabolites such as sugars, fatty acids, amino and nucleic acids, as well as chemicals considered ubiquitous to all plants for growth and development (Wu and Chappell, 2008). Secondary metabolites are structurally and chemically much more diverse than the primary metabolites and refer to compounds present in specialised cells that are not directly essential for basic photosynthetic or respiratory metabolism but are thought to be required for the survival of plants in the environment.

Phenolic compounds are the most widely distributed secondary metabolites, ubiquitously present in the plant kingdom, even if the type of compound present varies according to the phylum under consideration. They are possibly the most explored natural compounds due to their potential health benefits as demonstrated in a number of studies (Del Rio et al., 2010). The generic terms phenolic compounds or polyphenolics refer to over 8000 compounds found in the plant kingdom and possessing at least an aromatic ring with one or more hydroxyl substituents, including functional derivatives like esters, methyl ethers, glycosides etc. (Ho, 1992). Organoleptic properties of plant foods (such as fruits, legumes, vegetables and cereals) and beverages (such as beer, tea, wine) are all partially ascribed to phenolic compounds. Phenolic compounds have varied chemical structures ranging from simple molecules to more complex polymerized compounds (Galleano et al., 2010). Phenolics derived from various natural sources are linked to antioxidant, anti-inflammatory, anti-allergic, anti-carcinogenic anti-hypertensive, cardioprotective, anti-arthritic and antimicrobial activities (Dai and

Mumper, 2010).

Phenolics found in food products can be divided into 3 major groups; simple phenols and phenolic acids, hydroxycinnamic acid derivatives and flavonoids (Ho, 1992). Also based on the number of carbon atoms present, phenolic compounds commonly found in plants can be classified into several groups. Phenolic acids, flavonoids and tannins are considered as the main dietary phenolics (Balasundram et al., 2006). Flavonoids constitute the largest group of low-molecular weight plant phenolics and have been studied extensively. Phenolic acids are significant components of fruits and vegetables. These compounds play an important role in colour stability, aroma profile and antioxidant activity. Tannins are the third important group of polyphenolics which can further be divided into two subcategories: condensed and hydrolysable tannins. Fruits, grains and legumes consist of condensed tannins which are mainly polymers of catechins and epicatechins. Hydrolysable tannins are polymers of gallic or ellagic acids and are found in berries and nuts (King and Young, 1999).

Numerous studies have been undertaken to determine the potential health benefits of plant polyphenolics. The potent antioxidative properties of plant phenols have been scientifically proven to prevent various oxidative stress-related chronic diseases such as cancer, cardiovascular and neurodegenerative diseases.

2.2.7 Alkaloids

Alkaloids are a highly diverse group of compounds that contain a ring structure and a nitrogen atom. In most cases, the nitrogen atom is located inside the heterocyclic ring structure. Alkaloids are a group of naturally occurring chemical compounds that contains mostly basic nitrogen atoms. This group also includes some related compounds with neutral (McNaught and Wilkinson, 1997) and even weakly acidic properties. Alkaloids are produced by a large variety of organisms which includes bacteria, fungi, plants and animals.

They rank among the most diverse, efficient and therapeutically significant plant substances.

There are around 5,500 alkaloids known presently. The name alkaloids is derived from the word “alkaline” and it was used to describe any nitrogen-containing base.

The presence of alkaloids and other secondary metabolites in plants enhances plant reproductive rates, either by improving defenses against biotic and abiotic stresses or by affecting pollinators and seed/fruit disperser visitation. Defensive strategies include predator repellence by toxicity or bitterness taste or damage repair by antioxidant system (Vilariño and Ravetta 2008; Matsuura and Fett-Neto 2013). Alkaloids are known to have muscle relaxant property. D-tubocurarine is one such example that possesses the antiparalytic activity due to its ability to obstruct the acetycholine receptor spots which enable the muscles to unwind at neuromuscular intersections (Das et al., 1997). Alkaloids are known to possess antioxidant activities due to their ability to act as scavenger of free radicals, metal chelating activity or electron or hydrogen donation ability.

2.2.8 Flavonoids

Flavonoids are a diverse group of plant metabolites with over 10,000 compounds that have been identified until now. They have several important functions in plants, such as providing protection against harmful UV radiation or plant pigmentation. In addition, they have antioxidant, antiviral and antibacterial properties. They also regulate gene expression and modulate enzymatic action (Pollastri and Tattini, 2011). All naturally occurring flavonoids possess three hydroxyl groups, two of which are on the ring A at positions five and seven, and one is located on the ring B, position three. Biochemical actions of flavonoids depend on the presence and position of various substituent groups that affect metabolism of each compound. They can be found in free or bound forms: aglycones or β-glycosides (Majewska and Czeczot 2009). The flavonoid subclasses, based on types of chemical structure, include: flavonols, flavones, flavanones, flavanols, anthocyanins and isoflavones (Małolepsza and Urbanek, 2000).The major active nutraceutical ingredients in plants are flavonoids. As is typical for phenolic compounds, they can act as potent antioxidants and metal chelators. The flavones and catechins seem to be the most powerful flavonoids for protecting the body against reactive oxygen species (ROS). Body cells and tissues are continuously threatened by the damage caused by free radicals and ROS which are produced during normal oxygen metabolism or are induced by exogeneous damage (Duthie and Morrice, 2012). The scavenging activity of flavonoids has been reported to be in the order: Myrcetin > quercetin > rhamnetin > morin > diosmetin > naringenin > apigenin > catechin > 5,7-dihydroxy-3',4',5'-trimethoxy-flavone > robinin > kaempferol > flavone (Majewska and Czeczot, 2009).

They also have long been recognized to possess anti-inflammatory, antiallergic, hepatoprotective, antithrombotic, antiviral, and anticarcinogenic activities. The well-recognised anti-oxidant properties of flavonoids resulted in the interest about their potential role in prevention of cardiovascular diseases (Majewska-Wierzbicka and Czeczot, 2012). A recent study clearly showed health benefits of dietary flavonoids as there was a positive association between their intake and reduction of the risk of cardiovascular death in adult Americans (McCullough et al 2012). The study demonstrated that both male and female subjects who consume large amounts of flavonoids (the top quintile) had the 18% lower mortality risk of cardiovascular diseases (CVD) compared to those whose intake was in the lowest quintile.

Antibacterial activity has been displayed by a number of flavonoids. Quercetin has been reported to completely inhibit the growth of Staphylococcus aureus. Most of the flavonones having no sugar moiety showed antimicrobial activities whereas none of the flavonols and flavonolignans tested showed inhibitory activity on microorganisms (Havasteen, 1983). A number of flavonoids isolated from the peelings of tangerine orange, when tested for fungistatic activity towards Deuterophoma tracheiphila were found to be active; nobiletin and langeritin exhibited strong and weak activities, respectively, while hesperidin could stimulate fungal growth slightly. Naturally occurring flavonoids with antiviral activity have been recognized since the 1940s but only recently have attempts been made to make synthetic modifications of natural compounds to improve antiviral activity. Quercetin, morin, rutin, dihydroquercetin (taxifolin), apigenin, catechin, and hesperidine have been reported to possess antiviral activity against some of the 11 types of viruses (Selway, 1986). The antiviral activity appears to be associated with the nonglycosidic compounds, and hydroxylation at the 3-position is apparently a prerequisite for antiviral activity.

Flavonoids, especially quercetin, has been reported to possess antidiabetic activity. Vessal et al (2003) reported that quercetin brings about the regeneration of pancreatic islets and proprably increases insulin release in strptozotocin-induced diabetic rats. Also in another study, Hif and Howell reported that quercetin stimulate insulin release and enhanced Ca^{2+} uptake from isolated islets cell which suggest a place for flavonoids in non-insulin-dependent diabetes (Hif and Howell , 1984, 1985).

Effectiveness of flavonoids in prevention of age--related neurodegenerative diseases has been much investigated in the recent years. It concerns particularly dementia, Parkinson’s and Alzheimer’s diseases. It seems that flavonoids can modulate neuronal function (Macready et al., 2009, Prasain et al., 2010). Diets rich in these substances were shown to beneficially affect maintenance of human cognitive functions, probably through protection of neurons, enhancement of their function and regeneration (Youdim and Joseph, 2001). Reactive oxygen and nitrogen species are involved in the development of many neurodegenerative diseases, whilst dietary flavonoids have been shown to counteract effectively oxidative neuronal damage.

Flavonoids are ubiquitous in plant foods and drinks and, therefore, a significant quantity is consumed in our daily diet. The toxicity of flavonoids is very low in animals. For rats, the LD_{50} is 2-10 g per animal for most flavonoids. Similar doses in humans are quite unrealistic.

As a precaution, doses less than 1mg per adult per day have been recommended for humans (Starvic, 1984). Dunnick and Hailey (1992) reported that high doses of quercetin over several years might result in the formation of tumors in mice. However, in other long-term studies, no carcinogenicity was found.

2.2.9 Saponins

Saponins are bioactive compounds produced mainly by plants, but also by some marine organisms and insects. Chemically, they generally occur as glycosides of steroids or polycyclic triterpenes (Kensil, 1996).They are one of many secondary metabolites found in natural sources, with saponins found in particular abundance in various plant species. More specifically, they are amphipathic glycosides grouped in terms of phenomenology, by the soap-like foaming they produce when shaken in aqueous solutions, and, in terms of structure, by their composition of one or more hydrophilic glycoside moieties combined with a lipophilic triterpene derivative (Hanausek et al., 2001). Saponins have a range of properties due to their extensive structural diversity, which includes certain features, bitter sweeteners, detergents and emulsifying properties, in addition to the biological, medical and pharmacological properties, such as haemolytic activity, antimicrobial, insecticides and molluscicides. Also noteworthy are the applications in pharmaceutical industries as raw material for the synthesis of steroidal drugs such as birth control, besides the intense use in the cosmetic industry (Vincken et al., 2007). They have many medicinal uses including, microbial, anti-tumor, anti-insect (Hostettmann and Marston, 1995) hepatoprotective, haemolytic (Zhou et al., 2011), and anti-inflammatory activities. They also decrease blood cholesterol level and may be used as adjuvant in vaccines. Saponins are effective in maintaining liver function, lowering blood cholesterol, preventing peptic ulcer, osteoporosis as well as platelet agglutination (Liby et al., 2008). The beneficial effects of saponins have been applied commercially in drugs and medicines, emulsifiers, adjuvants, taste modifiers, sweeteners and precursors of hormone synthesis (Hanausek et al., 2001).

Su et al. (2011), investigated antitumor activity of polysaccharides and saponin extracted from sea cucumber. These results indicated that the in vitro anti-tumor effect of saponins is more potent than polysaccharides (Liby et al., 2008). Several reports have demonstrated that plant saponins can reduce the risk of colorectal cancer. It has been reported that ingestion of saponin containing food decreases cholesterol levels in the bloodstream and as a result decreases the risk of cardiovascular diseases. It was also, reported that ginseng saponins decrease blood cholesterol levels in rabbits by increasing cholesterol excretion through bile acid formation (Kang et al., 2011) .Elekofehinti et al. in 2012 showed that consumption of saponin from *Solanum anguivi* fruit lead to reduction in the risk of hyperlipidemic symptoms and heart diseases (Liu et al., 1993)

2.3 Free radicals and Antioxidant activity in foods

Plants are able to produce a large number of diverse bioactive compounds. High concentrations of phytochemicals, which may protect against free radical damage, accumulate in fruits and vegetables. These phytochemicals may act as natural antioxidants in the human body (Altemimi et al., 2017). Vast amounts of different foods such as vegetables, fruits, mushrooms and herbs, are usually eaten for their nutritional and or their therapeutic benefits. In recent times, examination of these foods have shown to bear important antioxidants of high nutritive and medicinal values.

Antioxidants are substances which when examined with those of an oxidizable substrate prevents or delays to a large extent the oxidation of that substrate (Halliwell and Gutteridge, 1989). Antioxidants possess the ability to prevent or reduce the impact of destruction such as lipid peroxidation, oxidative damage to cells, glycation of proteins and demobilization of enzymes caused by free radicals. Abundant evidence has revealed that oxidative stress that occurs as a result of the work of reactive oxygen species (ROS), which include free radicals are involved in important roles in the advancement of many medical conditions. These have been linked in the aetiology of medical conditions related to cardiovascular diseases, diabetes, inflammatory diseases, cancer, Alzheimer and Parkinson's disease, monogolism, ageing process and maybe dementia (Amin et.al., 2004). Although free radicals and other ROS are produced regularly within our cells during normal cell activity, examples of which includes energy synthesis in the mitochondria electron transport chain, ovulation, fertilization, and in xenobiotic metabolism (Halliwell and Gutteridge, 2007), free radicals can also be found outside the body in extraneous environments, examples of which include food products, medications, fumes from fires and cigarettes and many more environmental pollutants. Organisms have internal and external antioxidant defensive mechanisms that fight or resist reactions of free radicals. According to Ames et al., (1993), the body's production of free radicals beyond its antioxidant scavenging ability results in oxidative stress. A connection has been established between these free radicals and aetiology of several disease causing conditions such as lipid peroxidation, protein oxidation, and DNA destruction. As a result, a lot of attention is being placed on the use of antioxidants especially naturally occurring ones as a medium of inhibiting and protecting damage resulting from free radicals and reactive oxygen species. The interest in natural antioxidants has increased over that of artificial ones, due to the possibility that the activity of artificial antioxidants may act as boosters for the occurrence of cancers. Epidemiological studies have established that vegetables and fruits possess compounds that have the capacity to protect the human body from oxidative damage by inhibiting or assuaging the effects of free radicals and reactive oxygen species, when eaten. Many plants including fruits and vegetables are acknowledged as good sources of naturally occurring antioxidants that can protect the body from oxidative stress and thereby play a cardinal role in the chemoprevention of diseases that have their root and pathophysiology in reactive oxygen species (Odukoya et al., 2001, Atawodi 2005). These positive impacts are believed to be creditable to the antioxidants; especially the carotenoids, flavonoids, lycopene, phenolics and β-carotene present in these foods (Amin et al., 2004).

2.3.1 Antioxidant and nutraceutical properties of some green leafy vegetables

2.3.1.1 Bitter leaf (*Vernonia amygdalina*)

Vernonia amygdalina is a green leafy vegetable belonging to the *Asteracea*e family. It is commonly referred to as bitter leaf in the English language. It is also known as 'awonyono' in the Akan language, and 'ewuro' in the Yoruba language. They have green leaves with a distinct odour and bitter taste (Akpaso et al., 2011). They are found mostly in tropical parts of Africa and Asia. They grow mostly around sewage systems and in forest areas or on farms. In most parts of the African continent, the bitter leaf is used in the preparation of soups after they have been thoroughly washed or boiled to get rid of their peculiar bitter taste. It is specifically used in the preparation of the popular Nigerian bitter leaf soup, "onugbo" and used in the preparation of a Cameroonian dish known as "Ndole". Bitter leaf has long been used in traditional folk medicine, particularly in sub Saharan Africa. This has required that a large amount of research be conducted to test the effectiveness of different parts of the plant in the management of a wide variety of disorders (Huffman and Seidu (1989), Yeap et al., (2010)). The entire plant for example, is used as a deworming agent, in the treatment of malaria, and in the prevention of constipation. Some people employ the use of the aqueous extract of the bitter leaf as a tonic to aid in digestion, an appetizer and also in the treatment of wounds. The leaf extract is also used to treat coughs in some parts of sub Saharan Africa (Ijeh et al., 2011). In Ethiopia, the leaf is used as hops in beer preparation. Traditional birth attendants in Malawi and Uganda use it as an aid for the removal of placenta after childbirth, assist in post-partum uterine contraction, induce lactation and control postpartum bleeding. Different extracts of *Vernonia amygdalina* (bitter leaf) have been satisfactorily expressed to possess antioxidative characteristics both invitro and invivo. Ayoola et al., (2008) investigated the invitro antioxidative characteristics of the ethanolic leaf extract of bitter leaf using 2,2-diphenyl-1- picrylhydrazyl (DPHH) radical. This plant contains naturally occurring antioxidants that fight against aqueous radicals and reactive species ions. Bitter leaf has been used in different parts of our continent in curing a diverse number of diseases including diabetes, malaria, and cancer. It also provides the body with general wellbeing. These folk remedies have in recent times been supported with scientific proof.

2.3.1.2 Water Leaf (*Talinum triangulare*)

Water leaf is an herbaceous annual plant which grows widely in tropical regions as a leafy vegetable. It is consumed mainly as a leafy vegetable and is used in the preparation of sauces and soups. It is a good source of several nutrients such as calcium, magnesium, vitamin C and pyridoxine (Oguntona, 1998). Research conducted by Ogodie-Oda and Oluowo (2009), revealed that extracts from the roots and leaves of water leaf is used to cure asthma. Another effective use of the plant is in the use as a diuretic (Mensah et al, 2008). Phytochemicals present in water leaf include carotenoids (Ogbonnaya and Chinnedum, 2013) and alkaloids, flavonoids, saponins and tannins which can found in the leaves (Aja et al., 2010). Medically, water leaf has been linked to the regulation of cardiovascular diseases (Adewunmi and Sofowara, 1980).

2.3.1.3 Kale (Brassica oleraceae L. var. acephala DC.)

Kale are cabbage-like plants native to the eastern Mediterranean or to Asia Minor. Their wild forms have become widely distributed from their place of origin and are found on the coasts of northern Europe and Britain. Kale is vegetable crop with high biological, nutritional and health values. Kale is considered as one of the highest-quality brassicas in terms of chemical composition. Younger and tenderer leaves of kale are used for human consumption and older leaves as fodder crop (Cartea et al., 2002). Kale has a long tradition of cultivation and has an important place in the diet of the population in the northern parts of Turkey (Ayaz et al., 2006), on the Pyrenean Peninsula (Velasco et al., 2007), southeast of the USA (Olson and Freeman, 2007), and insular and coastal parts of Croatia (Batelja et al., 2009). Compared to other types of vegetables, kale has a higher content of beta carotene and lutein (USDA, 2002). Kale leaves are rich in amino acids (Lisiewska et al., 2008). In recent years, kale has gained the attention of the scientific community due to its high content of bioactive compounds such as vitamin C, provitamin A, glucosinolates, phenolic antioxidants, dietary fiber, micronutrients (iron, zinc and manganese) and macronutrients (calcium and magnesium) (Ayaz et al., 2006). Likewise, in vitro and in vivo studies suggest that kale has a positive impact on the prevention of chronic diseases such as cardiovascular diseases (Kahlon, Chapman, & Smith, 2007; Kim et al., 2008).

2.3.1.4 Spinach (*Spinacia oleracea*)

Spinach is an edible flowering plant in the family *Amaranthaceae*. Spinach has a high nutritional value. It is a rich source of vitamin A, vitamin C, vitamin K, magnesium, manganese, folate and iron. The nutritional value of spinach indicates it to be a very nutrient-dense food. It is low in calories yet very high in vitamins, minerals, and other phytonutrients. Spinach is also packed with a number of anti-oxidants like polyphenols, flavonoids and carotenoids, which are shown to possess anti-inflammatory effects, anti-mutagenic potential, anti-neoplastic effects as well as chemo-preventive activities (Boivin et al., 2009; Hait-Darshan et al., 2009).

2.3.1.5 Dandelion greens (*Taraxacum officinale*)

Dandelion, a member of the *Asteraceae* family (Damylo et al.,1984) , commonly found in the temperate zone of the Northern hemisphere (Ali, 1989), is a herb that grows to a height of about 12 inches, producing spatula-like leaves and yellow flowers that bloom year round. Dandelion is used in many traditional and modern herbal medical systems, as particularly has been documented in Asia, Europe, and North America. Dandelion is grown commercially in the United States and Europe.The leaves and roots are used in herbal medicine. It is commonly used as a food. It is used for treatment of jaundice and disorders of the liver, gallbladder and other various hepatic ailments (You et al., 2010; Ahmed et al., 2013). The folk medicines of China, India, and Russia have recognized dandelion's effect as a liver tonic. Traditional Chinese medicine combines dandelion with other herbs to treat hepatitis (Modaresi, 2012). It has been reported to be used for the treatment of various ailments, including liver and gallbladder disorders. It is used to enhance the immune response to upper respiratory tract infections, bronchitis and pneumonia, and as a topical compress to treat mastitis, anemia and inflammation (Blumental et al. 2000). Wolbis et al., 1993 carried out an analysis in which he mentioned and isolated various polyphenolic compounds from *T. officinale* plant extracts thereby showing that the plant is rich in various antioxidants and can have a direct effect of these phytochemicals on health of an organism. Cinnamic acid, coumarins and flavonoids and other phytochemicals bearing important medicinal and therapeutic importance have been isolated from different tissue of *T. officinale* plant by various analytical methods by Williams et al., (1996). Modern pharmacological research suggests this plant has broad-spectrum antibacterial (Woods-Panzaru et al., 2009), anti-fungal (Odintsova et al., 2010), antiviral, antidiabetic, choleretic, antirheumatic, anti-inflammatory (Koh et al., 2010), hepatoprotective, diuretic, and tumor apoptosis-inducing properties (Schutz et al., 2006).

2.3.1.6 Broccoli (*Brassica oleracea*)

Broccoli (*Brassica oleracea*) is a plant from the *Brassicaceae* family. It has been stated that plants from the Brassica genus have been cultivated for over 2,500 years, though the varieties of broccoli that we know today may have been developed from selections made in Italy in the last 2,000 years (Buck, 1956). Broccoli is an excellent source of bioactive compounds, and thus, it is considered a functional food. Phenolic compounds are among the nutraceuticals present in broccoli, mainly hydroxycinnamic acids and flavonoids (Vallejo et al., 2003). It has been shown that these compounds possess a great antioxidant activity and may play a role in the prevention of several diseases, such as diabetes (Balasubashini et al., 2004), cardiovascular diseases (Rodríguez-Cantú et al., 2004), and neurodegenerative diseases (Kanski et al., 2001; Kim et al., 2005). Additionally, broccoli contains high concentrations of vitamin C, an essential nutrient. Vitamin C is a hydrosoluble vitamin necessary for a normal development and it is used for wound healing, repairing of cartilage and bones, and collagen synthesis, an essential protein found on skin and ligaments (Iqbal et al., 2004). Moreover, vitamin C may act as a potent antioxidant, helping to prevent atherosclerosis and cancer (Padayatty et al. 2003). Carotenoids can also be found in broccoli (Villareal-Garcia et al. 2015, Alanis- Garza 2015). Lutein, a carotenoid of the xanthophylls group, is one of the most abundant carotenoids present in broccoli. It is present throughout the retina, and it has been reported that it protects the eye by filtering hazardous light, preventing age-related macular degeneration and cataracts (Krinsky et al. 2003). Besides, previous studies have shown that lutein exhibits chemo protective activity against different types of cancer (Kim et al., 1998, González et al., 2003).

2.3.1.7 Cocoyam leaves *(Colocasia esculenta)*

Cocoyam is a starchy edible tuber and bears broad greenish leaves. It is grown in several places around the world. Its roots tubers or leaves, locally called kontomire are the parts usually consumed. Both the root and leaves have many health benefits for the body because they are rich in nutrients. One cup of cocoyam leaves contains about 145mg of Vitamin C, about 86% of our body's daily requirement. This will help boost your immune system effectively. Cocoyam leaves are rich in vitamin C which acts as an antioxidant. This fights against free radicals that cause cancer**.** Cocoyam leaves are rich in vitamin A in addition to the vitamin C (Onwueme, 1994). The amount of vitamin A can be as high as 123% of our daily requirement. It is very good for eyes to stay healthy, maintain the visual acuity, and prevent the eyes diseases such as myopia, cataract and blindness. The high dietary fibre in cocoyam leaves helps in food digestion and absorption. Cocoyam leaves can prevent digestive problems such as indigestion, constipation, and diarrhoea. Cocoyam leaves have no cholesterol and only 1% of total fat, and so, is one of the best diets for reducing cholesterol. The dietary fibre and methionine contained in cocoyam leaves can reduce the cholesterol effectively. They bind and break down fat and cholesterol especially triglyceride. Cocoyam leaves are low in fat and high in protein as well as contain Omega 3 fatty acids which play a role in inflammation process and can inhibit the release of inflammatory substances. It can help to treat diseases like arthritis, gastritis, or lupus disease.

The vitamin B complex including thiamin, riboflavin, niacin, and vitamin B6 in cocoyam leaves protect the nervous system. They also boost the immune system.The Omega 3, and essential fatty acid, help produce hormones to control the contraction and relaxation of arterial walls. Besides its rich nutrients content, the leaves also contain folate which is essential for the development of fetal brain and nervous system. It is, therefore, good for pregnant women to consume cocoyam leaves when pregnant. A cocoyam leaf diet is recommended in the prevention of anaemia. This is because they contain iron mineral which helps in red blood cell formation. The vitamin C content additionally helps in maximum absorption of the iron.

The consumption cocoyam leaves help to prevent preeclampsia (a pregnancy complication characterised by high blood pressure and signs of damage to another organ system, often the kidneys) during pregnancy. The magnesium mineral helps in muscle relaxation and can be used to prevent preeclampsia. They contain the amino acid called threonine. The threonine helps in the formation of elastin and collagen which are good for the healthy skin. They prevent the skin from wrinkles and rejuvenate skin.

Cocoyam leaves present one of the best energy sources for the body through its essential amino acid called isoleucine. This protein regulates the blood sugar and increases the muscle strength and energy levels. Cocoyam leaves release dopamine (a monoamine neurotransmitter found in the brain and essential for the normal functioning of the central nervous system) which acts in the brain and nervous system. Synthesized by phenylalanine, it enhances your brain memory and controls your mood.

Cocoyam leaves contain tyrosine, a crucial amino acid in the human body. It becomes an adaptogen substance which helps to minimize the effect of nicotine, cocaine, and coffee addiction. Histidine, one of the essential amino acids is also contained in cocoyam leaves. It serves as a detoxification agent that helps to remove the heavy metals from the body and protect the body from damage from radiation.

2.3.1.8 Eggplant (*Solanum macrocarpon*) leaves

S. macrocarpon is a vegetable commonly called "Gboma" in the local language of the Ewe people of Ghana. It is a plant of the family *Solanaceae* like tomato and pepper. The leaves and young fruits are prepared and eaten as a vegetable (Sodipo et al, 2012). The leaves constitute an important part of the diet because they are considered to be of high nutritional value and, therefore, used in the preparation of soups and stews. The leaves are rich in protein, fat, crude fibre, calcium, and zinc and are found to contain appreciable amounts of the sulphur-containing amino acid methionine (Sodipo et al, 2008). Several research results have revealed anti-inflammatory, antiasthmatic, antiglaucoma, hypoglycemic, hypolipidemic, and weight reduction effects of this green leafy vegetable (Dougnon et al 2012). These pharmacological properties have been attributed to the presence of certain chemical substances in the plants, such as polyphenols. Phytochemical studies of S. macrocarpon leaves showed that the leaves contained appreciable quantities of polyphenols, especially the flavonoids, which could contribute to strong antioxidant properties.

2.3.1.9 Amaranthus leaves

Amaranthus is highly nutritious. It is an annual, upright, tall and broad leafed plant. Amaranth species have huge number of varieties. The greens are edible leafy vegetables and nutritious. The leaves are utilized for human as well as for animal food (Tucker, 1986). The species vary slightly in their nutritional value and chemical composition. The nutritional value of amaranth has been extensively studied (Martirosyan, 2001 and 2003). It has been shown that amaranth leaves are excellent sources of protein, with its maximal accumulation in the blossoming phase (Kadoshnikov et al., 2005). They are regarded as storehouse of phytonutrients as well as antioxidants which assist to lower inflammation in the body and boost nutrition to maintain overall health. The leaves have adequate soluble and insoluble fiber that offers various health benefits. Its intake helps to lower weight and hinder heart disease as it reduces cholesterol in blood. Nutritionists recommend to intake high dose of amaranth leaves in diet for managing weight and high blood pressure. They possess a high content of vitamin C. A serving of 100 grams offers 70% of daily requirement of Vitamin C, a water soluble vitamin required to comb at infections and speeds up healing process. It also lowers the effect of free radicals in environment that results in aging and cancer.

2.3.2 Antioxidant and nutraceutical properties of some herbs

2.3.2.1 Basil (*Ocimum and Gratissimum*)

There are about 50 different species of the genus *ocimum* on the continent of Africa alone. *Ocimum basilicum* and *Ocimum gratissimum* are the two species known on the African continent to be used in the management of several different ailments. They are in the family of the herbaceous plant, *Lamiaceae*. This herb is locally referred to as 'nunum' among the Akan people of Ghana, 'Efirin' in Yoruba and 'ai-doya ta gida' in Hausa. They have a characteristic pleasant aroma due to the presence of volatile oils (Mindel et al., 1992). The leaf of *Ocimum gratissimum*, or the whole plant is popularly used in the treatment of diarrhea (Dalziel 1956).

The plant is heavily imbued with volatile oils, containing about 75% of thymol, whose antimicrobial properties is widely known. In fact, evidence exists to prove that the antimicrobial properties of the water-saturated oil is proportionate to the amount of thymol present (Said et al., 1969). *Ocimum gratissimum* has shown an effectiveness in the treatment of infections occurring in the upper respiratory tract, headaches, diarrhea, skin diseases, fever, conjunctivitis and pneumonia, (Onajobi 1989). *Ocimum basilicum* is used in traditional folk medicine in the treatment of various ailments, such as headaches, coughs, diarrhea, warts, constipation, worms and kidney malfunction. It is used in chicken and meat dishes for seasoning and for flavouring soups and stews. It is also thought to be an antispasmodic, stomachicum, carminative, antimalarial, febrifuge and stimulant (Wome 1982).

2.3.2.2 Lemongrass (*Cymbopogan citratus*)

Commonly found in Asia, Africa, Australia and Tropical islands, is an aromatic perennial tall grass with rhizomes and densely tufted fibrous roots. Lemongrass is grown for its medicinal and culinary purposes due to their peculiar lemon-like smell hence their name. They are of the *poaceae* family. Lemongrass is an important herb with over 120 species which grows in tropical and subtropical regions all over the world (Dutta et al., (2014). According to Jagadish, (1975), of the 120 species of lemongrass, 45 species natively belong to India alone. *Cymbopogan* species contain an abundance of essential oils in monoterpenes such as citral, citronellal, citronellol, linalool, elemol, 1,8-cineolo,limonene, geraniol, methyl heptenone, geranyl acetate, and geranyl formate (Ganjewala et al., (2008). Studies conducted by Oloyede, (2009) and Preira et al., (2009), revealed that, lemongrass leaf extracts contained antioxidant, antifungal and antimicrobial compounds. In traditional folk medicine, lemongrass is mostly employed in the treatment problems related to the GIT and the nervous system. Lemongrass oil, has antispasmodic, analgesic, anti-inflammatory, anti-pyretic, diuretic and sedative properties (Santin et al., (2009).

2.3.2.3 Rosemary (Rosmarinus Officinalis)

This herb is one of the world's most popular cooking herb, found in most kitchens the world over. It is a perennial herb belonging to the *Lamiaceae* family. It can be used in both its fresh and dried states. Rosemary can be employed in a variety of ways. Some of these includes sauces and stews, as a marinade, as a tea in small amounts, and its extracts as an antioxidant to increase the shelf life of foods. It is employed in various traditional folk remedies. Among its pharmacological validated medicinal uses are, its use as an antibacterial, anticancer, antidiabetic, and anti-inflammatory agent (Bozin et al., (2007), Cheung and Tai (2007) and Yesil-Celiktas et al., (2010)). The ability of rosemary to play diverse roles in both culinary and medicinal uses is as a result of a vast number of plant secondary metabolites such as camphene, borneol, 1,8-cineole present in it (Atti-Santos et al., 2002). Another group of secondary metabolites present in rosemary are, polyphenolic compounds such flavonoids and phenolic acid derivatives like rosmarinic acid (Bai et al., (2010)).

2.3.2.4 Bay Leaf (*Laurus nobilis L.*)

Bay leaf belongs to the laureacea family. It is native to warm Mediterranean regions like France, Italy, Portugal and Spain. It's most common culinary uses include spicing and flavouring meat dishes, stews and rice (Camejo-Rodrigues et al., 2003). Folk medicine application of bay leaf include the use of its dry leaf infusions to combat gastric diseases and as carminative and stomachic remedies (Afifi et al., 1997; Dall'Acqua et al., 2009). Its leaves and extracts are used to suppress high blood sugar, fungal and bacterial infections, to treat eructation, flatulence and gastrointestinal problems. It also exhibits anti-inflammatory, anticonvulsive, antiepileptic and antioxidant properties (Ferreira et al., 2006). Its ability to serve in this wide capacity of medicinal uses is as a result of the presence of compounds such as α-limonene, β-linanol, 3-carene, delta cadinene, quercetin, kaemferol and luteolin.

2.3.3 Antioxidant and nutraceutical properties of some spices

2.3.3.1 Cloves (*Eugenia caryophyllata*)

Cloves have been scientifically proven to bear antibacterial agents and as such is seen to be widely used in various dental creams, toothpastes, mouth washes, and throat sprays to get rid of harmful and disease causing microorganisms. It is also used to alleviate pain that occurs in the gums and maximise overall dental health. They are sometimes used as an aphrodisiac and are also in other instances used as an anti-inflammatory agent. This property of cloves is due to their high flavonoid content. Their pure oils are used to cure the symptoms of chronic aches in the body and in joints. Cloves are employed as a carminatives to increase HCL content in the stomach and to improve movement of food in the GIT. Cloves possess strong antioxidative properties, which can be compared to the activities of synthetic BHA (butylated hydroxyl anisole) and Pyrogallol (Dorman et al., 2000).

2.3.3.2 Alligator pepper (*Aframomum melegueta*)

Aframomum melegueta (Alligator pepper) is a plant with both nutritive and medicinal values. It is commonly found in the rain forest region of tropical West African countries such as Ghana and Nigeria (Agoha 1974). Its seeds are commonly used in flavoring food in Eastern Nigeria (Okwu 2005). It is used in alcoholic beverages, medicine for intermittent fevers, dysentery and gastrointestinal problems (Agoha 1974; Okwu 2005). The seeds are used to spice up food and wine (Enwere 1998). The seeds have a spicy, hot and slightly bitter taste, due to the presence of a volatile oil. It contains hydroarylalkanone and acetone extracts (Okwu 2005). The constituents present in alligator pepper consist of essential oils, paradol, resin, and tannins (Gill 1992). Alligator pepper is extensively used as a common ingredient of traditional folk medicine. It is generally used as a stimulant and is usually used to lower body temperatures to alleviate fevers (Gill 1992).

2.3.3.3 Ashanti black pepper *(Piper guineense)*

Piper guineense commonly referred to as the Ashanti black pepper, grows as a climber. It is a slender climber with prominent nodes, common in forest areas. The fruits occur in clusters of small, reddish or reddish brown berries when ripe and blacken when dried (Agoha 1974). They are commonly found in the Southern part of Nigeria and the forest areas of Ghana and other sub Saharan African countries (Okwute 1992). The black berries are used as a spice in food and various local drinks. It was reported by Addae Mensah et al. (1977), Oliver (1986), Okwute (1992), and Okwu (2001) that the bioactive constituents comprising of piprine, amide alkaloids (terpenes) and dihydropiperine have effective physiological effects when administered to animals. The piprine and alkaloids phytoconstituents also have anti-microbial, anticonvulsant, antihypertensive, sedative, tranquilizing and insecticidal properties (Oliver 1986; Okwute 1992; Okwu 2001). *P. guineense* seeds are used not only to relieve pain from gripping conditions of the stomach after childbirth but also to restore the uterus to its normal state (Ojimelukwe et al. 2000; Okwu (2001). *P guineense* is used extensively in foods meant for nursing mothers. The fruits are also used to spice up or flavour all kinds of foods such as soups, rice and stews.

2.3.3.4 Fruit of Tetrapleura tetraptera

T. tetraptera contains compounds like resins, carbohydrates, fats, colouring matter and fatty acids (Okwu 2001). A scientific study of the fruits of *T. tetraptera* showed the presence of oleanic acid, triglycoside and scoplatin, a coumarin (Okwu 2001, 2005). The presence of coumarin is most likely responsible for the unique aroma the fruits often impart in food and its ability to serve as a possible condiment in soups (Okwu 2001, 2006). In Nigeria, the fruits of *T. tetraptera* are used in traditional folk medicine for the treatment of infertility in women (Igoli et al., 2005). In some West African countries the infusion of fruits of *T. tetraptera*, is used to treat and reduce the risk of certain cardiovascular conditions such as hypertension.

The fruit is often reduced to a powder and added to soups and sauces.

2.3.3.5 Calabash nutmeg (*Monodora myristica*)

Phytochemical screening of *M. myristica* revealed the presence of alkaloids, tannins, general glycosides, steroids, terpenoids and saponins (Firempong et al., 2016). Alkaloids have been reported to bear the most effective medicinally important phytochemical (Njoku and Akumfela 2007). Their pain relieving, antispasmodic and bacterial properties have been reported and are widely used as cancer chemotherapeutic agents. An analysis on phytochemical properties established that *Monodora myristica* has high levels of glycosides, flavonoids, saponins and steroids but showed very little cyanogenic glycosides, tannins, oxalates and phytates. Flavonoids, saponins and tannins are known to possess antimicrobial activity (Sofowara 1980, Evans 2005). This therefore is an indication that calabash nutmeg is a good source of antimicrobial properties. In fact, flavonoids which occur in calabash nutmeg, have a large number of biochemical and pharmacological activities occurring in mammals and in other biological systems. They also possess anti-inflammatory, anti-oxidant, anti-allergic, hepatoprotective, anti-thrombic, antiviral and anticarcinogenic activities (Middleton et al., 2000)

2.3.3.6 Ginger (Zingiber officinale)

It belongs to family "*Zingiberaceae*" which is very famous due its medicinal herbal plants like, cardamom and turmeric (Park et al., 2006). It has been cultivated in South-East Asia from thousands of years. After that it gains much popularity in European and African countries due to its therapeutic effects. Currently, ginger and its products are used in many traditional medicinal systems, due to its rich phytochemistry and diseases preventive properties (Shukla and Singh, 2007). Ginger is a magnificent pungent spice with a great history of cultivation. India is the largest producer of this herb and it is used in Indian and Chinese traditional medicines to treat many disorders over 5000 years. Many health claims of ginger were documented in many countries like China. It has been used to cure abdominal distensions, coughing, vomiting, diarrhoea, rheumatism, and toothaches for over 2500 years. In Nigeria and West Indies, it is used for the treatment of yellow fever, malaria and urinary tract infections. It was migrated to Europe during Roman and Greek times. It is one of the oldest spices used in Europe since the 9th century. Due to its carminative effects, the Greek people directly incorporated it into bread and generated the idea of ginger incorporation in food products. In India, people still prepare the cough syrup from ginger and honey to get relief from common cold (Grant and Lutz, 2000). Ginger is very excellent source of a variety of biologically active components, which shows remarkable pharmacological and physiological benefits. The well reputed and most pungent bioactive molecule of ginger is 6-gingerol. The use of ginger and ginger products is commonly considered as safe but still more researches are needed to understand the complete mechanism behind its therapeutic effects (Tapsell et al., 2006). Due to the phytochemical profile and pharmacological properties, ginger and ginger products are widely administrated into human diet to diminish different kinds of ailments, such as hypertension (Ali et al., 2008; Nicoll and Henein 2009). Fresh ginger rhizome is composed of fat (1.0%), minerals (1.2%), protein (2.3%), fiber (2.4%), carbohydrate (12.3%) and water (80.8%). The minerals present in ginger are sodium, potassium, calcium, magnesium iron, and phosphorous (Odebunmi et al., 2009). The distinct aroma of fresh ginger comes from volatile oils ranging from 1-3% (Evans, 2002). The bioactive components which possess pharmacological activities are of two types discussed below due to rich phytochemistry ginger is considered as remedy for many health complications from cold to cancer, from thousands of years. It is a good source of many functional and nutraceutical components gingerols, shogaols and paradolsetc (Ali et al., 2008). All these components have been shown strong antioxidant potential and helpful in scavenging the free radicals. The administration of ginger in the in vivo studies on rats claimed many therapeutic effects such as the improvement of antioxidant status, prevention from lipid peroxidation, carcinogens, glucose and LDL lowering effects and many others (Nirmala et al., 2010). The evidence for the effectiveness of ginger as an antioxidant, hypocholesterolemic, hypoglycemic, anti-inflammatory, anti-nausea, and anticancer agent as well as the protective effect of ginger against other disease conditions are claimed.

2.3.3.7 Garlic (*Allium sativum*)

Garlic, Allium sativum L. is a member of the Alliaceae family, has been widely recognized as avaluable spice and a popular remedy for various ailments and physiological disorders. The name garlic may have originated from the Celtic word 'all' meaning pungent. Cultivated practically throughout the world, garlic appears to have originated in central Asia and then spread to China, the Near East, and the Mediterranean region before moving west to Central and Southern Europe, Northern Africa (Egypt) and Mexico (Lutomski, 1987). Garlic is considered to be rich in medicinal properties. The undamaged bulbs contain allin which will be enzymatically converted to allicin during cutting. Allicin, is the major bioactive compound found in garlic followed by other organosulfur compounds. Garlic is claimed to be effective against diseases due to its scavenging property for oxygen free radicals. High pressure liquid chromatography method was used to investigate the ability of allicin which is the active ingredient in garlic to scavenge the hydroxyl radicals. The decrease in hydroxyl radicals has shown the effectiveness of the antioxidant property of allicin by preventing lipid peroxidation (Prasad et al., 1995). Due to its biological active component allicin and its derivative, garlic has been used as a medicine to cure a wide range of diseases and conditions related the heart and blood system including high blood pressure, high cholesterol, coronary heart disease, heart attack, and “hardening of the arteries” (atherosclerosis) (Mikaili et al. 2013). Amagase (2006), noticed garlic is used to prevent various types of cancer comprising colon cancer, rectal cancer, stomach cancer, breast cancer, prostate cancer, prostate cancer and bladder cancer, and lung cancer. It is also used to treat Cardiovascular disease including: Antilipemic, antihypertensive, anti-atherosclerotic, an enlarged prostate (benign prostatic hyperplasia; BPH), diabetes, osteoarthritis, hayfever (allergic rhinitis), traveler's diarrhea, high blood pressure late in pregnancy (pre-eclampsia), cold and flu. It is also used for building the immune system, preventing tick bites, and preventing and treating bacterial and fungal infections. Garlic is a broad spectrum antibiotic, killing a wide variety of bacteria. Garlic appears to have antibiotic activity whether taken internally or applied topically. Researchers found that the urine and blood serum of human subjects taking garlic had activity against fungi (Caporaso et al. 1983). Ajoene is an active compound found in garlic which plays a great role as topical antifungal agent (Ledezma and ApitzCastro, 2006). Garlic has been shown to inhibit growth of fungal diseases as equally as the drug ketoconazole, when tested on the fungi *Malassezia furfur, Candida albicans, Aspergillus, Cryptococcus* and other *Candida* species (Shams Ghahfarokhi et al., 2006). A report from a Chinese medical journal delineates the use of intravenous garlic to treat a potentially fatal and rare fungal infection of the brain called Cryptococcus meningitis. In the report, the Chinese compared the effectiveness of the garlic with standard medical treatment which involved a very toxic antibiotic called Amphotericin-B. The study revealed that, intravenous garlic was more effective than the drug and was not toxic regardless of its dosage (Lemar et al., 2007). A study found that Candida colonies were substantially reduced in mice that had been treated using liquid garlic extract. The study also revealed that garlic stimulated phagocytic activity. This implies that infections such as Candida may be controlled because garlic stimulates the body’s own defenses. Garlic oil can be used to treat ringworm, skin parasites and warts if it is applied externally. Lesions that were caused by skin fungi in rabbits and guinea pigs were treated with external applications of garlic extract and began to heal after seven days.

2.3.3.8 Cumin (Cuminum cyminum L.)

Cuminum cyminum L., belonging to the family *Apaiaceae*, is one of the old cultivated medicinal food herbs in Asia, Africa and Europe. Its seeds have been commonly used for culinary and flavouring purposes as well as folklore therapy. In various countries dried ripe seeds of *C. cyminum* are usually used for medicinal or culinary purposes. In Iranian traditional medicine, Cumin seeds were used for their therapeutic effects on gastrointestinal, gynaecological and respiratory disorders, and also for the treatment of toothache, diarrhoea and epilepsy. The seeds were also documented as stimulant, carminative and astringent. (Zargari, 2001). It has been recently reported that medicinal usage of Cumin seeds has also been widespread in diverse ethnomedical systems from Northern Europe to the Mediterranean regions, Russia, Iran, Indonesia and North America, where these have remained as an integral part of their folk medicines. (Johri 2011). Antimicrobial activity has been reported from the volatile oils and aqueous extract of Cumin. Cumin seed oil and alcoholic extract inhibited the growth of *Klebsiella pneumoniae* and its clinical isolates by improving cell morphology, capsule expression and decreasing urease activity. Cuminaldehyde is the main active compound of Cumin for this property (Derakhshan et al., 2008). Limonene, eugenol, α- and β-pinenes and some other minor constituents have been found in cumin oil and suggested as the active antimicrobial agents (Derakhshan et al., 2008). The Cumin oil is reported as a high antioxidant mainly due to the presence of monoterpene alcohols (De Martino, 2009). The presence of phytoestrogens in Cumin has been reported which related to its anti-osteoporotic effects. Methanol extract of Cumin showed a significant reduction in urinary calcium excretion and augmentation of calcium content and mechanical strength of bones in animals (Shirke et al., 2008). Furthermore, the aqueous extract of Cumin seeds indicated the protective effect against gentamycin-induced nephrotoxicity, which decreased the gentamycin-induced elevated levels of serum urea and enhanced the clearance of the drug (Mahesh et al., 2010).

2.3.4 Antioxidant and nutraceutical properties of some fruits

There is epidemiological evidence that shows a correlation between consumers whose diets are rich in fresh fruits and vegetables and a marked reduction in the risk of cardiovascular diseases and certain types of cancers. These plants often exhibit wide ranges of biological and pharmacological activities, such as anti-inflammatory, anti-fungal and anti-bacterial properties.

2.3.4.1 Pawpaw (*Carica Papaya*)

Pawpaw (*Carica papaya)* belonging to the *Carica* genus in the myrtle family (*Caricaceae*). Pawpaw is indigenous to Central American countries but has been introduced and become wide spread throughout tropical Africa. It is popularly known as pawpaw in most English speaking West African countries. Papaya is one of the most nutritious fruits grown and eaten over the world. *Carica papaya* is not only an edible and tasty fruit, but it has also been used in most African countries for its healing properties. The pawpaw fruits as well as other plant parts have been known to be used in treatment of a wide variety of medical conditions, from stomach problems to bronchial disorders and even STD's. *C. papaya* is best known for its use as a deworming agent. Its leaves are usually boiled with other herbs with the aim to getting rid of worms when ingested (Neuwinger, 2000). A resultant extraction of the powdered seeds of the pawpaw has been employed in similar ways. Its leaves are regularly incorporated in the treatment of harmful organisms that reside in the gut (Iwu 1993). In Madagascar, the entire fruit is also sometimes cooked in water and the resulting tea ingested to treat stomach ulcers. Its leaves are sometimes brewed into a tea and the infusion used in the treatment of stomach ulcers as well as general stomach aches (Novy 1997). Among the Congolese people, a solution made from boiling the milled ripe seeds have evidently proven to be very adequate in curing dysentery (Tona et al., 1998). Pawpaw is also believed to be effective in malaria treatment. Several research findings revealed that pawpaw fruits and their leaves exhibited elevated antioxidative activities as a result of their high vitamin B levels which were present in the leaves, vitamin C and E, present in fruits, as well as carotenoids (Tona et al., 1998).

2.3.4.2 Avocado (Persea americana)

Persea americana is of the family *Lauraceaea*. The same family to which cinnamon, and camphor belong. Avocado has been proven to possess certain phytochemicals which have many valuable curative properties. These phytochemicals may be divided into alkanols, terpenoids, glycosides, several furan ring-containing derivatives, flavonoids, and coumarin (Kashman et al., 1969). Avocados are a rich source of nutrients such as Vitamin K, dietary fiber, pyridoxine, ascorbic acid, folate and copper, carbohydrates, soluble fibres, insoluble fibres and potassium. They are a rich source of oils, mainly containing monounsaturated fatty acids. However, oil contents of avocados are dependent on factors such as difference in variety and the stage at which the extraction of oil by the cold-press method was conducted. The existence of the afore mentioned phytochemicals and vitamins make this fruit an excellent source of antioxidants, making them very competent in the combating and prevention of a sizeable number of ailments which are usually the result of an unreasonable amount of free radicals in the biological system. Avocados possess the ability through their bioactive compounds to lessen and inhibit the occurrence of mouth and skin cancers, as well as prostate cancers. This study was conducted at a primary stage by medical researchers, mostly using cancerous cells or conducting laboratory experiments that involved nonhuman subjects and their ingestion of avocado extracts. Although this anti-cancer research is not yet extended to human subjects, the impression is that the initial results are spectacular enough. The anti-cancerous activities of this fruit is most likely related to its eclectic mixture of anti-inflammatory and antioxidative nutrients (Donnarumma et al., 2010). The link between its anti - inflammatory factors and antioxidative factors is understandable due to the fact that cancer risk factors almost always include excessive inflammation and oxidative stress. The story of the avocado gets especially interesting when we come to the realization that in sound cells, avocado performs the function of alleviating inflammatory and oxidative stress levels, whereas in cancer ridden cells, bioactive components in the avocado increases oxidative stress and shift the cancer cells over into a scheduled cell death cycle (apoptosis), reducing the cancer cell numbers (Ding et al., 2009). This therefore means that, avocado seems to selectively tip cancerous cells "over the edge" when it comes to the area of strains which are as a result of reactive oxygen species and heightens their probability of expiration. In the same instance, avocados are involved actively in assisting the health of cancer free cells by elevating their reservoir of antioxidative and anti- inflammatory nutrients.

2.2.4.3 Bitter kola (*Garcinia kola*)

Garcinia kola is to a very large extent used in traditional herbal medicines and as a food. It is highly valued in many sub Saharan African countries because of its diverse medicinal uses. Bitter kola seeds are also chewed in some countries because of its possible aphrodisiac properties, it is also used in the cure of coughs, dysentery, and chest colds (Farombi et al., 2005). In addition, it possesses hepatoprotective, analgesic and hypoglycaemic activities (Braide, 1991; Akintonwa and Essien 1990). A study conducted by Ogunmoyole et al., (2005), showed that, *G. kola* seeds were high in phenolic acids, and other bioactive compounds such as flavonoids and ascorbic acid.

2.3.4.4 Guava (Psidium guajava L.)

Psidium guajava L belonging to the myrtle family (*Myrtaceae*), is commonly referred to as guava in the English language. Guava is an excellent source of minerals such as iron, calcium, and phosphorus and also many nutrients such as vitamin A, pantothenic acid, carotenoids such as B- carotene, lycopene, and niacin (Mercandante et al., 1999). The guava fruit has about four times the concentration of vitamin C as an orange will contain (Misra et al., 1968). Analysis on its fruit has also revealed them to possess saponins along with oleanolic acid (Misra et al., 1968). Studies conducted on the fruit have revealed the presence of flavonoids and phenolic compounds such as ellagic acid, anthocyanin, guaijavarin, and quercetin. Anti-microbial compounds have also been isolated in the fruit. A study conducted by Lim et al., (2002) aimed at comparing the antioxidative activities of a large number of fruits found in the tropics revealed that guava possesses principal antioxidative properties. This was determined using methods of DPPH radical scavenging and iron (III) reducing assays (Lim et al., 2002). This gives the guava fruit the ability to be used in either preventive or protective roles, against diseases arising from oxidative stress.

2.3.4.5 Olives (*Olea europaea L.*)

The Olive tree belongs to the family *Oleaceae* and is native to tropical and warm temperate regions of the world. According to an estimate of Food and Agriculture Organization (FAO), in 2009, 9.9 million hectares were planted with olive trees with production of oil about 2.9 million tonnes worldwide. Olive oil has been used as a nutritious food, drug and as cosmetics for centuries by the Mediterranean people. During last few decades' olive has been a subject of much scientific interest for approving its multiple biological, therapeutic and functional food applications. Numerous epidemiological and clinical studies acknowledged olive oil as a source of food and medicine. The most important functional properties of olive oil are antioxidant, anti-microbial, anti-inflammatory and anti-cancer as evident from a variety of studies. These biological activities and individual taste are due to the presence of unique bioactive compounds in the olives, namely phenolics (e.g., oleuropein, hydroxytyrosol, verbascoside and derivatives), tocopherols and carotenoids, amongst others (Rahele et al., 2012). Olive fruit contains both lipophilic and hydrophilic phenolics. Among the lipophilic phenols the most important are cresols while the major hydrophilic phenols include phenolic acids, phenolic alcohols, flavonoids and secoiridoids (Rahele et al., 2012). Flavonoids are abundantly present in fruit tissues at the early stages of growth and development.

Accumulation of polyphenols in fruit tissue at the early stages of development of olive and many other fruits has been a common biosynthetic pathway (Bendini et al., 2007). The distribution and structure of the chemical constituents of olive fruit is complex and dependent on parameters including variety, cultivation practices, geographical origin, and the level of maturation. The therapeutic utilities of *O. europaea* have been indicated in traditional medicine. It has been known to reduce blood sugar, cholesterol, and uric acid. It has also been used to treat diabetes, hypertension, inflammation, diarrhoea, respiratory and urinary tract infections, stomach and intestinal diseases, asthma, haemorrhoids, rheumatism, laxative, mouth cleanser, and as a vasodilator. Many phenolic compounds, especially secoiridoids and iridoids (Bendini et al., 2007), and their pharmacological activities have been the focus of attraction for scientists in the last decade (Ryan and Robards, 1998; Ghisalberti, 1998). Oleuropein, a major constituent of olives, has got much attention and a lot of work has been done on its pharmacological properties (Soler-Rivas et al 2000; Omar, 2000). Olive has widely been explored as a functional food (Erbay and Icier, 2010; Galanakis, 2011) with various biophenols and other bioactive constituents (Obied et al, 2005; Saija and Uccella, 2000). Volatile constituents from olive oil and their applications in flavour development have also been a hot area of the current research.

2.3.5 Antioxidant and nutraceutical properties of edible fungi

2.3.5.1 Mushrooms

Mushrooms for many generations have been eaten because of their high nutritional content, and used as seasoning products as well as for their health benefits (Tel et al., 2012). Because of their unique flavours and aromas, mushrooms are held in high regard in various countries. Chang and Miles (2004), have defined mushrooms as ‘a macrofungus with a peculiar fruiting body, which can be hypogeous or epigeous, large enough to be visible to the naked eye and to be harvested by hand’. There are several thousands of known mushroom species in the world.

Of this large amount of mushroom species, only about 10% have been identified (Lindequist et al., 2005). Research conducted have indicated that mushrooms have potential antiviral, antimicrobial, anticancer, anti-hyperglycemic, cardio protective, and anti-inflammatory, activities (Kumar, 2015). Bioactive compounds identified in mushrooms consisting of antitumor substances, have been isolated in a large number of mushroom species over the last few years. Polysaccharides are the predominant and most potent compounds found in and derived from mushrooms. Fresh mushrooms have been proven to possess both soluble and insoluble fibres. The soluble fibre is mainly made up of beta-glucan polysaccharides and chitosans which are components found in the cell walls (Sadler 2003). Soluble fibre present in mushrooms prevents and manages cardiovascular diseases that occur in the human system (Chandalia et al., 2000). The antioxidant properties of mushrooms have been scientifically established. They are considered to be organisms which possess naturally occurring antioxidants. There is also a correlation between their phenolic and polysaccharide compounds.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study design

The study was conducted in two parts. A study was carried out using a questionnaire in four market centres, namely Madina, Makola, Adenta and Dome markets to find out what foods Ghanaian consumers perceive to be functional in nature and how easily accessible it was in their communities. The second part of the study, involved chemical analysis conducted on selected foods that respondents considered to possess nutraceutical properties, for identification and quantification of bioactive compounds.

3.2 Consumer survey

The survey was a cross sectional one, conducted in 4 markets centres in the Greater Accra region. Market centres were used in this study because, they are places where people from all walks of life, social classes, different religious and ethnic backgrounds converge. As such, it was a good place to sample views of a wide range of people.

3.2.1 Sample size calculation

The sample size used was 283 consumers. It was calculated using the formula given by Charan and Biswas (2013). $(Z_{1-\alpha/2}{}^{2}\ SD^{2}) \div d^{2}$

$Z_{1-\alpha/2}$ = standard normal variate SD = standard deviation variable d = Absolute error or precision
The inclusion criteria was willingness of participants to partake in the study, without any coercion.

3.3 Ethical Clearance for Data Collection

Ethical clearance was obtained from the Ethical committee of the College of Basic and Applied Sciences. Verbal consent as well as a signed consent form, was obtained from participants, taking part in the survey.

3.4 Materials

Samples were obtained from Madina and Makola market centres. The criteria for sample selection was based on lesser known functional foods in Ghana, identified from the earlier consumer survey, conducted as part of this study.

3.4.1 Sample selection

The selected samples, were a part of a list of indigenous foods that participants perceived to have functional properties. In total, ninety-six (96) different food commodities were identified by respondents to possess nutraceutical properties. The most frequently mentioned foods included *abeduru* (*solanum torvum*), bitter leaf, *dawadawa* (fermented *Parkia biglobosa*), *kontomire* (cocoyam leaves), basil, orange leaves and bitter kola. Of the ninety-six (96) mentioned foods, seven (7) were selected to determine their nutraceutical properties. They include, Ashanti black pepper, cloves, bitter kola, anise, and fruit of *Tetrapleura tetraptera,* alligator pepper and calabash nutmeg. The Seven (7) selected for analysis was because, they are indigenous to Ghana, and research conducted on them is limited.

3.4.2 Determination of Total Phenolic Content (TPC)

Total phenolic content was estimated using Folin Ciocalteu's reagent, and the protocol as outlined by Singleton and Rossi, (1965). A volume of 0.04ml of each sample's extract was mixed with 0.2ml Folin Ciocalteu's reagent in a 100ml test tube. The mixture was allowed to sit for 5 mins, before addition of 0.5ml of 20% sodium carbonate. The volume was adjusted to 5 ml with distilled water and vortexed for approximately 10 secs. The mixture was then incubated at 45°C for 30 mins and allowed to cool to room temperature. Reading was then taken at 750nm using a UV spectrophotometer. The total phenolic content were quantified and expressed as Gallic Acid Equivalent (GAE) mg/g.

Calculation of Total phenolic content in percent is based on gallic acid standard.

Total phenols % = [(A sample × W sample × 50) ÷ (A standard × W sample × 50)] × 100%

Where A is absorbance at 760nm and W is the volume

3.4.3 Phytochemical profile determination (flavonoids, alkaloids, Saponins)

3.4.3.1 Flavonoids

To determine the flavonoid content of food samples, 10g of each sample was extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The resultant solutions were filtered through whatman no. 4 filter paper. The filtrates were then transferred into a crucible and evaporated into dryness over a water bath and weighed to a constant weight. Obadoni and Ochuko (2001).

3.4.3.2 Saponins

In the test for saponins, the protocol as outlined by Obadoni and Ochuko (2001) was employed. The samples were first reduced to powder using a mill and 20 g of each weighed sample put into a conical flask and 100ml of 20% aqueous ethanol added. The extracts were heated over a hot water bath at a temperature of 55°C for 4h. The samples were stirred continuously during the heating period. The mixture was filtered and the residue re-extracted with another 200 ml of 20% ethanol. The combined extracts were reduced to 40 ml over water bath at about 90°C. The concentrate was transferred into a 250 ml separatory funnel and 20 ml of diethyl ether was added with vigorous shaking. The aqueous layer was then separated from the ether layer, which was then discarded. The purification process was repeated once more. 60 ml of n-butanol was added. The combined n-butanol extracts were washed twice with 10 ml of 5% aqueous sodium chloride. The remaining solution was heated in a water bath until most of the aqueous layer had evaporated. The samples were dried in the oven to a constant weight; the saponin content was calculated as percentage.

3.4.3.3 Alkaloids

An amount 5 grams of each selected food product was measured into a 250 ml beaker. 200 ml of 10% acetic acid in ethanol was then measured and added to the samples. The solution was covered and allowed to sit for 4 hours. The solution was then separated using Whatman no. 4 filter paper. The resulting extract was then heated on a water bath, until it was concentrated to a quarter of its initial volume. The extract was then added to in a dropwise manner to a concentrated solution of ammonium hydroxide until complete precipitation was achieved. The precipitated solution was then allowed to settle, after which the precipitate was collected and washed using dilute ammonium hydroxide and afterwards filtered. The residue remaining was the alkaloid, which was then dried to a constant weight (Harbone, 1998).

3.4.3 Determination of Antioxidant potential using 2,2-diphenyl-1-picryhydrazyl (DPPH)

The Antioxidant potential of the extracts using the DPPH radical was determined using the method according to Brand-Williams et al., (1995). DPPH radicals have an absorption maximum wavelength of 515 nm, which disappears with reduction by an antioxidant compound. The DPPH solution in methanol (6×10^{-5}M) was prepared, and 3 mL of this solution was mixed with 100µL of methanolic solutions of plant extracts. The extracts of the samples were incubated for up to 20 minutes at 37 °C in a water bath. After that, absorbance was measured at 515 nm. This reading was the absorbance of the plant extract (A_E). A blank sample containing100 µL of methanol in the DPPH solution was prepared, and its absorbance was measured also at 515nm. This reading was the absorbance of the blank (A_B). The analysis was conducted in triplicate, and averages recorded. The radical scavenging activity was calculated using the following formula:

$$\% \text{ inhibition} = [(A_B - A_E)/A_B] \times 100$$

Where A_B = absorbance of the blank sample, and A_E = absorbance of the plant extract.

3.4.4 Determination of the effect of processing on the phytochemical profile of selected food samples

The determination of the effect of processing on phytochemical contents of the selected samples was carried out by steam cooking, using the method of blanching. Blanching was conducted on each of the samples at 5 minutes intervals for up to 1 hour. The physicochemical analysis stated in section 3.5 was repeated on all the food samples after each blanching time to establish the effect of heating on the phytochemical contents of the samples.

3.5 Analysis of results

Analysis of results from the consumer survey were tabulated and frequencies and percentages calculated using Microsoft Excel. The physicochemical values were analysed using one way ANOVA. The software used were SPSS and STAT Graphics.

CHAPTER 4

RESULTS AND DISCUSSION

This section presents results obtained from both the consumer survey, and laboratory analysis of the selected samples used in the study.

4.1 Consumer survey on indigenous foods Ghanaian considered to be functional foods

4.1.1 Consumer background characteristics

Table 4.1 outlines the background characteristics of respondents who took part in the survey. Characteristics of consumer markets is based on demographics which include differences in gender, age, ethnic background, income, occupation, education, household size, religion, generation, nationality and even social class. Most of these demographic categories are further defined by a certain range. The total number of respondents interviewed in this survey was 283. Of this number, 201 (71%) were females and the remaining 82 (29%) were males. This is due to the fact that more trading in market centres is carried out by women than men .The respondents fell between the ages of 15-65, with the highest percentage of 27.6%, falling within the age bracket of 15-25, and the least (11.7%) in the 56-65 age bracket. In terms of marital status, the highest percentage (48.1%) were single with the 4.9% being widowed. The highest percentage being single can be attributed to the fact that most of the respondents were between 15-25 years. For their religious affiliations, 91.5% of respondents asserted to be Christians, 7.1% Moslems, and 1.1% traditionalists, with the remaining 0.4% being Rastafarians. Ghana being a predominantly Christian country with the next largest religious group being Islam can account for this. In terms of ethnicity, 60.7% of respondents were Akans which constituted the largest group.

Table 4.1: Background characteristics of consumers

Variables	Total (n=283)	Percentage (%)
Gender		
males	82	29
females	201	71
Age		
15-25	78	27.6
26-35	59	20.8
36-45	68	24.0
46-55	45	15.9
56-65	33	11.7
Marital status		
Single	136	48.1
Married	108	38.2
Divorced	25	8.8
Widowed	14	4.9
Religion		
Christianity	259	91.5
Islam	20	7.1
traditionalist	3	1.1
Rastafarian	1	0.4
Ethnicity		
Akan	170	60.7
Ga/Adangbe	40	14.1
Ewe	47	16.6
Northern ethnicity	18	6.3
Krobo	8	2.8

4.1.2 Indigenous foods listed by Ghanaian consumers to possess functional properties

Indigenous foods can be described as foods that people have eaten for ages. These foods have become part of traditions and cultures. The data from the survey as shown in Table 4.2 indicated that, the indigenous foods mostly perceived to possess functional properties were *Solanum torvum*, locally as *Abeduru or kantose*. Cocoyam leaves (*kontomire*), ginger, cassava leaves, bitter leaves (*awonyono*), and fruit of *Tetrapleura tetraptera* (*prekese*), fermented *Parkia biglobosa* (*dawadawa*) and *Talinum triangulare* (*bokorbokor*).

Table 4.2: Indigenous foods perceived to possess functional properties

Food product	**Frequency**	**Percentage (%)**
Turkey berries *(Abeduru/Kantose)*	276	97.5
Cocoyam leaves *(kontomire)*	276	97.5
Bitter leaves *(awonyono)*	206	72.7
Solanum macrocarpon *(gboma)*	156	55.1
Amaranthus species *(alefu)*	156	55.1
Moringa oleifera	136	48.0
Talinum triangulare (bokorbokor)	129	45.5
Dandelion	125	44.1
Cassava leaves	123	43.4
Fruit of Tetrapleura tetraptera *(prekese)*	94	33.2
Bissap *(sobolo)*	71	25.1
Garcinia kola (michi goro)	69	24.4
Fermented parkia biglobosa *(dawadawa)*	43	15.2
Garlic	41	14.5
Ginger	36	12.7
Ashanti black pepper *(soro wisa)*	35	12.4
Calabash nutmeg *(widie aba)*	28	9.9
Alligator pepper *(efom wisa)*	16	5.6
Anise *(nkitinkiti)*	12	4.2
Cloves *(pepre)*	12	4.2

Indigenous foods are generally perceived as foods with beneficial properties due to genuineness, local production, propagation and minimal or no industrial processing. According to FAO (2008), traditional food products represent an expression of culture and lifestyle resulting from the local climatic, agricultural and economic conditions that determine production and processing practices. The foods listed by consumers as frequently consumed such as cocoyam leaves (kontomire), turkey berries, cloves, dandelion etc. are easily and readily available on the local markets and sometimes can even be found growing wild in homes and neighbourhoods.

The perceived curative or preventive properties of the foods as reported by consumers are presented on Table 4.3.

Table 4.3: Perceived medicinal properties of some indigenous food products as stated by respondents.

Food product	**Perceived medicinal properties**
Turkey Berries (Abedru/Kantose)	Anaemia prevention , treatment of intestinal worms
Cocoyam leaves *(kontomire)*	Anaemia prevention, immune system booster
Bitter leaves *(awonyono)*	Reduces high blood pressure, fever treatment, prevents anaemia
Solanum macrocarpon (gboma)	Improves vision, prevents anaemia, lowers high blood pressure
Amaranthus species *(alefu)*	Improves vision, prevents anaemia, lowers high blood pressure
Moringa	Lowers blood sugar and cholesterol, prevents cancer and stroke
Talinum triangulare (bokorboko)	Prevents anaemia, regulation of blood sugar levels
Dandelion	Lowers blood pressure, immune system booster, reducing blood sugar
Cassava leaves	Relieves constipation, prevents anaemia,

	treatment of diarrhoea
Fruit of *Tetrapleura tetraptera (prekese)*	Lowers blood pressure, fever reduction, reducing blood sugar
Bissap *(sobolo)*	Lowers blood pressure, promotes weight loss
Garcinia kola (michi goro)	Aids digestion, improves sexual function, lowers high blood pressure
Fermented P*arkia biglobosa (dawadawa)*	Promotes good eye sight, lowers high blood pressure, immune system booster
Garlic	Lowers high blood pressure, colds, detoxification, improves digestion
Ginger	Nausea, colds, coughs, indigestion, lowers high blood pressure
Ashanti black pepper *(soro wisa)*	Coughs, colds, intestinal worms, joint pains, immune system booster
Calabash nutmeg *(widie aba)*	Colds, coughs, nausea, high blood pressure
Alligator pepper *(efom wisa)*	Asthma, indigestion, period cramps, malaria, stomach pain
Anise *(nkitinkiti)*	Stomach aches, asthma, indigestion, colds
Cloves *(pepre)*	Treatment of tooth aches, coughs and colds

4.1.3 Level of consumption of the stated foods

The consumption levels amongst consumers were 24% for those who consumed them daily, 23% for those who consumed them occasionally, 22% for monthly consumers and 20% for those who consumed it twice a week. 11% of consumers reported consuming the foods three or more times a week (Figure 1a). In terms of ease of availability of these foods in communities, 223 respondents reported that it was easy to find these foods in their communities whilst 19 said it was not easy to access them in their communities (Figure 1b). The easy accessibility of these foods can be attributed to the fact that Accra is a cosmopolitan city with inhabitants coming from all over the country so traders bring a lot of these to Accra, making these foods available in markets and communities in Accra. For those who said they foods are not accessible to them, one main reason given was that, those particular functional foods were peculiar to their ethnic groups and were not easily accessible in areas outside their hometowns.

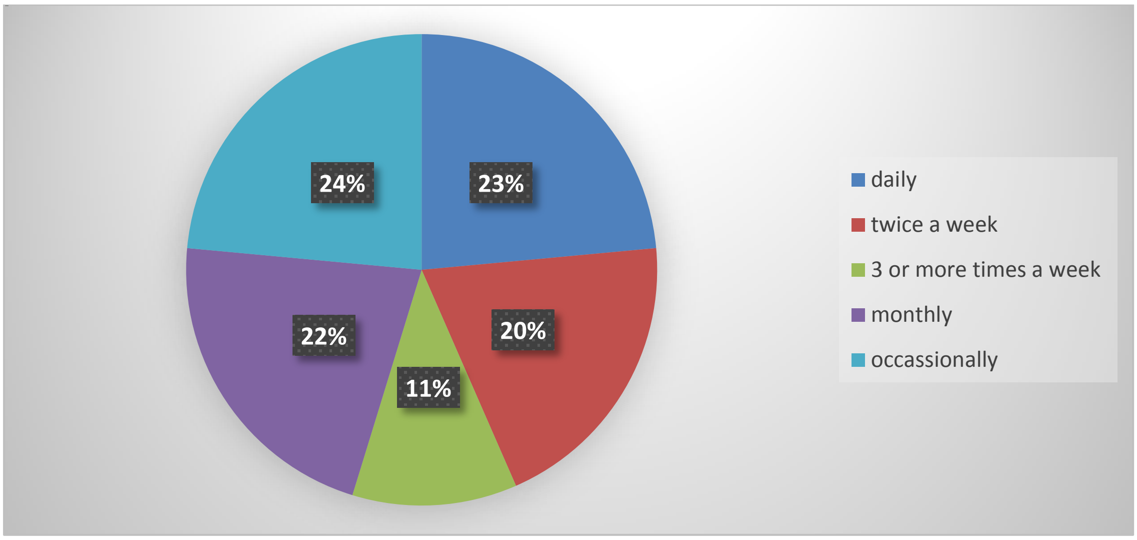

Figure 1a: Reported consumption of functional food patterns amongst consumers

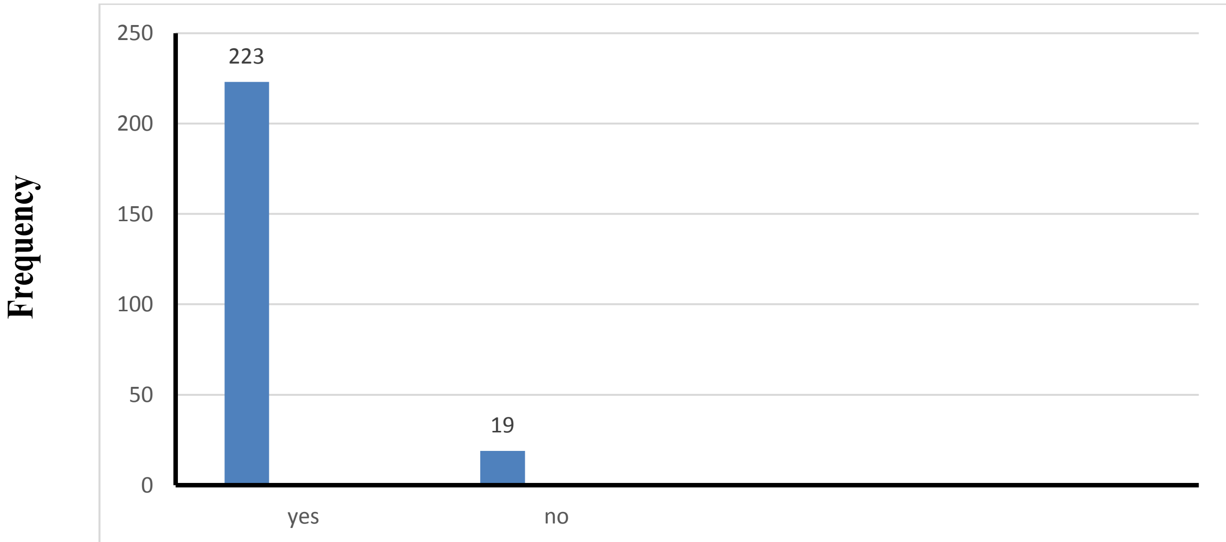

Figure 1b: Ease of availability of functional foods in communities

4.2 Chemical Analysis of selected food samples

For the purposes of this study, seven (7) indigenous Ghanaian foods were selected from those stated by the respondents.

Figure 2: Selected food samples. L-R top (Ashanti black pepper, cloves, bitter kola) L-R bottom (Anise, fruit of *Tetrapleura tetraptera*, Alligator pepper and Calabash nutmeg)

These were Ashanti black pepper, cloves, bitter kola, Anise, fruit of *Tetrapleura tetraptera*, Alligator pepper and Calabash nutmeg (figure 2). They were analysed for their Total Phenolic Content (TPC), Antioxidant scavenging capacity and phytochemical profile.

4.2.1 Total Phenolic Content (TPC)

There were significantly differences ($p > 0.05$) among the foods for the levels of total phenolics (Table 4.4).

Table 4.4: Total Phenolic Content (TPC) of selected food samples

Sample	Total Phenolic Content (mg GAE/g) (mean ± S.D)
Ashanti black pepper	15.523 ±0.083[b]
Cloves	12.256 ±0.081[c]
Bitter kola	45.233 ±0.351[a]
Anise	2.960 ±0.000[d]
Fruit of *Tetrapleura tetraptera*	15.503 ±0.351[b]
Alligator pepper	2.236 ±0.045[e]
Calabash nutmeg	3.306 ±0.089[d]

Figures within the same column bearing the same superscript are statistically the same at $p<0.05$

Bitter kola had a total phenolic content of 45.233mg GAE/g which is comparable with levels of 45.2mg GAE/g obtained by Ogunmoyole et al. (2012). The values obtained in this study for cloves (12.256mg GAE/g) was in close proximity to those obtained by Seranthinata et al. (2012) who had 11.78mg GAE/g. They stated that such amount of polyphenols are high enough to exhibit curative properties such as anti-cancer, anti-microbial and anti-diabetic. Nwoba (2015) reported a TPC of 0.373mg GAE/g for *Tetrapleura tetraptera* and concluded that the fruit contains appreciable levels of TPC making them a good source for promotion of good health. Values recorded in this study (15.803mg GAE/g) was even much higher. As demonstrated by Thomas et al. (2018), the variations in the total phenolic content might be due to several factors such as genetic variability, environmental pressure, cultivation techniques, age, maturity of the plants and postharvest treatments. The TPC of calabash nutmeg (3.306mg GAE/g) and anise (2.96mg GAE/g) were in close proximity to those reported by Womeni et al. (2013). TPC of Alligator pepper was 2.236mg GAE/g.

Phenolics are secondary aromatic compounds (Abdelaaty et al., 2014). They have been reported to be associated with functions such as nutritional and antioxidant properties (Robbins, 2003). The presence of phenols in cloves can be attributed to their ability to act as pain relievers for tooth aches and a cure for coughs and colds. Antibacterial activity of clove essential oil has been reported against Staphylococcus aureus (Mishra and Sharma 2014). Eugenol a type of phenolic compound present in cloves is a routine analgesic agent widely used in dental clinics due to its ability to alleviate tooth pain. The effects have been attributed to its capability to suppress prostaglandins and other inflammatory mediators such as leukotriene. It is also believed to depress the sensory receptors involved in pain perception (Raghavenra et al., 2006). These support claims made by consumers of its ability to treat tooth aches, coughs and colds.

Phenolic content of calabash nutmeg has been reported to be potent in killing *Staphylococcus aureus, Bacillus subtilis* and *Canadidia albicans* (Nwaiwu and Imo, 1999, Nwankwo, 2015) Also Oluwafemi and Taiwo reported on the reversal of toxigenic effects of aflatoxin by alcoholic extracts of *Monodora myristica*.

The total phenolic content in a food sample is a determinant of its curative ability for several diseases. Total phenolic content has a direct relationship to antioxidant activities. The higher the total phenolic content, the higher the antioxidant activity (Al-Mamary et al., 2002).

The levels of TPC recorded in the different food samples, are an indication that these foods possess the ability to cure or prevent disease as stated by consumers. The presence of phenols at different levels in the foods further indicates that could act as anti-inflammatory, anticlotting and immune enhancers. Phenols have been the subjects of extensive research as disease preventatives (Duke, 1992). Phenols have been responsible in having the ability to block specific enzymes that causes inflammation. This could justify the health claims made by consumers concerning these foods.

4.2.2 Antioxidant scavenging capacity

Results of this is recorded in Table 4.5. There was a marked reducing activity of the extracts. According to Nataraj et al., (2013) the marked reducing activity of the extracts may be as a result of the presence of polyphenols, which may act as reductants by donating the electrons and reacting with free radicals to convert them to more stable products and terminate radical chain reaction. The activities of natural antioxidants in influencing diseases are closely related to their ability to reduce DNA damage, mutagenesis, carcinogenesis, and inhibition of pathogenic bacterial growth (Roginsky and Lissi (2005).

Table 4.5: Antioxidant scavenging capacity of selected food samples

Antioxidant scavenging capacity (%)	(mean ±S.D)
Ashanti black pepper	0.798 ± 0.0004^{e}
Cloves	0.933 ± 0.0000^{a}
Bitter kola	0.877 ± 0.0004^{c}
Anise	0.789 ± 0.0004^{f}
Fruit of *Tetrapleura tetraptera*	0.867 ± 0.0013^{d}
Alligator pepper	0.928 ± 0.0000^{b}
Calabash nutmeg	0.709 ± 0.0000^{g}

Figures within the same column bearing the superscript are significantly the same at $p < 0.05$

Food samples which recorded high total phenolic contents therefore, equally recorded relatively high antioxidant capacities. High levels of antioxidant scavenging potential is a sign that a particular food is able to remove free radicals that may be present in the body, and are usually the cause of many diseases that occur in the body. A positive correlation can therefore be made between these food samples, and claims made as to their curative properties. Bitter kola for example has been purported to bear preventive properties in terms of cancer. Its relatively high level of antioxidant scavenging capacity (0.877%) could be the reason for such claims. However, Vasco et al. (2008) analysed fruits such strawberries, passion fruit and bananas reported that an antioxidant capacity of between 4 to 17% obtained were low for fruits. The samples analysed in the current study were mostly spices and hence will not provide an appreciable level of antioxidant capacity unless used in high amounts. Low values could also be due to extraction methods and storage conditions of the commodity (Vasco et al., 2008).

Cloves had an antioxidant scavenging capacity of 0.933%. A study conducted by Ou et al (2006), showed that Eugenol, a major phenolic component from clove oil (Eugenia caryophyllata), has demonstrated several biological activities, such as anti-inflammatory activity by inhibiting the enzyme cyclooxygenase-II, analgesic activity due to selective binding at the capsaicin receptor, anti-oxidation activity, and antibacterial activity against both gram-positive and gram-negative microorganisms. In a research conducted by Onoja et al (2014) extracts of alligator pepper revealed that it has a potent antioxidant activity comparable to vitamin C which was used as a reference standard. They concluded that the demonstrated antioxidant and antilipid peroxidation effects of the extract of *A. melegueta* may be the rationale behind some of its folkloric uses and also may be responsible for some of its pharmacological effects.

4.2.3 Phytochemical profile (Alkaloids, Saponins, Flavonoids)

Table 4.6 shows results regarding the levels of some individual phytochemical constituents in the selected food samples

Table 4.6: Phytochemical profile of selected food samples

Sample	Alkaloids	Flavonoids	Saponins
	(mean ±S.D)	(mean ±S.D)	(mean ±S.D)
Ashanti black pepper	0.343 ±0.0351[c]	8.250 ± 0.0794[a]	4.376 ±0.0057[f]
Cloves	0.236 ±0.0115[c]	3.130 ± 0.0265[a]	1.886 ± 0.0057[f]
Bitter Kola	0.670 ±0.0173[c]	2.040 ± 0.0000[d]	12.470 ±0.0200[g]
Anise	0.380 ±0.0173[c]	1.340 ± 0.0000[d]	7.790 ±0.0265[g]
Fruit of Tetrapleura tetraptera	0.300 ±0.0100[c]	2.120 ± 0.0173[d]	9.013 ±0.0152[g]
Alligator pepper	0.290 ± 0.0173[c]	6.10 ± 0.0000[a]	1.220 ±0.0451[f]
Calabash nutmeg	0.493 ± 0.0152[b]	0.220 ± 0.0152[e]	9.790 ± 0.0265[g]

Figures within the same column bearing the same superscript are statistically the same at $p<0.05$

The phytochemical content of ashanti black pepper showed it having a high content of flavonoid followed by its saponin content and then its alkaloid content. Alkaloids possess anti-malarial, antihypertensive, antiarrhythmic and anticancer properties (Heikens et al 1995). The flavonoids present are also responsible for the antioxidant, anti-inflammatory, and their anti-allergic properties (Okoye and Ebeledike 2013). The anti-inflammatory properties of flavonoids present in ashanti black pepper is responsible for its ability to relieve joint pains as stated by consumers. According to Mba (1994), it is used as an adjuvant in the treatment of rheumatic pains and as an anti-asthmatic. Saponins also have anti-carcinogenic properties.

Alkaloids are bioactive compounds that contain elements such as nitrogen, and are biologically active, bearing sedative and analgesic properties for relieving pains, anxiety and depression (Jisika et al., 1992). They are a cluster of biological compounds found in various plant parts. Alkaloids can act in either a beneficial or destructive medium. Some alkaloids stimulate the nervous systems; others can cause paralysis, raise blood pressure or lower it this explains why certain alkaloids alleviate pain, while others serve as tranquilizers. Others have also been noted to contain antimicrobial properties (Adesuyi et al., 2011). Flavonoids have also been reported to possess protective effects including anti- inflammatory, anti-oxidant, antiviral, and anticarcinogenic properties. (Middleton et al., 2000). The high saponin content of a food has been linked to that food, possessing high cholesterol binding abilities.

Some traditional remedies, prescribe foods made with or from fruit of *Tetrapleura tetraptera* and calabash nutmeg for people who suffer from high blood pressures and this can be attributed to the presence of the phytochemicals in the commodities. Work done by Adesina, (2016) showed that the extracts of *tetrapleura tetraptera* and some of the isolated compounds showed sedative, hypotensive, molluscicidal, CNS depressant, anti-inflammatory, antimicrobial, wound-healing, contraceptive, analgesic, hypoglycemic, antioxidant, hypolipidemic, antimalarial, muscle-relaxant, anticonvulsant, hypothermic, and anxiolytic effects in experimental animals. This is as a result of the presence of phytochemicals like alkaloids, glycoside, saponins, and flavonoids. This supports claims made by consumers concerning the ability of *tetrapleura tetraptera* to reduce blood sugar as well as blood pressure. Flavonoid content present in calabash nutmeg was 0.220. As compared to research conducted by Ekeanyanwu and Nwachuku (2010) and Effiong et al (2005) showed large amounts of flavonoids present in calabash nutmeg. This variation could be attributed to many factors, such as climatic, edaphic and time of exposure to dryness. Such differences may arise from variations in soil micronutrients. It could also be partly attributed to the method of analysis (Bimakr, 2010).

Research carried out by Naiho and Ugwu (2009), on bitter kola showed that it is rich in phytochemicals such as flavonoids, tanins, saponins, biflavonoids and resins. The research further revealed *Garcinia kola* is capable of lowering blood pressure due to the presence of these phytochemicals. This provides scientific proof to claims made by consumers concerning the ability of consumption of bitter kola to reducing high blood pressure.

4.3 Effect of heating on the TPC, Antioxidant scavenging capacity and phytochemical profile of selected food samples

4.3.1 Total Phenolic Content and Antioxidant scavenging capacity

The technique used in processing the food samples was blanching. Blanching is the process by which food is exposed to mild heating in water for short periods of time (Patras et al., 2011). Blanching is typically carried out by treating food products for 1-10 min at 75-95°C. The time-temperature combination used, is usually dependent on the type of vegetable being processed (Cano, 1996). The process of blanching has been recorded to either reduce or give rise to antioxidant activity of agricultural products (Pujimulyani et al., 2012). From Figure 3, the antioxidant scavenging capacities of all the food samples showed a gradual decline during blanching. In alligator pepper for example, after about 20 minutes of blanching time, antioxidative capacity was stable over a period of 25 minutes, before another marked change was seen. A similar trend is seen in all the other samples. The effect of blanching on the total phenolic content also showed a gradual decline, with the TPC holding steady after some time of blanching, just as was seen with the antioxidant activity.

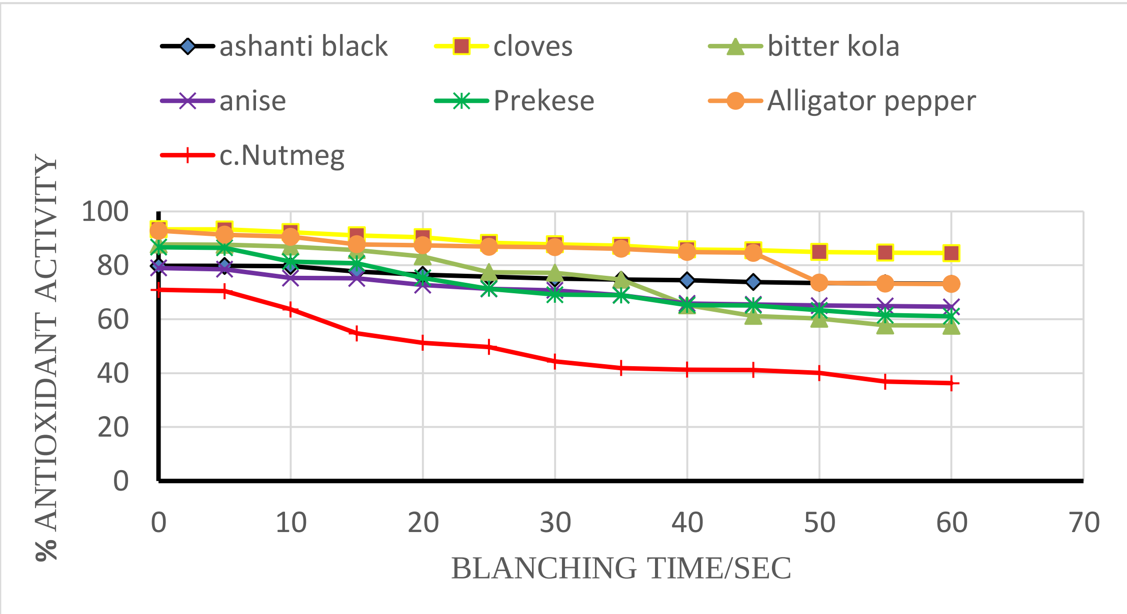

Figure 3: Effect of blanching time on the antioxidant capacity of selected food samples

According to Goncalves et al. (2010), high intensity heat treatment leads to the maximum loss of phenolic content which may be due to several reasons like thermal degradation and leaching or diffusion of component into water. Similar results were reported by Jaiswal et al. (2012) during blanching of cabbage. These results can be compared to work done by Sharma et al. (2014). Phytochemicals are heat sensitive and so when exposed to heat over a period of time, they will break down. In some studies however, total phenolic content and antioxidant capacities increased with heating time as reported by Sinha et al., (2015). These variations can be attributed to the different types of heating techniques used. For example, samples that were treated with dry heat methods such as microwave heating, both antioxidant capacity and total phenolic content increased. However, those treated with wet heat methods showed a decrease in total phenolic content as well as antioxidant capacity.

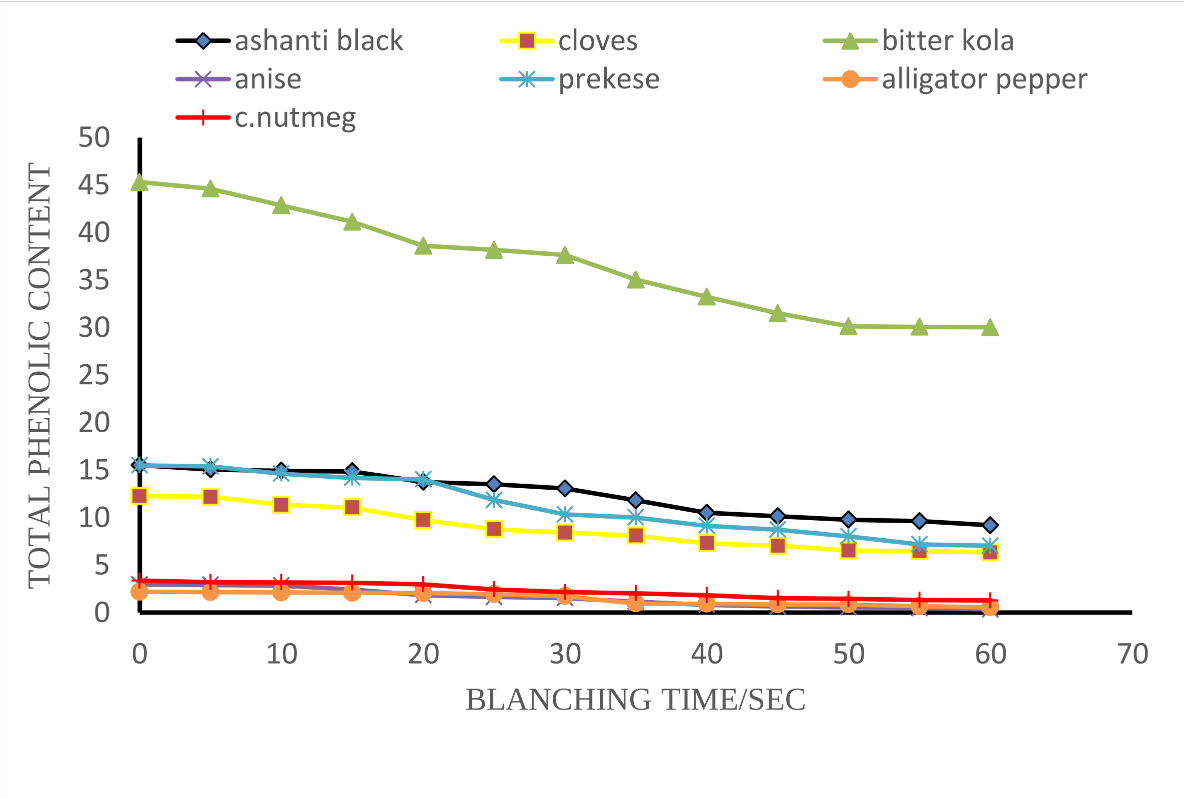

Figure 4: Effect of blanching time on Total phenolic content of selected foods

4.3.2 Phytochemical profile

Most vegetables are cooked either by boiling, steaming or microwaving before being consumed (NG et al, 2011). Several studies have reported that these heating processes cause many changes in the chemical composition of vegetables. For example, the antioxidant capacity and total phenolic content of pepper (Capsicum spp.), green bean (Phaseolus vulgaris), broccoli (Brassica oleracea), spinach (Spinacia oleracea), and sweet corn (Zea mays) increase after boiling, steaming, or microwaving (Dewanto et al, 2002, Turkment et at 2005).

The effects of heating on the phytochemical profile of the selected food samples are shown on Figures 4 to 10.

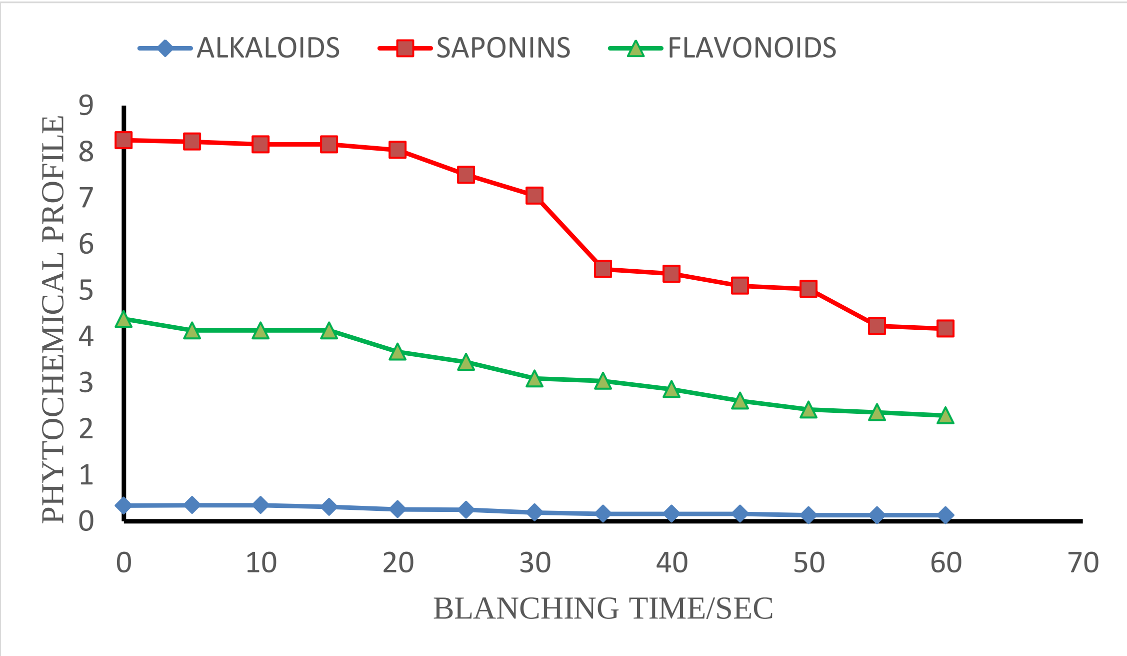

Figure 5: Effect of blanching time on the phytochemical profile of Ashanti black pepper

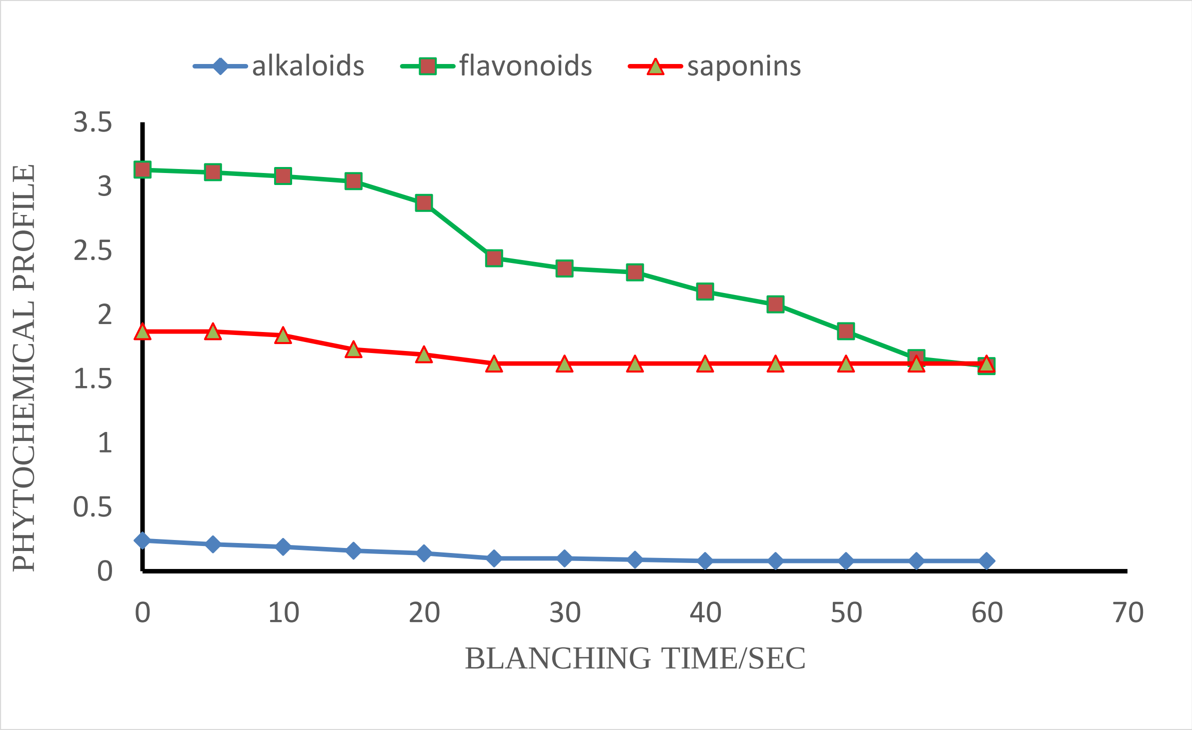

Figure 6: Effect of blanching time on the phytochemical profile of cloves

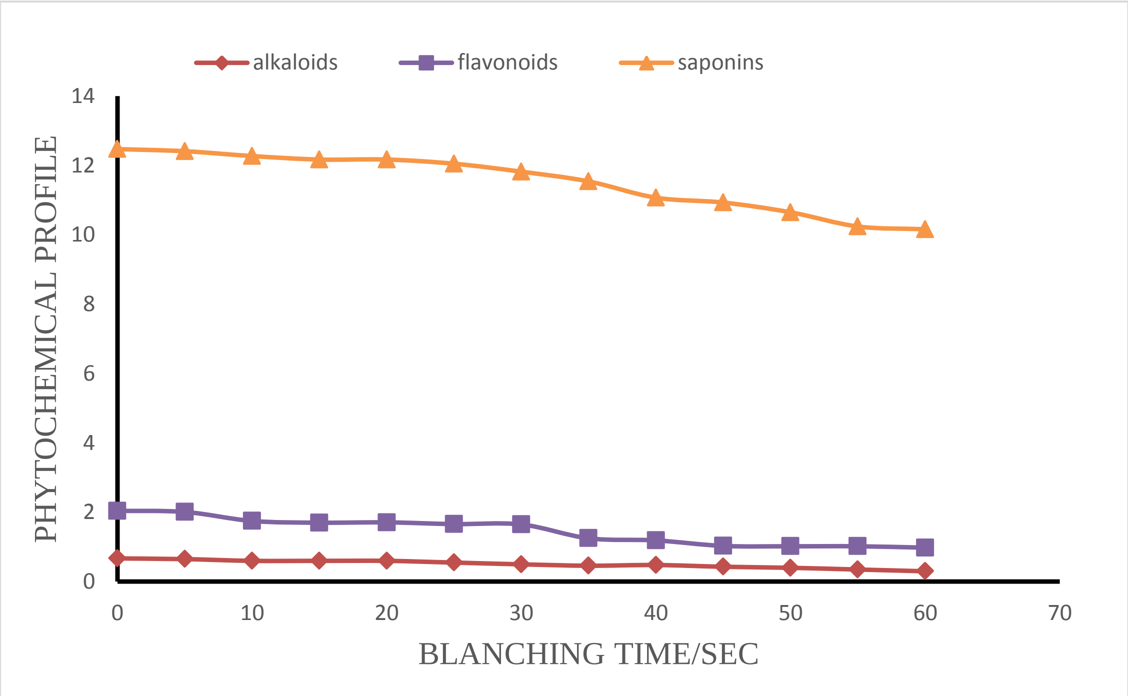

Figure 7: Effect of blanching time on the phytochemical of Bitter kola

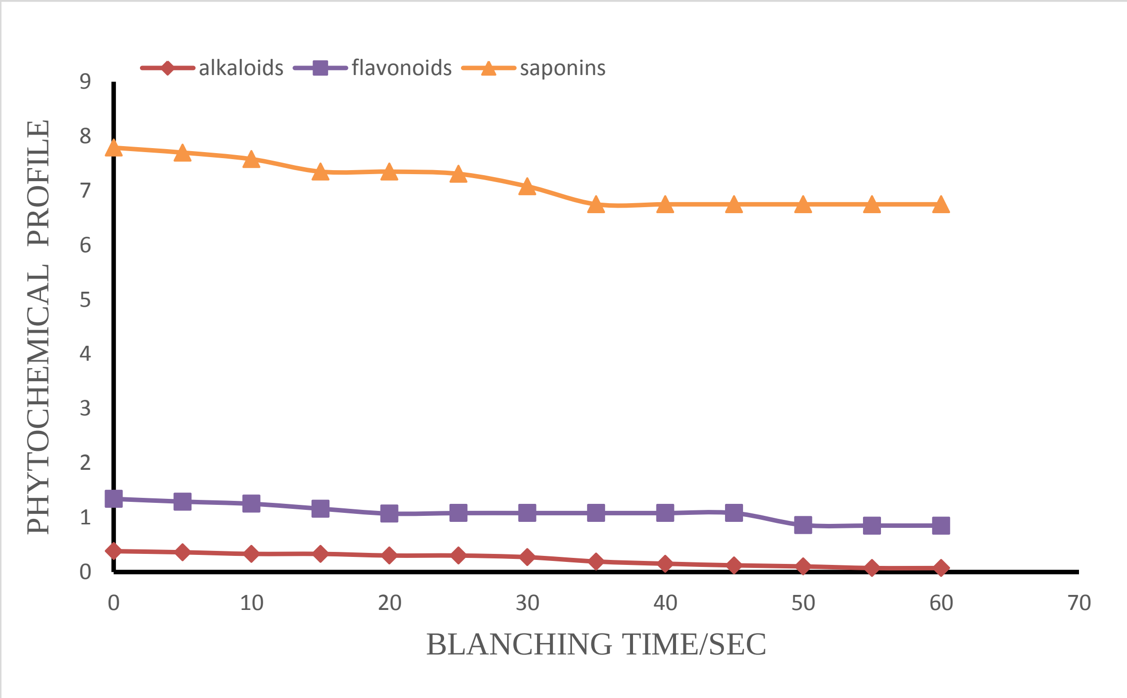

Figure 8: Effect of blanching time on the phytochemical profile of Anise

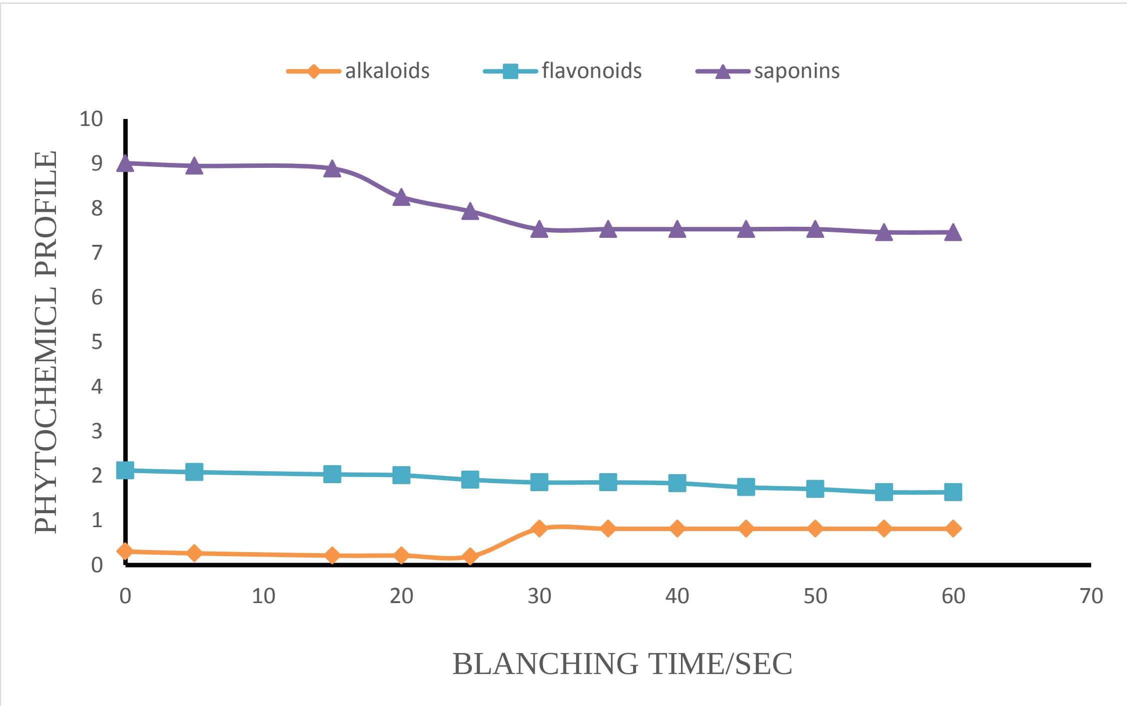

Figure 9: Effect of blanching time on the phytochemical profile of fruit of *Tetrapleura tetraptera*

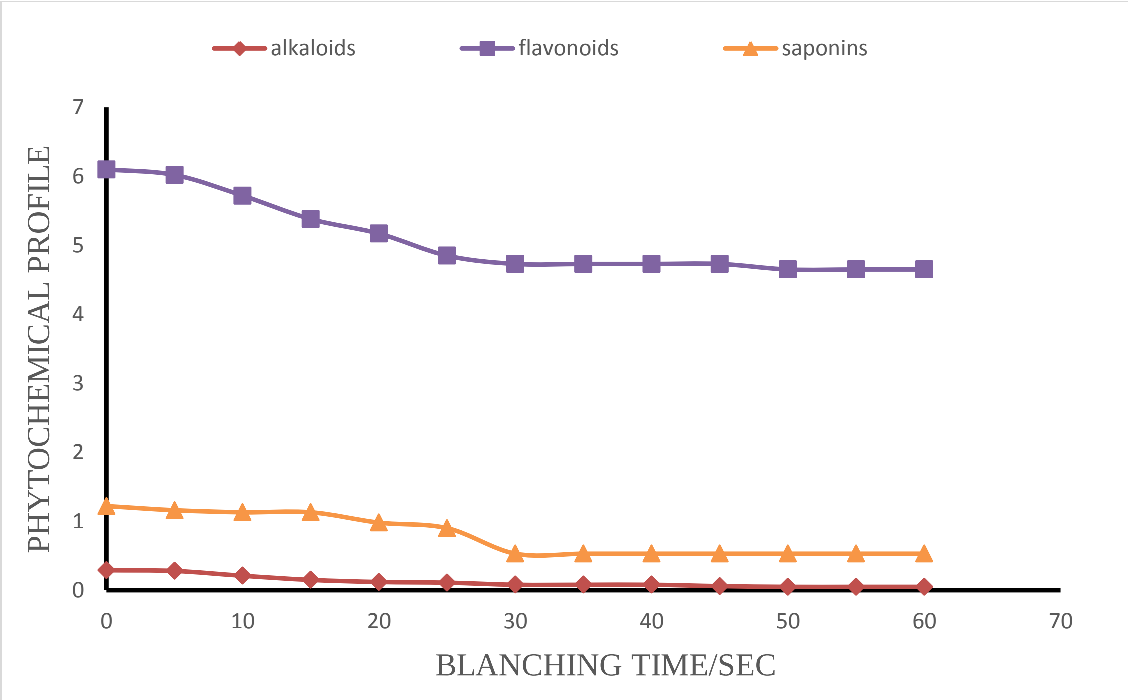

Figure 10: Effect of blanching time on the phytochemical profile of Alligator pepper

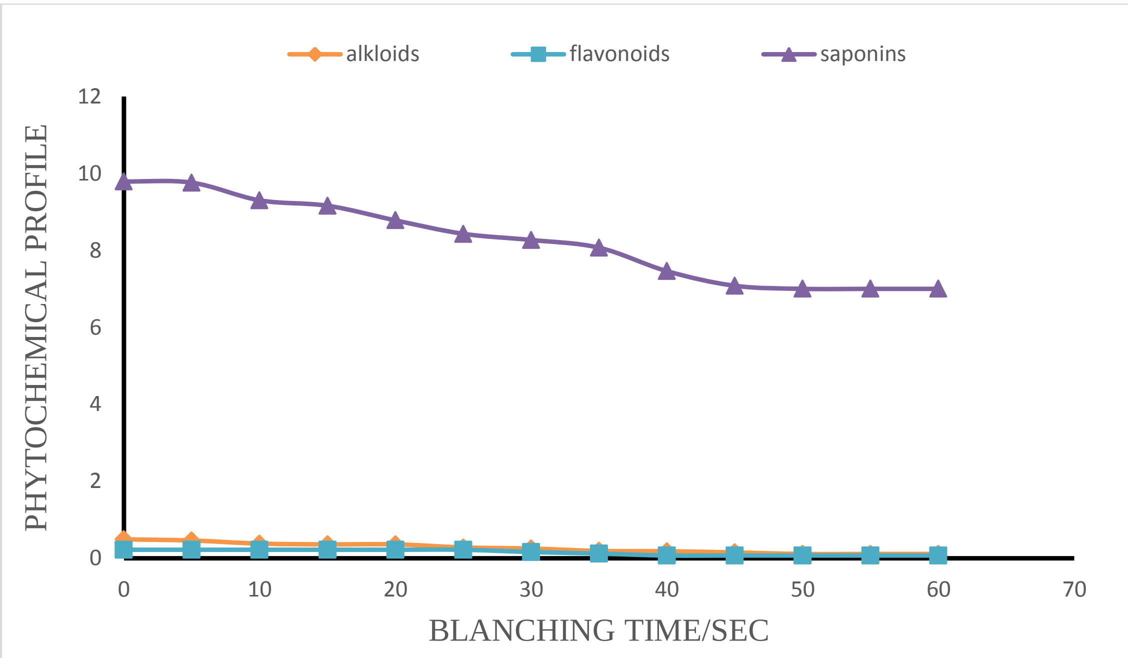

Figure 11: Effect of blanching time on the phytochemical profile of calabash nutmeg

There is a general trend of reduction of the levels of phytochemicals with time after blanching. However, in Figure 9, which is the fruit of *Tetrapleura tetraptera*, for its alkaloid content, after an initial decline, there was an increase in alkaloid levels, higher than the initial. Other reports have shown that the bound phenolic compounds might be more easily released upon heating as recorded for fruit of *Tetrapleura tetraptera* plant (Choi et al, 2006). It held steady until blanching time ended. These results are in line with the study conducted by Babalola and Opeyemi (2015). They reported a decrease in alkaloid, flavonoid and saponin contents between fresh product and blanched product.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The consumers interviewed mentioned certain indigenous foods that were considered by them to be functional foods. The foods considered to have nutraceutical properties included alligator pepper, calabash nutmeg, kola nut, fermented parkia biglobosa, anise, fruit of Tetrapleura tetraptera (*prekese*) and ashanti black pepper.

Analysis of the above indigenous foods revealed appreciable amounts of phenolic compounds, phytochemicals (alkaloids, saponins and flavonoids) and antioxidants which are bioactive compounds responsible for the functionality of foods. The claim by those interviewed as having medicinal or curative properties is therefore justified, as these bioactive compounds isolated have been reported to be responsible for the prevention and curing of many diseases.

Blanching showed that heating reduces the level of their bioactive compounds, that is, the phytochemicals, the total phenols, and the antioxidant scavenging potential. This provides the necessary knowledge about the harmful effect of heating on the nutraceutical properties of such foods. However, for some samples like fruit of *Tetrapleura tetraptera* (*prekese*), there was an increase in their alkaloid content after blanching. This could infer that to obtain the optimum benefits from the fruit of *Tetrapleura tetraptera*, it should be heated to activate the alkaloid levels.

The study provided knowledge of these lesser known foods. This could encourage their consumption by consumers.

5.2 Recommendations

Based on the finding in this study further work is being recommended on the following:

- Further studies should be carried out using a larger sample size and carried out in different parts of the country to be able to identify other lesser known indigenous functional foods.
- Survey should be carried out in other institutions like schools, hospitals and churches where people are given education talks on some of these medicinal foods to know their level of knowledge on more lesser known foods.
- Detailed chemical analysis of the selected food commodities to find other phytochemicals in them should be carried out to determine the specific nutraceuticals in those functional foods and the specific roles they play in disease prevention or cure.
- The effect of cooking on other local functional foods should be determined since most local foods are cooked before eating.
- There be should sensitization and education of the benefits of functional foods to promote consumption.

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APPENDICES

APPENDIX 1: INFORMED CONSENT FORM

UNIVERSITY OF GHANA

OFFICE OF RESEARCH, INNOVATION AND DEVELOPMENT
Ethics Committee for Basic and Applied Science (ECBAS)

Official Use only
Protocol number

PROTOCOL CONSENT FORM

Section A- BACKGROUND INFORMATION

Title of Study:	Evaluation of lesser known functional foods in Ghana, for their nutraceutical properties.
Principal Investigator:	Rose Yaa Amoah Mante
Certified Protocol Number	

Section B– CONSENT TO PARTICIPATE IN RESEARCH

General Information about Research

You are invited to participate in a research study conducted by Ms. Rose Yaa Amoah Mante, who is a Masters student from the Nutrition and Food Science Department, University of Ghana, Legon. Ms. Rose Yaa Amoah Mante is conducting this study for her Masters dissertation.

Your participation in this study is entirely voluntary. You should read the information below and ask questions about anything you do not understand, before deciding whether or not to participate.

Purpose of the study
The purpose of this study is to determine the phytochemical properties of some lesser known functional foods in Ghana, and evaluate them for their nutraceutical properties. It also seeks to find out, if there is a correlation between claims made about such foods in regards to their health benefits, and their nutraceutical properties.

Procedures
If you volunteer to participate in this study, we will ask you the following:
Questions on what you know about functional foods
Questions about these foods and what health benefits you derive from them

Questions about how accessible these foods are to you and how often you eat them

Benefits/Risk of the study
There are no risks involved in participating in this study.
Your participation will indirectly benefit your community and the nation as a whole by helping us to gather information that will be useful in assessing the health benefits of lesser known indigenous foods through their nutraceutical properties.

Confidentiality
We will not tell anybody what you say or give out any information about you. Only the people involved in this research will have access to your information. You will not be named in any oral or written reports and no individual reference will be made that could be linked to your information.

Compensation
There is no compensation and there is no cost to you for participating in this study. However, a small gift of a napkin, will be given to you in appreciation of your time.

Withdrawal from Study
You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer. There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled.

Contact for Additional Information
This statement should indicate whom to contact for answers to any questions about the research and whom to contact in case of research-related injury.
Names, addresses and telephone numbers (including mobile numbers) should be made accessible to all participants.

Section C- VOLUNTEER AGREEMENT

"I have read or have had someone read all of the above, asked questions, received answers regarding participation in this study, and am willing to give consent for me, my child/ward to participate in this study. I will not have waived any of my rights by signing this consent form. Upon signing this consent form, I will receive a copy for my personal records."

____
Name of Volunteer

____
____
Signature or mark of volunteer Date

If volunteers cannot read the form themselves, a witness must sign here:
I was present while the benefits, risks and procedures were read to the volunteer. All questions were answered and the volunteer has agreed to take part in the research.

____
Name of witness

____
____
Signature of witness   Date

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

____
Name of Person who obtained Consent

____
____
Signature of Person who obtained Consent   Date

APPENDIX 2: CONSUMER SURVEY QUESTIONNAIRE

UNIVERSITY OF GHANA
NUTRITION AND FOOD SCIENCE DEPARTMENT

QUESTIONNAIRE ON THE CONSUMER PERCEPTION ON LESSER KNOWN FUNCTIONAL FOODS IN GHANA, THEIR LEVEL OF CONSUMPTION AND EASE AVAILABILITY

Questionnaire No: …………………Contact: ………………………………
Name of community…………………………………………………………………….

This survey is being conducted on consumers' perception of functional foods, and their knowledge on their nutraceutical properties. Your participation in this survey is voluntary. Any personal information gathered from this survey will not be published.

BACKGROUND INFORMATION

1) SEX:

2) Male 2) Female

2) AGE:

1) 15-25 2) 26-35 3) 36-45 4) 46-55 5) 56-65

3) MARITAL STATUS:

1) Single 2) Married 3) Divorced 4) Widowed

4) RELIGION:

1) Christianity 2) Islam 3) Traditionalist 4) Other please specify ………..........

5. ETHNICITY …………………………………………………

6. HOMETOWN (REGION): ………………………………………………………....

7) Have you heard of any local foods that have any medicinal properties? If yes, please list them.
………………………………………………………………………………………
……………………………………………………………………………………..

8) Do you use such foods? YES NO

9. Why do you use these foods? ....
……………………………………………………………………………………..

10) If yes, how long have you been using these foods?

Daily 2) Twice a week 3) 3 or more times a week 4) Monthly 5) Occasionally

11) Are these foods easily accessible to you in your community? YES NO

12) What are some of the health benefits you derive from these foods?

Name of food	Health benefits

13) Are there any special conditions, for which you consume such foods? YES NO

14) If YES, what are they? ……………………………………………………………..
……………………………………………………………………………………….

15) Are there any possible side effects to these foods? YES NO