KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

CHARACTERIZATION OF OIL EXTRACTED FROM NINE HIGH-IN-OIL GROUNDNUT ACCESSIONS

BY

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THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY MANAGEMENT

BY

BERNARD KWASI BONAH

JUNE, 2017

DECLARATION

I declare that I have wholly undertaken to study reported herein under the supervision of and that except portions where references have been duly cited, this dissertation is the outcome of my research.

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DR. JACOB AGBENORHEVI …… ……

Supervisor Signature Date

ABSTRACT

Groundnut is a rich source of oil in the diet based on its physicochemical properties. The objectives was to evaluate the physicochemical properties of oil from nine new high-in-oil accession produced by the Council for Scientific and Industrial Research (CSIR), Crop Research Institute, Fumesua. Free fatty acid, peroxide value, acid value, saponification value and iodine value were determined for all nine groundnut accessions using HPLC. The groundnut accession has the percentage of oil yield in a range of 37%- 51%. The results revealed that the variety G 203 had the highest saponification value of 230 mgKOH/g is an indication of higher number of fatty acid of lower molecular weight hence good for industrial purpose. Variety G 204 and G 210 both recorded the highest acid value of 0.49 mg KOH/g and indication of faster deterioration. G 204 and G 210 also recorded the highest free fatty acid of 0.23 and

0.20 content / g respectively. Peroxide value of 5.09 mEq/kg was the highest recorded for sample G/C 214 which is indicative of fast oxidation. The high iodine value is indicative of dehydrogenation and it was recorded in sample G/C 210. Analysis of the fatty acid profile revealed 24 different acyl glycerides among the various accession. The number of acyl glyceride present in each sample ranged between 16-18 carbon. These indicate that those samples were free from contamination and of high quality. The properties of all the groundnut accession were within the standard limits and this is an indicative of a quality oil for industrial purposes.

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LIST OF ABBREVIATIONS OF FATTY ACID

ALS	Arachidonic Linoleic Stearic
AOO	Arachidonic Oleic Oleic
DG	Decahexanoic Gundoic acid

LLL	Linoleic lauric linolenic acid
LLS	Linoleic Linolenic Stearic
LOO	Linoleic Oleic Oleic
MLP	Myristic linoleic Palmitic
MOL	Myristic Oleic Linoleic
MOM	Myrsistic Oleic Myristic
MOO	Myrisitc Oleic Oleic
MOP	Myristic Oleic Palmitic
OLL	Oleic Linoleic Linoleic
PLL	Palmitic Linoleic Linolenic
PLP	Palmitic Linoleic Palmitic
PLS	Palmitic Linoleic Stearic
PLS	Palmitic linoleic Stearic
POL	Palmitic Oleic Linoleic
POO	Palmitic Oleic Oleic
POP	Palmitic Oleic Palmitic
POS	Palmitic Oleic Stearic
PPP	Palmitic Palmitic Palmitic
SLO	Stearic Linoleic Oleic
SLS	Stearic Linoleic Staeric
SOO	Stearic Oleic Oleic
SOS	Stearic Oleic Stearic

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background to the Study

Oils are constituents of a balanced diet. In the form of biodiesel, it complements societal energy needs as well as acting as a very important energy source. The physical and chemical properties help us to assay the quality and also give a very good description of the present condition of the oil (Anyasor *et al*., 2009).

Whether the origin is animal, marine or vegetable, fats and oils constitute the highest energy source per unit weight that man can eat-up. Despite the fact that fat is a source of energy reserve in the body, deposited fats also insulates the body thereby preventing heat loss and also protecting essential organs from mechanical injury. As a vital source of food for man, they are also essential for cosmetic, drug dispersant in therapeutics, nutritional and are used in the supply of essential fatty acids like arachidonic and linoleic acids (Rauken and Kill, 1993).

There is a wide distribution of the *genus arachis* in the family *leguminosea*e in the Mediterranean regions and the tropics. *Arachis hypogaea* (groundnut) a widely grown leguminous food crop it is a herbaceous plant with a lot of varieties like Campala, Boro Red, Boro light, Ela, Mokwa and Guta (Anyasor *et al.*, 2009). Throughout SubSaharan Africa Groundnuts are an important crop. When it comes to areas where groundnut is harvested in the world, 40% is harvested in these areas, yet they only contribute 26% of groundnut produced in the world ((ICRISAT), 2012) The crop groundnuts is eaten cooked or raw and is used to produce oil. Groundnut is a nourishing constituent of diets and because it is cash crop it provides revenue for farmers in developing country (Carlberg, 2012). Groundnut is a vital crop eaten in

homes and also revenue generating crop in Ghana (Debrah and Waliyar, 1996) and therefore play a chief role in the Ghanaian food because is one of the major sources of vegetable protein.

In a lot of countries around the world, groundnut contributes to their diet. The seed of groundnut is a very good origin of fatty acids and lipids for the consumption of man (Grosso *et al*., 1999, Grosso *et al.*, 1997, Grosso and Guzman, 1995). Wallerstein *et al.* (1989) established the various contents of 3-virginia type peanut which is the alcohol soluble sugars, protein, oil, lignin and mineral ash content

Oils derived from groundnut are not expensive yet of high quality. In developing countries, malnutrition has been reduced drastically by incorporating groundnut into their food and this is done to improve the level of proteins. The incorporation of groundnut helped to improve the flavour and taste of food making it generally acceptable (Asibuo *et al*., 2008). Adeyeye and Ajewole (1992), have stated that the oil product quality obtained from groundnut depends on quality, conditions of growth, geographical location, the relative proportion of fatty acids and the season (Adeyeye and Ajewole, 1992)

Oil from groundnut (Arachis oil) because is an organic oil have similar taste and aroma as the parent legume. This oil is advertised as groundnut oil in the United Kingdom. This oil is assessed to contain from 47 to about 50 % of natural oil. The oil has a specific flavour and odour of groundnut and has a pale yellow colour (O‟Brien, 2000). The main constituent fatty acids are 26.7% of linoleic acid and 56.6% of oleic acid. The oil also contains some arachidic acid, palmitic acid, arachidonic acid, lignoic acid, behenic acid and other fatty acids.

The quality and stability of oil is vital for the customers (Jambunathan *et al.*, 1985).

The chemical constituent of an aboriginal peanut seed which is grown in Uruguay was assessed and the iodine value composition, carbohydrate contents, ash, protein, fatty acid and oil of some wild peanut species seeds (Grosso *et al*., 2000, Grosso and Guzman, 1995). A lesser amount of free fatty acids is frequently existing in oils along with the triglycerides. Acid value or acid number is the term for the content of free fatty acids. The keeping quality of oil is therefore accounted upon the free fatty acid value (Sadasivam, 1996). The fatty acid composition of the oil in seed crops plays a vital role in defining the functional properties, nutritional value, self-life and flavours of the food products resulting from them (Lea, 1962).

The saponification number is the amount of the reactive groups of alkali which is found in oils and fats which is then written in the form one milligram of KOH that is Potassium Hydroxide in reaction with a sample mass of one gram. The iodine number measures unsaturation extent in the oil. In assessing the oxidative rancidity of oil, the number of iodine is a beneficial parameter, this is because the higher the unsaturation the more likely the oil will become rancid (Sadasivam, 1996). Fats are oxidized at the sites where there are unsaturated bonds in a fatty acid chain. Oxidation of unsaturated bonds leads to the formation of a lot of compounds like free radicals and hydroperoxides. The Ip which is the peroxide value is number that expresses in milliequivalents of active oxygen the amount of peroxide contained in 1000 g of the substance.

Groundnut may be one of the most cardioprotective foods readily consumed according to the Groundnut Institute. The health benefits of groundnut come from its monosaturated fatty acid content. Diets higher in monosaturated fatty acids from groundnut butter improve blood lipid profiles (Kris-Etherton, 1999). The regular consumption of groundnuts and groundnut products help to lower the blood

cholesterol level (Lokko *et al.*, 2007). Kris-Etherton (1999) reviewed the scientific data concerning groundnut consumption and coronary heart disease and concluded that regular consumption of groundnuts significantly reduces risk. The monosaturated fats and antioxidant properties found in the groundnuts prevents low density lipoprotein cholesterol from being oxidised.

Shelf-life and nutritional value of the oil and other groundnut foods are influenced by the composition of fatty acid. Oleic (O) and linoleic (L) acids are nutritionally important and together make-up for the 75% to 80% of all the fatty acids that is found in groundnut oil (Dwivedi *et al*., 1993).

1.2 Problem Statement

In many food industries as well as its application industries, edible oils which are derived from plant origin is preferred because of its specifically desired textures and flavours to food as essential component of diet (Odoemelam, 2005), it serves as oleo chemical sources (Morrison *et al*., 1995). The groundnut oil varies in amount of geographical setting, relative amount of fatty acid, seasons and factors of growth (Adeyeye and Ajewole, 1992).

In many countries, the composition of fatty acids and the level of protein was used to characterise the composition of groundnut seeds chemically (Grosso and Guzman, 1995, Young *et al.*, 1973). Because of diseases related to fat derived from animal sources, the request for vegetable oil is on the rise. In the formulation of food for infants, groundnut cake has proven to be very beneficial (Asibuo *et al*., 2008). From literature, a lot of health benefits have been realised from the consumption of peanut which includes the inhibition of cancer. Micro nutrients like folate, α-tocopherol,

minerals, phytochemicals which improves health like ferulic acid, resveratrol and other phenolic compounds has been attributed these benefits (Yu *et al*., 2004).

However the new high-in-oil groundnut accession produce at CRI-CSIR have not been characterized.

1.3 Justification

Edible oil from plant origin are of interest in numerous food and application industries. They offer typical flavours and textures to foods as vital diet constituents (Odoemelam, 2005) and also aid as a source of oleochemicals (Morrison *et al.*, 1995). Oleochemicals are completely degraded biologically and so could replace a number of petrochemicals (Ayoola and Adeyeye, 2010). Vegetable oils has made a vital influence to the nutrition in many countries, serving as a good source of lipid, protein and fatty acids for human nutrition including the repair of worn-out tissues, formation of new cells as well as a beneficial source of energy (Grosso *et al*., 1997).

Because of diseases related to fat derived from animal sources, the request for vegetable oil is on the rise. In the formulation of food for infants, groundnut cake has proven to be very beneficial (Asibuo *et al*., 2008). From literature, a lot of health benefits have been realised from the consumption of peanut which includes the inhibition of cancer. Henceforth data from this study will be useful for further breeding works based on its specific application, food and nutritional security.

1.4 Main Objectives

To determine the chemical composition and properties of oil from new high-in-oil groundnut accessions.

1.5 Specific Objectives

The aim of this study was to investigate the physiochemical properties of the nine new high-in-oil groundnut accession from (CSIR-CIR) at Fumesua Kumasi.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Nutrition is relevant for the well-being of all individuals. Fats and oils have been recognised as important nutrients in the diets of both human and animals. They provide energy, supply fatty acids, provide a feeling of satiety, serve as carriers of vitamins (fat-soluble) and make food more delicious. There are diverse food sources that contain fats and oils. Fats and oils from vegetables, milk products, fish, meat and nuts are known to be the principal sources of fats. Fruits and vegetables however contain fats in small quantities.

In foods, 90% of the fats are made up of fatty acids which are the monomers of lipids. The fatty acids are the compounds of importance when labelling of fats and oils are concerned. Fatty acids are grouped into two namely saturated and unsaturated. Saturated fatty acids are hydrocarbon chains with carbon-carbon single bonds. They are found in fats and oils obtained from animals. The unsaturated fatty acids are however characterised by the presence of double bonds (one or more) in the carbon chain. These are found in plant and sea foods.

Vegetable oils (soybean, olive, mustard, sunflower, sesame oils) have low amounts of saturated fats. The melting point of these oils can be increased by hydrogenation. Hydrogenation has also been used to develop the melting oxidative stability. In industries, hydrogenation does not remove all double bonds. This gives foods an extended shelf life and more consistent flavour. The hydrogenation process converts cis-unsaturated fats into the trans form.

Trans fatty acids are normally found in shortening and margarine or in baked and fried foods such as cake, bread, cookies etc. The trans fatty acids are known to lessen the amount of high density lipoprotein(HDL) cholesterol (Stender and Dyerberg, 2003)

As an important monounsaturated fat source, groundnut is the type of fat accentuated in the heart-healthy Mediterranean diet. Groundnuts are also important proteins manganese, niacin, folate, and vitamin E sources. Depending on the variety, oils derived from nuts can be edible or inedible. The oils are obtainable for an industrial and chemical applications as raw materials. Nuts because of their great energetic and nutritive value give an interesting supply of nutrient. They are not attractive to some consumers that prefer foods low in fat because of their high content of fatty acid.

Groundnut whose oil prevents heart related disease and also reduce cholesterol level is one of the world‟s most important oil crop. Some of the uses of groundnut oil are cancer prevention, decreasing appetite to help an individual lose weight, as an ointment for treating constipation

In the year 2003, the production of groundnut in Ghana was 450,000 tons making it an important legume in the country (FAO, 2004). Groundnut is planted in all the regions that is from the dry savannah regions to the moist forest areas and mostly enjoyed with cooked maize which helps to lessen the effect of starvation in the lean season by which time there is a shortage in a lot of produces. Groundnut is also used for numerous diets for children like stews, cereal mixtures, and soups, which improves their nutritional taste and quality. Oil extraction from groundnut offers revenue for women in the small-scale business.

2.2 The Groundnut Plant

Groundnut is an essential oilseed plant in the world. It is of second importance in terms of cultivated grain legume and ranks third and fourth as the most important vegetable protein and principal oilseed plant respectively in the world (Lusas, 1979, Shilman *et al.*, 2011). Groundnut is grown extensively throughout the semi-arid tropics of Africa, Asia and North and South America, with its global production of 38 million tons from 24 million hectare area (Faostat, 2013). Groundnut is grown primarily for human consumption. It contains 40–50% oil, 20–50% proteins and 10–20% carbohydrates. Groundnut is a great source of diverse essential vitamins and minerals (Belamkar *et al*., 2011). All the parts of the groundnut plant have a use: kernels for human intake, branches and leaves as feed for cattle and provision of nitrogen to the soil due to the presence of nitrogen-fixing bacteria in its roots.

Ghana, the 10th leading producer of groundnut in the world produces 530,887 MT of in-shell groundnut. Ghana ranks 4th in Africa, behind Nigeria, Senegal and Sudan (Faostat, 2013). In terms of the total value and production, groundnut is the most significant legume crop (Tsigbey *et al*., 2003). Groundnut is produced mostly in the northern savannah zone, where the highest yield of 1.92 MT/Ha has been recorded (MoFA, 2011). According to data on the 2010 agricultural production, the Northern and Upper West Regions produced about eighty percent of the total groundnut in Ghana (MoFA, 2011). Groundnut is mostly grown with crops such as maize, yam and millet (Tsigbey *et al.*, 2003). Similar to the rest of Sub-Saharan Africa, groundnut is a staple food for many Ghanaians and a valuable cash crop in the country (MoFA, 2011).

Groundnut is widely used to make dishes such as soup, stews, and cereal mixtures by processing them into paste (butter) (Asibuo *et al*., 2008)In the Northern Region,

groundnut can be processed into cakes which serve as a snack(kulikuli) or grinded into a powder (kulikuli zim). Groundnut cake from oil processed in industries is mostly used for human and livestock feed especially in the south (Awuah *et al.*, 2009). Despite the recognition of Ghana as one of the principal producers of groundnut in the world, yield on farmers,, field continue to be less than the attainable yield of 2-3 MT/ha due to biotic and abiotic including unstable rainfall patterns, diseases and pest infestation, lack of quality seeds and favourable agronomic practices. These problems have led to low yield and low marketability of groundnut in the international market.

2.3 Uses of Groundnut

Groundnut is a crop that produces oil, feed and food and cultivated in more than hundred countries. In the world, it occupied twenty-four million ha area and has a production(total) of 38 million tons in 2010 (Faostat, 2013). About ninety-five percent of the groundnut area in the world is cultivated using rain and with low investments from poor farmers in Asia and Africa. Groundnut production provides income and livelihoods to farmers. It also serves as a source of nutrition of farmers and families through consumption of the nutrient dense kernels from groundnut and provides livestock with nutrient-rich feed. The maintenance of mixed farming systems (crop and animal production) in the semi-arid areas is promoted by groundnut cultivation. Groundnut is a good source of energy contributed by oil and protein in proportions of 48–50% and 25–28% respectively present in the kernels. From 100 g of kernels, 564 kcal of energy can be obtained (Jambunathan, 1991).

The groundnut kernels are rich in mono-unsaturated fatty acids and consists of many health-promoting nutrients such as vitamins, antioxidants and minerals. Groundnut and its products can be promoted as nutrient-rich foods to provide energy, micronutrient and protein to eliminate malnutrition among the poor. Groundnut-based

Plumpy„nut, a readily made therapeutic food has saved the lives of many children suffering from malnutrition ((UNICEF), 2007).

As a result of the its high smoking point, groundnut oil is a good cooking material (Singh and Diwakar, 1993). (Asibuo *et al*., 2008) reported that the cake remaining after extracting the oil is used in the preparation of nutritious and digestible food for the young and elderly persons, in the animal feed industry and as soil alteration.

In North and South America and Europe, about seventy-five percent of the groundnut produced is used as food whereas thirty-five percent is utilized as it is used in Asia (Birthal *et al*., 2010). The most common product made from groundnut in the USA, Canada, and Australia is peanut butter. Groundnut seed can be taken in raw (uncooked), roasted and boiled. It could also be used to prepare sweets and its flour for baking. The groundnut shells are used for producing particle boards, fuel or filler in fertilizer and feed industry. Groundnut haulms makeup nutritious fodder for livestock. Groundnut, a legume crop, helps in refining the soil‟s health and fertility by depositing N_2 and organic matter in the soil.

2.4 Oil and Protein Content in Groundnut

Apart from the physical factors such as shape and mass of the seed, integrity of seed taste and blanching efficiency and sensory factors such as colour, texture, and flavour, the nutritional factors such as oil and protein contents as well as fatty and amino acids composition are essential in the food trade.

On a dry seed basis, groundnut seeds contain oil and proteins in proportions of 4456% and 22-30% respectively (Savage and Keenan, 1994). Jambunathan *et al*. (1985) reported protein to range between 16 to 34%. After analysis of twenty groundnut varieties (Asibuo et al., 2008) investigated that they contain about 33.6 to 54.95% oil.

Five groundnut varieties consisted of more than 50% oil. Varieties of groundnut from subspecies *fastigiae* had less oil than the hypogea varieties. Analysis of the constituents of 152 groundnut genotypes of seed samples from China showed that the protein, oil and oleic acid, sucrose content, and linoleic acid content, as percentage of total fatty acids, ranged from 18.93 to 30.22%, 37.42 to 55.69%,20 to 80.51% 2.73 to 14.65%, and 2.91 to 41.82%, respectively (Wang *et al*., 2011). The percentage of oil from groundnut has been found to be 35.8 -54.2 percent and average near 45 percent (Jambunathan, 1991, Jambunathan *et al*., 1985). Pancholy *et al*. (1978), reported that per cent oil ranged from 46 to 52.6 per cent. Gupta *et al.* (1982), analyzed twenty-five varieties of groundnut for oil content. Highest oil content of 48.60 per cent and lowest of 44.52 was observed. Rajgopal *et al*. (2000), evaluated 118 bold seeded accessions for 2 years and reported range of oil content from 48 per cent to 51.4 per cent. Significant difference for oil content was observed among test genotypes, highest was 53.8 and lowest 47.3 (Manivel *et al*., 2000). Dwivedi *et al*. (1993), reported a range of 16 to 34 per cent protein from 8000-germplasm accession analyzed at ICRISAT. However, these ranges of variation were not maintained when selected genotypes with such variation were tested over season and locations. Pancholy *et al.* (1978), reported a range of between 22 and 30% crude protein of whole seeds showing a large difference, which is due to genotype and environments.

Shelf-life and nutritional quality of the oil and other groundnut products are influenced by composition of fatty acid. Oleic (O) and linoleic (L) acids are nutritionally important and responsible for 75 to 80 percent of the total fatty acids in groundnut oil (Dwivedi *et al.*, 1993).

2.5 Improvement of Groundnut in Ghana

One of the major reasons for low export market of groundnut in Ghana is that little or no hybridization work has been done to develop and release high yielding varieties that have local and international acceptable characteristics suited for the confectionery market. Information on groundnut hybridization in Ghana is scarce and there is no record of a groundnut variety that has been released from a groundnut hybridization programme.

Tremendous work on the evaluation of confectionery groundnut varieties is on-going at the Council for Scientific and Industrial Research (CSIR)-Crop Research Institute (CRI), Kumasi, and a few has been released in 2012. Confectionery varieties presently released by CRI include; Oboshie, and Obolo. Non confectionery varieties were also released by CRI in 2004. They are resistant to the rosette virus and other field diseases and are also high yielding, but have high oil, low protein and smaller seed size, they include; Adepa, Nkosour, Jenkaah, and Azivivi.

To improve the marketability of both types of groundnut (confectionery and nonconfectionery), crosses between one of the confectionery (Oboshie) and two nonconfectionery (Nkosour and Jenkaah) and their reciprocals had been made. This study, therefore, forms an integral part of the ongoing groundnut breeding work at CRI. The data about the inheritance of seed size, oil and protein contents would help choose appropriate breeding strategies for development of confectionery varieties which will attract both local and foreign consumers.

2.6 Physio-chemical Properties of Groundnut Oil

Groundnut is a principal oil-producing seed cultivated on large scale worldwide. It is an important food crop and also used as feed. It is grown mainly for its edible oil and

its rich protein kernel (Ayoola and Adeyeye, 2010). Oil produced from groundnuts is used as a major source of oil production in some countries. On dry seed basis, the groundnut seed is known to contain about 44-56% of oil and about 22-30% of protein. It has high levels of minerals such as phosphorus, calcium, magnesium and potassium. It again serves as a good source of vitamin K, E and B (Savage and Keenan, 1994).

Plant sources of edible oil are a major interest of food processors. These plant sources provide flavour and texture to foods (Odoemelam, 2005). They also serve as sources of oleochemicals in the diet of human (Morrison *et al.*, 1995). These oleochemicals can be degraded biologically and can be used to replace some petrochemicals (Ayoola and Adeyeye, 2010). Vegetable oils are important contributors to the diet of man in many nations. Aside providing energy, they also serve as good sources of lipids and fatty acids as well proteins for human consumption. This include repair of worn-out tissues and new cell formation (Grosso *et al*., 1997).

Groundnut is a cheap source of dietary protein and oil. Malnutrition in developing countries have been reduced by incorporating groundnut in diets. They are added to improve on the protein content of the foods. They also provide a favourable taste and flavour to consumers. This makes them acceptable to the consumer (Asibuo *et al.*, 2008). Indices of the quality of oils and its product is dependent on the fatty acid amount, conditions of the environment, season of planting and the geographical location (Adeyeye and Ajewole, 1992).

Groundnut oil is an organic material obtained from groundnut seed. It is noted for its aroma and taste. This is normally provided by its parent legume. The major fatty acid component of groundnut oil are oleic and linoleic acids. Oleic acid contains about

56.6% whereas linoleic acid has about 26.7% of the oil. The oil contains some amounts of palmitic acid, arechidic acid, arachidonic acid, lignoic acid, behenic acid and other fatty acids.

The groundnut institute has been named as one of the most cardio protective foods. It is readily absorbed in the body. The monosaturated fatty acid content of groundnut is responsible for its health benefits. Diets containing higher amounts of monosaturated fatty acids from butter made from groundnut improve the blood lipid profile (KrisEtherton, 1999). Consumption of groundnut and its products are linked with lowering blood cholesterol levels (Lokko *et al*., 2007).

Physico-chemical properties of major importance to ground nuts include iodine value, saponification value, free fatty acids, acid number and peroxide value.

Chemical properties (iodine value, peroxide value, saponification value, acid value) and some physical properties such as colour, solidification temperature, appearance etc. factors on which the food value of edible lipids depend on. To prevent the solidification of oil made from sesame at temperatures which are low, (Shibasaki and Yamane, 2000) used lipase catalysed self-interesterifiction to reduce the substantial oil melting temperature.

2.6.1 Free Fatty Acids of Oil

A small quantity of free fatty acids as well as triglycerides is usually present in oils along with the triglycerides. Acid number or acid value refers to the free fatty acids content. The composition of free fatty acid determines the ability of oil to be kept for a long time (Sadasivam, 1996). The composition of fatty acids in the oil in seed crops performs a key role in determining the functional properties, shelf-life, nutritional value and flavours of the food products derived from them (Lea, 1962).

Half of the acid value gives the free fatty acid (FFA) of an oil or fat. It is the fatty acid existing in oil after breakdown by lipase and which has not been neutralized.

Acid value depends upon the degree of rancidity (an index of freshness) (Khan *et al*., 2006). The work of Onyeike and Oguike (2003) shows the percentage of the oleic acid that is the fatty acids which are free from raw groundnut to be 2.68 %.

The number of fatty acid that is free which is in an oil or fat is known as the FFA. The acid number or value in fat or an oil is defined as the amount of KOH that is potassium hydroxide in milligrams required to neutralize the free acid in 1.0 g of the oil. It could also be defined as the measure of the total acidity of the oil from all the constituent fatty acids that make up the oil or fat.

The measure of the level of breakdown of the glycerides in the oil by the lipase is the acid value. Rancidity leads to the forming of FFA, therefore the acid value or FFA measure is used as a way of assessing the class and edibility of oil (Onyeike and Oguike, 2003). The nutritional value of a fat has been reported to depend to some extent on the number of free fatty acids which it produces (e.g. butyric acid amount which is found in butter). Vegetable oils are the most common nutritional oil in the tropics and therefore the free fatty acid content must be in the limits of 0.0 to about 3.0 % to produce desirable results (Bassir, 1971).

The breakdown of triglycerides to form free fatty acids is partially the cause of the deterioration which occurs when raw materials which we get fat from or original fat after isolation is stored. In the preparation of edible fats, these free fatty acids must be removed (Ihekoronye and Ngoddy, 1985). According to Pomeranz and Meloan (1987) acid value can be converted to FFA (expressed as oleic) by using the formula: Acid value = 1.99 × % FFA.

The major fatty acids in groundnut oil are linoleic and oleic which account for 77.89 % of the total fatty acids (Asibuo *et al.*, 2008).

Acid value (AV) is vital pointer to the quality of vegetable oil. The value of the acid is used to access the degree of degradation of glycerides by lipase and some external factors like heat and light (Demian, 1990).

2.6.2 Saponification Value

The saponification value is a measure of the groups that react with alkali in oils and fats. It is written as the amount of potassium hydroxide (in milligrams) which react with sample mass of one gram.

The saponification numbers of the oil is directly proportional to the solubility of the soap that can be made from it (Alyas *et al.*, 2006). The low number of saponification in the oil implies that the mean molecular weight of fatty acids is lesser than that of other vegetable oil or that the number of ester bonds is smaller in comparison to that of other vegetable oil.

Saponification value is an indicator of the size or nature of fatty acid chains that have been esterified to glycerol. Together with acid values, saponification values are important in providing information with respect to the quantity, type of glycerides and mean weight of the acids in a given oil sample. If the oil is for industrial purposes and has no nutritional significance, then the saponification value is of sole interest. Determination of the saponification value is a rational means of characterizing the fat because each fat has a limit in variation biologically (Sulaiman *et al*., 2012).

The saponification number is the amount of KOH in milligrams required to hydrolyse or saponify 1.0 g of fat/oil (Onyeike and Oguike, 2003). Saponification value is an indication of the mean molecular weight of fat. For pure fatty acids, the saponification

value equals the acid value (Pomeranz and Meloan, 1987). Onyeike and Oguike (2003) reported a saponification value of 161.3 mg KOH/g oil for oil obtained from unprocessed groundnut. Akinhanmi *et al*. (2008), reported that saponification values for groundnut oil falls within the range of 188-196 mg KOH/g oil. The higher the saponification number, the larger the number of fatty acids of low molecular weight. This makes the oil beneficial in soap industries and in the making of lather shave creams (Eka, 1980). Low saponification value suggests that the oil may not be industrially useful whiles high saponification values indicate that the oil has potential for use in the industry (Amoo *et al*., 2004).

The saponification value is only of interest if the oil for industrial purposes and therefore has no nutritional significance (Asiedu, 1991). The higher the saponification number, the higher the ability of the oil to be used for soap production (Nielsen, 1994).

2.6.3 Iodine Value

The iodine value is a measure of the extent of unsaturation in an oil. It remains constant for each oil or fat. Iodine value is important factor in studying oxidative rancidity of oils because the greater the degree of unsaturation the higher the tendency of the oils to become rancid (Sadasivam, 1996). The value recorded for iodine is the degree of the total unsaturation of vegetable oils, as well as a pointer of their predisposition to become oxidised (Knothe, 2006). The categorisation of vegetable oil into four main groups is dependent on their iodine value: saturated oils have iodine value between 5 and 50, mono-unsaturated oils between 50 and 100, di-unsaturated oils also known as semi-siccative between 100 and 150 and tri-unsaturated oils called siccative (over 150).

The measure of the level of oil and fat unsaturation is the iodine value. It is defined as the amount of iodine absorbed per gramme of the sample (i.e. percent iodine absorbed) during oxidation, which consumes the double bonds resulting in a reduction in iodine. It is an indicator for double bindings in the molecular structure, which influences the stability of the oil over a long period of time (i.e. important for storage). Oils with high iodine number are polyunsaturated signifying the extent of unsaturation and are preferred by oil processors, while a low iodine number is indicative of poor quality (Sulaiman *et al*., 2012).

The iodine value is a measure of the degree of unsaturation. A decrease in the iodine value is as a result of decline in the number of double bonds in heated oil during oxidation. During frying, the iodine values of the oil varies indicating the increased rate of oxidation. According to Augustin and Berry (1983), a major change in the iodine values can be noted when the oil deteriorates too much.

In a research work carried out by (Jaswir *et al.*, 2000), the iodine values of all the samples treated reduced significantly from day 0-6. The authors reported a percentage loss of unsaturation as 27, 24 and 24 % for control, sage-treated oils and rosemary respectively.

In another studies by Abdulkarim *et al*. (2007), alterations in the iodine value over the five-day period of frying from the first values for canola oil; 109.9-103.0 was greater followed by soybean oil; 116.9-111.8. Reduced variations were found in palm oil; 56.8-53.7 and *Moringa oleifera* oil; 65.9-62.2. *Moringa oleifera* oil and palm oil had prolonged induction period since there were no significant changes within the early two days of frying. Soyabean oil and canola oil had significant changes in the iodine

values after the first day of frying, signifying shorter induction periods. This was mainly due to the high amounts of linolenic acid present in the two oils.

The generally accepted parameter for stating the extent of unsaturation of a fat or oil is the iodine value (or iodine number), which is the grams of iodine that react with 100g of sample (Allen, 1955). The iodine number is also an index for assessing the tendency of the oil turn rancid (Amoo *et al.*, 2004, Eka, 1980). Iodine value is a signal of the number of unsaturated fatty acids in a fat and has been used to predict the shelf life of fat and oils (How and Young, 1983). Iodine is not existing in oils and fats however the test measures the quantity of iodine which can be absorbed by the unsaturated fatty acids. A property of unsaturated organic compounds is how the double bonds react, particularly the tendency to form addition compounds with halogens. On adding the iodine, measurement of the quantity absorbed is an indication of the number of double bonds (Ihekoronye and Ngoddy, 1985).

Low iodine number suggests the low degree of unsaturation and hence low susceptibility to turn rancid by oxidation (Onyeike and Oguike, 2003). High levels of polyunsaturated fatty acid present in the product is indicated by high iodine values. The shelf life of groundnut oil is measured by the days before the onset of oxidative rancidity due to exposure of the seed or oil to heat and air (Kratz *et al*., 2002). Research have indicated that a high degree of unsaturation (high iodine value) leads to a greater tendency of the fat to undergo oxidative rancidity (Joseph, 1977). Asibuo et al. (2008) analyzed oils from twenty (20) groundnut varieties and indicated that the iodine values from 85.77 to 98.43 mg/100g. Onyeike and Oguike (2003), analysed oils from groundnut and indicated that the oil from raw groundnut has an iodine number of 87.6 mg/100g. The ratio of polyunsaturated to saturated fatty acid in oil

obtained from groundnut is 2:1. The oil is useful in cooking and manufacture of margarine, mayonnaise, salad oils and cosmetics (Weiss, 1983).

The iodine value is useful in classifying oils and fats (Pomeranz and Meloan, 1987). When the iodine value is lower than one hundred (100), the oil or fat is classified as non-drying. When the iodine value is between one hundred (100) and one hundred and thirty (130), the oil or fat is classified as semi-drying. When the iodine value is between one hundred and thirty (130) and two hundred (200), the oil or fat is classified as drying.

2.6.4 Peroxide Value

Fats are oxidized at the sites of unsaturated bonds in fatty acid chains. Oxidation of unsaturated bonds causes the formation of a variety of compounds to be formed including free radicals and hydroperoxides. The peroxide value Ip (in milliequivalents of active oxygen) is a measure the amount of peroxide contained in 1000 grams of the substance.

The peroxide value is the active oxygen weight present in oil of fat with a weight of 1g (Horwitz *et al*., 1970). It therefore shows the extent of oxidation of oil and a pointer to the level of degradation of fats and oils (Okechalu *et al*., 2011). A newly refined oil is expected to possess a zero peroxide value.Cheman and Wanhussin (1998) stated that a good quality vegetable oil should have a peroxide value (PV) lower than 2 meq/kg. A reduction in peroxide value during frying Duve and White (1991) has been observed by many researchers (Vieira and Regitano-D‟Arce, 1999, Zhang and Addis (1992).

However, others ((Jaswir *et al*., 2000);(Tan and Man, 1999) have confirmed a rise in

PV of oil as a result of frying. Some researchers have observed an early rapid increase in the peroxide value from day 0-1 after which the rate slowed down throughout the frying time (Abdulkarim *et al.*, 2007). Peroxide value as a single parameter is not a appropriate parameter to evaluate the extent of frying oil deterioration. A rise in the PV during frying period is as a result rapid formation of peroxides due to oxidation. However, peroxides have been reported to be unstable under deep frying conditions. As oil deterioration endures, the hydroperoxides degrades to carbonyl and aldehyde compounds causing the peroxide value to decrease (Shahidi and Wanasundara, 2002). Augustin and Berry (1983), states that hydroperoxides, formed from primary oxidation, react to form secondary products such as aldehydic compounds which are measured by the anisidine test.

2.7 Fatty Acid

Triglyceride is the form in which fatty acid (the main food fat form) occurs in food. The classification of fatty acid which is mainly based on their state of saturation, is not enough to determine the health implications of the fatty acid group however, knowing the function of each fatty acid is essential in health studies. Due to this, fatty acids would be explained in this order: polyunsaturated, monounsaturated, saturated, cis and trans. Fatty acids are consumed as a part of foods that consist of other nutrients and compounds; these have additive as well as synergistic effects on health and relate in complex ways that are difficult to outline.

2.7.1 Fatty Acid Classification System

Structures of fatty acids differ considerably by the length of hydrocarbon chain and degree of saturation. Although the length of carbon chain can differ by 2 to 40 carbons, most dietary fatty acids consist of 12 to 22 carbons (O Keefe, 2002). In the

grouping of fatty acids, one to six carbons are short chain and medium chain has between eight to twelve carbon chains.

Though hydrocarbon chain length is an essential determining factor, the function of fatty acids is mostly classified based on whether there is no double bond (SFA), a double bond (MUFA) or more double bonds (PUFA) in the carbon chain of the fatty acid, also whether the double bond is in Cis or Trans configuration. Furthermore, the position of the first double bond counting from the fatty acid methyl end, creating n-3 and n-6 fatty acids is also a basis for the classification of PUFAs. In n-3s, the third carbon is where the first double bond is positioned, of the chain of fatty acid from the methyl end whiles the first double bond in the n-6s is positioned on the sixth carbon in the chain of fatty acid (Ratnayake and Zehaluk, 2005). Chain length differences and saturation rate determines the performance of oil in food and its function in the individual and the effect on human health and dangers of developing disease.

2.7.2 Impacts on Health

Specific fatty acids have distinctive implications on health because there is a structural variation in every fatty acid. It is always difficult to outline the effects of every fatty acid in the occurrence of diseases because chronic diseases take several years to develop and is the sum up of various lifestyle and genetic factors.

This intricacy causes randomized well-ordered trials of nutritional interventions to be unfeasible, but these trials, in addition to observational, mechanistic and epidemiologic studies offer very good confirmation of the well-being consequences of dietary fat and specific fatty acids. Due to the fact that individual who are in good health are more considered for the study, fatty acid consumption effect is not explained for those suffering from chronic disease. Although it has not been

established, individuals in good health can have disease risk issues (eg, obesity, high glucose and high *low-density lipoprotein* [LDL] cholesterol) which are affected by consumption specific fatty acid. Variation of recognised and developing risk factors, like chronic low-grade inflammation by dietary fatty acid intake can positively affect the increase of common diseases like cardiovascular disease, depression, diabetes, Alzheimer‟s and dementia. For instance, proof obtained from randomized clinical trials and observational studies gives conclusive confirmation that insufficient consumption of long-chain n-3 fatty acids results in high risk of sudden cardiac death (Mozaffarian, 2008). Aiming multiple risk issues by change of food, especially fatty acids, helps in improving the health of the public and achieving significant decreases in disease risk in individuals who are healthy.

2.7.3 Need for Knowledge

Fatty acids cannot be divided in broad groups (unsaturated and saturated) because specific fatty acids belonging to these groups have diverse effects on disease-causing risk and the health status. For instance, saturated fats like palmitic acid (16:0) and stearic acid (18:0) differs only in carbon chain length which is by two carbons, yet having differs effects on LDL cholesterol circulation (Nicolosi, 1997).

Another instance is the variance between the position of the first double bond on the fatty acid carbon chain. The existence of the double bond on the third or sixth carbon (as in PUFA n-3 and PUFA n-6) makes a vital biological functional difference (eg, vasodilation vs vasoconstriction).

Therefore, having a knowledge on the scope of data while defining specifics about different dietary fatty acids is vital. RDNs have the prospect and responsibility to convert research into practice for the general population.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Materials Collection

The experiment was analyzed at the Food Science and Technology Laboratory, KNUST - Kumasi and Ghana nuts Laboratory, Techiman. The chemicals used were of analytical grade. All the nine species of groundnut sample used in this project were obtained from the (CSIR-CRI) Council for Scientific and Industrial Research-Crop Research Institute, Fumesua – Ghana.

3.1 Preparation of Sample

The groundnut sample were sorted out to remove the unwholesome ones and stones from the lot. The samples were grinded into smaller particles and placed into zipped lock bags. All analysis were carried out in duplicates.

3.2 Extraction of Oil

The process was done using the Soxhlet extraction method. A total of 300g of each sample were extracted in smaller quantities of 60g. These were placed in a cheese cloth in the extraction chamber which was suspended below a condenser and above a flask containing the solvent petroleum ether. The flask was heated at a temperature of about 60◦C, the solvent evaporated and moved up into the condenser and in the condenser it was changed into a liquid that trickles into the extraction chamber containing the sample. The solvent surrounding the sample overflows and trickles back into the boiling flask at a certain level in the extraction chamber. The process continued for four (4) hours after which the oil was poured into an already weighed flask and left on the bench until the remaining solvent was evaporated. The weight of the flask and oil was taken and the percentage of lipid calculated.

3.3 Chemical Analysis

The chemical composition was determined using the methods (AOAC, 1990).

3.3.1 Saponification Value (SP#)

Two (2) g of the oil was weighed into a 250 mL ground-neck conical flask and 25mL of alcoholic potassium hydroxide solution (0.5N) was added. The mixture was then heated gently under reflux on water bath for one (1) hour and titrated against 0.5N HCl, using phenolphthalein as indicator.

$$SP\# = \frac{(B-S) \times 56.1}{\text{Weight of sample (g)}}$$

B: titre for blank.

S: ml of HCl required to neutralize the KOH. (i.e. titre value).

3.3.2 Iodine Value (I.V)

Approximately 0.25 g of the oil was weighed into a 250 mL conical flask. 5 mL of chloroform and 5 mL of Wij‟s reagent (Iodine Mono-chloride Solution, Wijs Reagent: Dissolve 26.0 g of reagent grade iodine (I2) in 2 L of reagent grade glacial acetic acid, heating gently if necessary to hasten solution. Cool to room temperature) was added; the solution was retained in fume cupboard for 10mins. 5 mL of 10% potassium iodide and 20 mL of distilled water were added. The solution was stirred several times to mix and titrated to a colorless endpoint with 0.025 N sodium thiosulfate. The procedure was repeated but without the sample and recorded as blank.

$$\text{Iodine Value} = \frac{(B - S) \times 0.00317 \times 0.001269 \times 100}{\text{Weight of Sample (g)}}$$

B: ml of $Na_2S_2O_3$ for blank
S: ml of $Na_2S_2O_3$ for sample
1ml 0.025 Na2S2O3 = 0.00317g

3.3.3 Acid Value (AV)

Five (5) g of the oil sample was weighed into a dried conical flask and 25 ml of absolute ethanol was added. Three (3) phenolphthalein indicator drops was added and heated at 65◦C for 10 minutes in a water bath with shaking, then cooled. The solution was titrated against 0.1 N KOH until there was an appearance of a pink color (endpoint). The acid value (AV) was calculated as follow:

$$AV = \frac{\text{ml of KOH x N x 56}}{\text{Weight of Sample}} = \text{mg of KOH}$$

N = Normality of KOH

3.3.4 Free Fatty Acid (FFA)

Five (5) g of the sample of oil was weighed into a dried conical flask. 50 mL of neutralized alcohol was added and shaken vigorously until the sample was completely dissolved. Three (3) phenolphthalein drops was added to the solution titrated against 0.5 M sodium hydroxide (NaOH) solution with constant swirling until the appearance of a first permanent pink colour.

$$FFA = \frac{\text{mL of NaOH x N x M}}{\text{Weight of Sample}}$$

N = Normality of NaOH M = 28.2, oleic acid for seed oils

3.3.5 Peroxide Value (PV)

Five (5) g of the oil sample was weighed into a 250 mL conical flask. 30 mL of glacial acetic acid - chloroform mixture (2:1) was added and shaken until it was completely dissolved, afterwards, 0.5 mL of saturated potassium iodide solution was also added,

stoppered and the contents swirled for some few minutes. 30 mL of distilled water was added immediately, stoppered and shaken vigorously to liberate the iodine from chloroform layer. About 1 mL of starch solution as an indicator was added to solution and titrated against 0.01 N sodium thiosulfate until the blue gray colour disappears in the aqueous layer. The above procedure was repeated but without the sample and recorded as blank.

$$PV = \frac{(S - B) \times N \times 1000}{\text{Weight of Sample}}$$

N = Normality of NaOH

3.4 Fatty Acids Analysis using HPLC

3.4.1 Sample Preparation

300µl of each extract was sampled into a vial bottle, 2 ml hexane was added and capped. The solutions were gently swirled to ensure a uniform mixture. The vials were placed in the tray of the HPLC and noting the vial number, the HPLC instrument was run.

3.4.2 Using of HPLC to run Sample

The online mode icon on the desktop was opened and the sequence TGLS was loaded. The sequence table was modified depending on the number of samples, sample name and sample vial number. The modified sequence was run by clicking on the start button.

3.4.3 Reading of Result and Data Analysis

The offline mode icon on the desktop was opened and the data analysis was selected.

The TGL SHEA was clicked on to show all sequence. The “sample run” was clicked to run the test. Double clicking the identified sample line of the sequence shows the

chromatogram. The peak and the area could be read on the chromatogram. The percentage (%) area corresponding to the identified peaks of the chromatogram were read and the data recorded.

3.4.4. Data Analysis

Statistical Package for Social Sciences (SPSS) and MS Excel was used for the data analysis and results were presented on graphs. Descriptive analysis was done and one way ANOVA was done to compare the mean between the nine new high in oil assertions.

CHAPTER FOUR

RESULTS AND DISCUSSSION

The groundnut accession has oil content ranged between 37 – 51%. The results of the physicochemical studies are discussed in the session below.

4.1 Saponification Value

The results on saponification number are presented in Figure 1. Sample G203 had the highest amount of saponification number, this was followed by sample G/C 209. Sample G/C 214 had the least saponification value.

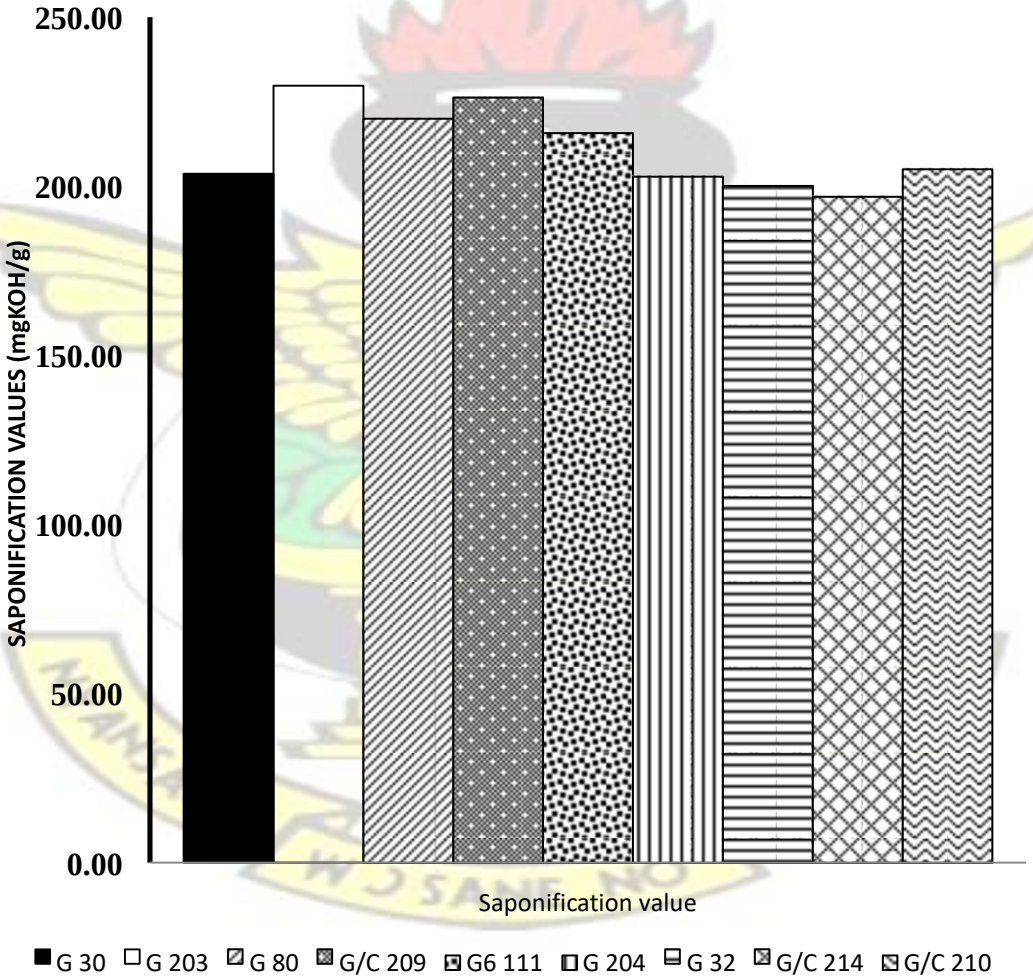

Figure 1: Saponification Value of Samples

At a level of significance of 0.05, statistical differences were found between the saponification value of all the samples ($F=7.273$; $p<0.05$). There were however some similarities in the samples studied. Homogenous test was conducted to establish the similarities in the samples. This is presented in the appendix.

Homogenous test concludes that samples GC214, G32, G204, G30 and GC210 have similar characteristics. They are therefore likely to perform the same functions. Again samples G80, GC209 and G203 also perform the same functions. Sample G6 111 has the ability to perform functions of the two groups.

Akihami et al (2008), reported that sarponifcation value of groundnut oil falls within the range of 188-196 mg KOH/g oil.

The high saponification value showed oxidation and its decrease suggest the onset of oxidation (Nkafamiya *et al*., 2007). The high saponification value also showed the existence of larger amount of ester bonds, which suggests that there was unbroken fat molecules (Denniston *et al.,* 2004). These properties make it useful in soap making industry. It is not attractive as a raw material because of its economic and nutritive implications.

It can therefore be concluded that samples G80, GC209 and G203 are good for soap making. Sample GC214, G32, G204, G30 and GC210 are also good for soap making but their quality will not be the same as that of samples G80, GC209 and G203 base in their differences on sarponification values. On the other hand sample G6 111 can be used for soap making.

4.2 Acid Value

The acid value of the various groundnut samples is presented in Figure 2. Samples G204 and GC210 had the highest amount of acid value. They are presented as 0.49mgKOH/g. The least was sample GC209 with an amount of 0.19mgKOH/g.

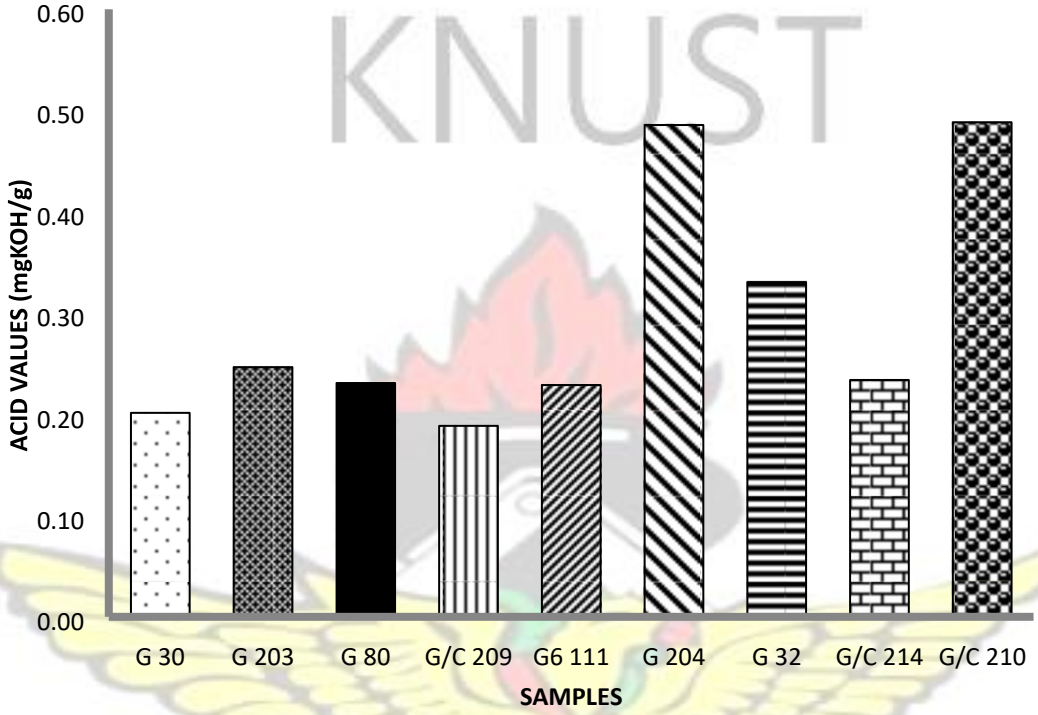

Figure 2: Acid Value of different Samples of Groundnut Oil.

Statistical analysis conducted on the samples revealed that differences occurred in the acid value of the samples ($F=10.073$; $p<0.05$). Further analysis conducted indicated that no differences were found in samples GC209 and G30. Samples G80, G6 111, GC214, G203 and G32 were found to have similar attributes. Samples G204 and GC210 also exhibit similar characteristics.

The acid value measures the degree at which lipase breaks down glycerides in the oil. Rancidity is followed by the formation of FFA and so acid value or FFA measure is used as a means of knowing the quality and edibility of oil (Onyeike and Oguike,

2003). Some suggestions show that fat nutritional value is subject to the quantity of the free fatty acid it forms (for example, the number of butyric acid in butter); and in the tropics where vegetable oils are the most available dietary lipid, it is necessary to certify that the content of the free fatty acid must be within 0.0 to 3.0 % (Bassir, 1971).

It can be concluded that samples G204 and GC210 would deteriorate faster than the other samples. The values obtained for the acid values are also within the limits set for quality oils. All oil samples are therefore of high quality.

4.3 Free Fatty Acid

Samples G204 and GC 210 recorded the highest content of free fatty acids. They recorded values of 0.23g and 0.2g respectively. The least amount of free fatty acid was recorded by sample G/C 209. The results again showed that samples G80, G6 111 and GC 214 all recorded 0.11g of free fatty acid content.

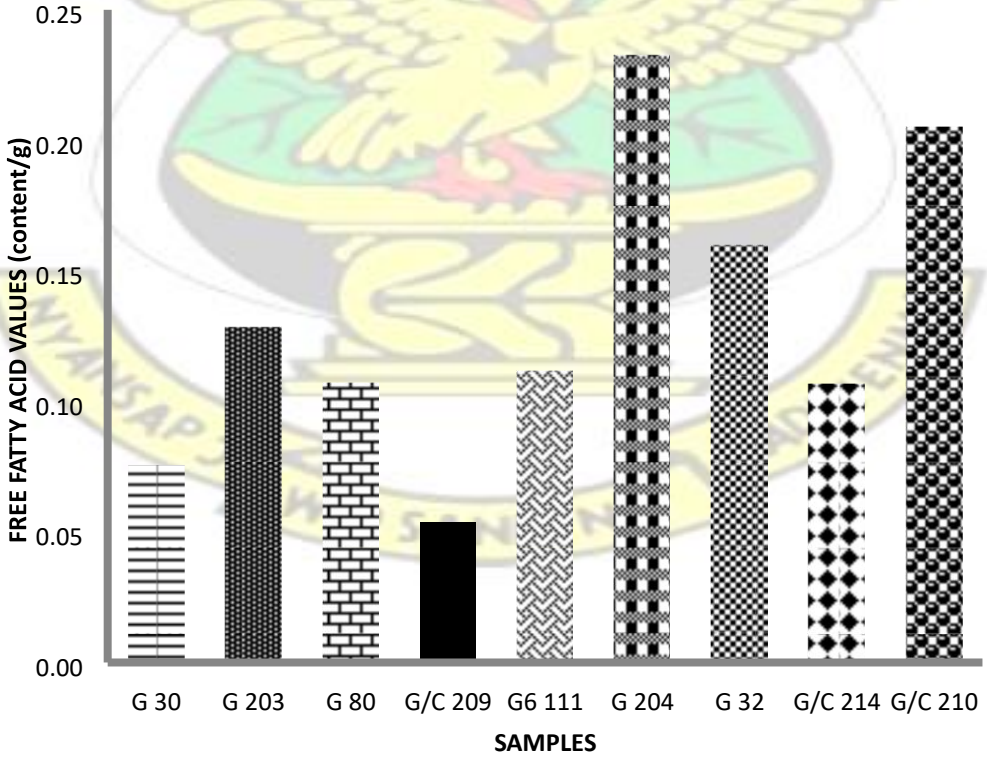

Figure 3: Free Fatty Acid of different Samples of Groundnut Oil

Statistical analysis conclude that differences exist in the free fatty acid of the samples ($F=31.937$; $p<0.05$). Table 3 shows the similarities which exist in the samples. The free fatty acids ranged from 0.05g to 0.23g. The free fatty acid of the oil is low. This indicates the stability of the products (Olaposi and Adunni, 2010). The presence of free fatty acid and other fatty materials in oil brings about the violent odour and taste in oil on long storage (Aluyor et al., 2009). Sample GC 209 is however the most stable sample among the samples presented.

4.4 Peroxide Value

The peroxide value of the groundnut oil samples are presented in figure 4. Sample G/C 214 reported the highest peroxide value of 5.09mEq/Kg. The least value was recorded by sample G6 111 with a value of 0.48mEq/Kg. Analysis of variance on the samples indicate that significant differences exist in the samples ($F=274.406$; $p<0.05$).

The low peroxide value indicated slow oxidation of oils, according to (Demian, 1990). The peroxide formation is slow initially during an induction period that may differ from few weeks to several months according to the specific oil and temperature (Pearson, 1981). The peroxide value is an indicator of deterioration of fat (Olaposi and Adunni, 2010).

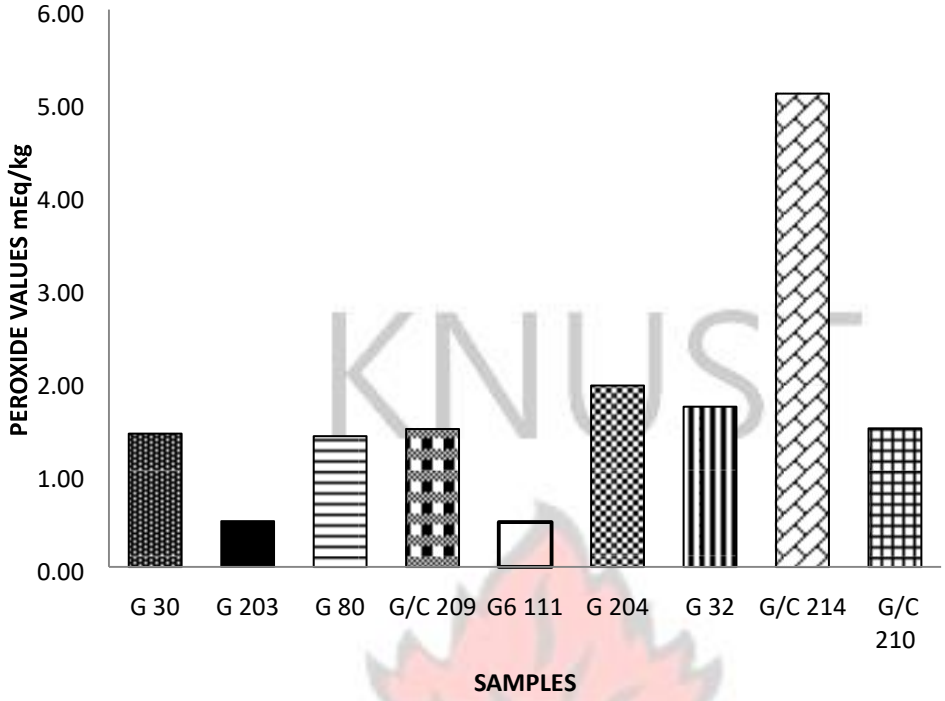

Figure 4: Peroxide Value of Groundnut Oil Samples

4.5 Iodine Value

Iodine value of samples is presented in figure 5. The highest amount of iodine content was recorded by sample GC210 with an amount of 46.18g/100ml and the least by G80 with a value of 42.48g/100ml. The high iodine value designates dehydrogenation. It is a measure of unsaturation in lipid, which again controls the amount of flow. Decrease in iodine value designates lipid oxidation and this might be as a result of metallic ions present among other factors, which enhances oxidation after the formation of hydroperoxide (Márquez-Ruiz et al., 1995).

Statistical analysis indicated that there were slight differences in the iodine value of samples studied ($F=2.215$; $p>0.05$). The samples presented can therefore be said to be devoid of contaminants such as metallic ions.

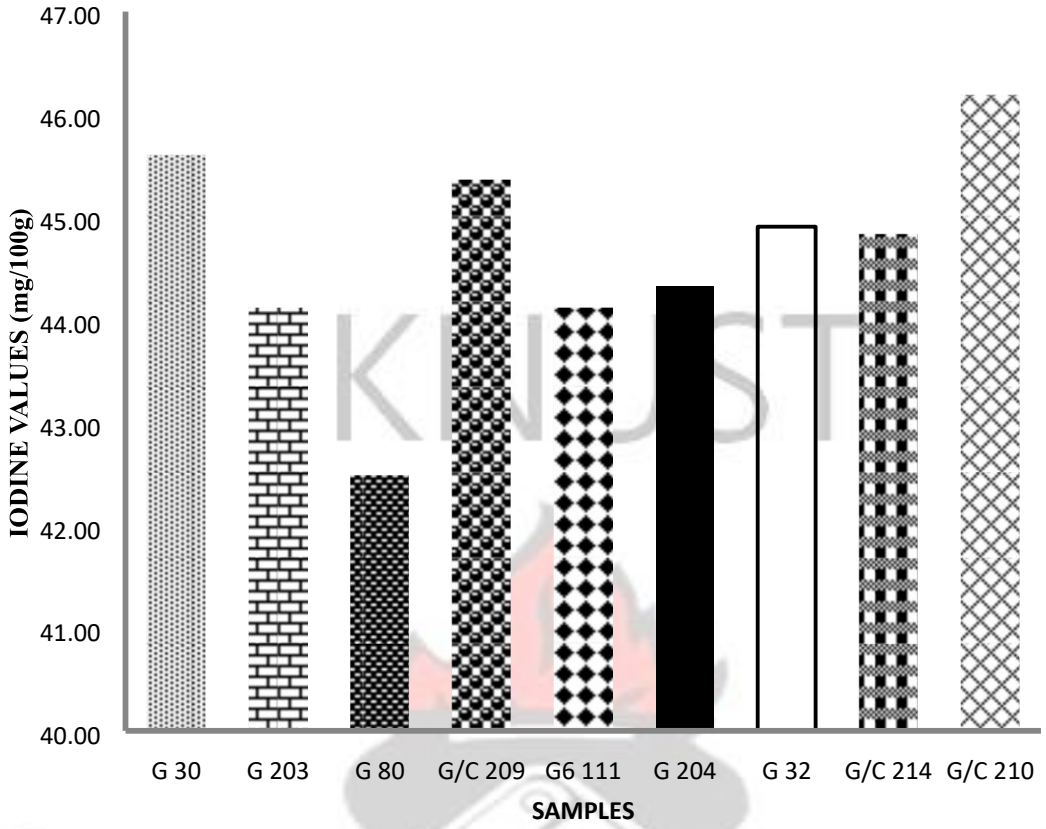

Figure 5: Iodine Value of Samples of Groundnut Oil

4.6 Fatty Acid and Triglyceride profile of Nine High-in-Oil Groundnut Assertion

The results revealed 24 different fatty acids in the different groundnut oil samples. Sample G210 contained 18 different triglycerides. Samples G214, G203, G6 111, G30 and G80 also contained 17 different triglycerides. Samples G 204 and G209 had the least number of triglycerides. Each had 16 of them (see appendix).

The triglycerides include DLG, LLL, OLL, PLL, MOL, MLP, MOM, LOO, LLS, POL_MOL, MOP, PLP, SLO, POP, POO, PLS, SLS, PPP, SOO, POS, PSS, ALS, AOO, and SOS. Only samples G32 and G80 contained the triglycerides LLS. POL_MOO was also found in only sample G209. Again only sample G80 had SLS and AOO. PPP was also found in only sample G32.

Statistical analysis concluded that differences existed in the content of the triglycerides in all samples at a level of significance of 0.05. Post Hoc analysis reveals that some of the samples showed similarities in their content. All samples presented differences in the following triglycerides; DG, MLP, MOM, LLS, POL_MOO, PLP, SLO, PPP, SOO P2S and AAA.

Some of the samples showed similarities in their triglycerides. G209 and G30 showed similarities in LLL. For OLL samples G204, G209 and G32 presented similarities in content. G30 and G210 also had similar content for PLL. For MOL the following samples were found to be similar G30 and G204, as well as G214, G6 111, G210 and G32. Sample G6 111 and G204 had similar content of LOO, the same was true for G203 and G209. Samples like G203, G30, G204, G210, G214 and G80 also had similar content of MOP. G214 and G203 had similar contents of POO. Groundnut oil sample G32 and G204 had similar content of PLS. G214 and G203 also had similar content of the triglycerides PLS and POP. Oil samples G6 111 and G210 also presented similar content of POP. Samples G203, G204 and G 214 also had similar content of POS and SOS.

CHAPTER FIVE

GENERAL CONCLUSION

5.1 Conclusion

The study worked on the nutritional and chemical composition of different varieties on groundnut. Results from the study concluded that the high saponification value of varieties G80, GC209 and G203 make them good for soap making. It can also be concluded that samples G204 and GC210 would deteriorate faster than the other samples. The existence of free fatty acid and other fatty materials in oil causes the bad

odour and taste in oil on prolonged storing. Sample GC 209 is expected to have an appealing odour since it has the lowest free fatty acid value. Variety GC210 is expected to deteriorate faster than the other varieties since it has the highest peroxide value. The low iodine values of the various varieties showed that they are free from contaminants. The fatty acid profile also revealed twenty-four different free acylglycerides among all samples studied. The values obtained for the acid values are also within the limits set for quality oils. All oil samples are therefore of high quality.

REFERENCES

(ICRISAT), I. C. R. I. f. t. S.-A. T. (2012) Food Safety and Health Risks: Aflatoxin contamination of groundnut – health and economic implications for India‟s rural poor.

Abdulkarim, S., Long, K., Lai, O. M., Muhammad, S. & Ghazali, H. (2007) Frying quality and stability of high-oleic Moringa oleifera seed oil in comparison with other vegetable oils. *Food Chemistry,* **105** (4)**,** 1382-1389.

Adeyeye, A. & Ajewole, K. (1992) Chemical composition and fatty acid profiles of cereals in Nigeria. *Food Chemistry,* **44** (1)**,** 41-44.

Akinhanmi, T., Atasie, V. & Akintokun, P. (2008) Chemical composition and physicochemical properties of cashew nut (Anacardium occidentale) oil and cashew nut shell liquid. *J Agric Food Environ Sci,* **2** (1)**,** 1-10.

Allen, R. (1955) Determination of unsaturation. *Journal of the American Oil Chemists' Society,* **32** (11)**,** 671-674.

Aluyor, E. O., Obahiagbon, K. O. & Ori-jesu, M. (2009) Biodegradation of vegetable oils: A review. *Scientific Research and Essays,* **4** (6)**,** 543-548.

Alyas, S., Abdulah, A. & NA Idris (2006) Change of β-Carotene Content During Heating of Red Palm Olein. *Oil Palm Research*. (Special Issue). 99-102.

Amoo, I., Eleyinmi, A., Ielaboye, N. & Akoya, S. (2004) Characteristics of oil extract from gourd (Cucubirta maxima) seed. *J. Food, Agriculture and Environment*,, **2,** 38-39.

Anyasor, G., Ogunwenmo, K., Oyelana, O., Ajayi, D. & Dangana, J. (2009) Chemical analyses of Groundnut (Arachis hypogaea) oil. *Pak. J. Nutr,* **8** (3)**,** 269-272.

AOAC (1990). *Official Methods of Analysis of the Association of Official Analytical Chemists* Association of Official Analytical Chemists Washington DC.

Asibuo, J. Y., Akromah, R., Safo-Kantanka, O., Adu-Dapaah, H. K., OhemengDapaah, S. & Agyeman, A. (2008) Chemical composition of groundnut, Arachis hypogaea (L) landraces. *African Journal of Biotechnology,* **7** (13).

Asiedu, J. J. (1991) *Processing tropical crops: a technological approach*. Karthala.

Augustin, M. & Berry, S. (1983) Efficacy of the antioxidants BHA and BHT in palm olein during heating and frying. *Journal of the American Oil Chemists' Society,* **60** (8)**,** 1520-1523.

Awuah, R., Fialor, S., Binns, A., Kagochi, J. & Jolly, C. (2009) Factors influencing market participants decision to sort groundnuts along the marketing chain in Ghana. *Peanut Science,* **36** (1)**,** 68-76.

Ayoola, P. & Adeyeye, A. (2010) Effect of heating on the chemical composition and physico-chemical properties of Arachis hypogea (Groundnut) seed flour and oil. *Pakistan Journal of Nutrition,* **9** (8)**,** 751-754.

Barku, V. A., Nyarko, H. & Dordunu, P. (2012) Studies on the physicochemical characteristics, microbial load and storage stability of oil from Indian almond nut (Terminalia catappa L.). *Journal of food science and quality management.,* **8**. 223-226.

Bassir, O. (1971) Handbook of practical biochemistry. *Ibadan University, Press, Ibadan, Nigeria***,** 53-54.

Belamkar, V., Selvaraj, M. G., Ayers, J. L., Payton, P. R., Puppala, N. & Burow, M. D. (2011) A first insight into population structure and linkage disequilibrium in the US peanut minicore collection. *Genetica,* **139** (4)**,** 411.

Birthal, P., Rao, P. P., Nigam, S., Bantilan, M. & Bhagavatula, S. (2010) Groundnut and soybean economies of Asia: facts, trends and outlook.Technical Report. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India. pp **56.**

Carlberg, E. J. (2012) An economic evaluation of groundnut research in Uganda and Ghana. *The University of North Carolina at Chapel Hill*.

Cheman, Y. & Wanhussin, W. (1998) Comparison of the frying performance of refined, bleached and deodorized palm oleic and coconut oil. *Journal of Food Lipids,* **5,** 197-210.

Chiou, R. Y.-Y., Ku, K.-L. & Chen, W.-L. (1997) Compositional characterization of peanut kernels after subjection to various germination times. *Journal of agricultural and food chemistry,* **45** (8)**,** 3060-3064.

Demian, M. (1990) *Principles of food chemistry*. Ed Van Nostrond Reihold internation company, London England.

Demir, F., & Kalyoncu, I. H. (2003). Some nutritional, pomological and physical properties of cornelian cherry (Cornus mas L.). *Journal of Food Engineering, 60*(3), 335-341.

Denniston, K. J., Topping, J. J. & Caret, R. L. (2004) *General, organic, and biochemistry*. McGraw-Hill Higher Education.

Dwivedi, S., Nigam, S., Jambunathan, R., Sahrawat, K., Nagabhushanam, G. & Raghunath, K. (1993) Effect of Genotypes and Environments on Oil Content and Oil Quality Parameters and Their Correlation in Peanut (Arachis hypogaea L.) 1. *Peanut Science,* **20** (2)**,** 84-89.

Eka, O. (1980) Proximate composition of bush mango tree and some properties of dikafat. *Nig. J. Nutr. Sci,* **1** (1)**,** 33-36.

FAO (2004) Food and Agriculture Organisation. Agriculture, pesticides, food security and food safety. *Environmental science & policy*, ***9*(7),** 685-692.

Faostat, F. (2013) Agriculture Organization of the United Nations, 2011. *FAO, Retrieved am from http://faostat3. fao. org/faostatgateway/go/to/download/Q/QC/S. Acceso,* **20**.

Grimm, D., Sanders, T., Pattee, H. & Sanchez-Dominguez, W. (1996) Chemical composition of Arachishypogaeavar. hirsute Peanuts. *Peanut Science,* **23,** 111116.

Grosso, N. & Guzman, C. (1995) Chemical Composition of Aboriginal Peanut (Arachihypogaea L) Seeds from Peru. *J.Agric.Food Chem,* **43,** 102-105.

Grosso, N. R., Lucini, E. I., López, A. G. & Guzmán, C. A. (1999) Chemical composition of aboriginal peanut (Arachis hypogaea L.) seeds from Uruguay. *Grasas y aceites,* **50** (3)**,** 203-207.

Grosso, N. R., Nepote, V. & Guzmán, C. A. (2000) Chemical composition of some wild peanut species (Arachis L.) seeds. *Journal of agricultural and food chemistry,* **48** (3)**,** 806-809.

Grosso, N. R., Zygadlo, J. A., Lamarque, A. L., Maestri, D. M. & Guzmán, C. A. (1997) Proximate, fatty acid and sterol compositions of aboriginal peanut (Arachis hypogaea L) seeds from Bolivia. *Journal of the Science of Food and Agriculture,* **73** (3)**,** 349-356.

Gupta, S., Dhawan, K., Kumar, P. & Yadava, T. (1982) Chemical composition of some groundnut strains. *Indian Journal of Agricultural Sciences (India)*. (**3**) 77-79

Horwitz, W., Chichilo, P. & Reynolds, H. (1970) Official methods of analysis of the Association of Official Analytical Chemists. *Official methods of analysis of the Association of Official Analytical Chemists.*

How, J. S. & Young, C. T. (1983) Comparison of fatty acid content of imported peanuts. *Journal of the American Oil Chemists' Society,* **60** (5)**,** 945-947.

Ihekoronye, A. I. & Ngoddy, P. O. (1985) *Integrated food science and technology for the tropics*. Macmillan.

Jambunathan, R. (1991) Uses of tropical grain legumes. International Crops Research Inst. for the Semi-Arid Tropics, Patancheru (India).

Jambunathan, R., Raju, S. M. & Barde, S. P. (1985) Analysis of oil content of groundnuts by nuclear magnetic resonance spectrometry. *Journal of the Science of Food and Agriculture,* **36** (3)**,** 162-166.

Jaswir, I., Man, Y. B. C. & Kitts, D. D. (2000) Synergistic effects of rosemary, sage, and citric acid on fatty acid retention of palm olein during deep-fat frying. *Journal of the American Oil Chemists' Society,* **77** (5)**,** 527-533.

Joseph, A. (1977) Measuring Flavour Deterioration of Fats, Oils and Foods. *General Food Cooperation Technical Center, New York***,** 1-7.

Khan, A. R., Tallat, T. & Ghous, T. (2006) Determination of Animals‟ Fats and Their Consumption by Women of Different Age Groups. *Pakistan Journal of Nutrition.* **(3)** 215-217.

Knothe, G. (2006) Analyzing biodiesel: standards and other methods. *Review. J Am Oil Chem Soc***,** 83 (10):823–833.

Kratz, M., Cullen, P., Kannenberg, F. & Kassner, A. (2002) Effects of dietary fatty acids on the composition and oxidizability of low-density lipoprotein. *European journal of clinical nutrition,* **56** (1)**,** 72.

Kris-Etherton, P. M. (1999) Monounsaturated fatty acids and risk of cardiovascular disease. *Circulation,* **100** (11)**,** 1253-1258.

Lea, C. (1962) The oxidative deterioration of food lipids. *SCHULTZ, HW Symposium on foods: lipids and their oxidation. Westport: AVI.*

Lokko, P., Lartey, A., Armar-Klemesu, M. & Mattes, R. D. (2007) Regular peanut consumption improves plasma lipid levels in healthy Ghanaians. *International journal of food sciences and nutrition,* **58** (3)**,** 190-200.

Lusas, E. (1979) Food uses of peanut protein. *Journal of the American Oil Chemists' Society,* **56** (3)**,** 425-430.

Manivel, P., Mathur, R., Bandyopadhyay, A., Samdur, M. & Misra, J. (2000) Evaluation of some confectionery type advanced breeding lines of groundnut. *International Arachis Newsletter,* (20)**,** 20-22.

Márquez-Ruiz, G., Tasioula-Margari, M. & Dobarganes, M. (1995) Quantitation and distribution of altered fatty acids in frying fats. *Journal of the American Oil Chemists' Society,* **72** (10)**,** 1171-1176.

MoFA (2011) Agriculture in Ghana: Facts and Figures. IN Agriculture, M. o. F. a.

https://www.google.com.gh/?gfe_rd=cr&ei=eltBWeG8GKf38Aex0oawBw#q=Agriculture+in+Ghana:+Facts+and+Figures.+IN+Agriculture,+M.+o.+F.+a.+(Ed.,+SRID.

Morrison, W., Hamilton, R. & Kalu, C. (1995) Sunflowerseed oil. *Developments in Oils and Fats.* Springer. (pp. 132-152)

Mozaffarian, D. (2008) Fish and n− 3 fatty acids for the prevention of fatal coronary heart disease and sudden cardiac death. *The American journal of clinical nutrition,* **87** (6)**,** 1991S-1996S.

Nicolosi, R. J. (1997) Dietary fat saturation effects on low-density-lipoprotein concentrations and metabolism in various animal models. *The American journal of clinical nutrition,* **65** (5)**,** 1617S-1627S.

Nielsen, S. (1994) *Introduction to the Chemical Analysis of Foods*, New York.

Nkafamiya, I., Aliyu, B., Manji, A. & Moddibo, U. (2007) Evaluation of deterioration of traditionally produced groundnut oil on storage. *Journal of Chemical Society of Nigeria,* **32** (1)**,** 137-142.

O‟Brien, R. (2000) *Fats and Oils*. CRC Press, Boca Raton USA.

Odoemelam, S. (2005) Proximate composition and selected physicochemical properties of the seeds of African oil bean (Pentaclethra marcrophylla). *Pakistan Journal of Nutrition*.

Okechalu, J., Dashen, M., Lar, M. & Tongriyang, G. (2011) **Isolation and Optimization of Lipase Producing Microorganism from Degrading Palm (Elaeis guineensis) Kernel Nut Oil**. *J. Microbiol. Biotech. Research*. 2, 107112.

Olaposi, A. R. & Adunni, A. O. (2010) Nutritional and physico-chemical properties of Bombax glabrum seeds. *Pakistan Journal of Nutrition,* **9** (9)**,** 856-857.

Onyeike, E. N. & Oguike, J. U. (2003) Influence of heat processing methods on the nutrient composition and lipid characterization of groundnut (Arachis hypogaea) seed pastes. *Biokemistri,* **15** (1)**,** 34-43.

Pancholy, S., Deshpande, A. & Krall, S. (1978) Amino acids, oil and protein content of some selected peanut cultivars. *Proceedings American Peanut Research and Education Association, Inc. New York*

Pomeranz, Y. & Meloan, C. (1987) *Food Analysis: Theory and Practice*. Van Nostrand Reinhold,, New York.

Rajgopal, K., Chandran, K., Misra, J., Bhalodia, P. & Mathur, R. (2000) Evaluation of bold seeded groundnut accessions for confectionery attributes. *International Arachis Newsletter,* **20,** 18-20.

Ratnayake, W. & Zehaluk, C. (2005) trans Fatty acids in foods and their labeling regulations. *Healthful lipids. AOCS Press, Champaign, IL***,** 1-32.

Rauken, M. & Kill, R. (1993) *Food Industry Manual*. Longmans, London.

Sadasivam, S. (1996) *Biochemical methods*. New Age International.

Savage, G. & Keenan, J. (1994) The composition and nutritive value of groundnut kernels. The Groundnut Crop. *Springer*, (**3**) 42.

Shahidi, F. & Wanasundara, U. N. (2002) Methods for measuring oxidative rancidity in fats and oils. *Food lipids: chemistry, nutrition and biotechnology***, (8)** 387403.

Shibasaki, H. & Yamane, T. (2000) Avoidance of solidification of sesame oil at low temperature by self-interesterification with immobilized lipase. *Bioscience, biotechnology, and biochemistry,* **64** (5)**,** 1011-1015.

Shilman, F., Brand, Y., Brand, A., Hedvat, I. & Hovav, R. (2011) Identification and molecular characterization of homeologous Δ9-stearoyl acyl carrier protein desaturase 3 genes from the allotetraploid peanut (Arachis hypogaea). *Plant molecular biology reporter,* **29** (1)**,** 232-241.

Singh, F. & Diwakar, B. (1993). Nutritive value and uses of pigeonpea and groundnut. International Crops Research Institute for the Semi-Arid Tropics. Skill Development Series no. 14. Pp. 49-60.

Stender, S. & Dyerberg, J. (2003) *The Influence of Trans Fatty Acids on Health; report from the Danish Nutrition Council*. Danish Nutrition Council. Pp 54.

Sulaiman, M., Bello, A., Itumoh, J., Bello, K., Bello, A. & Arzika, A. (2012) Physicochemical properties of some commercial groundnut oil products sold in Sokoto metropolis Northwest Nigeria. *J. of Biological Science and Bioconvervation,* **4** (1)**,** 38-44.

Tan, C. & Man, Y. C. (1999) Differential scanning calorimetric analysis for monitoring the oxidation of heated oils. *Food Chemistry,* **67** (2)**,** 177-184.

Tsigbey, F., Brandenburg, R. & Clottey, V. (2003) Peanut production methods in Northern Ghana and some disease perspectives. *World Geography of the Peanut Knowledge Base Website,* **9**. 33-38.

Vieira, T. M. & Regitano-d'Arce, M. A. (1999) Ultraviolet spectrophotometric evaluation of corn oil oxidative stability during microwave heating and oven test. *Journal of agricultural and food chemistry,* **47** (6)**,** 2203-2206.

Wallerstein, I., Merin, U. & Rosenthal, I. (1989) Comparison of kernels of three Virginia-type peanut cultivars. *Lebensmittel-Wissenschaft+ Technologie= Food science+ technology*.

Wang, C. T., Tang, Y. Y., Wang, X. Z., Chen, D. X., Cui, F. G., Chi, Y. C., Zhang, J. C. & Yu, S. L. (2011) Evaluation of groundnut genotypes from China for quality traits. *Journal of SAT Agricultural Research,* **9,** 5pp.

Weiss, E. A. (1983) *Oilseed crops*. Longman Group Ltd.

Young, C., Waller, G. & Hammons, R. (1973) Variations in total amino acid content of peanut meal. *Journal of the American Oil Chemists Society,* **50** (12)**,** 521523.

Yu, J., Chang, P.-K., Ehrlich, K. C., Cary, J. W., Bhatnagar, D., Cleveland, T. E., Payne, G. A., Linz, J. E., Woloshuk, C. P. & Bennett, J. W. (2004) Clustered pathway genes in aflatoxin biosynthesis. *Applied and environmental microbiology,* **70** (3)**,** 1253-1262.

Zhang, W. & Addis, P. (1992) Evaluation of frying oil filtration systems. *Journal of food science,* **57** (3)**,** 651-654.

APPENDIX

SAPONIFICATION VALUE

	SAMPLE CODE	N	Subset for alpha = 0.05		
			1	2	3
GC 214		2	196.8850		

Duncan[a]	G32	2	200.1000		
	G 204	2	202.8500	202.8500	
	G 30			203.7500	
	GC 210	2	203.7500	205.0400	
	G6 111	2	205.0400		
	G 80	2		215.6950	215.6950
	GC 209	2			219.9800
	G 203 Sig.	2			226.2150
		2			229.7650
			.261	.089	.067

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

ACID VALUE

	SAMPLE CODE	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	GC 209	2	.1900		
	G 30	2	.2000		
	G 80	2	.2300	.2300	
	G6 111	2	.2300	.2300	
	GC 214	2	.2350	.2350	
	G 203 G32	2	.2450	.2450	
	G 204 GC 210	2		.3300	
	Sig.	2			.4850
		2			.4900
			.355	.111	.926

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

	SAMPLE CODE	N	Subset for alpha = 0.05				
			1	2	3	4	5

	GC 209	2	.0500			
	G 30	2	.0750	.0750		
	G 80	2		.1050	.1050	
	G6 111 Duncan	2		.1100	.1100	
	GC 214	2		.1100	.1100	
a	G 203	2			.1300	.1300
	G32	2				.1600
	GC 210	2				.2050
	G 204 Sig.	2				.2350
			.128	.056	.151	.075 .075

Means for groups in homogeneous subsets are displayed.

FREE FATTY ACID

a. Uses Harmonic Mean Sample Size = 2.000.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
DG	Between Groups	12.068	8	1.508	578.936	.000
	Within Groups	.023	9	.003		
	Total	12.091	17			
LLL	Between Groups	93.182	8	11.648	14661.456	.000
	Within Groups	.007	9	.001		
	Total	93.189	17			
OLL	Between Groups	440.478	8	55.060	21926.458	.000
	Within Groups	.023	9	.003		
	Total	440.501	17			
PLL	Between Groups	26.208	8	3.276	1946.164	.000
	Within Groups	.015	9	.002		
	Total	26.223	17			
MOL	Between Groups					.000

	Within Groups	.068	8	.009	109.411	
		.001	9	.000		
	Total	.069	17			
	Between Groups	445.827	8	55.728	477671.405	.000
	Within Groups	.001	9	.000		
	Total	445.828	17			
MOM	Between Groups	25.895	8	3.237	58264.375	.000
	Within Groups	.001	9	.000		
	Total	25.896	17			
LOO	Between Groups	64.682	8	8.085	103953.554	.000
	Within Groups	.001	9	.000		
	Total	64.683	17			
LLS	Between Groups	3.707	8	.463	16683.200	.000
	Within Groups	.000	9	.000		
	Total	3.708	17			
POL_MOO	Between Groups	.032	8	.004	729.000	.000
	Within Groups	.000	9	.000		
	Total	.032	17			
MOP	Between Groups	34.710	8	4.339	18594.649	.000
	Within Groups	.002	9	.000		
	Total	34.712	17			
PLP	Between Groups	9.757	8	1.220	1844.830	.000
	Within Groups	.006	9	.001		
SLO	Total	9.763	17			

POO	Between Groups	22.157	8	2.770	38348.038	.000
	Within Groups	.001	9	.000		
	Total	22.157	17			
	Between Groups	4.341	8	.543	3255.525	.000
	Within Groups	.002	9	.000		
	Total	4.342	17			
	Between Groups	7.185	8	.898	812.406	.000

MLP	Within			

PLS	Within			
		.010	9	.001
	Groups			
	Total	7.195	17	

POP	Between Groups	.833	8	.104	986.303	.000
	Within Groups	.001	9	.000		
	Total	.834	17			
PPP	Between Groups	1.392	8	.174	3481.000	.000
	Within Groups	.000	9	.000		
	Total	1.393	17			
SOO	Between Groups	7.855	8	.982	5198.390	.000
	Within Groups	.002	9	.000		
	Total	7.857	17			.
SLS	Between Groups	.578	8	.072	.	
	Within Groups	.000	9	.000		
	Total	.578	17			
POS	Between Groups	2.173	8	.272	407.433	.000
	Within Groups	.006	9	.001		
	Total	2.179	17			
P2S	Between Groups	.476	8	.059	5351.625	.000
	Within Groups	.000	9	.000		
	Total	.476	17			
AOO	Between Groups	.528	8	.066	11881.000	.000
	Within Groups	.000	9	.000		
	Total	.528	17			
ALS	Between Groups	4.780	8	.598	4136.779	.000
	Within Groups	.001	9	.000		
	Total	4.782	17			
SOS	Between					.000

	Groups	1.521	8	.190	977.836	
	Within Groups	.002	9	.000		
	Total	1.523	17			

Post Hoc Tests Homogeneous Subsets

DG Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05							
		1	2	3	4	5	6	7	8
G6 111	2	3.0000							
G214	2		3.3700						
G32	2			3.5500					
G30 106	2				4.3650				
G209	2					4.7350			
G80	2					4.8250	4.8250		
G203	2						4.8850	4.8850	
G204	2							4.9950	
G210	2								5.5900
Sig.		1.000	1.000	1.000	1.000	.112	.270	.060	1.000

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

LLL Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05							
		1	2	3	4	5	6	7	8
G6 111	2	8.9950							
G209	2		13.1950						
G30 106	2		13.2500						
	2				14.6800				
G32				13.7450					
G204	2								

	2								
G210						15.6250			
G214	2						15.8750		
G203	2							16.2750	
G80	2								17.04
					1.000		1.000	1.000	50
Sig.		1.000	.083	1.000		1.000			1.000

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

OLL Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
G204	2	2.2400						
G209	2	2.2650						
G32	2	2.3150						
G6 111	2		9.2050					
G30 106	2			11.8250				
G210	2				12.1650			
G214	2					13.3450		
G203	2						13.6050	
G80	2							14.1350
Sig.		.186	1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

PLL Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
G209	2	.0000					
G32	2	.0000					
G204	2	.0000					
G6 111	2		1.3450				
G30 106	2			2.2350			
G210	2			2.2850			
G214	2				2.6500		
G203	2					2.8500	
G80	2						2.9500

Sig.		1.000	1.000	.254	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

MOL

Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
G80	2	.0000					
G209	2		.1150				
G30 106	2			.1450			
G204	2			.1450			
G214	2			.1650	.1650		
G6 111	2				.1750	.1750	
G203	2					.1900	
G210	2						.2100
G32	2						.2150
Sig.		1.000	1.000	.058	.286	.123	.585

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

LOO

Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
G210	2	1.2150						
G6 111	2		1.2800					
G204	2		1.2800					
G30 106	2			1.3250				
G214	2				1.3750			
G203	2					1.3950		
G209	2							
G32	2					1.4050	1.4650	
G80	2							
Sig.	2	1.000			1.000		1.000	
	2							7.3700
			1.000	1.000		.286		1.000

Means for groups in homogeneous subsets are displayed. a.
Uses Harmonic Mean Sample Size = 2.000.

Duncan

LLS

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05		
		1	2	3
G209	2	.0000		
G210	2	.0000		
G214	2	.0000		
G203	2	.0000		
G6 111	2	.0000		
G30 106	2	.0000		
G204	2	.0000		
G32	2		.2200	1.4550
G80	2			1.000
Sig.		1.000	1.000	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

POL_MOO

Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05	
		1	2
G210	2	.0000	
G214	2	.0000	
G203	2	.0000	
G6 111	2	.0000	
G30 106	2	.0000	
G32	2	.0000	
G80	2	.0000	
G204	2	.0000	

Duncan

G209	2		.1350
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

MOP

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05				
		1	2	3	4	5
G203	2	.1350				
G30 106	2	.1350				
G204	2	.1400				
G210	2	.1550	.1550			
G214	2	.1600	.1600			
G80	2		.1850			
G6 111	2			.2400		
G209	2				2.7650	
G32	2					4.0750
Sig.		.164	.093	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

PLS Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
G210	2	.5550						
G32	2		.6650					
G204	2		.7300					
G209	2			.8850				
G80	2				1.5350			
G214	2					1.8700		

Duncan

G203	2					1.9350		
G6 111 G30	2						2.0850	
106	2							2.1950
Sig.		1.000	.082	1.000	1.000	.082	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

POP

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05						
		1	2	3	4	5	6	7
G32	2	.0000						
G80	2		.2300					
G214	2			.3350				
G203	2			.3500				
G204	2				.4550			
G209	2					.4950		
G30 106	2						.5500	
G6 111	2							.7000
G210	2							.7200
Sig.		1.000	1.000	.178	1.000	1.000	1.000	.083

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

PPP Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05	
		1	2
G209	2	.0000	
G210	2	.0000	
G214	2	.0000	
G203	2	.0000	

Duncan

G6 111	2	.0000	
G30 106	2	.0000	
G80	2	.0000	
G204	2	.0000	
G32	2		.8850
Sig.			1.000
		1.000	

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

POS

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05				
		1	2	3	4	5
G32	2	.0000				
G80	2	.0000				
G203	2		.6750			
G210	2		.7050	.7050		
G214	2		.7150	.7150		
G204	2			.7400		
G30 106	2				.8350	
G209	2				.8500	
G6 111	2					1.0500
Sig.				.227		1.000
		1.000	.172		.576	

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

P2S Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05		
		1	2	3

Duncan

G209	2	.0000		
G214	2	.0000		
G203	2	.0000		
G6 111	2	.0000		
G30 106	2	.0000		
G80	2	.0000		
G204	2	.0000		
G210	2		.1450	.5150
G32	2			1.000
Sig.		1.000	1.000	

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

AOO

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05	
		1	2
G209	2	.0000	
G210	2	.0000	
G214	2	.0000	
G203	2	.0000	
G6 111	2	.0000	
G30 106	2	.0000	
G32	2	.0000	
G204	2	.0000	
G80	2		.5450
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Duncan

ALS Duncan

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
G209	2	.0000					
G210	2	.0000					
G32	2	.0000					
G80	2		.2800				
G203	2			.5750			
G204	2				.7400		
G214	2				.7600		
G30 106	2					.8250	
G6 111	2						1.6700
Sig.		1.000	1.000	1.000	.130	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SOS

SAMPLES OF FATTY ACIDS	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
G32	2	.0000					
G80	2	.0000					
G203	2		.3600				
G204	2		.3600				
G214	2		.3850				
G30 106	2			.4300			
G6 111	2				.6150		
G209	2					.7950	
G210	2						.8900
Sig.		1.000	.120	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.