KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI,

GHANA

COLLEGE OF SCIENCE



# AMINO ACID AND FATTY ACID PROFILES OF SOME SELECTED LOCAL VARIETIES OF RICE, SOYBEAN AND GROUNDNUT

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (FOOD SCIENCE AND TECHNOLOGY)

BY

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JUNE, 2011

## DECLARATION

STUDENT:

I hereby declare that this thesis is the outcome of my own research and that it is neither in part nor whole been presented for another certificate in this university or elsewhere.

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We hereby declare that the preparation of this project work was supervised in accordance with guidelines on the supervision of project work laid down by the Kwame Nkrumah University of Science and Technology.

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## DEDICATION

This work is dedicated to my loving parents, husband and siblings.

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## ABSTRACT

The aim of this study was to determine the amino acid and fatty acid profiles of some locally grown rice, soybean and groundnut varieties and to make recommendations for their use in formulating various weaning diets. This was considered a crucial research area as part of efforts being made towards the determination of the total nutritional quality of foodstuffs, especially in their possible utilization in complementary weaning food formulation. The amino acid profiles of five rice varieties; Digang, Nerica-1, Jasmine-85, Nerica-2 and Sikamo were determined. The amino acid and fatty acid profiles of four varieties of soybean; Anidaso, Jenguma, Quarshie and Salintuya and four varieties of groundnut; Sinkarzie, Chinese, Manipinta and F-Mix, all grown in Ghana, were also determined. For amino acid analyses, the method used was acid hydrolysis followed by HPLC analysis employing ELSD detection. For fatty acid analyses of the extracted oils, methylation followed by gas chromatography employing flame detection was used. Results obtained showed that Nerica-1, Sinkarzie and Quarshie had the best amino acid profile for rice, groundnut and soybean varieties respectively. Results also showed that Salintuya and F-Mix had the best fatty acid profiles for soybean and groundnut respectively. The study has shown that Nerica-1 can be used to complement F-Mix in weaning food formulation. Salintuya can be used to complement both Nerica-1 and F-Mix due to its excellent amino acid and fatty acid profiles. Anidaso and Manipinta can also be used as alternatives to Salintuya and F-Mix respectively to complement Nerica-1.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AA | Arachidonic acid |
| ALA | Apha linolenic acid |
| DGLA | Dihommogamma-linolenic acid |
| DHA | Docosahexaenoic acid |
| EAA | Essential amino acid |
| EFA | Essential fatty acid |
| EPA | Eicosapentaenoic acid |
| FAME | Fatty acid methyl esters |
| GC | Gas chromatography |
| GLA | Gamma linolenic acid |
| LA | Linoleic acid |
| MUFA | Monounsaturated fatty acid |
| NEAA | Non essential amino acid |
| PUFA | Polyunsaturated fatty acid |
| SFA | Saturated fatty acid |
| TAG | Triacylglycerol |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background to the study

Several studies have reported that most of the weaning foods consumed in many parts of developing nations are deficient in essential macronutrients and micronutrients (Plahar and Hoyle, 1991; Levin *et al.*, 1993; Brabin and Coulter, 2003; Milward and Jackson, 2004). This is because these foods are mainly semisolid porridges prepared from staple cereals, legumes and condiments (Ladeji *et al.*, 2000; Solomon, 2005). Due to the lack of knowledge on the nutritional value of these foodstuffs, the weaning foods are poorly complemented resulting in a lack of essential nutrients.

In view of this challenge, several strategies have been used by food scientists to formulate weaning foods in many parts of Africa through a combination of locally available foods that complement each other in order to create a new pattern of essential nutrients that provide the recommended daily allowance for infants (Plahar and Hoyle, 1991; Badamosi *et al.*, 1995; Solomon, 2005; Ijarotimi and Bakare, 2006). For instance, cereals are deficient in lysine but have sufficient sulphur-containing amino acids which are the limiting factors in legumes (Tsai *et al.*, 1975).

Plant foods are becoming popular sources of essential nutrients such as amino acids and fatty acids. They are low priced, have high proximate assessment values and are low in saturated fats and cholesterol. Grain legumes are widely used as cheap protein sources for man and livestock and have been adjudged to be of good nutritional value (Agbede,

2000; Agbede and Aletor, 2003). Legumes are also used as main sources of vegetable oils and have been known to contain an appreciable amount of unsaturated fatty acids. Cereals are good sources of energy and minerals. They are also known to contain some essential amino acids and fatty acids though in smaller concentrations.

It is widely appreciated that the developing countries do not produce enough protein from animal sources to meet their nutritional needs. Consequently, the larger segment of the population in developing countries gets most calories from cereal grains, starchy roots and tubers (Aletor, 2010).

Rice is a predominant staple food and dietary energy supplier for several countries in Africa. It is also a good source of essential vitamins such as thiamine, riboflavin and niacin. Rice is a high-carbohydrate food with about 85% of the energy from carbohydrate, 7% from fat, and 8% from protein (Oelke, 1976). More importantly, rice has been shown to have an excellent spectrum of amino acids, with high levels of glutamic and aspartic acids (Sekhar and Reddy, 1982). Rice is also said to contain an appreciable amount of linoleic acid although compared to other foods is in low quantity.

Soybeans are grown primarily for their protein content, and secondarily for their oil. Soybeans are higher in protein than other legumes; they contain about 35 to 38 % crude protein and have a complete amino acid profile (Ihenkoronye and Ngoddy, 1985). Soybean oil is a significant contributor to the intake of polyunsaturated fatty acids in human diets. It is also a good source of omega-3 fatty acids (Kris-Etherton *et al.*, 2006). Soybeans are greatly employed in the production of baby foods because of their

essential amino acid and fatty acid profiles. Soy protein products can be used to replace animal-based foods without requiring major adjustments elsewhere in the diet.

Groundnut is well known in Ghana as a good source of vegetable oil. Groundnut contains sufficient quantities of protein, carbohydrate, fat and appreciable amounts of micronutrients. Its protein content is known to be higher in essential amino acids particularly methionine compared to other legumes other than soybean (Brough and Azam – Ali, 1992). It has also been employed often as protein supplements for cereal-based diets in Africa and its residue added to animal feed (Elegbede, 1998). Oleic and linoleic acid, both unsaturated fatty acids, constitute about 80% of the total fatty acids in peanut oil (Knauft *et al*., 1993).

Eshun (2009) studied the proximate and physicochemical properties of seven local varieties of rice, four local varieties of soybean and five local varieties of groundnuts. The rice varieties, including Sikamo and Jasmine-85 had crude fat content between 0.14% and 0.77% and crude protein content between 5.29% and 8.53%. The crude fat of the soybean varieties which included Anidaso and Jenguma ranged between 13.05% and 18.59% whilst crude protein ranged between 34.92% and 39.25%. The groundnut varieties were also found to contain 23.53% to 28.88% crude protein as well as 38.11% to 48.79% crude fat.

The study was extended to include the nutritional and sensory properties of two diets prepared from a chosen blend of rice, groundnut and soybean. The choice of the varieties used (Jasmine-85, Chinese and Anidaso) was based on proximate analysis results. Diet A which contained approximately 64.30% cereal and 35.70% legume had a

crude protein value of 15.87% and crude fat value of 8.99%. Diet B which contained 50% cereal and 50% legume had a crude protein content of 17.66% and a crude fat value of 12.86%.

## 1.2 Problem Statement

Ghana, like many developing countries, is struggling with protein malnutrition and infant mortality. Available data shows that there is a high dependence on inadequately processed, traditional foods consisting mainly of unsupplemented cereal porridges made from maize, sorghum and millet as weaning foods for infants (Dandali, 2003).

Research conducted by the Ghana Statistical Service and the Noguchi Memorial Institute for Medical Research showed that about 5 million deaths of children in developing countries was due to protein-energy malnutrition. The major reason given for these issues was financial, that is the inability of parents to afford the nutritious diets commercially available to feed their babies (GSS and NMIMR, 2004).

For food scientists attempting to develop possibly cheap but quality weaning formulae, there is minimal information on the complete nutritional value of the local cereals and legumes being exploited for their research; especially relating to amino acid, fatty acid and energy profiles. This vacuum of knowledge prevents them from fully complementing the nutrients in each staple and therefore the resulting diet is still deficient of essential nutrients such as amino acids and fatty acids.

## 1.3 Justification

Ghana grows a substantial quantity of cereals and legumes but most of these foodstuffs are underutilized due to the lack of information on their total nutritional value. The varieties chosen for this study include some newly improved varieties and already acceptable local varieties. Preliminary information obtained on these varieties was based on research done by Eshun (2009) who studied their proximate and physicochemical properties. Their results confirmed that the varieties were rich sources of essential macro- and micronutrients and could be used to develop nutritious weaning foods. However little work has been done locally towards determining the amino acid and fatty acid profiles of these cereals and legumes.

Since basing product quality on the proximate, physicochemical and sensory properties of the raw materials is not enough to assess its full nutritional status, research into the amino acid and fatty acid profiles of some of these locally grown varieties would serve as useful data for food scientists who would now be able to fully exploit them in the development of well complemented weaning food for infants or food for other vulnerable groups.

## 1.4 Objectives

### 1.4.1 General objective

To study the amino acid and fatty acid profiles of some locally grown rice, groundnut and soybean varieties.

### 1.4.2 Specific objectives

a) To determine the amino acid profiles of five locally grown varieties of rice, four locally grown varieties of groundnut and four locally grown varieties of soybean.

b) To determine the fatty acid profiles of the groundnut and soybean varieties.

c) To establish which varieties could be used to complement each other in weaning food formulation.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

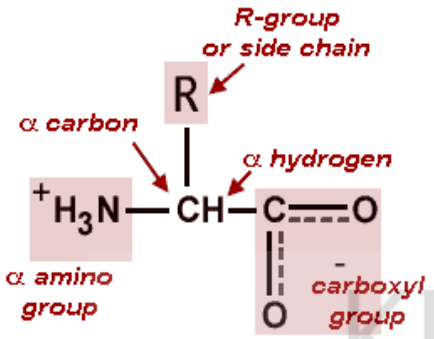
### 2.1 Amino acids

#### 2.1.1 General information on amino acids

At least three hundred amino acids have been described in nature but only twenty of these are typically found as components in human peptides and proteins (Copland *et al*., 2009). Amino acids are classified as non essential if they can be produced by the body, or nutritionally essential if they cannot be made or stored within the body and so must be obtained from foods in our daily diet (Copland *et al*., 2009). Therefore it is important for food scientists and technologists to research into such an important area of our highly consumed local foods and make the findings available for use.

Amino acids are significant to life, and have many functions in metabolism. They are also important in many other biological molecules, such as forming parts of coenzymes, as in S-adenosylmethionone, or as precursors for the biosynthesis of molecules such as heme (Whitney and Rolfes, 2002). In addition to their role in protein and enzyme synthesis, amino acids are extremely fundamental for good health. They contribute significantly to the health of the nervous system, muscular structure, hormone production, vital organs and cellular structure. Low levels of essential amino acids result in hormonal imbalances, irritability, low concentration, and depression (Escott-Stump, 2008).

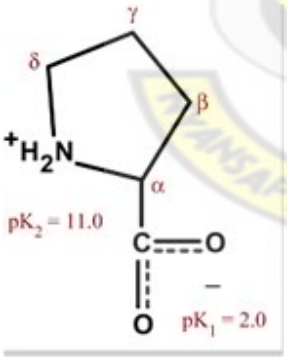
### 2.1.2 Chemical structure of amino acids




(Source: www.biology.arizona.edu)

**Figure 2.1: Chemical structure of an amino acid**

All amino acids have common structural features; including an α-carbon to which an amino group, a carboxyl group, and a variable side chain are bonded (the chemical structure is shown in Figure 2.1). Only proline differs from this basic structure as it contains an unusual ring to the N-end amine group, which forces the CO–NH amide moiety into a fixed conformation (Creighton, 1993).




(Source: www.biology.arizona.edu)

The side chains of the regular amino acids have a great diversity of chemical structures and properties; from just a hydrogen atom in glycine, to a methyl group in alanine, through to a large heterocyclic group in tryptophan. Side-group characteristics such as

shape, size, composition, electrical charge, and pH work together to determine each protein's specific function (Nelson and Cox, 2005).

### 2.1.3 Essential and non-essential amino acids

The amino acids that an organism cannot synthesize by itself are referred to as essential amino acids. Key enzymes that synthesize certain amino acids, such as aspartokinase which catalyzes the first step in the synthesis of lysine, methionine, and threonine from aspartate, are not present in animals. Essential amino acids include isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Another amino acid, histidine, is considered semi-essential because the body does not always require dietary sources of it (Furst and Stehle, 2004). However nonessential amino acids are synthesized by the human body from the essential amino acids or obtained from the normal breakdown of proteins. The nonessential amino acids are arginine, alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine, and tyrosine (Reeds, 2000).

Methionine and phenylalanine are required as specific precursors for the synthesis of the dispensable amino acids cysteine and tyrosine. Leucine, isoleucine, and valine are called branched-chain amino acids (BCAAs) because of their chemical structure. They are also more critical to human beings because a combination of these three amino acids make up approximately one-third of skeletal muscle in the human body. Tyrosine, phenylalanine and tryptophan are called aromatic amino acids. Each one contains a side chain with a ring-shaped formation. These three amino acids are needed for neurotransmitter production (Escott-Stump, 2008).

Failure to obtain a sufficient amount of even one of the nine essential amino acids results in degradation of the body's proteins—muscle and so forth—to obtain the one amino acid that is needed. Unlike fat and starch, the human body does not store excess amino acids for later use; therefore these essential amino acids must be contained in the food every day. Plants, as a major difference, are able to synthesise all the amino acids needed for their metabolic processes (Whitney and Rolfes, 2002). This makes plants different from animals.



### 2.1.4 Uses of amino acids

Information about the significant functions of some amino acids in the human body, *http://www.anyvitamins.com/amino-acids-info*, is outlined below:

#### 2.1.4.1 Uses of essential amino acids:

**Histidine** is found in large quantities in hemoglobin, it has been used in the treatment of rheumatoid arthritis, allergic diseases, ulcers and anemia.

**Leucine** and **isoleucine** provide ingredients for the buildup of other essential biochemical components in the body, some of which are utilized for the production of energy, stimulants to the upper brain and aiding one to be more alert.

**Lysine** ensures the adequate absorption of calcium; assists in the formation of collagen (bone cartilage and connective tissues) and aids in the production of antibodies, hormones and enzymes. Recent studies have shown that lysine may be effective against herpes by improving the balance of nutrients that reduce viral growth.

**Methionine** is a principle supplier of sulfur, which in effect, prevents disorders of the hair, skin and nails. It helps lower cholesterol levels by increasing the liver's production of lecithin. Methionine also reduces liver fat and protects the kidneys. Methionine is a natural chelating agent for heavy metals; it regulates the formation of ammonia and creates ammonia-free urine which reduces bladder irritation. Methionine also improves hair follicles and promotes hair growth.

**Phenylalanine** is used by the brain to manufacture norepinephrine, a chemical that transmits signals between nerve cells and the brain; keeps the body awake and alert; reduces hunger pains; functions as an antidepressant and helps improve memory.

**Threonine** is an important constituent of collagen, elastin, and enamel protein. It aids in the prevention of fat build-up in the liver. Threonine also helps the digestive and intestinal tracts to function efficiently and supports metabolism and assimilation.

**Tryptophan** is a natural relaxant; it helps alleviate insomnia by inducing normal sleep; reduces anxiety and depression and helps in the treatment of migraine headaches. Tryptophan also helps the immune system by reducing the risk of artery and heart spasms. Tryptophan works with lysine to reduce cholesterol levels in the body.

**Valine** promotes mental vigor, muscle coordination and calm emotions.

### 2.1.4.2 Use of non-essential amino acids

**Alanine** is an important source of energy for muscle tissue, the brain and central nervous system. It strengthens the immune system by producing antibodies and helps in the metabolism of sugars and organic acids.

**Arginine** has been shown to improve immune responses to bacteria, viruses and tumor cells as well as promote wound healing and regeneration of the liver. It causes the release of growth hormones and is considered crucial for optimal muscle growth and tissue repair. Current research has shown that arginine reduces fat mass in diet-induced obese rats and could help fight human obesity. The research found dietary arginine supplementation shifts nutrient partitioning to promote skeletal-muscle gain.

**Asparagine** is required by the nervous system to maintain equilibrium and is also required for amino acid conversion from one form to the other which is accomplished in the liver.

**Aspartic acid** aids in the expulsion of harmful ammonia from the body. Recent studies have shown that aspartic acid may increase resistance to fatigue and increase endurance.

**Cysteine** functions as an antioxidant and is a potent aid in protecting against radiation and pollution. It can help slow down the aging process, deactivate free radicals and neutralize toxins. It aids in protein synthesis and presents cellular change. Cystine is necessary for the development of the skin, and aids in the recovery from burns and surgical operations. Hair and skin are made up 10-14% cystine.

**Glutamic acid** is considered to be nature's "brain food". It improves mental capacities; helps speed the remedial of ulcers; gives a "lift" from fatigue; helps control alcoholism, schizophrenia and the craving for sugar.

**Glutamine** is converted to glutamic acid in the brain, which is essential for cerebral functions, and increases the amount of GABA (gamma-aminobutyric acid), which is required for brain functioning and mental activity. It is used in the muscles for the synthesis of muscle proteins and is employed in the cure of wasting muscles after illness or post-operative care.

**Glycine** helps trigger the release of oxygen to the energy requiring cell-making process and is essential in the manufacture of hormones responsible for a strong immune system.

**Proline** is extremely important for the proper functioning of joints and tendons. It also helps maintain and strengthen heart muscles.

**Serine** is a storage source of glucose by the liver and muscles. It also helps strengthen the immune system by providing antibodies and synthesizes fatty acid sheath around nerve fibers.

**Tyrosine** transmits nerve impulses to the brain; helps overcome depression; improves memory; increases mental alertness and promotes the healthy functioning of the thyroid, adrenal and pituitary glands.

## 2.2 Amino Acid Profile of Foods

### 2.2.1 Amino acid profiling in food

Amino acid profiles are in essence the amino acid composition of a protein, determined mainly by chromatographic methods. Information on the amino acid profile of foods is critical because it enables one to establish the nutritional value of the food. More information is required in establishing the ability of some local diets to meet protein needs. It is apparent that more attention be given to the digestibility of the proteins in a mixed diet (Fasuyi, 2006).

### 2.2.2 Amino acid profile of rice

Studies of the amino acid profile of rice shows that it is high in glutamic and aspartic acid, while lysine is the limiting amino acid (Sekhar and Reddy, 1982). Previous studies conducted by Sekhar and Reddy (1982) suggested that the scented varieties of rice possessed better amino acid profiles and exhibited superior nutritional qualities compared to the non-scented varieties. Studies by Oelke (1976) on wild rice varieties in Canada showed that the wild rice grains had nearly twice the percentage of the amino acids alanine, arginine, aspartic, lysine, and methionine than wheat grain. He also reported that the wild rice varieties also had slightly higher percentages of alanine, arginine, aspartic, and methionine than oats (Oelke, 1976).

The protein and amino acid composition of several rice varieties grown in North Vietnam, and their digestibility was studied by Khoi *et al.* (2006). They established that the protein content of rice cultivars ranged from 7.0% to 10.8% of which 70%-80% was

in the glutelin fraction. In general, lysine and threonine were found to be the first and second nutritionally limiting amino acids in the rice varieties analysed (Khoi *et al*., 2006).

Research done by Anderson (1976) revealed that the sulfur amino acid content of wild rice is about the same as white rice and oats but somewhat greater than that found in wheat. With the exception of lysine and threonine, the amount of each of the other essential amino acids of wild rice approximately equals or exceeds the Pattern (Anderson, 1976). Table 2.1 shows the amino acid content of ungerminated rough rice grown in Thailand. The predominant amino acids, of all the rice samples, were non essential amino acids (NEAA). In ungerminated rice, the glutamic acid content showed the highest amount, followed by alanine, and aspartic acid. Details are shown below:

**Table 2.1 Amino acid contents (essential amino acids and non essential amino acids in ungerminated rice (g/kg dry weight)**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid and Lysine | 12.92 |
| Histidine | 2.21 |
| Threonine | 2.55 |
| Isoleucine | 1.36 |
| Leucine | 6.95 |
| Phenylalanine | 3.30 |
| Tryptophan | - |

| | |
|---|---|
| Valine | 5.39 |
| Glycine | 5.61 |
| Serine | 3.99 |
| Aspartic acid | 7.31 |
| Alanine | 7.48 |
| Tyrosine | 2.98 |
| Proline | 3.29 |
| Arginine | - |

(Source: Moongngarm and Saetung, 2010)

Table 2.2 shows the amino acid composition of white rice grown in the United States of America. Amino acids with the highest composition values are glutamic acid and lysine together, others with high values include aspartic acid, leucine, alanine, serine and phenylalanine.

**Table 2.2 Amino acids in white rice, long grain, raw (g/kg)**

| **Amino Acid** | **Composition (g/kg)** |
|---|---|
| Glutamic acid and Lysine | 15.74 |
| Histidine | 1.60 |
| Threonine | 2.44 |
| Isoleucine | 2.94 |
| Leucine | 5.63 |
| Phenylalanine | 3.64 |
| Tryptophan | 0.79 |

| | |
|---|---|
| Valine | 4.16 |
| Glycine | 3.10 |
| Serine | 3.58 |
| Aspartic acid | 6.40 |
| Alanine | 3.95 |
| Tyrosine | 2.28 |
| Proline | 3.21 |
| Arginine | 5.68 |

(Source: USDA National Nutrient Database for Standard Reference, 2010)

The amino acid composition of ten Malaysian brown rice varieties is shown in Table 2.3 below. The amino acid with the highest value was aspartic acid followed by glutamic acid and serine with lysine as the limiting amino acid. Details are shown below:

**Table 2.3 Total amino acid profile and protein contents of different Malaysian brown rice varieties expressed as g/kg**

| Amino Acid | Malinja | S.Malaysia. I | S.Malaysia. II | Sekembang | Manik | Makmur | MR 103 | MR 106 | MR 159 | MR 185 | Mean (g/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Glycine | 3.2 | 3.4 | 3.2 | 2.8 | 3.2 | 3.0 | 3.1 | 3.1 | 3.4 | 3.4 | 3.18 |
| Serine | 5.8 | 3.6 | 3.7 | 2.7 | 3.1 | 3.0 | 3.1 | 4.0 | 3.5 | 3.2 | 3.57 |
| Aspartic acid | 6.9 | 6.4 | 6.9 | 6.0 | 6.6 | 5.6 | 6.5 | 6.1 | 5.8 | 6.2 | 6.30 |
| Alanine | 4.2 | 4.5 | 4.2 | 3.5 | 3.8 | 3.5 | 3.8 | 4.1 | 3.8 | 3.8 | 3.92 |
| Threonine | 1.7 | 1.9 | 1.7 | 1.4 | 2.1 | 1.7 | 1.8 | 2.1 | 2.4 | 1.8 | 1.86 |
| Glutamic acid | 12.4 | 12.6 | 12.5 | 11.1 | 11.9 | 10.1 | 11.1 | 12.2 | 11.8 | 11.2 | 11.69 |
| Histidine | 1.2 | 1.1 | 1.0 | 0.8 | 1.1 | 0.9 | 1.1 | 1.6 | 1.2 | 1.3 | 1.13 |
| Proline | 3.2 | 3.3 | 3.1 | 2.8 | 3.1 | 2.7 | 3.0 | 3.1 | 3.2 | 2.5 | 3.00 |
| Arginine | 3.9 | 4.1 | 4.3 | 3.4 | 3.8 | 3.5 | 3.7 | 4.0 | 3.9 | 3.7 | 3.83 |
| Valine | 2.0 | 2.2 | 1.9 | 1.9 | 1.9 | 1.6 | 1.7 | 1.9 | 1.9 | 1.7 | 1.87 |
| Tyrosine | 1.4 | 1.0 | 0.8 | 1.1 | 1.0 | 1.1 | 1.0 | 1.7 | 1.8 | 1.6 | 1.25 |
| Isoleucine | 3.0 | 3.1 | 2.8 | 3.1 | 2.9 | 2.7 | 2.9 | 3.2 | 3.0 | 2.8 | 2.95 |
| Leucine | 3.1 | 5.2 | 5.5 | 7.6 | 5.8 | 4.5 | 4.9 | 8.6 | 7.8 | 10.9 | 6.39 |
| Phenylalanine | 1.2 | 1.1 | 1.0 | 1.1 | 1.0 | 1.4 | 2.1 | 3.4 | 3.2 | 3.6 | 1.91 |
| Lysine | 2.1 | 2.0 | 2.0 | 1.8 | 2.0 | 1.6 | 2.0 | 1.9 | 1.9 | 2.0 | 1.93 |
| Methionine | 1.2 | 1.3 | 1.1 | 1.2 | 1.1 | 1.0 | 1.1 | 1.1 | 1.2 | 1.3 | 1.16 |
| **Total EAA** | 16.90 | 18.90 | 17.80 | 20.00 | 18.90 | 16.50 | 18.60 | 25.50 | 24.40 | 27.00 | |
| **Total NEAA** | 39.60 | 37.90 | 37.90 | 32.30 | 35.50 | 31.40 | 34.30 | 36.60 | 35.40 | 34.00 | |

(Source: Roohinejad *et al.*, 2009)

### 2.2.3 Amino acid profile of soybean

Soybean can produce at least twice as much protein per acre than any other major vegetable or grain crop (Abbey *et al*., 2001). About 35 to 38 percent of the calories in soybeans are derived from protein, compared to 20 to 30 percent in most other beans. Soy protein contains enough of all the essential amino acids to meet biological requirements when consumed at the recommended level of protein intake (Pennington, 1994; WHO, 2007).



A recent meta-analysis of 38 soybean research data by Anderson *et al*. (1995) concluded that consuming soy protein decreases total cholesterol, low density lipoprotein cholesterol and triglycerides, without lowering high density lipoprotein cholesterol, in humans with high cholesterol. As little as 25 grams of soy protein per day was shown to reduce cholesterol levels in hypercholesterolemic men (Anderson *et al*., 1995).

Tables 2.4 to 2.6 show the essential and non essential amino acid composition of selected soybean varieties from China, the U. S. A. and Brazil. In Table 2.4, the amino acid composition of Brazilian soybean used as starter feed for broiler chicks is detailed. Tables 2.5 and 2.6 show the amino acid composition of Chinese and U.S.A. soybean as found in international nutrient databases. In all three cases, the glutamic acid composition is the highest for all amino acids followed by arginine whilst leucine, an essential amino acid, is the third highest.

**Table 2.4 Amino acid composition of Brazilian soybean (g/kg weight)**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid+Lysine | 31.55(Lys) |
| Histidine | 11.50 |
| Threonine | 19.39 |
| Isoleucine | 22.59 |
| Leucine | 32.14 |
| Phenylalanine | 21.70 |
| Tryptophan | 4.51 |
| Valine | 22.89 |
| Glycine | - |
| Serine | - |
| Aspartic acid | - |
| Alanine | - |
| Tyrosine | 12.87 |
| Proline | - |
| Arginine | 29.12 |

- Indicates no value for the particular amino acid (Source: Smith, 1988)

**Table 2.5 Amino acid composition of Chinese soybean (whole bean, dried, raw)**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid+Lysine | 92 |
| Histidine | 10 |
| Threonine | 14 |
| Isoleucine | 16 |
| Leucine | 27 |
| Phenylalanine | 18 |
| Tryptophan | 4.7 |
| Valine | 17 |
| Glycine | 16 |
| Serine | 18 |
| Aspartic acid | 42 |
| Alanine | 16 |
| Tyrosine | 11 |
| Proline | 18 |
| Arginine | 26 |

(Source: www.wholefoodcatalog.info, 2011)

**Table 2.6 American soybean (essential and non-essential amino acid composition)**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid+Lysine | 100.58 |
| Histidine | 10.97 |
| Threonine | 17.66 |
| Isoleucine | 19.71 |
| Leucine | 33.09 |
| Phenylalanine | 21.22 |
| Tryptophan | 5.91 |
| Valine | 20.29 |
| Glycine | 18.80 |
| Serine | 23.57 |
| Aspartic acid | 51.12 |
| Alanine | 19.15 |
| Tyrosine | 15.39 |
| Proline | 23.79 |
| Arginine | 31.53 |

(Source: USDA National Nutrient Database for Standard Reference, 2010)

### 2.2.4 Amino acid profile of groundnut

Early experiments to determine the limiting amino acids in raw and roasted groundnuts showed that the limiting amino acid sequence were lysine, threonine and methionine in

equal levels (McOsker, 1962). Experiments were performed on peanut (*Arachis hypogaea* L.) to determine the relationship of fatty acid and amino acid profiles of 6 high oleic acid (HO) and 10 normal oleic acid genotype. Glutamine/glutamic acid and asparagine/aspartic acid accounted for 36 to 40% of the total amino acids; amino acids present in lowest proportions were the sulfur-containing amino acids (cysteine and methionine) followed by threonine and lysine. There was no significant relationship between the proportion of individual or total essential amino acids and the HO trait (Anderson *et al*., 1998).

Amino acid composition, protein fractions and chemical scores of 8 cultivars of *Arachis hypogaea* were evaluated to study their inter-relationships. Protein content varied significantly from 48.8% to 55.6%. Limiting amino acids methionine and lysine varied significantly from 0.80 to 1.20 and 3.30 to 3.90 g/16 g N, respectively. Chemical score for sulphur amino acids and lysine ranged from 37 to 50% and 47 to 55% respectively (Mann *et al*., 2006). The amino acid profiles of different groundnut varieties are shown in Tables 2.7 to 2.9 below. For JL 24, proline was the highest amino acid followed by aspartic acid (Table 2.7). An investigation of the amino acid composition of Egyptian groundnut by El-Badrawy *et al*. (2011) showed high levels of glutamic acid, aspartic acid, arginine and moderate amounts of isoleucine, phenylalanine and serine (Table 2.8). Table 2.9 displays the amino acid composition of U.S.A. groundnuts as can be found in their national nutrient database (USDA National Nutrient Database for Standard Reference, 2010).

**Table 2.7 Amino acid composition of groundnut variety JL-24**

| Amino Acid | Composition(g/kg) |
|---|---|
| Glutamic acid+Lysine | 23.26 |
| Histidine | 5.86 |
| Threonine | 6.89 |
| Isoleucine | 10.01 |
| Leucine | 16.22 |
| Phenylalanine | 12.66 |
| Tryptophan | 3.06 |
| Valine | 11.34 |
| Glycine | 12.32 |
| Serine | - |
| Aspartic acid | 34.39 |
| Alanine | 17.92 |
| Tyrosine | 9.72 |
| Proline | 64.12 |
| Arginine | 27.95 |

(Source: Ingale and Shrivastava, 2011)

**Table 2.8 Amino acid composition of Egyptian peanut, raw**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid+Lysine | 56.20 |
| Histidine | 6.00 |
| Threonine | 8.80 |
| Isoleucine | 16.70 |
| Leucine | 9.10 |
| Phenylalanine | 13.40 |
| Tryptophan | - |
| Valine | 10.80 |
| Glycine | 10.50 |
| Serine | 12.70 |
| Aspartic acid | 31.50 |
| Alanine | 10.30 |
| Tyrosine | 11.90 |
| Proline | 11.40 |
| Arginine | 30.90 |

(Source: El-Badrawy, 2011)

**Table 2.9 Amino acid composition of American peanut, unprocessed**

| Amino Acid | Composition (g/kg) |
|---|---|
| Glutamic acid+Lysine | 61.44 |
| Histidine | 6.34 |
| Threonine | 8.59 |
| Isoleucine | 8.82 |
| Leucine | 16.27 |
| Phenylalanine | 13.00 |
| Tryptophan | 2.45 |
| Valine | 10.52 |
| Glycine | 15.12 |
| Serine | 12.36 |
| Aspartic acid | 30.60 |
| Alanine | 9.97 |
| Tyrosine | 10.20 |
| Proline | 11.07 |
| Arginine | 30.01 |

(Source: USDA National Nutrient Database for Standard Reference, 2010)

## 2.3 Fatty Acids

### 2.3.1 General information on fatty acids

Most naturally occurring fatty acids have a chain of an even number of carbon atoms, from four to twenty-eight (IUPAC, 1997). Fatty acids are usually derived from triglycerides or phospholipids. When they are not attached to other molecules, they are known as "free" fatty acids. Fatty acids vary in the length of their carbon atom chain (from 4 to 22) and the number of double bonds they contain. The vast majority of fatty acids, both in the diet and in the body, contain 16-18 carbon atoms. Saturated fats contain no double bond, monounsaturated fats contain one double bond and polyunsaturated fats contain two or more (Bowman and Russell, 2001).

### 2.3.2 Chemical structure and classification of fatty acids

Saturated fatty acids normally found in nature contain between twelve and twenty-four carbon atoms and no double bonds whilst unsaturated fatty acids contain at least one double bond between the carbon atoms in the chain. The two carbon atoms in the chain that are bound to either side of the double bond can occur in a cis or trans configuration (Bowman and Russell, 2001).

In addition to saturation, fatty acids have different carbon lengths, often categorized as short, medium, or long. Short chain fatty acids have fewer than six carbons; medium-chain fatty acids have six to twelve carbons and long-chain fatty acids have more than 12 carbons. Very long chain fatty acids have more than 22 carbons (Berg *et al*., 2007).

In dealing with essential fatty acids, a slightly different terminology applies. Short-chain essential fatty acids are those with 18 carbons and long-chain essential fatty acids have 20 or more carbons. The term omega, as it relates to fatty acids, refers to the terminal carbon atom farthest from the functional carboxylic acid group (–COOH). The designation of a polyunsaturated fatty acid (PUFA) as an omega-3 fatty acid, for example, defines the position of the first site of unsaturation relative to the omega end of that fatty acid. Thus, an omega-3 fatty acid like Docosahexaenoic acid (DHA) (Figure 2.2), which harbors six carbon-carbon double bonds (i.e sites of unsaturation), has a site of unsaturation between the third and fourth carbons from the omega end whilst an omega-6 fatty acid like arachidonic acid (Figure 4) which harbors four carbon-carbon double bonds (i.e sites of unsaturation), has a site of unsaturation between the sixth and seventh carbons from the omega end (King, 2011).

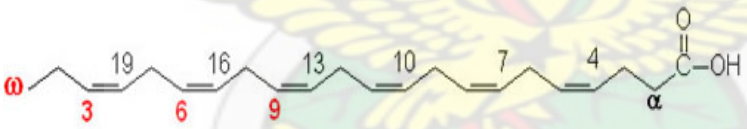



**Figure 2.2: Docosahexaenoic acid (DHA)**

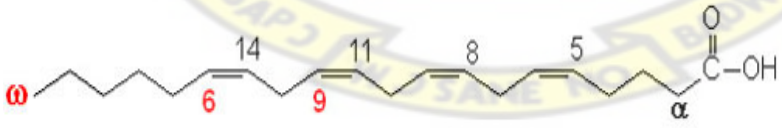



**Figure 2.3: Arachidonic acid**

### 2.3.3 Essential and non-essential fatty acids

Saturated and monounsaturated fatty acids are non-essential to humans. Common ones found in nature include palmitic acid, stearic acid and oleic acid. Essential fatty acids (EFAs) are polyunsaturated fatty acids that are vital for, but cannot be made by, the human body. Humans lack the ability to introduce double bonds in fatty acids beyond carbons 9 and 10, as counted from the carboxylic acid side. This is due to the absence of enzymes necessary to introduce a double bond at the omega-3 position or omega-6 position. The two families of EFAs are the Omega-3 (n-3) series and the Omega-6 (n-6) series. The Omega-3 (n-3) series includes eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The Omega-6 (n-6) series includes linoleic acid (LA), dihommogamma-linolenic acid (DGLA) and arachidonic acid (AA). (Shahidi and Finley, 2001)

The omega-3 parent fatty acid is called alpha linolenic acid (LNA or ALA) and comes from seeds such as flax, hemp and pumpkin, from nuts such as walnuts, and to a lesser extent from soya and green vegetables. The omega 6 parent fat is called linoleic acid (LA) and is found in seeds such as hemp, flax, sunflower and sesame as well as in nuts (Simopoulos *et al*., 1999). Only plants can make the vital omega 3 and 6 parent fatty acids which human enzymes then convert to other fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which are building blocks of the brain and nervous system (Simopoulos *et al*., 1999).

### 2.3.4 Uses of fatty acids

Short and medium-chain fatty acids have antimicrobial properties; contribute to the health of the immune system; and do not need to be acted on by the bile salts but are

absorbed directly for quick energy. For this reason, they are less likely to cause weight gain. Physiological studies have shown that ingestion of triglycerides containing these medium-chain fatty acids may result, as for short-chain fatty acids, in increased energy expenditure. Thus, they facilitate weight control when included in the diet as a replacement for long-chain triglycerides (St-Onge and Jones, 2002).

**Palmitic** acid is the commonest saturated fatty acid in plant and animal lipids. It usually forms less than 5% of the total fatty acids, sometimes as much as 10% in common vegetable oils (peanut, soybean, corn, coconut) and in marine-animal oils.

**Stearic acid** is an 18-carbon saturated fatty acid extracted from many types of animal fats, vegetable fats, and some oils. Stearic acid is used in many food products because it is stable during storage and frying. Even though it is a saturated fat, it seems to have little effect on cholesterol levels in the blood. The reason for this seems to be that a high proportion of it is converted to oleic acid, which is a monounsaturated fat (Hunter, 2001)

Essential fatty acids are important factors in maintaining body temperature, insulating nerves, and cushioning body tissue. They are also precursors to prostaglandins, hormone-like substances that are critical to the body's overall health maintenance (Shahidi and Wanasundara, 1998). Linoleic acid and arachidonic acid are said to be very important for the health of the human skin (Adoracion and Bienvenido, 2006).

Newborn babies are able to synthesize Docosahexaenoic acid (DHA), an omega-3 fatty acid, DHA from **α-linolenic acid** (ALA) (Koletzko *et al*., 2008). DHA is an integral component of cell membranes in the developing brain and retina; and it is one of the

essential fatty acids for infant development (Elamadfa and Majchrzak, 2000). A number of studies found that DHA in infant formula influenced the cognitive ability, motor ability, visual acuity and visual maturation of infant (Carlson *et al*., 1996; Gibson and Makrides, 1999; Hoffman *et al*., 2004; Neuringer, 2000).

**Eicosapentaenoic acid (EPA)** is needed for brain function, concentration, and vision, and is also converted into a powerful anti-inflammatory agent.

**GLA (gamma-linolenic acid)** is well known for its anti-inflammatory properties and its utilization in female hormonal balance (Shahidi and Wanasundara, 1998).

## 2.4 Fatty Acid Profile of Foods

### 2.4.1 General information on fatty acid profiling

Gas chromatography (GC) has become widely adopted as a highly applicable tool in micro-scale analysis of fatty acids in different research areas (Harvey, 2000). The basic features of polyunsaturated fatty acids and especially of essential fatty acid metabolism could be verified in high detail by GC analysis. Individual fatty acids can usually be identified by GC with reasonable certainty from their **relative retention times**, especially if the analysis is carried out with a variety of stationary phases. There are many circumstances when it must be recognized that GC analysis permits a tentative identification only (Harvey, 2000).

### 2.4.2 Fatty acid profile of rice

Due to the fact that the fat content of wild rice is quite low, approximately 1% by hexane extraction, it contributes little to the nutritive spectrum of wild rice. However, in analyzing the hexane extract, previous research showed that wild rice lipid is unique when compared with white rice, wheat, and oats, because it contains a rather high level of linolenic acid (30%). Research by Anderson (1976) obtained data to support the assertion that rice contains essential fatty acids. His findings showed that linoleic and linolenic acids make up more than 65% of the total fatty acid of the hexane-extracted lipid of wild rice. Since these acids are highly susceptible to oxidation, they are probably responsible for development of rancid odors in wild rice stored for a long time. Since linoleic acid is one fatty acid known to be essential for man, the high level of this acid in wild rice surely contributes to the nutritional quality of this food (Anderson, 1976).

A comparison of the fatty acid composition of different rice types is shown in Table 2.10. Wild rice is shown to be the best source of linoleic and linolenic acids followed by brown rice. White rice on the other hand has a higher level of saturated and monounsaturated fatty acids. Details of the fatty acid composition as discovered by Lugay and Juliano (1964) are shown as follows:

**Table 2.10 Fatty acid composition of hexane extracts of different rice types using Gas Chromatography (% of total fatty acids)**

| Fatty acid | Wild rice | Brown rice | White rice |
|---|---|---|---|
| Palmitic acid | 14.5 | 20.4 | 33.8 |
| Stearic acid | 1.1 | 1.6 | 2.7 |
| Oleic acid | 15.9 | 41.3 | 43.3 |
| Linoleic acid | 37.7 | 34.5 | 18.0 |
| Linolenic acid | 30.0 | 1.0 | 0.6 |

(Source: Lugay and Juliano, 1964)

### 2.4.3 Fatty acid profile of soybean

Soybean oil is a significant contributor to the intake of polyunsaturated fatty acids (PUFA), i.e., Linoleic acid (LA) and alpha-Linolenic acid (ALA). Soybean oil has a balanced fatty acid profile that provides a good source of LA (52%), as well as a good source of monounsaturated fatty acids (MUFA) (24%). Furthermore, soybean oil is relatively low in saturated fatty acids (SFA) (24%) and has one of the highest concentrations of ALA (7%). Thus, soybean oil has a fatty acid profile that facilitates meeting current dietary recommendations to achieve nutrient adequacy and decrease risk of chronic disease (Kris-Etherton, 2006).

The fatty acid compositions of soybean oil obtained from different sources are shown in Tables 2.11 to 2.13 below:

**Table 2.11 Fatty acid profile of Chinese soybean oil**

| Fatty acid | Carbon No. | % Composition |
|---|---|---|
| Palmitic | C16:0 | 11.0 |
| Stearic | C18:0 | 4.1 |
| Oleic | C18:1 | 22.0 |
| Linoleic | C18:2 | 54.0 |
| Linolenic | C18:3 | 7.5 |

(Source: www.chinese-school.netfirms.com)

For Chinese varieties of soybean, as shown in Table 2.11, Linoleic acid content exceeds 50%. This compares fairly with Brazilian soybean varieties which also have about 55% to 58% of Linoleic acid as shown in Table 2.13. On the other hand, tropical varieties of soybean, as those found in Nigeria, have Linoleic acid content of 37% to 44% (Table 2.12). However, all varieties of soybean from the different sources have good ratio of polyunsaturated fatty acids to saturated fatty acids. PUFA/SFA ratio ranges from 3.15-3.67 for tropical varieties and 3.40 to 4.10 for Brazilian varieties.

**Table 2.12 Fatty Acid Composition of Selected Tropical Soybean Seed Oils (g fatty acid per 100 g oil)**

| Fatty acid | Carbon No. | TGX 1660-15F | TGX 1740-6F | TGX 1740-2F | TGX 1649-11F | TGX 1681-3F |
|---|---|---|---|---|---|---|
| Palmitic | C16:0 | 10.49 | 10.44 | 9.77 | 9.64 | 9.74 |
| Hexadecadienic | C16:2n-4 | 1.96 | 1.91 | 1.75 | 1.80 | 1.85 |
| Stearic | C18:0 | 3.25 | 3.48 | 3.56 | 2.93 | 3.59 |
| Oleic | C18:1n-9 | 22.32 | 24.13 | 22.48 | 21.21 | 15.78 |
| Oleic (isomer) | C18:1n-7 | 1.54 | 1.31 | 1.23 | 1.35 | 1.11 |
| Linoleic | C18:2n-6 | 44.32 | 38.47 | 37.42 | 38.49 | 43.91 |
| Linolenic | C18:3n-6 | 0.46 | 0.40 | 0.38 | 0.40 | 0.44 |
| Linolenic | C18:3n-3 | 5.66 | 5.32 | 5.13 | 4.72 | 6.39 |
| Arachidic | C20:0 | 0.33 | 0.33 | 0.34 | 0.37 | 0.44 |
| Godoleic | C20:1n-9 | 0.24 | 0.21 | 0.21 | 0.29 | 0.22 |
| Behenic | C22:0 | 0.41 | 0.37 | 0.40 | 0.44 | 0.53 |
| **Saturated** | | 14.49 | 14.62 | 14.08 | 13.58 | 14.31 |
| **PUFA** | | 52.45 | 46.05 | 44.63 | 45.36 | 52.52 |
| **P/S ratio** | | 3.62 | 3.15 | 3.17 | 3.34 | 3.67 |

(Source: Ezeagu *et al.*, 1998)

**Table 2.13 Fatty acid profiles of transgenic and conventional Brazilian soybean varieties (g/100g)**

| Fatty acid | Embrapa 58 | BRS 242RR* | Embrapa 59 | BRS 244RR* | BRS 133 | BRS 245RR* | BRS 134 | BRS 247RR* |
|---|---|---|---|---|---|---|---|---|
| C16:0 | 13.27 ± 0.62a | 12.62 ± 0.23a | 13.27 ± 0.11a | 12.70 ± 0.08b | 14.01± 1.08a | 12.32 ± 0.19a | 13.4± 0.19a | 12.14 ± 0.08b |
| C18:0 | 3.59 ± 0.26a | 4.19 ± 0.00a | 2.94 ± 0.33a | 4.05 ± 0.06b | 4.20 ± 0.05a | 3.75 ± 0.09b | 4.39± 0.18a | 3.99 ± 0.01a |
| C18:1n-9 | 19.31 ± 0.18a | 17.35 ± 0.13b | 18.12 ± 0.04a | 18.36 ± 0.11a | 16.86 ±0.14a | 16.66 ± 0.16a | 16.3± 0.10a | 17.40 ± 0.05b |
| C18:1n-7 | 1.98 ± 0.00a | 1.41 ± 0.07b | 2.16 ± 0.05a | 1.25 ± 0.07b | 1.61 ± 0.05a | 1.34 ± 0.03b | 1.74± 0.02a | 1.40 ± 0.04b |
| C18:2n-6 | 55.51 ± 0.27a | 57.01 ± 0.34b | 57.44 ± 0.51a | 56.80 ± 0.23a | 56.1± 0.82a | 58.45 ± 0.23a | 57.0± 0.05a | 57.97 ± 0.26b |
| C18:3n-3 | 6.34 ± 0.09a | 7.42 ± 0.17b | 6.06 ± 0.07a | 6.84 ± 0.08b | 7.17 ± 0.11a | 7.49 ± 0.20a | 7.02± 0.07a | 7.10 ± 0.18a |
| **PUFA** | 61.85 ± 0.29a | 64.43 ± 0.38b | 63.50 ± 0.51a | 63.64 ± 0.25a | 63.32 ± .83a | 65.93 ± 0.30a | 64.0± 0.08a | 65.06 ± 0.31b |
| **MUFA** | 21.29 ± 0.18a | 18.76 ± 0.15b | 20.28 ± 0.06a | 19.62 ± 0.13b | 18.47 ±0.15a | 18.00 ± 0.17a | 18.12 ±0.10a | 18.80 ± 0.06b |
| **SFA** | 16.86 ± 0.67a | 16.81 ± 0.23a | 16.21 ± 0.35a | 16.74 ± 0.10a | 18.21 ±1.08a | 16.07 ± 0.21a | 17.79 ±0.26a | 16.13 ± 0.08b |
| **PUFA/SFA** | 3.67 ± 0.15a | 3.83 ± 0.06a | 3.92 ± 0.09a | 3.80 ± 0.03a | 3.49 ± 0.21a | 4.10 ± 0.06a | 3.60 ± 0.05a | 4.03 ± 0.03b |

(Source: Milinsk *et al*., 2007)

### 2.4.4 Fatty acid profile of groundnut

Oleic acid, a monounsaturated fatty acid, and linoleic acid, a polyunsaturated acid, constitute approximately 80% of the total fatty acid composition of groundnut (Knauft

*et al*., 1993). Twelve fatty acids have been reported in groundnut but eight major fatty acids constitute 98% of fatty acids in groundnut (Tai, 1972).

A previous experiment was done to determine the physical and chemical properties and fatty acid composition of peanuts, peanut butter and their oils from Turkey. The major fatty acid components were found to be oleic, linoleic, palmitic and stearic acids. Predominant free fatty acids were oleic, linoleic, palmitic and arachidic acids (Özcan and Seven, 2003). Table 2.14 shows the fatty acid profiles for two Turkish peanut varieties:



**Table 2.14 Fatty acid composition of peanut kernel and peanut butter oils (%)**

| **Fatty acid** | **Kernel** | | **Butter** | |
|---|---|---|---|---|
| | **ÇOM** | **NC-7** | **ÇOM** | **NC-7** |
| Myristic | 0.13±0.05* | 0.23±0.13 | 0.33±0.21 | 0.23±0.15 |
| Palmitic | 8.70±0.17C** | 13.03±0.31A | 9.37±0.31C | 10.83±0.49B |
| Palmitoleic | 0.30±0.10 | 0.23±0.15 | 0.37±0.15 | 0.47±0.31 |
| Stearic | 3.77±0.15c*** | 4.53±0.21a | 4.00±0.10bc | 4.23±0.32ab |
| Oleic | 55.07±0.32A | 43.13±0.45C | 55.10±0.76A | 48.40±0.30B |
| Linoleic | 25.13±0.57D | 35.20±0.46A | 26.53±0.47C | 31.93±0.21B |
| Linolenic | 0.20±0.10 | 0.30±0.26 | 0.23±0,153a | 0.27±0,15a |
| Arachidic | 1.90±0.10a | 1.53±0.15a | 1.93±0.15a | 1.67±0.15a |
| Gadoleic | 1.37±0.25A | 0.40±0.30C | 1.23±0.15AB | 0.63±0.25BC |
| Behenic | 3.17±0.21AB | 2.40±0.24B | 3.47±0.42A | 2.43±0.31B |
| **SFA** | 15.64 | 19.96 | 16.84 | 17.49 |
| **PUFA** | 25.33 | 35.20 | 26.76 | 32.20 |
| **PUFA/SFA** | 1.62 | 1.76 | 1.59 | 1.84 |

* means ± standard deviation, ** Mean values followed by the same capital letter within each column are not significantly different ($p>0.05$) and *** Mean values followed by the same small letter within each column are not significantly different ($p<0.01$) (Source: Özcan and Seven, 2003)

A detailed study on the chemical composition of twenty groundnut varieties grown in Ghana was conducted by Asibuo *et al.* (2008). Of interest is the fatty acid profiles for the five major fatty acids; palmitic, stearic, oleic, linoleic and behenic. The linoleic acid content varied between 17.35 and 36.0%. Oleic and linoleic acids together accounted for 77.9% of the total fatty acids in the 20 groundnut varieties analyzed. The values of oleic/linoleic acid ratio of all the groundnut varieties exceeded 1.0. They varied between 1.14 and 3.66. The content of palmitic acid varied between 9.05 and 12.85%. Stearic acid ranged from 1.75 to 3.65%. The content of arachidic acid ranged from 1.05 to 1.70% and that of eicoseanoic acid from 0.77 to 1.50%. The sum of the means of oleic, linoleic and palmitic acid was 89.35% (Asibuo *et al.,* 2008). Details are presented in Table 2.15 below:

**Table 2.15 Percentage of fatty acids of twenty groundnut Ghanaian varieties**

| Variety | Palmitic | Stearic | Oleic | Linoleic | Behenic | SFA | PUFA | PUFA/SFA |
|---|---|---|---|---|---|---|---|---|
| Dagomba | 9.05 | 2.95 | 63.55 | 17.35 | 3.90 | 15.90 | 17.35 | 1.09 |
| F-Mix | 10.65 | 1.75 | 51.95 | 27.55 | 3.70 | 16.10 | 27.55 | 1.71 |
| Nkatepa | 10.20 | 2.25 | 55.35 | 24.65 | 3.35 | 15.80 | 24.65 | 1.56 |
| Manipinta | 9.45 | 2.45 | 55.35 | 24.30 | 3.65 | 15.55 | 24.30 | 1.56 |
| Sinkarzie | 10.25 | 2.90 | 57.50 | 21.80 | 3.55 | 16.70 | 21.80 | 1.31 |
| Kumawu early | 12.25 | 3.55 | 44.85 | 31.45 | 3.90 | 19.70 | 31.45 | 1.60 |
| Nkate kokoo | 9.20 | 2.85 | 62.90 | 18.15 | 3.10 | 15.15 | 18.15 | 1.20 |
| Baasare | 11.75 | 2.60 | 43.85 | 36.00 | 3.80 | 18.15 | 36.00 | 1.98 |
| Broni nkatee | 12.05 | 2.50 | 40.85 | 36.00 | 4.40 | 19.95 | 36.00 | 1.90 |
| Afu | 12.15 | 2.95 | 43.25 | 33.55 | 4.15 | 19.25 | 35.55 | 1.74 |
| Nkoranza local | 12.85 | 3.15 | 42.25 | 34.05 | 3.95 | 19.95 | 34.05 | 1.71 |
| Atebubu local | 12.40 | 3.55 | 43.60 | 33.05 | 3.75 | 19.70 | 33.05 | 1.68 |
| Aprewa | 12.40 | 2.85 | 42.65 | 34.55 | 3.80 | 19.05 | 34.55 | 1.81 |
| Kintampo local | 12.60 | 3.65 | 43.40 | 33.35 | 3.20 | 19.45 | 33.35 | 1.71 |
| Shitaochi | 12.30 | 3.65 | 46.40 | 30.75 | 3.35 | 19.30 | 30.75 | 1.59 |
| Broni | 11.65 | 2.90 | 44.0 | 32.75 | 4.35 | 18.90 | 32.75 | 1.73 |
| Kamaloo | 11.95 | 2.75 | 42.80 | 34.60 | 3.90 | 18.60 | 34.60 | 1.86 |
| Kofi Nsarko | 11.95 | 3.40 | 43.30 | 33.65 | 3.90 | 19.25 | 33.65 | 1.75 |
| Kowoka | 11.75 | 3.20 | 43.25 | 34.05 | 3.85 | 18.80 | 34.05 | 1.81 |
| Broni fufuo | 12.20 | 2.65 | 42.65 | 34.40 | 4.00 | 18.85 | 34.40 | 1.82 |

(Source: Asibuo *et al*., 2008)

The fatty acid composition of crude and refined groundnut oil made from local groundnuts grown in Nigeria was studied by Aluyor *et al.* (2009). His findings are shown in Table 2.16.

Oleic acid was found to be the major unsaturated fatty acid and it recorded 58.7% in the crude oil and 57.7% in the refined oil followed by linoleic acid content was 21.8% in the crude oil and 21.5% in the refined oil. The percentage of saturated fatty acid was recorded to be 16.82% in the crude oil and 20.37% in the refined oil with palmitic acid recording the highest both in the crude oil (8.23%) and the refined oil (11.74%) respectively followed by stearic acid (Aluyor *et al*., 2009).

**Table 2.16 Fatty acid composition of crude and refined groundnut oil**

| Fatty acid | Crude composition (%) | Refined composition (%) |
|---|---|---|
| Palmitic acid (C16:0) | 8.23 | 11.74 |
| Stearic acid (C18:0) | 2.46 | 2.06 |
| Oleic acid (C18:1) | 58.69 | 57.68 |
| Linoleic acid (C18:2) | 21.76 | 21.54 |
| Linolenic acid (C18:3) | 0.34 | 0.28 |
| Behenic acid (C22:0) | 3.88 | 2.37 |
| **SFA** | 14.57 | 16.16 |
| **PUFA** | 22.11 | 21.82 |
| **PUFA/SFA** | 1.52 | 1.35 |

(Source: Aluyor *et al*., 2009)

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Source of Raw Materials

Five varieties of rice were used for the study; three lowland varieties namely Sikamo, Digang and Jasmine-85 were obtained from the Crops Research Institute, Fumesua, Kumasi whilst two upland varieties namely Nerica-1 and Nerica-2 were obtained from the Savannah Agriculture Research Institute, Tamale. Four groundnut varieties were used for the study; Sinkarzie, F-mix, Chinese and Manipinta. These were all obtained from the Crops Research Institute, Fumesua, Kumasi. Four varieties of soybean were used for the study; Anidaso was obtained from the Crops Researckh Institute, Fumesua, Kumasi whilst Salintuya 1, Quarshie and Jenguma were obtained from the Savannah Agriculture Research Institute, Tamale. Samples were stored at 4°C.

### 3.2 Amino Acid Analysis

The foremost step in the determination of amino acids is the digestion of the sample in acid medium to completely hydrolyze the protein fraction.

#### 3.2.1 Sample preparation

5 g of each sample was minced using a mincing device (Retch Mm 440) at a frequency of 30 Hz for 30 seconds.

#### 3.2.2 Hydrolysis and evaporation

5ml of 6N Hydrochloric acid/3% Phenol was added to 40 mg of a previously blended sample in a glass tube. Sample was incubated at 110°C for 16 hours in a heating block (Liebisch). After cooling, 1 ml of standard solution (0.6560 mg/ml norleucine) was pipetted into the glass tube. The solution was then divided into portions of 1ml each, washed repeatedly with water and dried in a Rotavap centrifuge under vacuum at temperature setting (60°C) for 2-3 hours to remove the excess water and HCl. After drying, the sample was reconstituted in 1ml of elution buffer A (0.7 % Trifluoroacetic acid/ 5mM Heptafluorobutyric acid) was added. (In some cases, a vortex or Ultrasonic bath was used to re-dissolve the amino acids. The re-dissolved sample was then filtered into HPLC vials using a 45µm filter and a syringe).

[The hydrolysis procedure causes variations in the determination and composition of amino acids (Darragh *et al.*, 2005; Bunka *et al.*, 2009; Foutakis, 1998). Cysteine and Methionine were oxidized into cystic acid and methionsulphon and therefore could not be included in the results].

### 3.2.3 High Performance Liquid Chromatography (HPLC) run of samples

Samples were analysed on the HPLC using ELSD (Polymer laboratories, PL-ELS2100, USA) detection. The C18 column (Grace alltech Prevail C18 5µm column, 4.6x250mm) was attached to the HPLC (SP thermo separation products) and two eluents were used (A: 5 mM heptafluorobutyric acid (0.653 ml 98% HFBA)/7 ml 0.7% trifluoroacetic acid solution and B: Acetonitrile). Settings used for the run were as follows: 0-6 min 0% B/ 6-8 min 15% B/ 8-25 min 35% B/ 25.5-30 min 0% B; Nebuliser temperature 60°C/ Carrier flow 2.0 SLM.

Calibration curves were prepared for each amino acid control. Area was plotted against concentration. Power trend lines were calculated from 5 dilutions. Regression coefficients were found in the range of 0.95-1.0. Trendline equations were used for further calculations. No correction was used for the internal standard because recovery was almost 100%. Amino acid chromatograms for the various varieties are shown in Appendix 3.



### 3.3 Fatty Acid Analysis

This was done according to the method developed by Ackman (2002) for gas chromatography of fatty acids. This analysis was done only on the groundnut and soybean varieties since the crude fat content of rice (about 8%), compared to the crude fat content of groundnut (about 40%) and soybean (about 20%), makes its fatty acid contribution to the total nutritional value of foods minimal. Secondly, the extraction of oil from rice samples requires a large quantity of the rice to yield a low amount of the oil for analysis.

#### 3.3.1 Oil extraction

Samples of soybean and groundnut samples (100 g each) were blended into smooth powders and dried in an oven (Gallenkamp, model OV 880, England) at 105°C to constant weight. Oil from the samples was extracted using soxhlet extraction method as stated in AOAC (1990). A 250ml quickfit round bottom flask was washed and dried in an oven (Gallenkamp, model OV 880, England) at 105°C for fifteen minutes and allowed to cool to room temperature. Twenty grams of each dried sample (groundnut and soybean) was weighed into a polyester thimble. This was inserted into the extraction

column with the condenser connected. Two hundred millilitres (200 ml) of the extracting solvent (hexane) was poured into the flask and fitted into the extraction unit. The flask was then heated with the aid of Electrothermal Heater at 60°C for sixteen hours. Losses of solvent due to heating were checked with the aid of the condenser which cooled and refluxed the evaporated solvent. After extraction, the thimble was removed and the solvent salvaged by distillation. The flask containing the fat and residual solvent was placed on a water bath to evaporate the solvent followed by further drying in the oven at 105°C for twenty minutes to completely evaporate the solvent. Values for the oil yield for the soybean and groundnut varieties were presented in gare shown in Appendix 1. The oils were stored in a refrigerator at 4°C.

### 3.3.2 Methyl esterification

The fatty acids in the extracted oil sample were derivatised by adding 2ml of methanoic KOH to 0.5g of the oil (extract) sample in the presence of 5mL of hexane placed in a 15 ml centrifuge tube. The mixture was shaken in an automated shaker equipment (Griffin flask shaker 896331, England) for 10 min and then allowed to stand for a minimum of thirty minutes for effective separation of the organic and inorganic layers of the various samples. The supernatant containing the esterified fatty acids in hexane was then collected for injection.

### 3.3.3 Gas Chromatography (GC) run of methyl esters of fatty acids in the oil samples

A Gas Chromatography Perkin Elmer autosystem XL, Germany was used for the fatty acid analysis. Nitrogen gas was used as the mobile phase and the stationary phase made

of 3% carbowax and hydrogen gas. A flame ionizing detector was used to identify the different eluents. One microliter (1µL) of the methyl ester of fatty acids in a sample was injected into the mobile phase at 150°C and allowed to run for forty minutes. The chromatograms for the triplicate runs of individual groundnut and soybean varieties are shown in Appendix 2. The fatty acid composition of the various varieties was presented as percentages of the individual fatty acids.



### 3.4 Statistical analyses

The significant differences between particular factors for the different varieties were determined using the Tukey's HSD test in the STATGRAPHICS Centurion Version XIV.I. Tables showing the various statistical analyses conducted on the fatty acid results are shown in Appendices 4 and 5 and statistical analyses (ANOVA) of amino acid data can be found in Appendices 6 to 8.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Amino Acid Composition of Five Ghanaian Rice Varieties

The amino acid compositions of five locally grown rice varieties; Sikamo, Jasmine-85 and Digang (lowland rice varieties) and Nerica-1 and Nerica-2 (upland rice varieties) are presented in Table 4.1. The results were obtained from a single HPLC run and chromatograms are shown in Appendix 3. In all, twelve amino acids were detected during the study; five essential amino acids (EEA) namely threonine, leucine, isoleucine, phenylalanine and histidine and seven non-essential amino acids (NEAA) namely serine, aspartic acid, alanine, tyrosine, proline and arginine. Their individual concentrations within a particular sample were presented in g/kg. The HPLC procedure used could however not detect lysine, the limiting amino acid in rice.

**Table 4.1: Composition of essential and non essential amino acids in five Ghanaian rice varieties (g/kg)**

| Amino Acid | Digang | Nerica-1 | Jasmine-85 | Nerica-2 | Sikamo | M | U.S.A. | T |
|---|---|---|---|---|---|---|---|---|
| Glutamic acid+Lysine | - | - | - | - | - | 13.62 | 15.74 | 12.92 |
| Histidine | - | - | - | 0.92 | - | 1.13 | 1.60 | 2.21 |
| Threonine | 10.70[a] | 21.17[b] | 11.86[c] | 17.58[d] | 13.49[e] | 1.86 | 2.44 | 2.55 |
| Isoleucine | 1.96[a] | 3.55[b] | 2.04[c] | 3.51[d] | 2.98[e] | 2.95 | 2.94 | 1.36 |
| Leucine | 4.13[a] | 6.81[b] | 4.82[c] | 7.27[d] | 5.95[e] | 6.39 | 5.63 | 6.95 |
| Phenylalanine | 3.55[a] | 4.91[b] | 3.80[c] | 5.03[d] | 4.45[e] | 1.91 | 3.64 | 3.30 |
| Tryptophan | - | - | - | - | - | - | 0.79 | - |
| Valine | - | - | - | - | - | 1.87 | 4.16 | 5.39 |
| **Total EAA** | 20.52 | 36.42 | 22.50 | 33.36 | 26.88 | 29.73 | 36.94 | 34.68 |
| Glycine | - | - | - | - | - | 3.18 | 3.10 | 5.61 |
| Serine | 13.69[a] | 29.30[b] | 12.53[c] | 17.03[d] | 15.71[e] | 3.57 | 3.58 | 3.99 |
| Aspartic acid | 4.72[a] | 7.56[b] | 5.07[c] | 7.50[d] | 5.86[e] | 6.30 | 6.40 | 7.31 |
| Alanine | 3.46[a] | 7.27[b] | 4.22[c] | 7.14[d] | 5.32[e] | 3.92 | 3.95 | 7.48 |
| Tyrosine | 1.07[a] | 2.93[b] | 1.50[c] | 2.70[d] | 2.10[e] | 1.25 | 2.28 | 2.98 |
| Proline | - | 2.11[b] | 1.52[c] | 2.28[d] | 1.68[e] | 3.00 | 3.21 | 3.29 |
| Arginine | 3.17[a] | 5.76[b] | 3.88[c] | 5.71[d] | 4.44[e] | 3.83 | 5.68 | - |
| **Total NEAA** | 26.16 | 54.90 | 28.68 | 42.36 | 35.16 | 25.05 | 28.20 | 30.66 |

* Different letters in the same row between corresponding pairs indicates significant differences (P<0.05) by Tukey's test. **M**=Malaysian brown rice varieties (Roohinejad *et al*., 2009); **U.S.A.**=United States of American Rice (USDA National Nutrient Database for Standard Reference, 2010); **T=**Thai rice (Moongngarm and Saetung, 2010); **EAA**=essential amino acid; **NEAA**=non-essential amino acid; - =not detected cc. Different letters in the same row between corresponding pairs indicates significant differences (P<0.05) by Tukey's test.

Histidine was detected only in Nerica-2, with a value of 0.92 g/kg. This value was lower than that for Malaysian rice (1.13 g/kg), U.S.A. rice (1.60 g/kg) and Thai rice (2.21 g/kg) (Roohinejad *et al*., 2009; National Nutrient Database for Standard Reference, 2010; Moongngarm and Saetung, 2010). The low value for Nerica-1 and the absence of histidine in the other rice varieties may be due to the fact that their levels were much lower than what could be detected by the equipment used. Generally histidine is a partial essential amino acid because the human body does not always require dietary sources of it (Berg *et al*., 2007).

Threonine is the essential amino acid that had the highest value for all the rice varieties studied. The lowest threonine value was recorded by Digang (10.70 g/kg) followed by Jasmine-85 (11.86 g/kg), Sikamo (13.49 g/kg), Nerica-2 (17.58 g/kg) and the highest value recorded for Nerica-1 (21.17 g/kg). The differences were significant ($P<0.05$) and could be attributed to varietal influences. Studies done by Chapman *et al*. (2008) revealed that a lack of threonine in piglets' diet resulted in decreased bovine serum albumin antibody concentrations. On the other hand, prolonged dietary excess of threonine fed to rats was neurotoxic or had negative behavioral consequences (Chapman *et al*., 2008). Therefore a further study of the levels of threonine in diets produced from these rice varieties would have to be conducted to ensure that they are within acceptable limits.

The essential amino acid that recorded the lowest values for all rice varieties was isoleucine. The variety with the highest value of isoleucine was Nerica-1 (3.55 g/kg) followed by Nerica-2 (3.51 g/kg), Sikamo (2.98 g/kg), Jasmine-85 (2.04 g/kg) and Digang with the lowest value (1.96 g/kg). Sample values obtained in this study

compared very well with literature although values for Nerica-1 and Nerica-2 were slightly higher (Table 4.1). Differences between isoleucine values for the rice varieties were significant ($P<0.05$). Isoleucine regulates metabolism, proper functioning of thymus gland, spleen, and pituitary glands. It is also employed in the formation of haemoglobin (Anne, 2006).

Values recorded for leucine were the second highest for all essential amino acids in the rice varieties. Values ranged from Digang (4.13 g/kg), Jasmine-85 (4.82 g/kg) Sikamo (5.95 g/kg), and Nerica-1 (6.81g/kg) to Nerica-2 (7.27 g/kg). Differences between the leucine values for the rice varieties were significant ($P<0.05$). Leucine is effective in maintaining muscle protein during fasting periods by interacting with the insulin signaling pathway to stimulate downstream signal control of protein synthesis (Layman and Walker, 2006).

Phenyalanine values obtained during this study were within the range of 3.55 g/kg and 5.03 g/kg. Only the value for Digang (3.55 g/kg) compared with literature, values for the other varieties were higher (Table 4.1). The differences in values were significant ($P<0.05$). Phenylalanine is needed in the human diet because it is used by the brain to produce norepinephrine, a chemical that transmits signals between nerve cells in the brain; promotes alertness and vitality; elevates mood; decreases pain and also aids memory and learning (Cooper, 1996).

The total essential amino acid value for all five varieties was determined. The highest value of 36.42 g/kg was recorded by Nerica-1 followed by Nerica-2 with 33.36 g/kg; these values were comparable with literature. The other three rice varieties, Jasmine-85,

Sikamo and Digang, recorded values lower than those quoted for Malaysian, U.S.A and Thai rice (Table 4.1). The occurrence of essential amino acids in plant proteins is crucial to the survival of humans in that it ensures the adequate supply of essential nutrients through one's diet. The acceptable levels of various EAA obtained for most rice varieties studied are beneficial to potential consumers.

For the non essential amino acids (NEAA), Serine recorded the highest values for all rice varieties. Values ranged between 12.53 g/kg (Jasmine-85) and 29.30 g/kg (Nerica-1). Values obtained for serine during this study were higher than that of literature and significantly different from each other ($P<0.05$). Serine has been found to be immunosuppressive and will be potentially useful in autoimmune diseases treatment (de Koning *et al*., 2003).

Aspartic acid recorded the second highest values for all NEAA detected during the study. The highest value was recorded by Nerica-1 (7.56 g/kg) followed by Nerica-2 (7.50 g/kg), these values were higher than that reported in literature. Sikamo (5.86 g/kg), Jasmine-85 (5.07 g/kg) and Digang (4.72 g/kg) recorded lower values than that reported in literature. Differences between the values were significant ($P<0.05$). Aspartic acid is found abundantly in nature and aids in the expulsion of waste from the body (Fürst and Stehle, 2004).

Values for alanine ranged between 3.46 g/kg (Digang) and 7.27 g/kg (Nerica-1). Differences in values were significant ($P<0.05$) and compared well with literature values for Malaysian brown rice, United States and Thai white rice (Table 4.1). Alanine has positive effects on blood sugar, liver function and prostate health (Berard, 2001).

Values obtained for arginine ranged from 3.17 g/kg for Digang to 5.76 g/kg for Nerica-1 (Table 4.1). Differences in arginine values were significant ($P<0.05$) and compared well with literature values (Table 4.1). Arginine is involved in wound healing, helping the kidneys remove waste products from the body and maintaining immune and hormone function (Reeds, 2000).

Tyrosine and proline had the lowest values for all rice varieties studied. Nerica-1 had the highest tyrosine value of 2.93 g/kg and Digang the lowest (1.07 g/kg) whilst for proline; Nerica-2 had the highest value of 2.28 g/kg. Since both amino acids are non essential, their low values will not greatly affect the total nutritional value of the food. Tyrosine is involved in the production of the stress hormones epinephrine and norepinephrine (Meyers, 2000). Proline is a precursor of collagen, which functions to support tissues of the body like skin, bones, muscles, tendons and cartilages (Betts and Russell, 2003).

Nerica-1 recorded the highest value for the total NEAA composition with 54.90 g/kg followed by Nerica-2 (42.36 g/kg), Sikamo (35.16 g/kg), Jasmine-85 (28.68 g/kg) and the lowest value of 26.16 g/kg for Digang. Although non-essential amino acids can be produced by the body, their availability in one's diet is important because it ensures the regular supply of nutrients for the body's biochemical activities.

A careful study of Table 4.1 showed that Nerica-1 stood out as the rice variety with the best amino acid profile with respect to both essential and non-essential amino acids. It had a total composition of 91.32 g/kg of amino acids detected during the study. The second best amino acid profile was exhibited by Nerica-2 with a total amino acid composition of 75.72 g/kg and Sikamo followed with a total amino acid composition of

65.39 g/kg whilst Jasmine-85 recorded a total amino acid composition of 51.18 g/kg. Digang had the lowest amino acid profile recording a total amino acid value of 46.68 g/kg.

## 4.2 Amino Acid Composition of Four Ghanaian Soybean Varieties

The amino acid compositions of four locally grown soybean varieties; Anidaso (Southern variety) and Salintuya, Jenguma and Quarshie (Northern varieties) are presented in Table 4.2. The results were obtained from a single HPLC run and chromatograms are shown in Appendices 4Av to 4Aviii. In all, sixteen amino acids were detected during the study; eight essential amino acids (EEA) namely lysine, histidine, threonine, isoleucine, leucine, phenylalanine, tryptophan, valine and eight non-essential amino acids (NEAA) namely glutamic acid, glycine, serine, aspartic acid, alanine, tyrosine, proline and arginine. Their individual concentrations within a particular sample were presented in g/kg. The HPLC procedure used could not detect methionine, the limiting amino acid in soybean.

**Table 4.2: Composition of essential and non essential amino acids in four Ghanaian soybean varieties (g/kg)**

| Amino Acid | Quarshie | Salintuya | Anidaso | Jenguma | B | C | U.S.A. |
|---|---|---|---|---|---|---|---|
| Glutamic acid+Lysine | 23.70[a] | 20.16[b] | 24.24[c] | 20.28[d] | 31.55(Lys) | 92 | 100.58 |
| Histidine | 7.32[a] | 7.02[b] | 6.78[c] | - | 11.50 | 10 | 10.97 |
| Threonine | 57.48[a] | 58.80[b] | 54.36[c] | 54.72[d] | 19.39 | 14 | 17.66 |
| Isoleucine | 20.16[a] | 20.04[b] | 19.38[c] | 19.14[d] | 22.59 | 16 | 19.71 |
| Leucine | 32.40[a] | 31.44[b] | 31.56[c] | 30.60[d] | 32.14 | 27 | 33.09 |
| Phenylalanine | 21.36[a] | 20.64[b] | 20.76[c] | 19.98[d] | 21.70 | 18 | 21.22 |
| Tryptophan | 2.46[a] | - | - | 3.12[b] | 4.51 | 4.7 | 5.91 |
| Valine | 4.26[a] | 6.78[b] | 3.90[c] | 6.48[d] | 22.89 | 17 | 20.29 |
| **Total EAA** | 169.14 | 167.94 | 160.98 | 154.32 | 166.27 | 198.70 | 229.43 |
| Glycine | 16.86[a] | 15.18[b] | 16.68[c] | 15.60[d] | | 16 | 18.80 |
| Serine | 46.08[a] | 48.30[b] | 55.92[c] | 52.44[d] | | 18 | 23.57 |
| Aspartic acid | 59.52[a] | 39.36[b] | 39.00[c] | 39.78[d] | | 42 | 51.12 |
| Alanine | 69.12[a] | 67.98[b] | 63.96[c] | 75.30[d] | | 16 | 19.15 |
| Tyrosine | 14.52[a] | 14.10[b] | 13.38[c] | 13.20[d] | 12.87 | 11 | 15.39 |
| Proline | 21.18[a] | 21.48[b] | 21.24[c] | - | | 18 | 23.79 |
| Arginine | 16.80[a] | 23.58[b] | 23.16[c] | 21.78[d] | 29.12 | 26 | 31.53 |
| **Total NEAA** | 244.08 | 229.98 | 233.34 | 218.10 | | 147 | 183.35 |

* Different letters in the same row between corresponding pairs indicates significant differences ($P<0.05$) by Tukey's test. **B** Brazilian soybean (Smith, 1988); **C** Chinese soybean(http://wholefoodcatalog.info/food/soybean,_whole_bean (china,_dried,_raw)/nutrients, 2011); **U.S.A.** United States of American Soybean (USDA National Nutrient Database for Standard Reference, 2010); **EAA** essential amino acid; **NEAA** non-essential amino acid; **-** =not detected

Glutamic acid and lysine eluted together for soybean varieties. Values ranged between 20.16 g/kg and 24.24 g/kg and were significantly different ($P<0.05$). The sample values were lower than that recorded in literature cited in Table 4.1 and this indicates that lysine levels in these varieties may be low.

Histidine was detected for three of the soybean varieties. Values obtained were Quarshie (7.32 g/kg), Salintuya (7.02 g/kg) and Anidaso (6.78 g/kg); these were significantly different from each other ($P<0.05$). Values recorded during the study were all lower than literature values which ranged between 10.00 g/kg and 11.50 g/kg (Table 4.2).

Threonine values for soybean varieties ranged between 54.36 g/kg and 58.80 g/kg. Since literature values ranged from 14.00 g/kg to 19.39 g/kg, it could be seen that these varieties had higher threonine content than what was cited for Brazilian, Chinese and American soybean (Table 4.2).

For isoleucine, Quarshie had the highest value (20.16 g/kg) followed by Salintuya (20.04 g/kg), Anidaso (19.38 g/kg) and Jenguma (19.14 g/kg). These values compared with that cited for Brazilian and USA soybean. Isoleucine is necessary in a baby's diet to support haemoglobin production and regulation of blood sugar.

Leucine levels in the varieties were shown to be comparable to that reported by USDA (2010) and Smith (1988). Quarshie recorded the highest leucine value (32.40 g/kg) followed by Anidaso (31.56 g/kg), Salintuya 931.44 g/kg) and Jenguma the lowest value (30.60 g/kg).

Phenylalanine values ranged between 19.98 g/kg (Jenguma) and 21.36 g/kg (Quarshie). The sample values compared with values cited for Brazilian and USA soybean (Table

4.2). Adequate supply of phenylalanine in a diet is converted to tyrosine which is required for the manufacture of brain chemicals, including epinephrine and norepinephrine, and thyroid hormones (MacLeod, 2009).

Tryptophan was detected only in Quarshie and Jenguma with values of 2.46 g/kg and 3.12 g/kg respectively. These values were lower than Brazilian soybean (4.51 g/kg), Chinese soybean (4.7g/kg) and USA soybean (5.91 g/kg) (Table 4.2). Tryptophan in weaning foods is essential because it is employed in the manufacture of serotonin which is needed for balancing mood and sleep patterns. This is important in infant development (Yogman *et al.*, 1982).

For valine, Quarshie recorded a value of 4.26 g/kg, Salintuya 6.78 g/kg, Anidaso 3.90 g/kg and Jenguma 6.48 g/kg. This was shown to be much lower than Brazilian soybean (22.89 g/kg), Chinese varieties (17 g/kg) and USA soybean (20.29 g/kg). Valine supports muscle coordination in the body and is needed for infants who are starting to crawl or walk.

The total essential amino acid (EAA) content of the different varieties of soybean showed Quarshie to have the highest value (169.14 g/kg) followed by Salintuya (167.94 g/kg), Anidaso (160.98 g/kg) and Jenguma (154.32 g/kg). The values of Quarshie and Salintuya were very close to that of Brazilian soybean varieties whilst those of Anidaso and Jenguma were a little lower.

Glycine values for the soybean varieties were 15.18 g/kg (Salintuya), 15.60 g/kg (Jenguma), 16.68 g/kg (Anidaso) and 16.86 g/kg (Quarshie). Values for glycine compared with that cited for Chinese soybean (www.wholefoodcatalog.info, 2011).

Glycine is a common amino acid in nature that is employed in the manufacture of hormones responsible for a strong immune system.

Values for serine were as follows: Anidaso (55.92 g/kg), Jenguma (52.44 g/kg), Salintuya (48.30 g/kg) and Quarshie (46.08 g/kg). These values did not compare with literature, sample values were high (wholefoodcatalog.info, 2011; USDA, 2010).

Aspartic acid values ranged between 39.00 g/kg and 59.52 g/kg (Table 4.2). The values for Salintuya, Anidaso and Jenguma were comparable to that cited for Chinese soybean. The value for Quarshie also compared with that cited for USA soybean. The differences between sample values were significant ($P<0.05$) and could be due to a variety of factors including soil condition, age, storage method and geographical location.

Alanine recorded the highest value for all amino acids detected in the soybean varieties. Values ranged from 63.96 g/kg to 75.30 g/kg. These values did not compare well with what was cited for Chinese and USA soybean (sample values were high) (Table 4.2). If the high level of alanine translates into a diet formulated from these varieties, it may result flushing and tingling in the muscle of consumers (Derave *et al*., 2007).

Tyrosine recorded the lowest values for all non essential amino acids detected for the soybean varieties; Quarshie (14.52 g/kg), Salintuya (14.10 g/kg), Anidaso (13.38 g/kg) and Jenguma (13.20 g/kg). These values compared well with literature (Table 4.2).

Values for proline for the soybean varieties were significantly different ($P<0.05$). The highest proline value was recorded by Salintuya (21.48 g/kg) followed closely by Anidaso and Quarshie with 21.24 g/kg and 21.18 g/kg respectively. There was no reading for Jenguma and this could be because proline levels in the variety were too low

to be detected. Sample values compared best with that cited for USA soybean (USDA, 2010).

Values obtained for arginine were 16.80 g/kg (Quarshie), 23.58 g/kg (Salintuya), 23.16 g/kg (Anidaso) and 21.78 g/kg (Jenguma). The sample values, apart from Quarshie's, compared with that cited for Chinese soybean (Table 4.2) and were significantly different ($P<0.05$).



The total NEAA values were higher than that cited in literature due to the very high values obtained for serine and alanine.

Overall, Quarshie had the highest total content of amino acids as well as essential amino acids (413.32 g/kg). Salintuya had the second highest value for total amino acids (397.92 g/kg) and essential amino acid total composition. Anidaso had the third highest composition of total amino acids (394.32 g/kg) and essential amino acids for the study whilst Jenguma had the least values for both total amino acid composition (372.42 g/kg) and essential amino acids.

## 4.3 Amino Acid Composition of Four Ghanaian Groundnut Varieties

The results of amino acid compositions of four locally grown groundnut varieties; Chinese, Manipinta and F-Mix (Southern varieties) and Sinkarzie (Northern variety) are presented in Table 4.3. The results were obtained from a single HPLC run and chromatograms are shown in Appendices 4Ai to 4Aiv. In all, fourteen amino acids were detected during the study; seven essential amino acids (EEA) namely lysine, threonine,

leucine, isoleucine, phenylalanine, valine and histidine and seven non-essential amino acids (NEAA) namely glutamic acid, serine, aspartic acid, alanine, tyrosine, proline and arginine. Their individual concentrations within a particular sample were presented in g/kg. The HPLC procedure used could not detect methionine, the limiting amino acid in groundnuts.

**Table 4.3: Composition of essential and non essential amino acids in four Ghanaian groundnut varieties (g/kg)**

| Amino Acid | Manipinta | Sinkarzie | F-Mix | Chinese | E | I | U.S.A. |
|---|---|---|---|---|---|---|---|
| Glutamic acid+Lysine | - | 10.32[a] | 10.20[b] | - | 56.20 | 23.26 | 61.44 |
| Histidine | - | 4.08[a] | 4.88[b] | 2.10[c] | 6.00 | 5.68 | 6.34 |
| Threonine | - | 41.64[a] | 34.74[b] | 38.58[c] | 8.80 | 6.89 | 8.59 |
| Isoleucine | 12.78[a] | 10.14[b] | 10.32[c] | 8.10[d] | 16.70 | 10.01 | 8.82 |
| Leucine | 24.12[a] | 18.12[b] | 17.82[c] | 14.28[d] | 9.10 | 16.22 | 16.27 |
| Phenylalanine | 18.90[a] | 13.08[b] | 13.74[c] | 12.06[d] | 13.40 | 12.66 | 13.00 |
| Tryptophan | - | - | - | - | - | 3.06 | 2.45 |
| Valine | 11.28[a] | 3.24[b] | 3.72[c] | 6.30[d] | 10.80 | 11.34 | 10.52 |
| **Total EAA** | 67.08 | 100.62 | 94.20 | 81.42 | 121.00 | 89.12 | 127.43 |
| Glycine | 26.22[a] | 17.40[b] | 16.14[c] | - | 10.50 | 12.32 | 15.12 |
| Serine | - | 31.40[a] | 30.48[b] | - | 12.70 | - | 12.36 |
| Aspartic acid | 14.38[a] | 27.30[b] | 25.26[c] | 22.02[d] | 31.50 | 34.39 | 30.60 |
| Alanine | - | 31.68[a] | 24.18[b] | 20.94[c] | 10.30 | 17.92 | 9.97 |
| Tyrosine | 12.96[a] | 9.90[b] | 8.64[c] | 7.08[d] | 11.90 | 9.72 | 10.20 |
| Proline | 11.16[a] | 8.34[b] | 7.32[c] | 6.78[d] | 11.40 | 64.12 | 11.07 |
| Arginine | 5.46[a] | 23.52[b] | 22.62[c] | 16.92[d] | 30.90 | 27.95 | 30.01 |
| **Total NEAA** | 70.38 | 149.88 | 134.64 | 73.74 | 119.20 | 166.62 | 119.33 |

* Different letters in the same row between corresponding pairs indicates significant differences ($P<0.05$) by Tukey's test. **E=**Egyptian groundnut varieties (El-Badrawy, 2011); **I**=Indian JL groundnut variety (Ingale and Shrivastava, 2011); **U.S.A.**=United States of American Peanuts (USDA National Nutrient Database for Standard Reference, 2010); **EAA=**essential amino acid; **NEAA**=non-essential amino acid; - =not detected.

The combination of glutamic acid and lysine was detected for Sinkarzie and F-Mix only with values of 10.32 g/kg and 10.20 g/kg respectively. These values were much lower than that reported in literature (Table 4.3). The other two varieties are limiting in lysine since values were too low to be recorded.

The essential amino acid with the lowest values for this study was histidine. Values obtained were 2.10 g/kg (Chinese), 4.08 g/kg (Sinkarzie) and 4.88 g/kg (F-Mix). No value was recorded for Manipinta. Sample values were lower than that cited in literature (Table 4.3).

Threonine recorded the highest value for all essential amino acids in the groundnut varieties studied. Sinkarzie recorded the highest value (41.64 g/kg) followed by Chinese (38.58 g/kg) and F-Mix with the lowest value (34.74 g/kg). Threonine was not detected in Manipinta. The sample values were higher than that reported for Egyptian, Indian and USA groundnuts (Badrawy, 2011; Ingale and Shrivastava, 2011; USDA National Nutrient Database for Standard Reference, 2010).

For isoleucine, values were within the range of 8.10 g/kg and 12.78 g/kg, the lowest value was recorded by Chinese. Values obtained in the study compared with literature (Table 4.3). The differences between the isoleucine values obtained were significant ($P<0.05$).

Leucine recorded the second highest values for essential amino acids detected for groundnut varieties. Manipinta had the highest value (24.12 g/kg) followed by Sinkarzie (18.12 g/kg), then F-Mix with 17.82 g/kg and finally Chinese (14.28 g/kg). Values

obtained for leucine for the groundnut varieties studied compared with that cited for Indian and USA groundnuts (Table 4.3).

The phenylalanine content for the groundnut varieties ranged between 12.06 g/kg and 18.90 g/kg (Table 4.3). All varieties except Manipinta compared with that in literature.

Values for valine were within a wide range of 3.24 g/kg and 11.28 g/kg. The highest value was for Manipinta and this compared well with the value for Indian groundnut JL 24 (Ingale and Shrivastava, 2011). The values for valine obtained by the other varieties were lower than literature (Table 4.3). Differences between the valine values were significant ($P<0.05$).

Sinkarzie obtained the highest total value for the essential amino acids. Its value of 100.62 g/kg compared well with literature (Table 4.3). F-Mix had the second highest total EAA value (94.20 g/kg) followed by Chinese (81.42 g/kg) and Manipinta (67.08 g/kg).

Glycine was detected in three varieties; Manipinta with the highest value (26.22 g/kg), Sinkarzie (17.40 g/kg) and F-Mix (16.14 g/kg). The values for glycine obtained during the study were significantly different ($P<0.05$). Values for Sinkarzie and F-Mix compared well with that reported for USA varieties (Table 4.3).

Serine was detected in only two varieties; Sinkarzie (31.40 g/kg) and F-Mix (30.48 g/kg). These values were higher than literature (Table 4.3). Consumers of high-serine diet formulated from these varieties may experience suppression of the immune system, cerebral allergies and other psychological symptoms (de Koning *et al.*, 2003).

The aspartic acid value for Manipinta (14.3 g/kg) was lower than that recorded for the other varieties. Aspartic acid values for Sinkarzie (27.30 g/kg), F-Mix (25.26 g/kg) and Chinese (22.02 g/kg) were also lower than that cited in literature (Table 4.3). Sample values were significantly different from each other ($P<0.05$).

Alanine was detected for all varieties studied except Manipinta. Sample values were higher than that reported in literature (El-Badrawy *et al*., 2011; Ingale and Shrivastava, 2011 and USDA National Nutrient Database for Standard Reference, 2010).

Tyrosine values obtained during the study compared well with Egyptian varieties (11.90 g/kg), Indian JL variety (9.720 g/kg) and USA groundnuts (10.20 g/kg) (Table 4.3). Chinese obtained the lowest tyrosine value for the study (7.08 g/kg) and Manipinta the highest value (12.96 g/kg). There was a significant difference ($P<0.05$) between tyrosine values for the different varieties.

Values for proline in groundnut varieties were significantly different ($P<0.05$). Manipinta recorded the highest value (11.16 g/kg), this compared with that of Egyptian and USA varieties. The other three varieties, Sinkarzie (8.34 g/kg), F-Mix (7.32 g/kg) and Chinese (6.78 g/kg), had lower values than those in literature.

For the four groundnut varieties, values for arginine were as follows: Sinkarzie (23.52 g/kg), F-Mix (22.62 g/kg), Chinese (16.92 g/kg) and Manipinta (5.46 g/kg). The differences between values were significant ($P<0.05$). Arginine values for Sinkarzie and F-Mix compared with that recorded for JL-24 (Ingale and Shrivastava, 2011).

Generally, Manipinta had the lowest total NEAA value (70.38 g/kg). This was because it had values for only five out of the eight NEAA detected for the other varieties.

Chinese had the second lowest total NEAA value (73.74 g/kg); it also had values for only five out of the eight NEAA detected. Eight NEAA were detected for Sinkarzie and F-Mix with Sinkarzie recording the highest total NEAA value of 149.88 g/kg and F-Mix the second highest value of 134.64 g/kg. These values compared well with literature values (Table 4.3).

A careful study of all the values obtained in this study revealed that Sinkarzie had the best amino acid profile out of the four varieties considered. F-Mix and Chinese had the second and third highest amino acid profiles respectively. Manipinta had the lowest amino acid profile, this could be because its amino acid levels were much lower than what could be detected using the chosen analytic procedure.

## 4.4 Fatty Acid Composition of Five Ghanaian Rice Varieties

The fatty acid profiles of the rice varieties chosen for this study were not determined due to the fact that the fat content of rice is approximately 8% and would require an excess use of materials to extract sufficient oil from the varieties for analysis. The low content of fat in rice also implies that its contribution to the total fatty acid content of any diet prepared from it would be less significant.

## 4.5 Fatty Acid Composition of Four Ghanaian Soybean Varieties

Results are averages of triplicate analysis; the individual results and statistical analyses are shown in Appendix 4. The five major fatty acids identified in the soybean oils extracted were Palmitic (C 16:0), Stearic (C 18:0), Oleic (C 18:1), Linoleic (C 18:2), and Linolenic acids (C 18:3). The individual fatty acids have been presented as percentages of the total fatty acids identified in the oil samples. The total saturated fatty

acids (SFA), total polyunsaturated fatty acids (PUFA) and the ratio of PUFA to SFA for a particular variety have also been shown in Table 4.5. Generally, the results obtained in this study were compared with fatty acid analysis results of soybean varieties from three different areas; Brazil, China and Nigeria. Details are shown as follows:

**Table 4.5: Percentage composition of fatty acids for four Ghanaian soybean varieties**

| FATTY ACID | ANIDASO | JENGUMA | QUARSHIE | SALINTUYA | N | C | B |
|---|---|---|---|---|---|---|---|
| Palmitic (C16:0) | 11.68±0.49$^{b}$ | 10.62±0.33$^{a}$ | 11.68±0.43$^{b}$ | 11.43±0.18$^{a,b}$ | 9.64-10.49 | 11.0 | 12.14-14.01 |
| Stearic (C18:0) | 3.46±0.21$^{a,b}$ | 3.63±0.18$^{b}$ | 3.57±0.21$^{a,b}$ | 3.13±0.10$^{a}$ | 2.93-3.59 | 4.5 | 2.94-4.39 |
| Oleic (C18:1) | 23.52±0.42$^{a}$ | 24.46±0.38$^{a}$ | 23.85±0.38$^{a}$ | 23.59±0.31$^{a}$ | 15.78-24.43 | 22.0 | 16.3-19.31 |
| Linoleic (C18:2) | 53.74±0.70$^{a}$ | 53.76±0.11$^{a}$ | 53.47±0.29$^{a}$ | 54.53±0.44$^{a}$ | 37.42-44.32 | 54.0 | 55.51-58.45 |
| Linolenic (C18:3) | 7.60±0.13$^{a}$ | 7.53±0.14$^{a}$ | 7.43±0.15$^{a}$ | 7.30±0.05$^{a}$ | 4.72-6.39 | 7.5 | 6.06-7.49 |
| SFA | 15.14±0.33$^{b,c}$ | 14.55±0.21$^{a}$ | 15.31±0.23$^{c}$ | 14.57±0.09$^{a,b}$ | 13.58-14.62 | 15.1 | 16.07-17.79 |
| PUFA | 61.34±0.58$^{a}$ | 61.29±0.24$^{a}$ | 60.90±0.15$^{a}$ | 61.83±0.39$^{a}$ | 44.63-52.52 | 61.5 | 61.85-65.93 |
| PUFA/SFA | 4.05±0.12$^{a,b}$ | 4.30±0.06$^{c}$ | 3.99±0.05$^{a}$ | 4.53±0.06$^{b,c}$ | 3.15-3.67 | 4.07 | 3.49-4.40 |

Results are expressed as mean ± standard deviation measured in triplicate. Same letters in the same row between corresponding pairs indicates no significant differences ($P<0.05$) by Tukey's test. **PUFA** = Total Polyunsaturated fatty acids; **MUFA** = Monounsaturated fatty acids; **SFA** = Total Saturated fatty acids. **N** (tropical soybean varieties (Ezeagu *et al*., 1998)), **C** (Chinese soybean oil (chinese-school.netfirms.com), **B** (Brazilian soybean varieties (Milinsk *et al*., 2007).

The first fatty acid peak for all the soybean chromatograms (Appendices 2A to 2D) was identified to be Palmitic acid, a 16-carbon fatty acid. Values ranged between 10.62% for Jenguma and 11.68% for both Anidaso and Quarshie. There was no significant difference between the palmitic acid values for Jenguma and Salintuya but these values differed from that of Anidaso and Quarshie. Sample values compared well with the Palmitic acid values obtained in literature. Sample values for palmitic acid were lower than that of tropical soybean (Ezeagu *et al*., 1998). The opposite was the case when samples were compared with Brazilian varieties worked on by Milinsk *et al*. (2007). They had lower values for palmitic acid than those obtained in this study. The level of palmitic acid (approximately 11%) in the oil samples is desirable because it gives the oil stability and reduces the occurrence of rancid flavor in foods during storage. Consumption of palmitic acid also contributes to vitamin A, D, E and K absorption in humans.

The second fatty acid that eluted (Appendices 2A to 2D) was identified to be another saturated fatty acid, stearic acid. There was a significant difference ($P<0.05$) between the value recorded for Jenguma and Salintuya. However no significant differences ($P>0.05$) were recorded between the values of Quarshie, Salintuya and Anidaso as shown in Table 4.5. Sample values for Stearic acid compared well with that of literature (Milinsk *et al*., 2007; Ezeagu *et al*., 1998; www.chinese-school.netfirms.com). Stearic acid has been shown to regulate blood pressure and clotting, lower cholesterol levels in the blood, and regulate immune response (Schneider *at al*., 2000). Stearic acid retains stability of oil and food during storage and frying.

The total saturated fatty acid (SFA) values for the four varieties studied ranged between 14.55 and 15.31. There was a significant difference ($P<0.05$) between the values of Salintuya and Anidaso. The case was the same for Jenguma and Quarshie ($P<0.05$). For Quarshie and Anidaso, there was no significant difference ($P<0.05$) between their SFA values as shown in Table 4.5. The sample SFA values compared well with those reported by Ezeagu *et al.* (1985) and www.chinese-school.netfirms.com and were found to be desirably within acceptable limits.

Oleic acid, a monounsaturated fatty acid, was the third identifiable fatty acid (Appendices 2A to 2D). The sample values for the four varieties ranged from 23.52% for Anidaso to Jenguma which had the highest value of 24.46%. There was no significant difference ($P>0.05$) between the values for the four varieties. Generally, the sample values for oleic acid were close to that in literature (Table 4.5). The average content of about 24% in the soybean samples has positive implications on their total nutritional value. This is for the reason that oleic acid is frequently used to replace saturated fatty acids in diets as it lowers the levels of low density lipoproteins in the blood, lowers blood pressure and promotes the production of antioxidants in the body (Massimo *et al*., 2009). Oleic acid is also less susceptible to rancidity compared with other unsaturated fatty acids.

Linoleic acid was the fatty acid with the highest percentage composition for all the four soybean varieties studied. Values ranged from 53.47% for Quarshie, 53.74% and 53.76% for Anidaso and Jenguma respectively and the highest value 54.53% for Salintuya. The sample values were not significantly different ($P>0.05$) from each other. The sample values compared well with literature values although sample values were

slightly higher than that of tropical soybean varieties (Ezeagu *et al*., 1998) and also lower than that of Brazilian varieties (Milinsk *et al*., 2007). The sample values also agree with research done by Balogun and Fetuga (1985) who studied the fatty acid composition of ten (10) seed oils grown in Nigeria. Their results showed all ten varieties to be higher in linoleic acid than oleic acid and three varieties actually exceeded fifty percent in their linoleic acid content. All four varieties of soybean used for this study also recorded a higher linoleic acid content than oleic acid. This is a very desirable attribute for the varieties because linoleic acid is an essential fatty acid. Linoleic is one of the parent fatty acids required for the manufacture of arachidonic acid and prostaglandins. They are needed for cell membrane stability and function, effective wound healing and hair growth (Ruthig and Meckling-Gill, 1999; Letawe *et al*., 1998). Therefore Linoleic acid is especially desirable for weaning food preparation.

Linolenic acid was the last fatty acid identified (Appendices 2A to 2D). This fatty acid had the lowest percentage composition for all four varieties studied (7%) ranging between 7.30% and 7.60%. This was consistent with linolenic acid content of most soybean varieties reported (Milinsk *et al*., 2007; Ezeagu *et al*., 1998; Balogun and Fetuga, 1985, www.chinese-school.netfirms.com). Low levels of linolenic acid in oils extend the shelf life of the product. Values for linolenic acid for all varieties studied were not significantly different ($P>0.05$) from each other.

Total polyunsaturated fatty acid (PUFA) content of all four varieties compared well with literature although content were slightly higher than that of tropical soybean varieties as reported by Ezeagu *et al*. (1998). The PUFA values for all four varieties were found to be non significant ($P>0.05$). A high percentage of PUFA is very desirable in foods

especially with the potential of developing into weaning foods because they would ensure the adequate production of long chain polyunsaturated fatty acids. The long chain PUFA's are required for proper brain and visual development, (Schuchardt *et al.*, 2010). Nutritionists generally agree that to treat severe malnutrition in children using cereal-dominated diets, emphasis should be placed on the provision for a high fat content to increase their energy density and the source of fat should be selected to supply optimal amounts of PUFAs especially n-3 fatty acids (Michaelsen *et al*., 2009). So a high percentage of PUFA in the soybean varieties studied provides a good nutritional source of foodstuff that can be exploited in the development of weaning foods for malnourished children.

The ratio of polyunsaturated fatty acids to saturated fatty acids for a particular soybean variety was also studied. This was done to enable one ascertain the influence of PUFAs on the total nutritional value of the sample in relation to the level of saturated fatty acids. For the four locally grown soybean varieties studied, the PUFA to SFA ratio ranged between 3.99 for Quarshie and 4.30 for Jenguma. Salintuya's PUFA to SFA ratio of 4.53 was close and non-significant ($P>0.05$) from Jenguma's ratio of 4.30. Anidaso and Quarshie also recorded lower values of 4.05 and 3.99 respectively. All the four soybean varieties fell within the ranges quoted in literature as seen in Table 4.5 ((Milinsk *et al*., 2007; Ezeagu *et al*., 1998; www.chinese-school.netfirms.com). The PUFA/SFA values for the four varieties studied in this work were all lower than that of tropical soybean varieties studied by Ezeagu *et al*. (1998). The PUFA/SFA values are nutritionally significant in that they play a role in blood and liver cholesterol levels. Research done by Chang and Huang (1998) reported that high PUFA/SFA values, that

are 5 or above, resulted in an increase in plasma total cholesterol, triacylglycerol, and phospholipids. Liver cholesterol level was also raised in the higher PUFA/SFA diet (Chang and Huang, 1998).

From Table 4.5, Salintuya had the best fatty acid profile with the highest composition of polyunsaturated fatty acids and a lower saturated fatty acid content. It also recorded the highest PUFA/SFA ratio of 4.53. Anidaso and Jenguma also had fairly good fatty acid profiles. With Quarshie, results showed the lowest PUFA content for all varieties studied, a high SFA content and a low PUFA/SFA ratio.

## 4.6 Fatty Acid Composition of Four Ghanaian Groundnut Varieties

The four locally grown groundnut varieties used for this study were Chinese, F-Mix, Manipinta and Sinkarzie. The results obtained after fatty acid analysis of the oils extracted from these groundnut varieties have been presented in Table 4.6. Results shown in Table 4.6 are the averages of triplicate analysis; the individual results and statistical analyses are shown in Appendix 5. The chromatograms obtained from the GC chromatograph are also shown in Appendices 2E to 2H.

The five major fatty acids identified in the groundnut oils extracted and analysed were Palmitic, Stearic, Oleic, Linoleic and Behenic acids. The individual fatty acids were presented as percentages of the total fatty acids identified in the oil samples. The total saturated fatty acids (SFA), total polyunsaturated fatty acids (PUFA) and the ratio of PUFA to SFA for a particular variety have also been shown in Table 4.6. Generally, the results obtained in this study were compared with fatty acid analysis results of groundnut varieties from Turkey, Nigeria and previous work done on Ghanaian groundnuts. Details are shown below:

**Table 4.6: Percentage composition of fatty acids for four Ghanaian groundnut varieties**

| FATTY ACID | CHINESE | F-MIX | MANIPINTA | SINKARZIE | T | N | G |
|---|---|---|---|---|---|---|---|
| Palmitic (C16:0) | 12.60±0.05$^{b}$ | 9.52±0.43$^{a}$ | 9.13±0.06$^{a}$ | 9.17±0.02$^{a}$ | 8.70-13.03 | 8.23 | 9.05-12.85 |
| Stearic (C18:0) | 2.61±0.22$^{b}$ | 3.19±0.05$^{c}$ | 2.15±0.03$^{a}$ | 3.48±0.10$^{c}$ | 3.77-4.53 | 2.46 | 1.75-3.65 |
| Oleic (C18:1) | 52.93±0.12$^{a}$ | 48.49±0.35$^{b}$ | 50.92±0.11$^{c}$ | 54.03±0.16$^{d}$ | 43.13-55.10 | 58.69 | 40.85-63.55 |
| Linoleic (C18:2) | 28.56±0.37$^{a}$ | 35.52±0.19$^{c}$ | 35.15±0.11$^{c}$ | 30.44±0.25$^{b}$ | 25.13-35.20 | 21.77 | 17.35-36.00 |
| Behenic (C22:0) | 3.30±0.09$^{b,c}$ | 3.27±0.21$^{c}$ | 2.64±0.02$^{a}$ | 2.88±0.10$^{a,b}$ | 2.40-3.47 | 3.88 | 3.10-4.40 |
| SFA | 18.51±0.26$^{c}$ | 15.99±0.52$^{b}$ | 13.92±0.01$^{a}$ | 15.53±0.18$^{b}$ | 15.64-19.96 | 14.57 | 15.15-19.95 |
| PUFA | 28.56±0.37$^{a}$ | 35.52±0.19$^{c}$ | 35.15±0.11$^{c}$ | 30.44±0.25$^{b}$ | 25.33-35.20 | 22.11 | 17.35-36.00 |
| PUFA/SFA | 1.54±0.04$^{a}$ | 2.23±0.08$^{b}$ | 2.52±0.01$^{c}$ | 1.96±0.07$^{d}$ | 1.59-1.84 | 1.52 | 1.09-1.98 |

Results are expressed as mean ± standard deviation measured in triplicate. Same letters in the same row between corresponding pairs indicates no significant differences (P<0.05) by Tukey's test. **PUFA** = Total Polyunsaturated fatty acids; **MUFA** = Monounsaturated fatty acids; **SFA** = Total Saturated fatty acids. **T** (Turkish peanut varieties (Özcan and Seven, 2003)); **G** (Ghanaian groundnut varieties (Asibuo *et al*., 2008)); **N** (Nigerian groundnut oil (Aluyor *et al*., 2009))

The first fatty acid peak for all varieties was identified to be palmitic acid. The values ranged from 9.13% for Manipinta to Chinese (12.60%). There was no significant difference ($P>0.05$) between the values of Manipinta, Sinkarzie and F-Mix. The palmitic acid values obtained for the groundnut varieties studied compared well with literature values except for Nigerian groundnut oil which was shown to have slightly lower values (Aluyor *et al*., 2009). The Chinese variety was the only one that had a statistically different value of 12.60% ($P<0.05$). This value compared well with Indian peanut varieties as reported by Karnataka (2008). He reported an average palmitic acid value of 12.93% after analyzing seventeen different varieties.

The second fatty acid peak for all groundnut varieties studied was identified as Stearic acid. The values of F-Mix and Sinkarzie were not significantly different ($P>0.05$) but were significantly different from that of Chinese and Manipinta ($P<0.05$). The Stearic acid values of Chinese and Manipinta compared well with that for Nigerian groundnut oil as reported by Aluyor *et al.* (2009). Stearic acid values obtained in this study compared well with previous work done on Ghanaian groundnut varieties (Asibuo *et al*., 2008). Stearic acid is a common fatty acid in most foods though it is found in low quantities.

Behenic acid, a 22-carbon saturated fatty acid was identified as the last fatty acid peak based on the position of the peak and the percentage composition compared with literature values. The behenic acid values of the groundnut varieties studied ranged between 2.64% for Manipinta and 3.30% for Chinese. These values were also not significantly different ($P>0.05$). Sample values compared well with literature values (Table 4.6). A low level of behenic acid in groundnut oil is desirable because this fatty

acid has been linked with atherogenicity of the groundnut oils (Cater and Denke, 2001). However, long chain fatty acids like behenic acid also have commercial importance since they assist in emulsification and stabilization of food products.

The total saturated fatty acids (SFA) for a particular variety was studied to ascertain their impact on the complete nutritional value of the variety. F-Mix and Sinkarzie had SFA values of 15.99% and 15.53% respectively. These values were not significantly different ($P>0.05$). The lowest SFA composition was recorded by Manipinta (13.92%) and the highest value recorded by Chinese (18.51%). The SFA values for the four varieties were comparable to that reported in literature (Özcan and Seven, 2003; Asibuo *et al*., 2008; Aluyor *et al*., 2009). This level of saturated fatty acids (13.92% to 18.51%) in the groundnut varieties show that they would impart stability, emulsion properties and enhance absorption of vitamins without increasing the susceptibility of consumers to cholesterol related diseases.

Oleic acid is the fatty acid with the highest percentage composition in groundnut oil. It is a monounsaturated fatty acid and is known to impart most of the desirable attributes of groundnut oil including flavor and cooking properties. The third fatty acid peak after the GC run of the sample oils was identified to be oleic acid. Percentage composition for all four varieties studied were significantly different ($P<0.05$). The highest oleic acid composition was recorded by Sinkarzie (54.03%) followed by Chinese variety (52.93%), Manipinta (50.92%) and finally F-Mix (48.49%). Comparatively, the sample values were lower than that obtained by Aluyor *et al*. (2009) as shown in Table 4.6. Possible reasons for these disparities could be varietal and environmental differences. The four varieties however compared well with oleic acid for Turkish and Ghanaian

varieties (Özcan and Seven, 2003; Asibuo *et al*., 2008). Oleic and linoleic acid make up almost 80% of the total fatty acid composition of groundnut (Knauft *et al*., 1993). High oleic acid content is a desirable attribute for groundnut oil because monounsaturated fatty acids have been shown to decrease total and LDL-cholesterol levels thereby reducing the risk of coronary heart disease (O'Byrne *et al*., 1997). Oleic acid also improves the keeping qualities of groundnut oil and food products containing groundnuts because it is less prone to oxidative rancidity. The varieties with high oleic acid content could be added to food products to improve their shelf life and their nutritional quality.

Linoleic acid in groundnut varieties is usually known to have the second highest composition value. The fourth fatty acid peak in the GC chromatograms produced was identified to be Linoleic acid with percentage composition values ranging from 28.56% to 35.52%. Chinese variety was found to have the lowest linoleic acid content (28.56%), followed by Sinkarzie (30.44%) then Manipinta (35.15%) and F-Mix (35.52%). Linoleic acid values for F-Mix and Manipinta were not significantly different ($P>0.05$). However, values for Chinese and Sinkarzie were significantly different ($P<0.05$). Sample values compared appreciably with literature (Table 4.6). The polyunsaturated linoleic acid in peanuts promotes antioxidant vitamin E intake in consumers. Linoleic acid is known to be the parent fatty acid which is employed in the production of other long chain polyunsaturated fatty acids in the omega-6 family. Fatty acids in the omega-6 family have been shown to lower LDL-cholesterol and thereby protect against heart disease. However, very large amounts of omega-6 polyunsaturated fats can cause a reduction in the 'good' HDL cholesterol levels. Linoleic acid is also essential in the

human diet for maintaining the structure and function of cellular and subcellular membranes (Shadidi and Finley, 2001).

For the groundnut varieties studied in this project, the PUFA/SFA ratios were found to be between 1.54 and 2.52. Differences between these ratios were significant ($P<0.05$). Sample PUFA/SFA ratios compared well with literature (Özcan and Seven, 2003; Asibuo *et al*., 2008; Aluyor *et al*., 2009). The ratios were acceptable because values above 1 confirm the availability of PUFA in a diet and less negative effect of saturated fatty acids. High PUFA/SFA values, 5 or above, result in an increase in plasma total cholesterol, triacylglycerol, and phospholipids. Liver cholesterol level has also been shown to increase with higher PUFA/SFA diet (Chang and Huang, 1998).

From Table 4.6, F-Mix had the best fatty acid profile with the highest composition of polyunsaturated fatty acids and low saturated fatty acid content. Manipinta followed with the second highest PUFA content and the lowest SFA content whilst Sinkarzie had the third best fatty acid profile of high PUFA and low SFA content. The Chinese variety had the poorest fatty acid profile with the lowest PUFA content and highest SFA content.

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMMENDATION

### 5.1 Conclusions

For rice varieties, Nerica-1 stood out as the one with the best amino acid profile with respect to essential and non-essential amino acids.

For soybean varieties, Salintuya was shown to be the variety with the best nutritional value. It had the second highest composition of essential amino acids, the highest PUFA content and a high PUFA/SFA ratio. Anidaso also had an appreciably good amino acid profile with a good concentration of all essential amino acids. For fatty acids, it had a low SFA content and high PUFA/SFA ratio.

For the groundnut varieties studied, Sinkarzie had the best amino acid profile. Its fatty acid content however showed a high SFA content. F-Mix on the other hand had the second best amino acid profile, a low SFA content and second best PUFA/SFA ratio. Chinese variety showed a low amino acid profile and high saturated fatty acid content. This suggests that it would not be ideal for use in weaning food preparation. Manipinta had a low amino acid profile with a low SFA content and the highest PUFA/SFA ratio.

Nerica-1 can be used to complement F-Mix in a weaning food formulation since the rice variety contains high levels of essential amino acids and can reduce the limitation of methionine in the groundnut variety. Salintuya in addition will complement the rice and groundnut varieties. Anidaso can also serve as a good alternate source to Salintuya.

Manipinta can be used as an alternative to F-Mix due to its appreciable fatty acid profile.

## 5.2 Recommendations

It is hereby recommended that further research should be conducted:

1. To determine the effect of processing methods on the amino acid and fatty acid content of a complementary weaning food developed from these raw varieties.
2. To determine the bioavailability of the essential amino acids using animal models.

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## APPENDICES

### APPENDIX 1

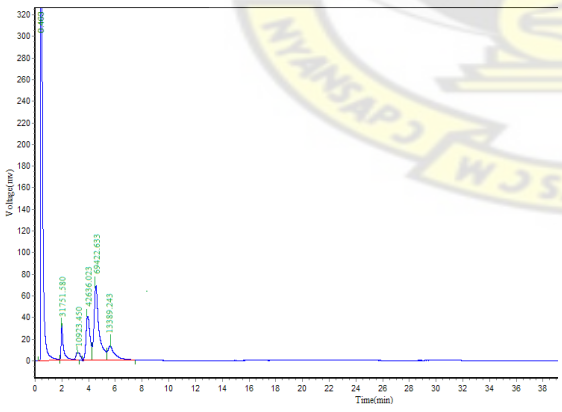
**Appendix 1A Oil Yield for Soybean and Groundnut Varieties**

| SAMPLE VARIETY | | Wt. of Sample | Wt. of flask | Wt. of flask and oil | % Wt. of oil |
|---|---|---|---|---|---|
| Soy bean | Quarshie | 22.58 | 122.10 | 125.12 | 13.38 |
| | Salintuya | 20.09 | 122.11 | 125.34 | 16.09 |
| | Anidaso | 19.96 | 120.74 | 123.75 | 15.05 |
| | Jenguma | 19.44 | 119.99 | 123.59 | 18.51 |
| Ground nut | Sinkarzie | 23.74 | 120.03 | 131.49 | 48.25 |
| | Manipinta | 19.51 | 124.58 | 133.72 | 46.87 |
| | Chinese | 19.17 | 122.06 | 130.10 | 41.95 |
| | F-Mix | 23.90 | 118.46 | 129.78 | 47.36 |

### APPENDIX 2

**GAS CHROMATOGRAMS FOR FATTY ACID PROFILES OF SOYBEAN AND GROUNDNUT VARIETIES**

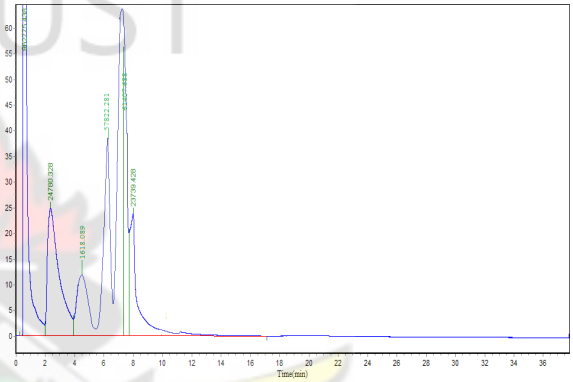
**Appendix 2Ai Gas Chromatogram for Quarshie Variety Fatty Acid Run 1**



| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.46 | 962758.94 | 8701881.00 | - |
| 2 | | 1.99 | 31751.58 | 415480.15 | 11.685 |
| 3 | | 3.59 | 10923.45 | 125191.92 | 3.521 |
| 4 | | 3.93 | 42636.02 | 851766.000 | 23.956 |
| 5 | | 4.54 | 69422.63 | 1900030.08 | 53.438 |
| 6 | | 5.60 | 13389.24 | 263106.57 | 7.400 |

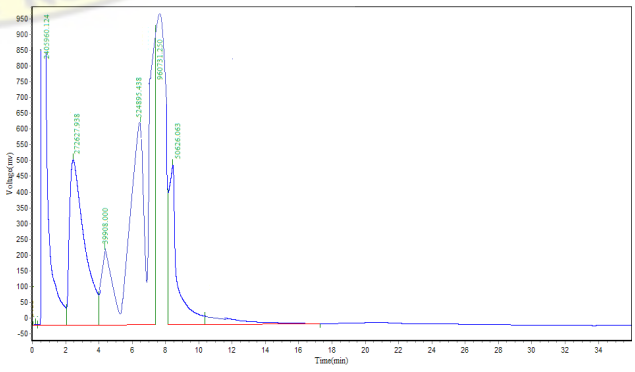
*solv=solvent, Ret Time=Retention time

**Appendix 2Aii Gas Chromatogram for Quarshie Variety Fatty Acid Run 2**



| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.57 | 962775.44 | 8968733.00 | - |
| 2 | | 2.35 | 24780.33 | 1389167.00 | 12.11 |
| 3 | | 6.93 | 1618.09 | 389380.81 | 3.39 |
| 4 | | 7.51 | 57822.28 | 2687852.27 | 23.42 |
| 5 | | 8.00 | 61407.69 | 6169947.99 | 53.77 |
| 6 | | 10.40 | 23739.43 | 837892.25 | 7.30 |

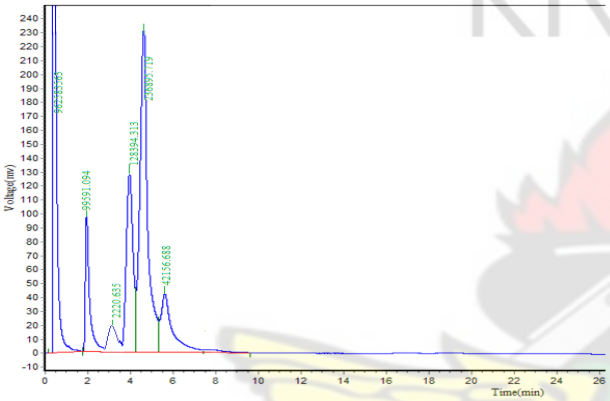
**Appendix 2Aiii Gas Chromatogram for Quarshie Variety Fatty Acid Run 3**



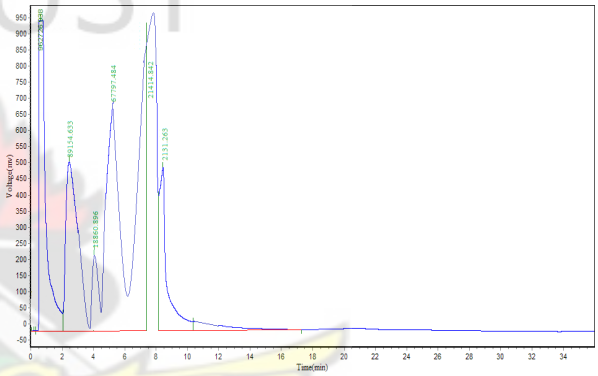
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.18 | 2405960.12 | 29661.17 | |
| 2 | | 0.65 | 262726.94 | 25992708.46 | 11.25 |
| 3 | | 5.45 | 39908.00 | 8754042.04 | 3.80 |
| 4 | | 6.80 | 524895.44 | 55791285.28 | 24.16 |
| 5 | | 8.44 | 960731.25 | 122878494.8 | 53.20 |
| 6 | | 10.84 | 50626.06 | 17527132.00 | 7.59 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.59 | 962825.31 | 9531245.00 | - |
| 2 | | 2.68 | 30736.67 | 2110835.22 | 11.44 |
| 3 | | 8.26 | 3217.43 | 582491.62 | 3.16 |
| 4 | | 10.17 | 62163.87 | 4312561.18 | 23.36 |
| 5 | | 12.44 | 57366.32 | 10108931.1 | 54.77 |
| 6 | | 12.89 | 21271.00 | 1342945.56 | 7.27 |

**Appendix 2Bi Gas Chromatogram for Salintuya Variety Fatty Acid Run 1**



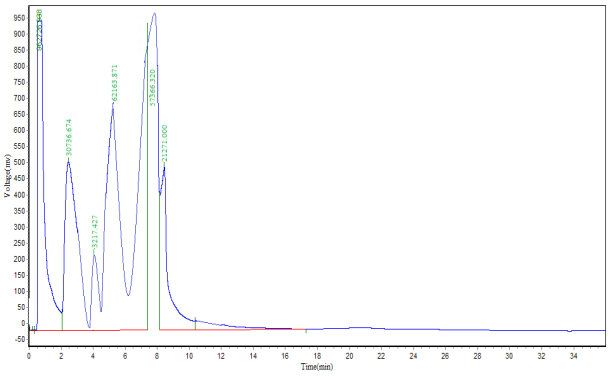

**Appendix 2Biii Gas Chromatogram for Salintuya Variety Fatty Acid Run**



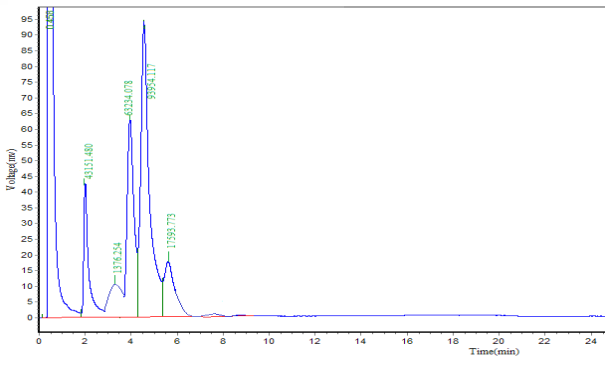

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.43 | 952583.56 | 3224374.00 | |
| 2 | | 1.94 | 99591.09 | 1377457.00 | 11.62 |
| 3 | | 3.57 | 2220.64 | 358252.14 | 3.02 |
| 4 | | 3.95 | 128394.31 | 2838560.50 | 23.95 |
| 5 | | 4.62 | 236895.72 | 6404402.43 | 54.02 |
| 6 | | 5.61 | 42156.69 | 754958.83 | 7.35 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.58 | 962822.00 | 19399348.00 | - |
| 2 | | 2.89 | 89154.63 | 3080734.35 | 11.25 |
| 3 | | 8.25 | 1860.90 | 879827.08 | 3.21 |
| 4 | | 10.98 | 67797.48 | 6423930.126 | 23.46 |
| 5 | | 11.25 | 21414.84 | 15005331.20 | 54.80 |
| 6 | | 12.23 | 2131.26 | 19928866.76 | 7.26 |

**Appendix 2Bii Gas Chromatogram for Salintuya Variety Fatty Acid Run 2**



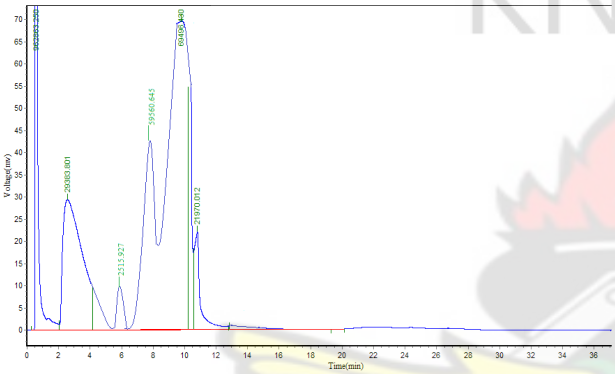

**Appendix 2Ci Gas Chromatogram for Jenguma Variety Fatty Acid Run 1**



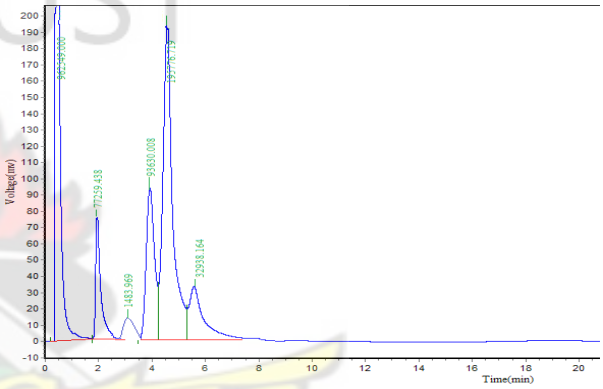
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.46 | 962739.31 | 8776794.00 | - |
| 2 | | 2.00 | 43151.48 | 578798.38 | 10.85 |
| 3 | | 3.68 | 1376.25 | 183411.48 | 3.44 |
| 4 | | 3.95 | 63234.08 | 1315373.13 | 24.65 |
| 5 | | 4.56 | 93954.12 | 2864366.19 | 53.69 |
| 6 | | 5.60 | 17593.77 | 393441.20 | 7.37 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.51 | 962832.31 | 7036067.00 | - |
| 2 | | 2.50 | 26491.05 | 2349546.00 | 10.24 |
| 3 | | 7.04 | 2699.06 | 867944.44 | 3.78 |
| 4 | | 10.08 | 57723.25 | 5669369.66 | 24.70 |
| 5 | | 10.64 | 67278.23 | 12324257.8 | 53.71 |
| 6 | | 11.07 | 21201.72 | 1736520.01 | 7.57 |

**Appendix 2Cii Gas Chromatogram for Jenguma Variety Fatty Acid Run 2**



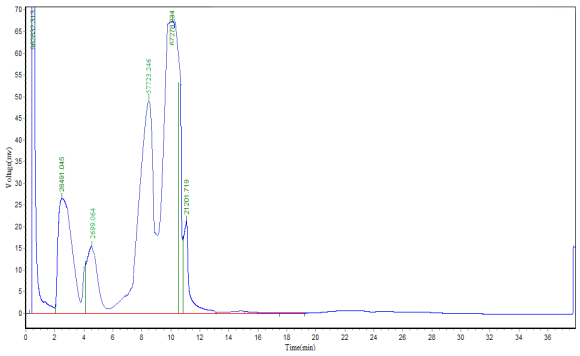
**Appendix 2Di Gas Chromatogram for Anidaso Variety Fatty Acid Run 1**



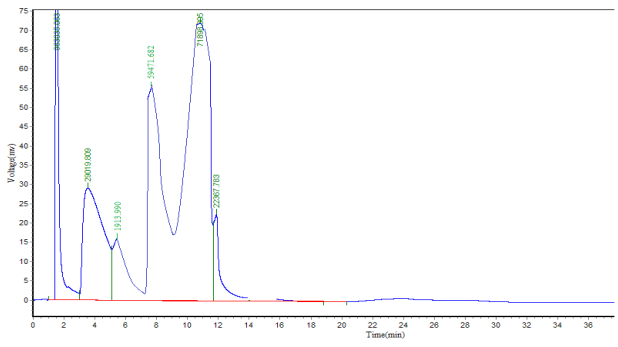
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.57 | 962863.25 | 7319372.00 | - |
| 2 | | 2.56 | 29383.80 | 2455203.25 | 10.76 |
| 3 | | 7.56 | 2515.93 | 836821.03 | 3.67 |
| 4 | | 9.79 | 59560.65 | 5480441.73 | 24.03 |
| 5 | | 10.38 | 69496.43 | 12292965.6 | 53.89 |
| 6 | | 10.81 | 21970.01 | 1746229.17 | 7.65 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.44 | 962549.00 | 8611656.00 | - |
| 2 | | 1.94 | 77259.44 | 8319230.00 | 12.13 |
| 3 | | 3.42 | 1483.97 | 560831.48 | 3.38 |
| 4 | | 3.92 | 93630.01 | 1610978.67 | 23.75 |
| 5 | | 4.57 | 195776.72 | 5246340.68 | 53.00 |
| 6 | | 5.57 | 32938.16 | 1289574.63 | 7.75 |

**Appendix 2Ciii Gas Chromatogram for Jenguma Variety Fatty Acid Run 3**



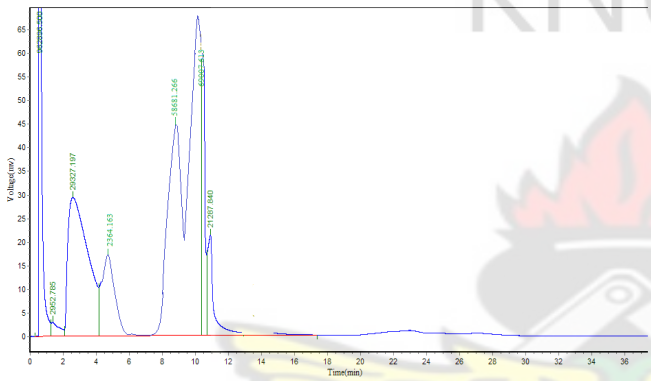
**Appendix 2Dii Gas Chromatogram for Anidaso Variety Fatty Acid Run 2**



| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 1.52 | 963035.06 | 7786337.50 | - |
| 2 | | 3.53 | 29019.81 | 2870658.08 | 11.75 |
| 3 | | 5.71 | 1913.99 | 807307.50 | 3.31 |
| 4 | | 9.24 | 59471.68 | 5623852.58 | 23.03 |
| 5 | | 10.81 | 71898.31 | 13533854.3 | 54.403 |
| 6 | | 11.87 | 22367.78 | 1835069.56 | 7.51 |

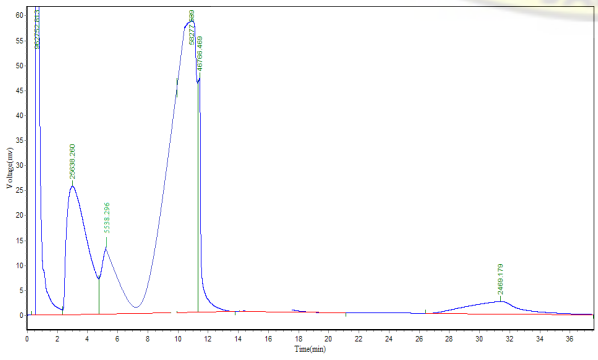
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.66 | 962752.81 | 9101061.00 | - |
| 2 | | 2.98 | 25638.26 | 2371926.75 | 12.63 |
| 3 | | 9.48 | 5538.30 | 461102.88 | 2.46 |
| 4 | | 10.92 | 58277.54 | 9923061.00 | 52.85 |
| 5 | | 11.95 | 53752.09 | 54123229.1 | 28.83 |
| 6 | | 31.38 | 2469.18 | 608332.75 | 3.24 |

**Appendix 2Diii Gas Chromatogram for Anidaso Variety Fatty Acid Run 3**

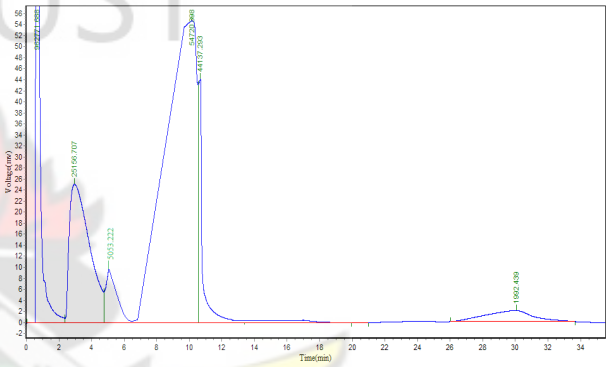


| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.59 | 962896.50 | 7047402.00 | |
| 2 | | 2.58 | 29327.20 | 2468851.52 | 11.16 |
| 3 | | 4.68 | 2364.16 | 819634.68 | 3.71 |
| 4 | | 9.96 | 58681.27 | 5258762.10 | 23.77 |
| 5 | | 10.50 | 69007.61 | 11902959.4 | 53.52 |
| 6 | | 10.91 | 21287.84 | 1669203.88 | 7.55 |

**Appendix 2Ei Gas Chromatogram for Chinese Variety Fatty Acid Run 1**

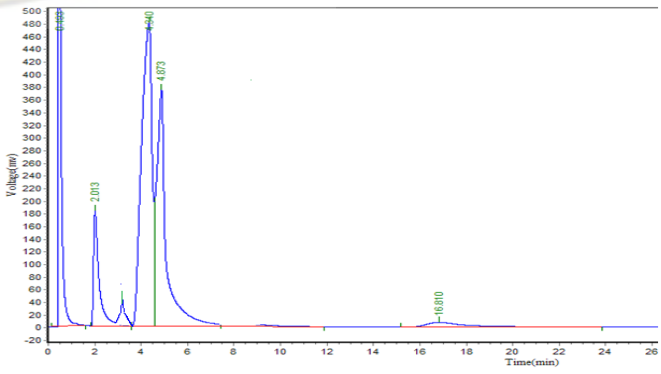


**Appendix 2Eii Gas Chromatogram for Chinese Variety Fatty Acid Run 2**



| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.67 | 962771.69 | 8413132.00 | - |
| 2 | | 2.96 | 25156.71 | 2172403.75 | 12.56 |
| 3 | | 10.18 | 5053.22 | 478466.00 | 2.77 |
| 4 | | 10.68 | 5472040 | 9167464.57 | 53.01 |
| 5 | | 11.07 | 44137.29 | 4894346.28 | 28.30 |
| 6 | | 30.06 | 1992.44 | 581245.16 | 3.36 |

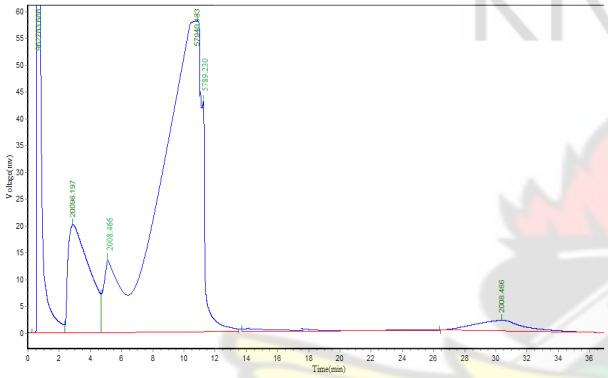
**Appendix 2Fi Gas Chromatogram for F-Mix Variety Fatty Acid Run 1**



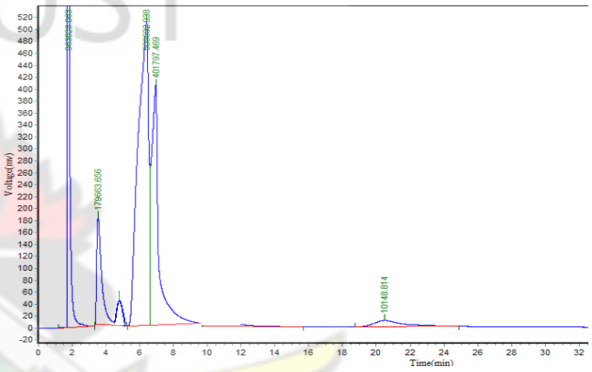
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.49 | 960774.94 | 29794924.00 | - |
| 2 | | 2.01 | 181408.73 | 3050454.25 | 9.91 |
| 3 | | 3.40 | 16764.08 | 969051.94 | 3.15 |
| 4 | | 4.34 | 479403.78 | 14852353.00 | 48.27 |
| 5 | | 4.87 | 373427.72 | 10923064.00 | 35.50 |
| 6 | | 16.81 | 7596.44 | 975832.75 | 3.17 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.66 | 962977.19 | 8000382.00 | - |
| 2 | | 2.87 | 20441.36 | 1679395.75 | 9.89 |
| 3 | | 7.26 | 4873.99 | 567305.87 | 3.24 |
| 4 | | 10.48 | 53418.13 | 8463538.41 | 48.32 |
| 5 | | 10.90 | 40145.22 | 36317695.5 | 35.34 |
| 6 | | 29.88 | 1841.81 | 615411.23 | 3.51 |

**Appendix 2Fii Gas Chromatogram for F-Mix Variety Fatty Acid Run 2**



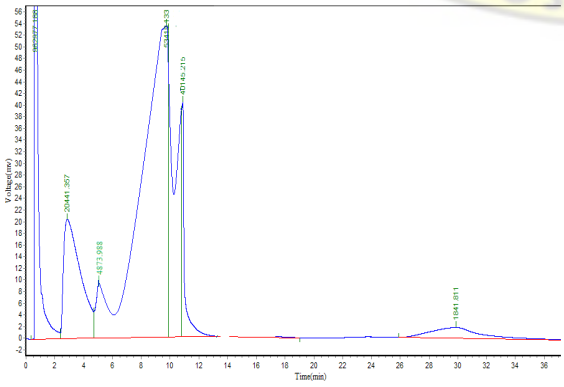
**Appendix 2Gi Gas Chromatogram for Sinkarzie Variety Fatty Acid Run 1**



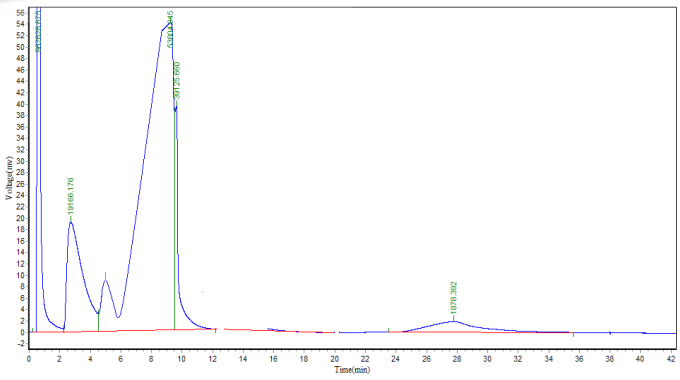
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.67 | 962783.69 | 8857347.00 | - |
| 2 | | 2.88 | 20096.20 | 1889392.13 | 9.06 |
| 3 | | 7.37 | 2008.47 | 663920.17 | 3.18 |
| 4 | | 9.27 | 57940.13 | 10195689.5 | 48.90 |
| 5 | | 10.85 | 5789.23 | 7446750.40 | 35.71 |
| 6 | | 30.86 | 23070.60 | 654886.62 | 3.14 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 1.79 | 963028.06 | 29639748.00 | - |
| 2 | | 3.53 | 179663.66 | 3706814.75 | 9.18 |
| 3 | | 4.97 | 21846.09 | 1418211.88 | 3.51 |
| 4 | | 6.41 | 509632.94 | 21877742.00 | 54.17 |
| 5 | | 6.94 | 401797.47 | 12178448.00 | 30.15 |
| 6 | | 20.50 | 10148.81 | 1207232.13 | 2.99 |

**Appendix 2Fiii Gas Chromatogram for F-Mix Variety Fatty Acid Run 3**



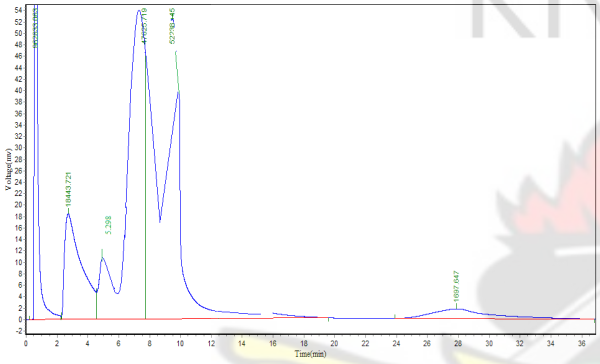
**Appendix 2Gii Gas Chromatogram for Sinkarzie Variety Fatty Acid Run 2**



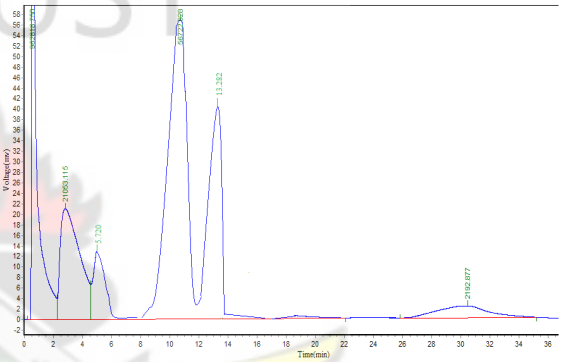
| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.60 | 962828.88 | 9267444.00 | - |
| 2 | | 2.72 | 19166.18 | 12740920.01 | 9.15 |
| 3 | | 7.74 | 4240.41 | 469229.58 | 3.37 |
| 4 | | 9.25 | 53804.95 | 7530986.75 | 54.07 |
| 5 | | 9.64 | 39125.66 | 4264058.17 | 30.61 |
| 6 | | 27.76 | 1878.39 | 391278.51 | 2.81 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.43 | 962910.19 | 3743230.75 | - |
| 2 | | 2.17 | 57828.94 | 959870.50 | 9.09 |
| 3 | | 3.98 | 4359.10 | 229520.70 | 2.17 |
| 4 | | 4.47 | 180689.39 | 4524612.50 | 45.85 |
| 5 | | 5.11 | 130061.23 | 4564526.50 | 40.23 |
| 6 | | 18.90 | 2259.85 | 280592.59 | 2.66 |

**Appendix 2Giii Gas Chromatogram for Sinkarzie Variety Fatty Acid Run 3**



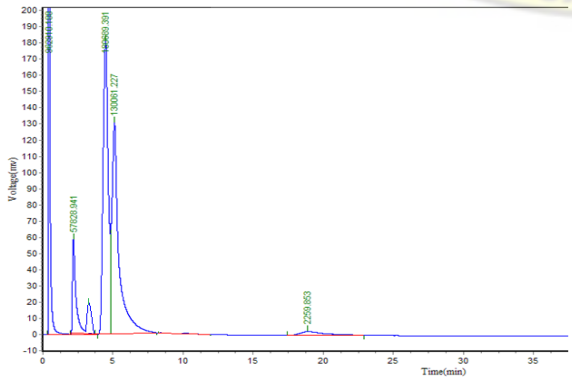
**Appendix 2Hii Gas Chromatogram for Manipinta Variety Fatty Acid Run 2**



| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.62 | 962833.06 | 8220404.00 | - |
| 2 | | 2.72 | 18443.72 | 1403705.12 | 9.19 |
| 3 | | 6.00 | 4686.33 | 542382.12 | 3.55 |
| 4 | | 7.67 | 52238.15 | 8225441.83 | 53.85 |
| 5 | | 9.49 | 47625.72 | 4667969.83 | 30.56 |
| 6 | | 27.87 | 1697.65 | 434286.78 | 2.84 |

| Peak No. | Peak ID | Ret Time | Peak Height | Peak Area | % Composition |
|---|---|---|---|---|---|
| 1 | solv | 0.56 | 96818.75 | 8850985.00 | - |
| 2 | | 2.81 | 21053.12 | 2043829.40 | 9.18 |
| 3 | | 8.72 | 6371.39 | 473659.81 | 2.13 |
| 4 | | 10.61 | 56722.83 | 11361098.5 | 51.00 |
| 5 | | 11.28 | 42213.08 | 7813248.92 | 35.07 |
| 6 | | 30.46 | 2192.88 | 584668.83 | 2.63 |

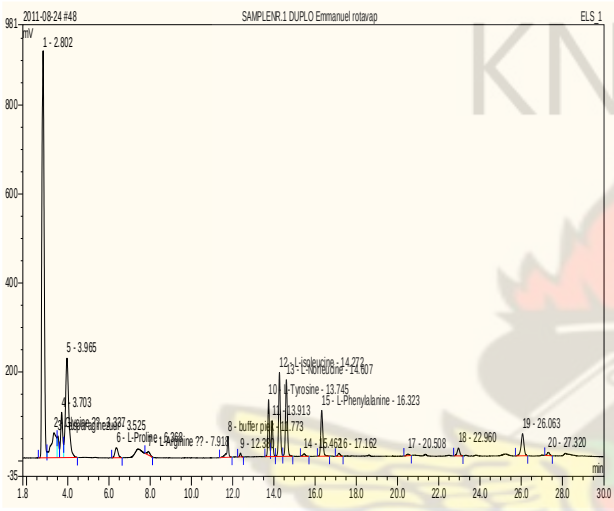
**Appendix 2Hi Gas Chromatogram for Manipinta Variety Fatty Acid Run 1**



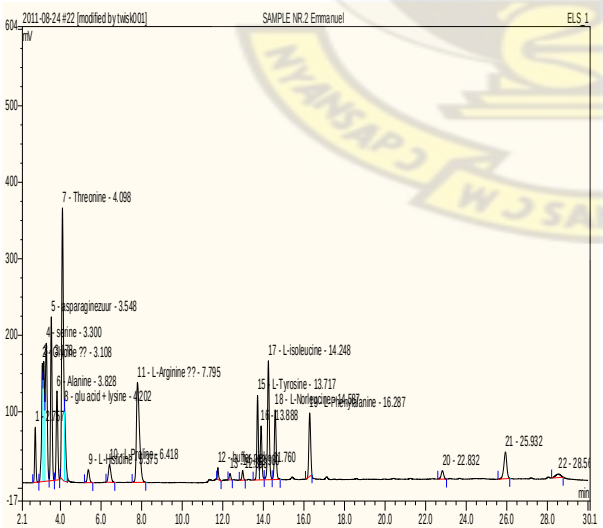
## APPENDIX THREE

## HIGH PERFORMANCE LIQUID CHROMATOGRAMS FOR AMINO ACID PROFILES OF LOCALLY GROWN RICE, SOYBEAN AND GROUNDNUT VARIETIES

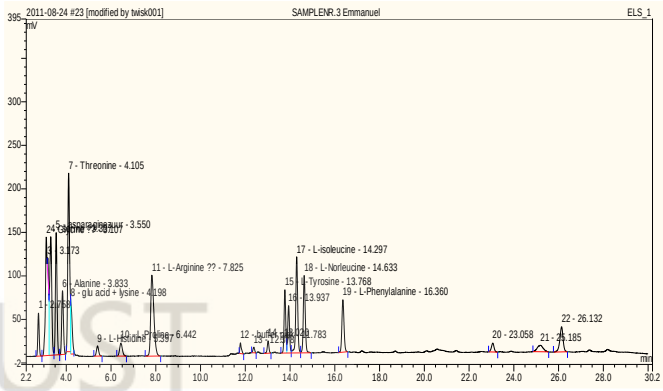
### Appendix 3A HPL Chromatogram for Amino Acid Run of Manipinta Variety



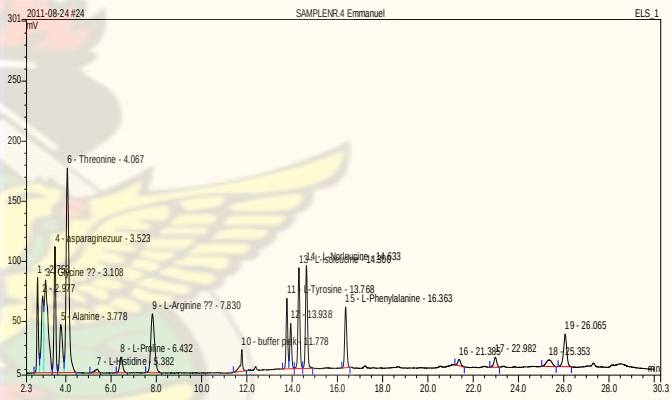

### Appendix 3B HPL Chromatogram for Amino Acid Run of Sinkarzie Variety



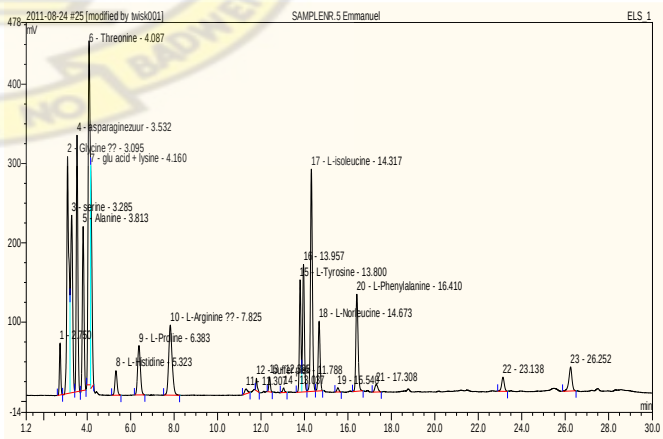

### Appendix 3C HPL Chromatogram for Amino Acid Run of F-Mix Variety



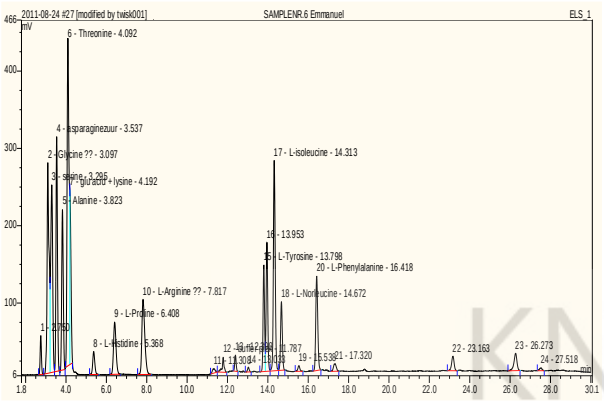

### Appendix 3D HPL Chromatogram for Amino Acid Run of Chinese Variety



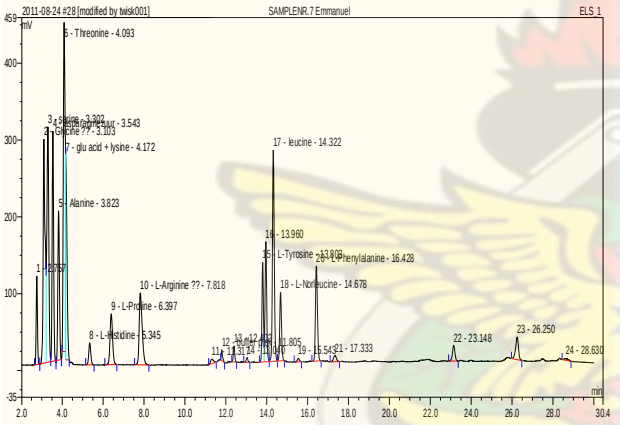

### Appendix 3E HPL Chromatogram for Amino Acid Run of Quarshie Variety



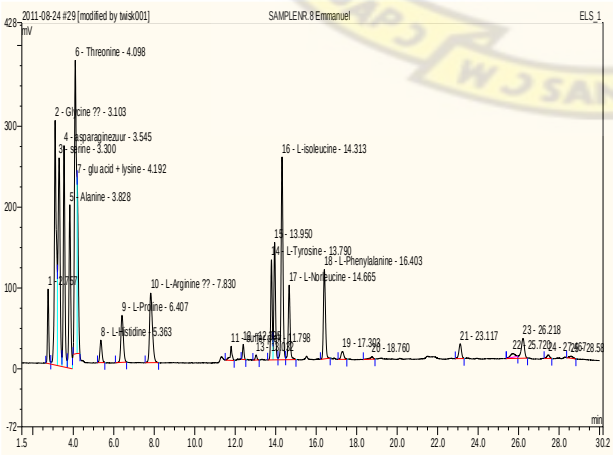
**Appendix 3F HPL Chromatogram for Amino Acid Run of Salintuya Variety**



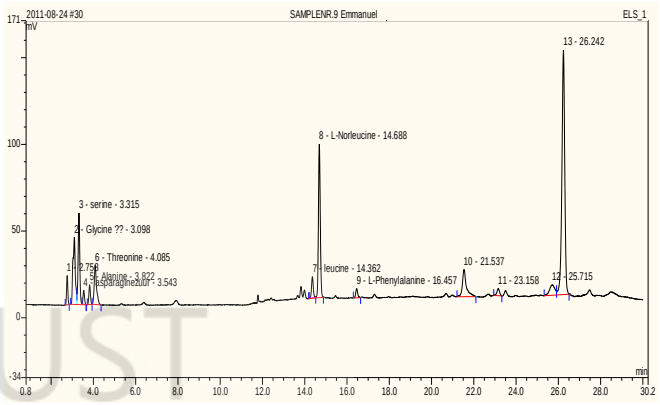

**Appendix 3G HPL Chromatogram for Amino Acid Run of Anidaso Variety**



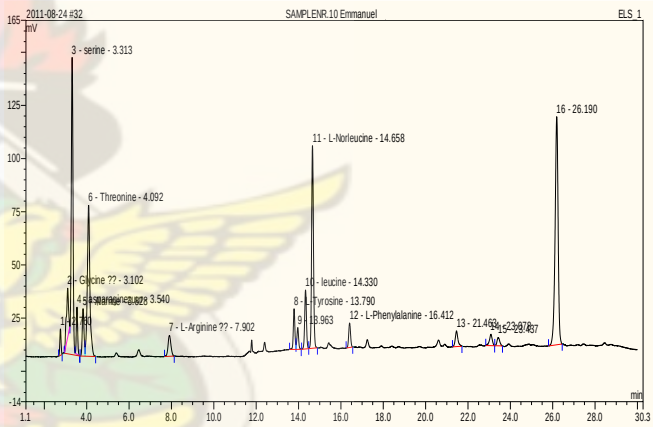

**Appendix 3H HPL Chromatogram for Amino Acid Run of Jenguma Variety**



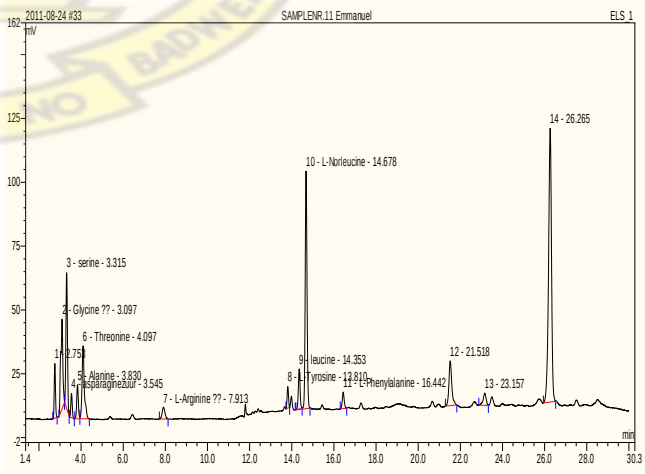

**Appendix 3I HPL Chromatogram for Amino Acid Run of Digang Variety**



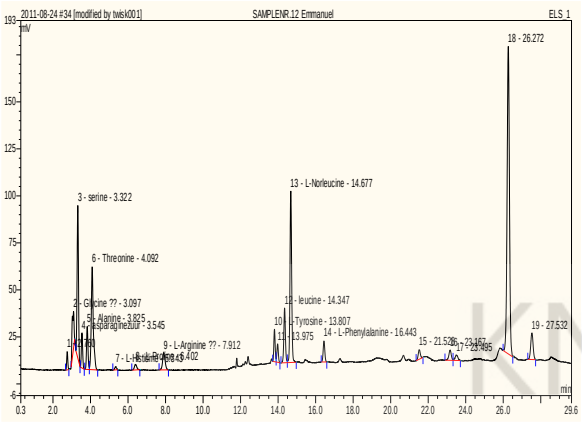

**Appendix 3J HPL Chromatogram for Amino Acid Run of Nerica-1 Variety**



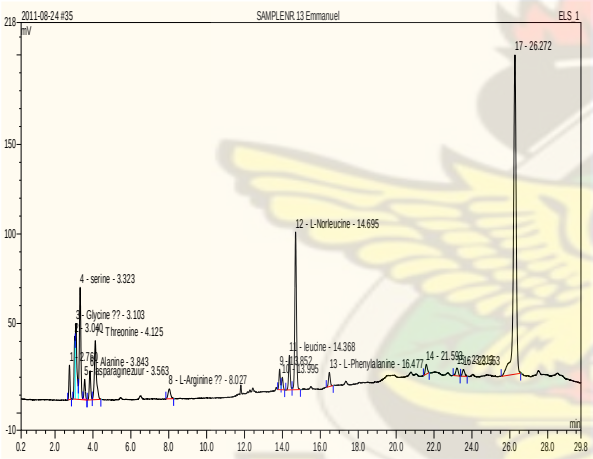

**Appendix 3K HPL Chromatogram for Amino Acid Run of Jasmine-85 Variety**



**Appendix 3L HPL Chromatogram for Amino Acid Run of Nerica-2 Variety**




**Appendix 3M HPL Chromatogram for Amino Acid Run of Sikamo Variety**




## APPENDIX 4

## STATISTICAL TABLES FOR FATTY ACID ANALYSES OF SOYBEAN VARIETIES

**Appendix 4A Multiple Range Tests for Palmitic Acid for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Jenguma | 3 | 10.6163 | X |
| Salintuya | 3 | 11.435 | XX |
| Anidaso | 3 | 11.68 | X |
| Quarshie | 3 | 11.682 | X |
| *Contrast* | *Sig.* | *Diff* | *+/- Limits* |
| Anidaso - Jenguma | * | 1.06367 | 0.980629 |
| Anidaso - Quarshie | | -0.002 | 0.980629 |
| Anidaso - Salintuya | | 0.245 | 0.980629 |
| Jenguma - Quarshie | * | -1.066 | 0.980629 |
| Jenguma - Salintuya | | -0.8187 | 0.980629 |
| Quarshie - Salintuya | | 0.247 | 0.980629 |

* Denotes A Statistically Significant Difference.

**Appendix 4B Multiple Range Tests for Stearic Acid for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Salintuya | 3 | 3.12967 | X |
| Anidaso | 3 | 3.46167 | XX |
| Quarshie | 3 | 3.57133 | XX |
| Jenguma | 3 | 3.62933 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | | -0.167667 | 0.470019 |
| Anidaso - Quarshie | | -0.109667 | 0.470019 |
| Anidaso - Salintuya | | 0.332 | 0.470019 |
| Jenguma - Quarshie | | 0.058 | 0.470019 |
| Jenguma - Salintuya | * | 0.499667 | 0.470019 |
| Quarshie - Salintuya | | 0.441667 | 0.470019 |

* Denotes A Statistically Significant Difference.

**Appendix 4C Multiple Range Tests for Oleic Acid for Soybean Varieties**

Method: 95.0 percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* | |
|---|---|---|---|---|
| Anidaso | 3 | 23.5177 | X | |
| Salintuya | 3 | 23.5887 | X | |
| Quarshie | 3 | 23.8457 | X | |
| Jenguma | 3 | 24.4613 | X | |
| *Contrast* | | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | | | -0.943667 | 0.979182 |
| Anidaso - Quarshie | | | -0.328 | 0.979182 |
| Anidaso - Salintuya | | | -0.071 | 0.979182 |
| Jenguma - Quarshie | | | 0.615667 | 0.979182 |
| Jenguma - Salintuya | | | 0.872667 | 0.979182 |
| Quarshie - Salintuya | | | 0.257 | 0.979182 |

* denotes a statistically significant difference.

**Appendix 4D Multiple Range Tests for Linoleic Acid for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Quarshie | 3 | 53.4707 | X |
| Anidaso | 3 | 53.7393 | X |
| Jenguma | 3 | 53.761 | X |
| Salintuya | 3 | 54.531 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | | -0.0216667 | 1.15706 |
| Anidaso - Quarshie | | 0.268667 | 1.15706 |
| Anidaso - Salintuya | | -0.791667 | 1.15706 |
| Jenguma - Quarshie | | 0.290333 | 1.15706 |
| Jenguma - Salintuya | | -0.77 | 1.15706 |
| Quarshie - Salintuya | | -1.06033 | 1.15706 |

* denotes a statistically significant difference.

**Appendix 4E Multiple Range Tests for Linolenic Acid for Soybean Varieties**

Method: 95.0 percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Salintuya | 3 | 7.296 | X |
| Quarshie | 3 | 7.43033 | X |
| Jenguma | 3 | 7.53167 | X |
| Anidaso | 3 | 7.60233 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | | 0.0706667 | 0.32176 |
| Anidaso - Quarshie | | 0.172 | 0.32176 |
| Anidaso - Salintuya | | 0.306333 | 0.32176 |
| Jenguma - Quarshie | | 0.101333 | 0.32176 |
| Jenguma - Salintuya | | 0.235667 | 0.32176 |
| Quarshie - Salintuya | | 0.134333 | 0.32176 |

* denotes a statistically significant difference.

**Appendix 4F Multiple Range Tests for SFA for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Jenguma | 3 | 14.2457 | X |
| Salintuya | 3 | 14.5647 | XX |
| Anidaso | 3 | 15.1417 | XX |
| Quarshie | 3 | 15.3083 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | * | 0.896 | 0.601033 |
| Anidaso - Quarshie | | -0.166667 | 0.601033 |
| Anidaso - Salintuya | | 0.577 | 0.601033 |
| Jenguma - Quarshie | * | -1.06267 | 0.601033 |
| Jenguma - Salintuya | | -0.319 | 0.601033 |
| Quarshie - Salintuya | * | 0.743667 | 0.601033 |

* Denotes A Statistically Significant Difference.

**Appendix 4G Multiple Range Tests for PUFA for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Quarshie | 3 | 60.901 | X |
| Jenguma | 3 | 61.2927 | X |
| Anidaso | 3 | 61.3417 | X |
| Salintuya | 3 | 61.827 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | | 0.049 | 0.99121 |
| Anidaso - Quarshie | | 0.440667 | 0.99121 |
| Anidaso - Salintuya | | -0.485333 | 0.99121 |
| Jenguma - Quarshie | | 0.391667 | 0.99121 |
| Jenguma - Salintuya | | -0.534333 | 0.99121 |
| Quarshie - Salintuya | | -0.926 | 0.99121 |

* Denotes A Statistically Significant Difference

**Appendix 4H Multiple Range Tests for PUFA/SFA for Soybean Varieties**

Method: 95.0 Percent Tukey HSD

| *Soybean Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Quarshie | 3 | 3.993 | X |
| Anidaso | 3 | 4.053 | XX |
| Salintuya | 3 | 4.22733 | XX |
| Jenguma | 3 | 4.303 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Anidaso - Jenguma | * | -0.25 | 0.196087 |
| Anidaso - Quarshie | | 0.06 | 0.196087 |
| Anidaso - Salintuya | | -0.174333 | 0.196087 |
| Jenguma - Quarshie | * | 0.31 | 0.196087 |
| Jenguma - Salintuya | | 0.0756667 | 0.196087 |
| Quarshie - Salintuya | * | -0.234333 | 0.196087 |

* Denotes A Statistically Significant Difference.

**APPENDIX 5**

**STATISTICAL TABLES FOR FATTY ACID ANALYSES OF GROUNDNUT VARIETIES**

**Appendix 5A Multiple Range Tests for Palmitic Acid for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Manipinta | 2 | 9.1325 | X |
| Sinkarzie | 3 | 9.17167 | X |
| F-Mix | 3 | 9.521 | X |
| Chinese | 2 | 12.597 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | 3.076 | 0.788341 |
| Chinese - Manipinta | * | 3.4645 | 0.863584 |
| Chinese - Sinkarzie | * | 3.42533 | 0.788341 |
| F-Mix - Manipinta | | 0.3885 | 0.788341 |
| F-Mix - Sinkarzie | | 0.349333 | 0.705114 |
| Manipinta - Sinkarzie | | -0.0391667 | 0.788341 |

* Denotes A Statistically Significant Difference.

**Appendix 5B Multiple Range Tests for Stearic Acid for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Manipinta | 2 | 2.15 | X |
| Chinese | 2 | 2.6115 | X |
| F-Mix | 3 | 3.19067 | X |
| Sinkarzie | 3 | 3.477 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | -0.579167 | 0.344849 |
| Chinese - Manipinta | * | 0.4615 | 0.377763 |
| Chinese - Sinkarzie | * | -0.8655 | 0.344849 |
| F-Mix - Manipinta | * | 1.04067 | 0.344849 |
| F-Mix - Sinkarzie | | -0.286333 | 0.308442 |
| Manipinta - Sinkarzie | * | -1.327 | 0.344849 |

* Denotes A Statistically Significant Difference.

**Appendix 5C Multiple Range Tests for Oleic Acid for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| F-Mix | 3 | 48.4953 | X |
| Manipinta | 2 | 50.925 | X |
| Chinese | 2 | 52.9295 | X |
| Sinkarzie | 3 | 54.0293 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | 4.43417 | 0.730482 |
| Chinese - Manipinta | * | 2.0045 | 0.800203 |
| Chinese - Sinkarzie | * | -1.09983 | 0.730482 |
| F-Mix - Manipinta | * | -2.42967 | 0.730482 |
| F-Mix - Sinkarzie | * | -5.534 | 0.653363 |
| Manipinta - Sinkarzie | * | -3.10433 | 0.730482 |

* Denotes A Statistically Significant Difference.

**Appendix 5D Multiple Range Tests for Linoleic Acid for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Chinese | 2 | 28.562 | X |
| Sinkarzie | 3 | 30.4413 | X |
| Manipinta | 2 | 35.1515 | X |
| F-Mix | 3 | 35.5177 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | -6.95567 | 0.755876 |
| Chinese - Manipinta | * | -6.5895 | 0.82802 |
| Chinese - Sinkarzie | * | -1.87933 | 0.755876 |
| F-Mix - Manipinta | | 0.366167 | 0.755876 |
| F-Mix - Sinkarzie | * | 5.07633 | 0.676076 |
| Manipinta - Sinkarzie | * | 4.71017 | 0.755876 |

* Denotes A Statistically Significant Difference.

**Appendix 5E Multiple Range Tests for Behenic Acid for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Manipinta | 2 | 2.641 | X |
| Sinkarzie | 3 | 2.88033 | XX |
| F-Mix | 3 | 3.275 | X |
| Chinese | 2 | 3.3005 | XX |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | | 0.0255 | 0.42944 |
| Chinese - Manipinta | * | 0.6595 | 0.470428 |
| Chinese - Sinkarzie | | 0.420167 | 0.42944 |
| F-Mix - Manipinta | * | 0.634 | 0.42944 |
| F-Mix - Sinkarzie | * | 0.394667 | 0.384103 |
| Manipinta - Sinkarzie | | -0.239333 | 0.42944 |

* Denotes A Statistically Significant Difference.

**Appendix 5F Multiple Range Tests for SFA for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Manipinta | 2 | 13.9235 | X |
| Sinkarzie | 3 | 15.529 | X |
| F-Mix | 3 | 15.9867 | X |
| Chinese | 2 | 18.509 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | 2.52233 | 1.05839 |
| Chinese - Manipinta | * | 4.5855 | 1.1594 |
| Chinese - Sinkarzie | * | 2.98 | 1.05839 |
| F-Mix - Manipinta | * | 2.06317 | 1.05839 |
| F-Mix - Sinkarzie | | 0.457667 | 0.946649 |
| Manipinta - Sinkarzie | * | -1.6055 | 1.05839 |

* Denotes A Statistically Significant Difference.

**Appendix 5G Multiple Range Tests for PUFA for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Chinese | 2 | 28.562 | X |
| Sinkarzie | 3 | 30.4413 | X |
| Manipinta | 2 | 35.1515 | X |
| F-Mix | 3 | 35.5177 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | -6.95567 | 0.755876 |
| Chinese - Manipinta | * | -6.5895 | 0.82802 |
| Chinese - Sinkarzie | * | -1.87933 | 0.755876 |
| F-Mix - Manipinta | | 0.366167 | 0.755876 |
| F-Mix - Sinkarzie | * | 5.07633 | 0.676076 |
| Manipinta - Sinkarzie | * | 4.71017 | 0.755876 |

* Denotes A Statistically Significant Difference.

**Appendix 5H Multiple Range Tests For PUFA/SFA for Groundnut Varieties**

Method: 95.0 Percent Tukey HSD

| *Groundnut Variety* | *Count* | *Mean* | *Homogeneous Groups* |
|---|---|---|---|
| Chinese | 2 | 1.5435 | X |
| Sinkarzie | 3 | 1.96033 | X |
| F-Mix | 3 | 2.22367 | X |
| Manipinta | 2 | 2.525 | X |
| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
| Chinese - F-Mix | * | -0.680167 | 0.177474 |
| Chinese - Manipinta | * | -0.9815 | 0.194413 |
| Chinese - Sinkarzie | * | -0.416833 | 0.177474 |
| F-Mix - Manipinta | * | -0.301333 | 0.177474 |
| F-Mix - Sinkarzie | * | 0.263333 | 0.158737 |
| Manipinta - Sinkarzie | * | 0.564667 | 0.177474 |

* Denotes A Statistically Significant Difference.

**APPENDIX 6**

**STATISTICAL TABLES FOR AMINO ACID**

**ANALYSIS OF RICE VARIETIES**

**Appendix 6A Multiple Range Tests for THR by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -1.16 | 0.0 |
| DIGANG - NERICA-1 | * | -10.47 | 0.0 |
| DIGANG - NERICA-2 | * | -6.88 | 0.0 |
| DIGANG - SIKAMO | * | -2.79 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -9.31 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -5.72 | 0.0 |
| JASMINE-85 - SIKAMO | * | -1.63 | 0.0 |
| NERICA-1 - NERICA-2 | * | 3.59 | 0.0 |
| NERICA-1 - SIKAMO | * | 7.68 | 0.0 |
| NERICA-2 - SIKAMO | * | 4.09 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6B Multiple Range Tests for ILE by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.08 | 0.0 |
| DIGANG - NERICA-1 | * | -1.59 | 0.0 |
| DIGANG - NERICA-2 | * | -1.55 | 0.0 |
| DIGANG - SIKAMO | * | -1.02 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -1.51 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -1.47 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.94 | 0.0 |
| NERICA-1 - NERICA-2 | * | 0.04 | 0.0 |
| NERICA-1 - SIKAMO | * | 0.57 | 0.0 |
| NERICA-2 - SIKAMO | * | 0.53 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6C Multiple Range Tests for LEU by RICE VARIETIES**

Method: 95.0 percent LSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.69 | 0.0 |
| DIGANG - NERICA-1 | * | -2.68 | 0.0 |
| DIGANG - NERICA-2 | * | -3.14 | 0.0 |
| DIGANG - SIKAMO | * | -1.82 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -1.99 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -2.45 | 0.0 |
| JASMINE-85 - SIKAMO | * | -1.13 | 0.0 |
| NERICA-1 - NERICA-2 | * | -0.46 | 0.0 |
| NERICA-1 - SIKAMO | * | 0.86 | 0.0 |
| NERICA-2 - SIKAMO | * | 1.32 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6D Multiple Range Tests for PHE by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.25 | 0.0 |
| DIGANG - NERICA-1 | * | -1.36 | 0.0 |
| DIGANG - NERICA-2 | * | -1.48 | 0.0 |
| DIGANG - SIKAMO | * | -0.9 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -1.11 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -1.23 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.65 | 0.0 |
| NERICA-1 - NERICA-2 | * | -0.12 | 0.0 |
| NERICA-1 - SIKAMO | * | 0.46 | 0.0 |
| NERICA-2 - SIKAMO | * | 0.58 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6E Multiple Range Tests for SER by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | 1.16 | 0.0 |
| DIGANG - NERICA-1 | * | -15.61 | 0.0 |
| DIGANG - NERICA-2 | * | -3.34 | 0.0 |
| DIGANG - SIKAMO | * | -2.02 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -16.77 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -4.5 | 0.0 |
| JASMINE-85 - SIKAMO | * | -3.18 | 0.0 |
| NERICA-1 - NERICA-2 | * | 12.27 | 0.0 |
| NERICA-1 - SIKAMO | * | 13.59 | 0.0 |
| NERICA-2 - SIKAMO | * | 1.32 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6F Multiple Range Tests for ASP by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.35 | 0.0 |
| DIGANG - NERICA-1 | * | -2.84 | 0.0 |
| DIGANG - NERICA-2 | * | -2.78 | 0.0 |
| DIGANG - SIKAMO | * | -1.14 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -2.49 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -2.43 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.79 | 0.0 |
| NERICA-1 - NERICA-2 | * | 0.06 | 0.0 |
| NERICA-1 - SIKAMO | * | 1.7 | 0.0 |
| NERICA-2 - SIKAMO | * | 1.64 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6G Multiple Range Tests for ALA by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.76 | 0.0 |
| DIGANG - NERICA-1 | * | -3.81 | 0.0 |
| DIGANG - NERICA-2 | * | -3.68 | 0.0 |
| DIGANG - SIKAMO | * | -1.86 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -3.05 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -2.92 | 0.0 |
| JASMINE-85 - SIKAMO | * | -1.1 | 0.0 |
| NERICA-1 - NERICA-2 | * | 0.13 | 0.0 |
| NERICA-1 - SIKAMO | * | 1.95 | 0.0 |
| NERICA-2 - SIKAMO | * | 1.82 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6H Multiple Range Tests for TYR by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.43 | 0.0 |
| DIGANG - NERICA-1 | * | -1.86 | 0.0 |
| DIGANG - NERICA-2 | * | -1.63 | 0.0 |
| DIGANG - SIKAMO | * | -1.03 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -1.43 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -1.2 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.6 | 0.0 |
| NERICA-1 - NERICA-2 | * | 0.23 | 0.0 |
| NERICA-1 - SIKAMO | * | 0.83 | 0.0 |
| NERICA-2 - SIKAMO | * | 0.6 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6I Multiple Range Tests for PRO by RICE VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| JASMINE-85 - NERICA-1 | * | -0.59 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -0.76 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.16 | 0.0 |
| NERICA-1 - NERICA-2 | * | -0.17 | 0.0 |
| NERICA-1 - SIKAMO | * | 0.43 | 0.0 |
| NERICA-2 - SIKAMO | * | 0.6 | 0.0 |

* denotes a statistically significant difference.

**Appendix 6J Multiple Range Tests for ARG by VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| DIGANG - JASMINE-85 | * | -0.71 | 0.0 |
| DIGANG - NERICA-1 | * | -2.59 | 0.0 |
| DIGANG - NERICA-2 | * | -2.54 | 0.0 |
| DIGANG - SIKAMO | * | -1.27 | 0.0 |
| JASMINE-85 - NERICA-1 | * | -1.88 | 0.0 |
| JASMINE-85 - NERICA-2 | * | -1.83 | 0.0 |
| JASMINE-85 - SIKAMO | * | -0.56 | 0.0 |
| NERICA-1 - NERICA-2 | * | 0.05 | 0.0 |
| NERICA-1 - SIKAMO | * | 1.32 | 0.0 |
| NERICA-2 - SIKAMO | * | 1.27 | 0.0 |

* denotes a statistically significant difference.

## APPENDIX 7

## STATISTICAL TABLES FOR AMINO ACID

## ANALYSIS OF SOYBEAN VARIETIES

**Appendix 7A Multiple Range Tests for GLU N LYS by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 3.96 | 0.0 |
| ANIDASO - QUARSHIE | * | 0.54 | 0.0 |
| ANIDASO - SALINTUYA | * | 4.08 | 0.0 |
| JENGUMA - QUARSHIE | * | -3.42 | 0.0 |
| JENGUMA - SALINTUYA | * | 0.12 | 0.0 |
| QUARSHIE - SALINTUYA | * | 3.54 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7B Multiple Range Tests for HIS by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - QUARSHIE | * | -0.54 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.24 | 0.0 |
| QUARSHIE - SALINTUYA | * | 0.3 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7C Multiple Range Tests for THR by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | -0.36 | 0.0 |
| ANIDASO - QUARSHIE | * | -3.12 | 0.0 |
| ANIDASO - SALINTUYA | * | -4.44 | 0.0 |
| JENGUMA - QUARSHIE | * | -2.76 | 0.0 |
| JENGUMA - SALINTUYA | * | -4.08 | 0.0 |
| QUARSHIE - SALINTUYA | * | -1.32 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7D Multiple Range Tests for ILE by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 0.24 | 0.0 |
| ANIDASO - QUARSHIE | * | -0.78 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.66 | 0.0 |
| JENGUMA - QUARSHIE | * | -1.02 | 0.0 |
| JENGUMA - SALINTUYA | * | -0.9 | 0.0 |
| QUARSHIE - SALINTUYA | * | 0.12 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7E Multiple Range Tests for LEU by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 0.96 | 0.0 |
| ANIDASO - QUARSHIE | * | -0.84 | 0.0 |
| ANIDASO - SALINTUYA | * | 0.12 | 0.0 |
| JENGUMA - QUARSHIE | * | -1.8 | 0.0 |
| JENGUMA - SALINTUYA | * | -0.84 | 0.0 |
| QUARSHIE - SALINTUYA | * | 0.96 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7F Multiple Range Tests for PHE by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 0.78 | 0.0 |
| ANIDASO - QUARSHIE | * | -0.6 | 0.0 |
| ANIDASO - SALINTUYA | * | 0.12 | 0.0 |
| JENGUMA - QUARSHIE | * | -1.38 | 0.0 |
| JENGUMA - SALINTUYA | * | -0.66 | 0.0 |
| QUARSHIE - SALINTUYA | * | 0.72 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7G Multiple Range Tests for TRP by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| JENGUMA - QUARSHIE | * | 0.66 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7H Multiple Range Tests for VAL by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | -2.58 | 0.0 |
| ANIDASO - QUARSHIE | * | -0.36 | 0.0 |
| ANIDASO - SALINTUYA | * | -2.88 | 0.0 |
| JENGUMA - QUARSHIE | * | 2.22 | 0.0 |
| JENGUMA - SALINTUYA | * | -0.3 | 0.0 |
| QUARSHIE - SALINTUYA | * | -2.52 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7I Multiple Range Tests for GLY by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 1.08 | 0.0 |
| ANIDASO - QUARSHIE | * | -0.18 | 0.0 |
| ANIDASO - SALINTUYA | * | 1.5 | 0.0 |
| JENGUMA - QUARSHIE | * | -1.26 | 0.0 |
| JENGUMA - SALINTUYA | * | 0.42 | 0.0 |
| QUARSHIE - SALINTUYA | * | 1.68 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7J Multiple Range Tests for SER by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 3.48 | 0.0 |
| ANIDASO - QUARSHIE | * | 9.84 | 0.0 |
| ANIDASO - SALINTUYA | * | 7.62 | 0.0 |
| JENGUMA - QUARSHIE | * | 6.36 | 0.0 |
| JENGUMA - SALINTUYA | * | 4.14 | 0.0 |
| QUARSHIE - SALINTUYA | * | -2.22 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7K Multiple Range Tests for ASP by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | -0.78 | 0.0 |
| ANIDASO - QUARSHIE | * | -20.52 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.36 | 0.0 |
| JENGUMA - QUARSHIE | * | -19.74 | 0.0 |
| JENGUMA - SALINTUYA | * | 0.42 | 0.0 |
| QUARSHIE - SALINTUYA | * | 20.16 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7L Multiple Range Tests for ALA by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | -11.34 | 0.0 |
| ANIDASO - QUARSHIE | * | -5.16 | 0.0 |
| ANIDASO - SALINTUYA | * | -4.02 | 0.0 |
| JENGUMA - QUARSHIE | * | 6.18 | 0.0 |
| JENGUMA - SALINTUYA | * | 7.32 | 0.0 |
| QUARSHIE - SALINTUYA | * | 1.14 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7M Multiple Range Tests for TYR by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 0.18 | 0.0 |
| ANIDASO - QUARSHIE | * | -1.14 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.72 | 0.0 |
| JENGUMA - QUARSHIE | * | -1.32 | 0.0 |
| JENGUMA - SALINTUYA | * | -0.9 | 0.0 |
| QUARSHIE - SALINTUYA | * | 0.42 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7N Multiple Range Tests for PRO by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - QUARSHIE | * | 0.06 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.24 | 0.0 |
| QUARSHIE - SALINTUYA | * | -0.3 | 0.0 |

* denotes a statistically significant difference.

**Appendix 7O Multiple Range Tests for ARG by SOYBEAN VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| ANIDASO - JENGUMA | * | 1.38 | 0.0 |
| ANIDASO - QUARSHIE | * | 6.36 | 0.0 |
| ANIDASO - SALINTUYA | * | -0.42 | 0.0 |
| JENGUMA - QUARSHIE | * | 4.98 | 0.0 |
| JENGUMA - SALINTUYA | * | -1.8 | 0.0 |
| QUARSHIE - SALINTUYA | * | -6.78 | 0.0 |

* denotes a statistically significant difference.

## APPENDIX 8

## STATISTICAL TABLES FOR AMINO ACID

## ANALYSIS OF GROUNDNUT VARIETIES

**Appendix 8A Multiple Range Tests for GLU N LYS by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| F-MIX - SINKARZIE | * | -0.12 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8B Multiple Range Tests for HIS by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -2.78 | 0.0 |
| CHINESE - SINKARZIE | * | -1.98 | 0.0 |
| F-MIX - SINKARZIE | * | 0.8 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8C Multiple Range Tests for THR by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | 3.84 | 0.0 |
| CHINESE - SINKARZIE | * | -3.06 | 0.0 |
| F-MIX - SINKARZIE | * | -6.9 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8D Multiple Range Tests for ILE by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -2.22 | 0.0 |
| CHINESE - MANIPINTA | * | -4.68 | 0.0 |
| CHINESE - SINKARZIE | * | -2.04 | 0.0 |
| F-MIX - MANIPINTA | * | -2.46 | 0.0 |
| F-MIX - SINKARZIE | * | 0.18 | 0.0 |
| MANIPINTA - SINKARZIE | * | 2.64 | 0.0 |

**Appendix 8E Multiple Range Tests for LEU by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -3.54 | 0.0 |
| CHINESE - MANIPINTA | * | -9.84 | 0.0 |
| CHINESE - SINKARZIE | * | -3.84 | 0.0 |
| F-MIX - MANIPINTA | * | -6.3 | 0.0 |
| F-MIX - SINKARZIE | * | -0.3 | 0.0 |
| MANIPINTA - SINKARZIE | * | 6.0 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8F Multiple Range Tests for PHE by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -1.68 | 0.0 |
| CHINESE - MANIPINTA | * | -6.84 | 0.0 |
| CHINESE - SINKARZIE | * | -1.02 | 0.0 |
| F-MIX - MANIPINTA | * | -5.16 | 0.0 |
| F-MIX - SINKARZIE | * | 0.66 | 0.0 |
| MANIPINTA - SINKARZIE | * | 5.82 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8G Multiple Range Tests for VAL by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | 2.58 | 0.0 |
| CHINESE - MANIPINTA | * | -4.98 | 0.0 |
| CHINESE - SINKARZIE | * | 3.06 | 0.0 |
| F-MIX - MANIPINTA | * | -7.56 | 0.0 |
| F-MIX - SINKARZIE | * | 0.48 | 0.0 |
| MANIPINTA - SINKARZIE | * | 8.04 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8H Multiple Range Tests for GLY by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| F-MIX - MANIPINTA | * | -10.08 | 0.0 |
| F-MIX - SINKARZIE | * | -1.26 | 0.0 |
| MANIPINTA - SINKARZIE | * | 8.82 | 0.0 |

**Appendix 8I Multiple Range Tests for SER by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| F-MIX - SINKARZIE | * | -0.92 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8J Multiple Range Tests for ASP by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -3.24 | 0.0 |
| CHINESE - MANIPINTA | * | 7.64 | 0.0 |
| CHINESE - SINKARZIE | * | -5.28 | 0.0 |
| F-MIX - MANIPINTA | * | 10.88 | 0.0 |
| F-MIX - SINKARZIE | * | -2.04 | 0.0 |
| MANIPINTA - SINKARZIE | * | -12.92 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8K Multiple Range Tests for ALA by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -3.24 | 0.0 |
| CHINESE - SINKARZIE | * | -10.74 | 0.0 |
| F-MIX - SINKARZIE | * | -7.5 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8L Multiple Range Tests for TYR by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -1.56 | 0.0 |
| CHINESE - MANIPINTA | * | -5.88 | 0.0 |
| CHINESE - SINKARZIE | * | -2.82 | 0.0 |
| F-MIX - MANIPINTA | * | -4.32 | 0.0 |
| F-MIX - SINKARZIE | * | -1.26 | 0.0 |
| MANIPINTA - SINKARZIE | * | 3.06 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8M Multiple Range Tests for PRO by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -0.54 | 0.0 |
| CHINESE - MANIPINTA | * | -4.38 | 0.0 |
| CHINESE - SINKARZIE | * | -1.56 | 0.0 |
| F-MIX - MANIPINTA | * | -3.84 | 0.0 |
| F-MIX - SINKARZIE | * | -1.02 | 0.0 |
| MANIPINTA - SINKARZIE | * | 2.82 | 0.0 |

* denotes a statistically significant difference.

**Appendix 8N Multiple Range Tests for ARG by GROUNDNUT VARIETIES**

Method: 95.0 percent Tukey HSD

| *Contrast* | *Sig.* | *Difference* | *+/- Limits* |
|---|---|---|---|
| CHINESE - F-MIX | * | -5.7 | 0.0 |
| CHINESE - MANIPINTA | * | 11.46 | 0.0 |
| CHINESE - SINKARZIE | * | -6.6 | 0.0 |
| F-MIX - MANIPINTA | * | 17.16 | 0.0 |
| F-MIX - SINKARZIE | * | -0.9 | 0.0 |
| MANIPINTA - SINKARZIE | * | -18.06 | 0.0 |

* denotes a statistically significant difference.