Article title: Evaluation of Soybean Varieties for Oxalate, Phytate and Polyunsaturated Fatty Acids Content

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Soybean (*Glycine max*) is a member of the *Leguminosae* plants that form root nodules housing nitrogen fixing bacteria (*Rhizobia*) in a symbiotic relationship; an event that is necessary for life on this planet earth. Soybean is a legume that grows in tropical, sub-tropical and temperate climate. Approximately half of the world soybean production occurs in the developing world and the other half in the developed world (IITA, 2002).

Soybean is an important source of inexpensive and high quality protein and oil (Khalid. *et al*, 2008). The cheap price and stable supply are favorable factors for legumes to emerge as one of the single food crop with nutritional content almost equal to that of animal product. It contains most of the amino acids with the exception of sulfur containing amino acids and is an essential source of fiber. Messina (2004) reported that soybean was relatively high in iron, phosphorus, copper, magnesium and manganese. Soybeans contain very little starch and about half of the total polysaccharide is composed of oligosaccharides.

However, the nutritional value of soybean is lower than expected due to the presence of various non-nutritional compounds which deter or inhibit the uptake of

nutrients and produce adverse physiological and biochemical effects in humans and animals. Anti nutritional factors may be defined as those substances that are generated in natural feed stuffs by the normal metabolism of the species and by different mechanisms which exert effects contrary to optimum nutrition (Soetan and Oyewole, 2009).

Thus, antinutrients are the way nature protects plants so that they can live long enough to effectively reproduce. They function as the immune system of plants, offering protection from the radiation of the sun, foraging by animals and from invasion by bacteria, viruses or fungi (Barbara, 2009). According to Desphande (2002), antinutrients may occur naturally in plants as secondary metabolites protecting plants from viral and fungal attack analogous to the immune system of animals. Antinutrients may also be produced in large amounts as a result of adverse environmental conditions.

The most important antinutrients in soybeans include: - phytates, saponins, protease inhibitors, lectins, tannins and oligosaccharides. Soybean oil is one of the commonly consumed oils and its production in 2003 was estimated to be 184.49 million metric tons out of 317.89 million metric tons total for vegetable oil crops, making soybean the world's largest oil crop and rivaled only by palm oil. Soybean oil of typical composition performs well as salad oil, but is usually hydrogenated for use as margarine stock or frying oil (Hammond *et al*, 2005).

This oil contains a high content of unsaturated fatty acids such as linoleic acids, α -linolenic acids (omega 3) , and arachidonic acids (omega 6), oleic acid (omega 9) that is suitable for human health, and saturated acids such as stearic acids and palmitic acids. Also, soybean oil has β -carotene and tocopherols (Nikolic, *et al.*, 2009). Soybean oil stability to oxidation is limited by its content of linolenic acids.

1.2 Statement of Problem

There are diverse antinutritional factors in soybeans that can be toxic to the body and negatively affect bioavailability of the nutrients in food. The amount of the antinutritional factors present in soybeans varies across genotypes. Soybeans being a major oil crop are known to contain poly unsaturated fatty acids that are of nutritional quality. This has also been reported to vary across genotypes. Information on the quantity of these factors is important for plant breeders' decision making during selection of genotypes as donor parents in breeding programs and for large scale soybean production.

1.3 Objectives of the study

The objectives of the study were to determine the:

- Oxalate content present in the soybean samples.
- Percentage (%) phytate composition present in the samples.

- % composition of Poly unsaturated fatty acids.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of Soybean

Soybean can be traced back to china as early as the 11th century BC. According to Chinese tradition, people of this region were nomadic food gathering people and became sedentary food producing agriculturist after Shen Nung the father of Agriculture and Medicine” taught his subjects how to cultivate soybean (Williams and Akiko, 2011).

The emergence of soybean as a domesticated plant occurred during the Chou dynasty (1027-221BC). From about the first century A.D. to the Age of Discovery (15-16th century), soybeans were introduced into several countries and land races were developed in Japan, Indonesia, Philippines, Vietnam, Thailand, Malaysia, Burma, Nepal and north India. These regions comprise the secondary gene center. The movement of the soybean throughout this period was due to the establishment of sea and land trade routes and the rapid acceptance of the plant as a staple food by other cultures like Indonesians.

2.2 Soybean Classification

Domain- Eukarya

Kingdom-Plantae

Phylum- Magnoliopsida

Order- Fabales

Family- Fabaceae

Genus- Glycine

Specie- Max

(www.bioweb.com).

2.3 History of Soybean Cultivation

The earliest known cultivation of soybean in Africa was in 1896 when they were grown in Algeria by a French agronomist Trabut at a government botanical station. Yield of Soybean as forage crop reached 2600kg/ha (William and Akiko, 2011). The next record of cultivation of soybeans in Africa dates from 1903, when they were grown in South Africa at Cedara in Natal and in Transval. The maximum yield that year was 1031 kg/ha (William and Akiko, 2011). It was further reported that soybean was first introduced in Nigeria in 1908 by the British

looking for new sources of supply from their colonies. Attempts to grow the crops at Moor plantation Ibadan at that time failed. In 1928 the soybeans was successfully introduced to Samaru, Zaria where it spread to other parts of Northern Nigeria. To meet the high European demand for oil seeds during World War II, average expanded rapidly and in 1947 the first exports of 9 tons was recorded. Yields of the popular Malayan variety reached 1100kg/ha. The soybean soon became a cash crop in the Tiv division and Benue valley of Benue Province which thereafter became the leading center.

2.4 Soybean Utilization

Food legumes are those species of the legumes family that are consumed by human beings or domestic animals commonly as dry seeds (Tiwari, *et al.*, 2011). Soybean being an oilseed is grown basically for its protein, oil content and as protein source (Pittaway, 2006). Soybean is used as food and also as multipurpose plant, serving for animal forage as well as soil improvement due to its ability to fix atmospheric nitrogen (Fabales, 2012).

Soybeans have a variety of uses some of which are explained below.

- **Food for humans**

Nearly all soybeans are processed for their oil. Soy processors take the raw soybeans and separate the oil from the meal. As a versatile source of food, soybean is hard to beat. Although they can be eaten after been boiled or roasted. Most soybean are changed into variety of foods such as

- **Soymilk, soy beverages**

Soybean soaked, ground fine and strained, produce fluid called soybean milk which is a good substitute for cow's milk. Soybeans milk is also sold as powder which must be mixed with water (Liu, 2004).

- **Tofu and Tofu products**

Tofu also known as soybean curd is a soft cheese like food made by cuddling fresh hot soymilk with a coagulant. Tofu is a bland product that easily absorbs the flavor of other ingredients with which it is cooked. Tofu is rich in high quality protein, B- vitamins and low in sodium. Fresh Tofu is dense and solid and can be cubed and served in soups, stir fried or grilled. These large soybeans are harvested when the beans are still green and sweet tasting and can be served as a snack or main vegetable dish, after boiling in slightly salted water for 15-20 minutes. They are high in protein and fiber and contain cholesterol. This is a type of delicacy in Asian countries (Liu, 2004).

- **Infant formulas**, soy based

Soybean infant formulas are similar to other infant formulas except that a soy protein isolate powder is used as a base instead of cow's milk. Carbohydrate and fats are added to achieve a fluid similar to breast milk (Dwevedi and Kayastha, 2011).

- **Lecithin**

Extracted from soybean oil, lecithin is used in food manufacturing as an emulsifier in products high in fats and oils. It promotes stabilization, anti-oxidation and spattering control (Dwevedi and Kayastha, 2011).

- **Meat alternatives** (meat analogues)

Meat alternatives made from soybeans contain soy protein or tofu and other ingredients mixed together to stimulate various kinds of meat. These meat alternatives are sold as frozen, canned or dried. Generally, they are lower in fat, excellent sources of protein, iron and B vitamins (Dwevedi and Kayastha, 2011).

- **Natto**

Natto is made of fermented, cooked whole soybeans. Because fermentation process breaks down the beans complex protein, natto is more easily digested than whole soybeans. It has a sticky, viscous coating with a cheesy texture. It is a

traditional diet in Asian countries that is served as a topping for rice (Dwevedi and Kayastha, 2011).

- **Soybean oil**

It is produced from soybeans by mechanical or solvent extraction. Crude soybean oil is further filtered to produce salad and cooking oils. In the US, most of what is sold as “vegetable oil” in the stores is really pure soybean oil. In other countries, it is often labeled as soybean oil, or soya oil. It is the primary oil used in the food processing industry and is found in vegetable oil shortenings and margarine. Soybean oil is high in polyunsaturated fats, low in saturated fats, and a good source of linoleic and linolenic acids, the omega-3 and omega-6 fatty acids also found in fish oils (Dwevedi and Kayastha, 2011).

- **Feed for animals**

The high protein fiber (which remains after processing and removal of oil) is prepared into animal feed for cattle, and pork, poultry, other farm animals and pets. The poultry and swine industries are major consumers of soybean meal. Over half of the soybeans processed for livestock feed is fed to poultry, about one-quarter to swine and the remaining, is used for beef cattle, dairy cattle and pet food. Soy protein is increasingly found in fish food, both for the home aquarium and for the fish grown for eating. Due to scarcity and increased cost of fish meal, producers

have switched to high protein soymeal for a variety of marine species (Dwevedi and kayastha, 2011).

2.5 Soybean in Biotechnology

The genetically modified (GM) foods are most commonly used to refer to crop plants created for human or animal consumption using the latest molecular biology techniques. These plants have been modified in the laboratory to enhance desired traits such as increased resistance to herbicides and pest, cold, drought and salinity tolerance, improving nutritional content, in pharmaceuticals and phytoremediation. The enhancement of desired traits can be traditionally undertaken through breeding but it is very time consuming and are often not very accurate. Soybeans and corn are the top two most widely grown GM crops followed by cotton, rapeseed (or canola) and potatoes.

Currently, in the United States GM soybeans have reached the marketplace to be use in animal feed. The major question that aroused about the effect of GM soybeans on the animals as reviewed from the results of 23 research experiments conducted over the past few years have revealed that there was negligible effects. In one of the study, separate groups of chickens, dairy cows, beef cattle and sheep were fed with GM as well as traditional soybean as a portion of their diet. Each experiment independently confirmed that there is no significant difference in the

ability of animals to digest the GM crops and no significant difference in the weight gain, milk production, milk composition, and overall health of the animals when compared to animals fed with traditional crops. It was also concluded that human consumption of milk, meat and eggs produced from animals fed GM crops would be as safe as products derived from animals fed conventional crops (www.biotechknowledge.monsanto.com). The soybeans used in the studies were produced by inserting a gene that causes the plant to be tolerant to the environmentally friendly herbicide glyphosate. This tolerance to glyphosate allows farmers to spray and kill weeds without killing the soybeans. In other studies the nutritional value of GM soybeans were compared with traditional ones. These studies showed significantly negligible difference in the nutritional composition of the beans (Herdt, 2006).

GM foods have the potential to solve many of the world's hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides and herbicides. Yet there are many challenges ahead for governments, especially in the areas of safety testing, regulation, international policy and food labeling. Several groups are of the opinion that genetic engineering is the inevitable wave of the future and that we cannot afford to ignore a technology that has such enormous potential benefits. However, caution must be taken to avoid causing unintended harm to human health and the

environment as a result of our enthusiasm for this powerful technology (Bonny *et al.*, 2008).

- **Source of various enzymes having industrial significance**

Soybean has enormous economic significance due to its role in oil industries as well in bio-diesel production. Leguminous plants are source of various industrial enzymes, particularly found during seed imbibition and germination as well as those involved in nitrogen metabolism (Dey, 1984). Recently, the approach is emphasizing to use soybean which is a legume for extraction of enzymes at industrial scale helpful for its economic significance. Most importantly, extract prepared from soybean used for enzyme isolation while leaving behind the residues is useful for various purposes viz. animal fodder, oil extraction, bio-diesel production etc. For various industrial applications, enzymes so extracted from leguminous seeds are immobilized onto suitable matrices leading to improvement in physico-chemical properties (Das, *et al.*, 1997; Kayastha & Srivastava, 2001; Tripathi, *et al.*, 2007; Dwevedi, *et al.*, 2009; Kumar, *et al.*, 2009).

Implementation of soybean at industrial scale as source of various enzymes will make it a multifaceted crop with enormous economic capabilities.

2.6 Soybean in treatment of various diseases

- **Lowers blood pressure and cholesterol levels; helpful for treatment of heart related diseases**

Effect of soy protein and soy isoflavones on blood pressure and cholesterol levels were studied in 61 middle-aged men, at high risk of developing coronary heart disease. For five weeks half the men consumed diets containing at least 20 g of soy protein and 80 mg of soy isoflavones per day. The effects on their blood pressure, cholesterol levels, and urinary excretion of isoflavones were measured, and then compared to those of the other half of the men who were given a placebo diet containing olive oil. The men consuming soy in their diet were found to have significant reductions in both diastolic and systolic blood pressure. Not only was their total blood cholesterol significantly lower, but their HDL cholesterol level significantly increased (Candy, 1996).

Soy protein has been shown in some studies to be able to lower total cholesterol levels by 30% and lower LDL levels by as much as 35-40 % (Dwevedi and Kayastha, 2011). This is important because high levels of cholesterol, especially LDL cholesterol, tend to become deposited into the walls of blood vessels, forming hard plaques. If these plaques grow too large or break, they can cause a heart attack or stroke. Some studies have even shown that soy protein may be able to raise

HDL Cholesterol levels. HDL cholesterol travels through the body collecting the cholesterol that has been deposited in the arteries, so it can be taken away and removed by the liver. One of the main goals of atherosclerosis treatment and prevention, therefore, is to lower LDL cholesterol levels while raising HDL levels; and soy is one food that may be able to do both at once (Beretz, *et al.*, 1988).

In addition, soybeans also contain very good amounts of fiber. When eaten, the fiber in soybeans binds to fats and cholesterol in food, thus less is absorbed. Soybeans fiber binds to bile salts and removes them from the body. Since the liver gets rid of cholesterol by transforming it into bile salts, their removal by fiber forces the liver to use more cholesterol to form more bile salts, leads to lowering of overall cholesterol levels (Beretz, *et al.*, 1988).

A recently discovered bioactive peptide found in soybeans, *lunasin* is likely to be a key factor in soy's cholesterol lowering actions. A study in which *lunasin* was added to human-liver cells demonstrated the compound's potential to significantly lower cholesterol by inhibiting the expression of the gene responsible for body's internal production of cholesterol and increasing the expression of a gene that reduces levels of LDL cholesterol in the blood. When added to a cell culture of HepG2 liver cells, lunasin slashed HMG-CoA reductase expression by 50%. HMG-CoA is the gene that directs production of HMG-CoA reductase, the enzyme responsible for cholesterol biosynthesis. At the same time, *lunasin* increased by

60% the expression of the gene which produces LDL cholesterol receptors that help clear plasma cholesterol (Anthony, 2000).

- **Increased nitric oxide production**

Soy protein protects against atherosclerosis by increasing blood levels of nitric oxide which helps in blood vessel dilation, inhibit oxidative damage of cholesterol and the adhesion of white cells to the vascular wall. It was found that when laboratory animal which are apolipoprotein-E deficient (a condition leading to development of atherosclerosis) are fed with soy protein, there is a significant increase in blood level of nitric oxide. Intensive study has concluded that soy protein has led to increased blood levels of L-arginine (the amino acid that the body uses to produce nitric oxide) and nitric oxide metabolites. Thus, soy protein rich diet helps in protection against atherosclerosis (Henrotin, *et al.*, 2003).

- **Stabilize blood sugar at healthy levels, lowers diabetes risk and protect against diabetes-related kidney and heart disease**

Soybeans can be very beneficial for diabetics, particularly type 2 diabetes. The protein in soybeans, and also in other legumes, is excellent for diabetic patients. The protein and fiber in soybeans prevent high blood sugar levels and help in keeping blood sugar levels under control. Soybeans have been shown to lower high triglyceride levels. Triglyceride levels tend to be high in diabetic patients and high

triglyceride levels is another factor of diabetics' increased risk for heart disease. A study was conducted on 64,227 middle-aged Chinese women with no previous history of diabetes, cardiovascular disease or cancer for 5 years. It was revealed an inverse association between eating legumes and incidence of type-2 diabetes. A high intake of all legumes resulted in a 38% reduction in risk, while a high intake of soybeans, specifically, was associated with a 47% risk reduction. Soy yogurt plays an important role in controlling high blood pressure in type-2 diabetic patients. High blood pressure is one of the problem for which diabetics are at increased risk. Soy yogurt contains angiotensin-I converting enzyme (ACE-I), which plays important role in the constriction of blood vessels and is a target of blood pressure-lowering medications (ACE-inhibitors) (Villegas, *et al.*, 2008).

A small clinical trial conducted on type 2 diabetes patients with nephropathy (diabetes related kidney damage) suggested that soy protein can help diabetics' hearts and kidneys from damage caused by the disease. The study was conducted on 14 type 2 diabetes male and female patients receiving medical care at an educational University hospital and private kidney disease clinic. For the first seven weeks, patients followed a diet (0.8 g/kg of protein, based on 70 % animal and 30 % vegetable protein) typically recommended to control nephropathy. After a washout period, they were re-admitted for another 7-week cycle consuming a diet containing 35 % soy protein and 30% vegetable protein. Following the soy diet, all

patients experienced significant reductions in total cholesterol, triglyceride and LDL-cholesterol, while levels of beneficial HDL cholesterol remained stable and renal function improved. Specifically, the patients' urinary urea nitrogen (a protein component that is not normally leaked into the urine) and proteinuria (protein in the urine, another indicator that the kidneys are beginning to fail) were both much lower on the soy protein diet (Teixeira. *et al.*, 2004).

- **Minifies Chronic Inflammation**

Egg yolks are the richest source of choline, followed by soybeans. Intake of diet rich in choline (~300 mg per day) containing food leads to reduction of inflammatory markers like C-reactive protein, interleukin-6, tumor necrosis factor alpha by ~20 %. Each of these markers of chronic inflammation has been linked to a wide range of conditions including heart disease, osteoporosis, cognitive decline and Alzheimer's, and type-2 diabetes. It has also been found that choline in association with betaine (found naturally in vegetables such as beets and spinach) work together in cellular process of methylation, which is not only responsible for the removal of homocysteine, but is involved in turning off the promoter regions of genes involved in inflammation. Recommended daily intakes of choline is 550 mg per day for men and 425 mg a day for women (www.veganhealth.org).

- **Protection against cancer**

A sphingolipid called soy glucosylceramide found in soybeans reduces colon cancer risk. In a study, laboratory animals exposed to carcinogen were given a diet containing 1% soy glucosylceramide, the proliferation of colon cancer cells were dropped by 56%. When the same diet was given to a strain of animals bred to spontaneously develop colon cancer, the rate at which tumors formed was dropped by 37%. Soy sphingolipids provided this protection by affecting the expression of 96 different genes in the cells that form the lining of the intestines. Soy's effects on these genes resulted in a decrease in the production of two factors associated with cancer initiation and promotion: hypoxia-induced factor 1 alpha and transcription factor 4. Other plants also contain sphingolipids but soy contains relatively high amounts of glucosylceramide.

A 9-year Japanese study involving 43,509 men ranging in age from 45 to 74 years found that eating soy food lead to significant lowering of localized prostate cancer risk. Among the men who were older than 60, the protective effect was strongest. It has been suggested that isoflavone found in soybeans protectively alter men's metabolism of estrogen (men do produce some estrogen! the prostate is the primary locus of estrogen production.). Soy's effect of increasing the amount of 2-hydroxy estrogen produced in relation to the amount of 16-hydroxyestrone made in prostate helps in prevention of prostate cancer. Earlier research linking soy to

protection against prostate cancer has suggested that soy's isoflavones reduce testosterone levels and inhibits 5-alpha-reductase (converts testosterone to its most potent form, DHT) which is linked to prostate growth and male baldness. A recent study of human prostate cancer cells demonstrated some of the mechanisms behind genistein's antiprostate cancer effects. Genistein blocks cell cycling and prevent the proliferation of cancerous cells in the prostate by inducing *apoptosis* of abnormal cells. Genistein, another isoflavone found in soybeans called *daidzen* has also demonstrated protective action against prostate cancer.

Soy's isoflavones also contribute to protective effect against breast cancer in women. The women, who ranged in age from 40 to 59 years, filled out a dietary questionnaire that included questions about soy consumption and were followed for 10 years. Whether prior postmenopausal, women who reported eating three or more cups of miso soup per day had a 40% lower risk of developing breast cancer compared to women who reported consuming less than one cup per day. Women with the highest intakes of isoflavones compounds in soy foods that can bind to estrogen receptors in the body and block out human estrogen, thus lessening its effects had a 54% lower risk of developing breast cancer compared to those whose intake of isoflavones was lowest. Soy foods may also reduce risk of endometrial cancer (cancer affecting the lining of the uterus). Eating soy foods is one of the reason due to which Asian women have the lowest incidence of endometrial cancer

in the world. The study included over 800 women (aged 30- 69 years) with endometrial cancer, and a disease-free, matched control group of over 800 women. When the data was evaluated, a significant inverse association was found between frequency of eating soy foods and endometrial cancer risk. Moreover, minimally processed soy foods are rich in dietary fiber, which has been shown to lower estrogen levels (Arjmandi.*et al*, 1998; Tong *et al.*, 1999; Miyazawa. *et al*, 1999; Zhou. *et al*, 1999).

- **Leads to healthy transition through menopause and reduction in various symptoms during post-menopause in women**

It has been found that consuming isoflavone-containing soy foods significantly inhibits bone loss and stimulates bone formation in menopausal women. Women whose daily diets provided soy isoflavones had much lower amounts of deoxypyridinoline (Dpyr, a bone resorption marker) in their urine, and much higher amounts of bone-specific alkaline phosphatase (BAP, a bone formation marker) in their blood (Welty. *et al*, 2007).

Women's risk for cardiovascular disease (CVD) increases after menopause, in part because levels of risk factors including homocysteine and excess body iron tend to rise. In this study, researchers looked at the effect of soy protein, specifically soy's isoflavones and phytate, on CVD risk factors in 55 postmenopausal women. To do

so, they randomly assigned the women to 1 of 4 soy protein (40 g per day) groups: soy containing its native phytate and native isoflavones, native phytate but low isoflavone, low phytate and native isoflavone, or low phytate and low isoflavone. After just 6 weeks, women in the groups given soy protein with its native phytate had significant reductions in homocysteine and excess iron concentrations. Soy protein with native isoflavones had no effect. Most interesting about this study is the fact that the phytate in soy, a compound which, because of its mineral-binding effects, has sometimes been considered problematic, that is responsible for some of the CVD-protective effects soy offers postmenopausal women (Kritz-Silverstein and Goodman-Gruen, 2002).

Eating soy nuts also resulted in significant improvements in the women's scores on the menopausal symptom quality of life questionnaire: a 19% average decrease in vasomotor symptoms score, 12.9% reduction in psychosocial symptoms score, 9.7% decrease in physical symptoms score, and a 17.7% reduction in sexual symptoms score (Welty *et al.*, 2007).

2.7 Soybean antinutrients

Soybean is a plant of the family *Fabaceae* (*Leguminosae*) or a fruit of this specific plant, characterized by seeds borne on pods (Megat, *et al.*, 2011) and often edible, though sometimes quite poisonous (Mazur, *et al.*, 1998).

Generally, despite the numerous advantages, soybeans have certain deficiency of sulfur amino acids, poor digestibility and the presence of antinutritional factors. There is a wide distribution of biologically active compounds throughout the plant kingdom, particularly in plants such as soybean used as animals feed stuff and in human nutrition (Igile, 1996). The knowledge that antinutrients elicit both toxic and advantageous biological responses has given rise to several investigations in recent times as to their possible physiological implications in diverse biological systems (Soetan and Oyewole, 2009). In order to survive during evolution, plants have developed defenses against herbivorous animals, microorganisms and viruses. The production of secondary metabolites (including lectins and toxic peptides) is of ultimate importance as a defense strategy in this context (Haborne, 1993 and Wink, 1992). Some of these chemicals have been shown to be biologically active (Zenk, 1991). They include saponins, tannins, flavonoids, alkaloids, trypsin (protease) inhibitors, oxalates, phytates, haemagglutinins (lecthins), cyanogenic glycosides, coumarins and gossypol (Kumar, 1992). In some cases antinutrients are simply toxic and cause undesirable physiological effects such as flatulence. On the other hand it has been discovered

that some antinutrients may have beneficial effects when ingested in small quantities and can even help in the prevention of certain illnesses such as cancer and coronary disease. As a result, they are now called non nutritional compounds, since they have no direct nutritional value but are not always harmful (Musquiz, 2004). The antinutritional factors may be classified on the basis of their effects on the nutritional value of feed stuffs, and on the biological response to them in the animal. Huisman and Tolman (2001) divided the antinutritional factors into the following classes:

- Factors with a depressive effect on protein digestion and on the utilization of protein, such as protein inhibitors, tannins, saponins and lectins ;
- Factors which affect the utilization of minerals which includes ; phytates, gossypol, oxalates and glucosinolates;
- Factors that stimulates immune system and may cause a damaging hypersensitivity reactions, such as antigenic proteins;
- Factors with a deleterious effect on the digestion of carbohydrates, such as amylase inhibitors, phenolic compounds and flatulence factors;
- Miscellaneous substances such as mycotoxins, mimosine, cyanogen, nitrates, alkaloids, photosynthesizing agents, phytoestrogens and saponins.

Although these limitations are not far from control as there exist recommended manipulation for their optimization.

2.7.1 Oxalic acid

Oxalic acid (ethanedioic acid, $\text{H}_2\text{C}_2\text{O}_4$) is a strongly oxidized and corrosive compound with good chelating activity, synthesized by a broad range of animals, plants and microorganisms (Stewart, *et al*, 2004). Oxalic acid and its salts are extensively spread in numerous plant tissues as the end products of metabolism. Just like other legumes, soybean contains oxalate. Oxalic acid occurs in two forms: soluble and insoluble oxalates. Oxalate usually form soluble salt with sodium (Na^+), potassium (K^+) and ammonium (NH_4^+) ions, and insoluble oxalate forms with calcium (Ca^{2+}), magnesium (Mg^{2+}) and iron (Fe^{3+}) ions (Holloway, *et al.*, 1989; Savage, *et al.*, 2000).

The accumulated oxalates in plants are in a range of 3-15 % (w/w) of their dry weight (Franceschi and Nakata, 2005). The physiological role of oxalate in plants is not precisely known, but it has been suggested that it is involved in seed germination, calcium storage and regulation, ion balance (Na^+ and K^+), heavy metal detoxification, structural strength, and insect repulsion (Libert and Franceschi, 1987; Franceschi and Nakata, 2005).

Oxalic acid content in foodstuffs has long been a concern in human diets, due to the negative health effects connected to a high intake of oxalic acid. Incidences of kidney stones, hypocalcaemia and hyposideremia (low plasma levels of calcium and iron) that correspond strongly with the intake of oxalic acid that perform as an absorption inhibitor are common (Palaniswamy, *et al.*, 2002). High oxalate content in urine and blood causes several diseases such as hyperoxaluria and vitamin deficiencies (Jiang, *et al.*, 1996). Small doses of oxalate in the body may result in pain, headaches, and twitching in muscles and cramps. Larger doses can result in a drop in blood pressure, weak, irregular heartbeat, and signs of heart failure. Large doses of oxalate may rapidly put a person in a shock-like state, causing convulsions (because of low plasma calcium), coma, and even death.

Consumption of foods high in oxalic acid in the long term can be troublesome. Healthy persons can securely consume such foods moderately, but those with gout, rheumatoid arthritis, kidney disorders, or certain forms of chronic vulvar pain (vulvodynia) are normally advised to stay away from foods high in oxalates or oxalic acid (Roy, *et al.*, 2010).

Despite the potential dire health and life-impacting nutritional outcome of oxalate consumptions associated with soy beans, there is insufficient information on oxalate contents in soy beans and other legumes usually consumed

by human beings. Plant food such as spinach and rhubarb and others that contain high oxalate have been well studied (Massey, *et al.*, 2001).

2.7.2 Phytate

Phytic acid (myo-Inositol hexakisphosphate or 1, 2, 3, 4, 5, 6-hexakis dihydrogen phosphate myo-Inositol), also abbreviated as InsP6 or IP6, is the main form of storage of phosphorus and inositol in seeds of cereals, legumes and oilseeds. However for humans and monogastric animals phosphorus is not available in that form, because these are not provided with sufficient activity of endogenous phosphatases (phytases) that are capable of releasing the phosphate group from phytic acid or inositol phosphates (Holm, *et al.*, 2002). This molecule is formed from the esterification of phosphate groups to each of the six hydroxyl groups in a molecule of myo-Inositol (Figure 1). Usually, it represents 65 to 85% of total phosphorus in seeds while forming insoluble salts with mono and divalent cat ions. By releasing H^+ ions from the phosphate groups, allows the molecule to interact with the ions Mn^{2+} , Fe^{2+} , Zn^{2+} and K^+ to produce the corresponding salts, which are known as phytates.

Phytates and phytins usually bind to proteins in the protein bodies; the latter are membrane- limited structures where storage proteins are deposited. Salts of phytic acid are accumulated in seeds during the maturation period and are

distributed uniformly in the cotyledons and embryonic axis in legumes (Reddy, 1981)

Figure 1.A) Chemical structure of myo-Inositol, B) Phytic acid structure (P) = H_2PO_4 (Raboy, 1998).

In soybean, phytic acid is uniformly distributed in the cotyledons, in the same way as in most legumes, probably as a soluble potassium phytate, which constitutes approximately 1.5 % of the total weight of the cotyledon. One gram of soybeans contains about 9.2-16.7 mg of phytate, which represents 57 % of organic phosphorus and 70 % of total phosphorus (Cheryan and Rackis, 1980).

Phytic acid is synthesized from 1D-myo-Inositol 3-phosphate (Ins3P1); in turn, the latter is formed from D-glucose-6-phosphate by action of synthase Ins3P1, and from myo-Inositol by action of myo-Inositol kinase; this reaction represents the first step in the metabolism of inositol and in the phytic acid biosynthesis. Subsequently, the phosphatidylinositol kinases catalyze the gradual

phosphorylation of Ins3P1 to produce myo-Inositol di-, tri-, tetra-, penta and hexaphosphate (Figure 2) (Loewus and murphy, 2000; Cosgrove and Irving, 1980; Honke *et al.*, 1998).

During germination, phosphorus and cat ions are released from phytates by the increased activity of an enzyme called phytase. They become available for use during the seedling growth. The enzyme phytase is capable of sequentially hydrolyzing phytic acid to myo Inositol, which produces intermediate products with a lower number of phosphate ester groups (IP5, IP4, IP3, and possibly di- and mono- phosphate inositol) and inorganic phosphate (Irving, 1980; Nayini and Markakis, 1986).

Figure 2.Biosynthesis of phytic acid (Loewus, 2000).

A clear role of phytic acid in the seed tissues metabolism is the storage and recovery of phosphorus, minerals, and myo-Inositol during germination and growth (Raboy, 2003). Another physiological functions of phytic acid in plants, is the inhibition of the metabolism, since, by binding to multivalent cations required for cellular processes, the metabolism is slower, so it could be a latency-inducing molecule. Furthermore, the antioxidant capacity of phytic acid increases the time of seed latency, as it prevents lipid peroxidation (Cosgrove and Irving, 1980, and Graf *et al*, 1987).

As well, phytates and also less-phosphorylated forms of phytic acid regulate diverse cellular functions such as DNA repair, chromatin remodelling, endocytosis, nuclear export of mRNA, and is an important hormonal marker for the development of seedlings and seeds (Laussmann *et al*, 2002).

Less-phosphorylated molecules of myo-Inositol are present in free form in nature, in small amounts, as transient intermediates in biochemical reactions.

The mono-bi-, tri- myo-Inositol Phosphates are important components of a group of phospholipids, known as phosphoinositides, which are present in any plant and

animal

tissues.

Figure 3. Pathways in plant biology that utilizes myo-Inositol (Raboy, 2009).

2.7.2.1 Bioavailability of minerals

Most studies on the interaction between phytic acid/inositol phosphates and minerals reveal the existence of an inverse relationship between the absorption of these micronutrients and Inositol phosphates, although there are substantial differences in individual behavior of each mineral element (Cheryan and Rackis, 1980).

The interaction of phytic acid with minerals and other nutrients is pH-dependent (Reddy and Sathe, 2002), since the degree of protonation of the phosphate groups is a function of pH (Nolan *et al*, 1989). The molecule works in a wide region of pH as a highly negatively-charged ion, so its presence in the diet has an adverse impact on the bioavailability of mineral monovalent, divalent and trivalent ions, such as Zn^{2+} , $\text{Fe}^{3+} / \text{Fe}^{3+}$, Ca^{2+} , Mg^{2+} , Mn^{2+} and Cu^{2+} (Fredland, *et al*, 2006); these complexes are more soluble at low or acid pH and insoluble at high or basic pH (Thompson, 1987).

2.7.2.2 Bioavailability of proteins

At low pH, below the isoelectric point of proteins, phytic acid phosphate esters bind to the cationic group of basic amino acids, for example, arginine, histidine and lysine, may form InsP-protein complexes.

At a pH above the isoelectric point of proteins, since the charge of proteins as well as that of the phytic acid is negative, the interaction would be impossible, however, interaction occurs through the formation of complexes with divalent such as Ca^{2+} or Mg^{2+} . This binding takes place via the formation of ionized carboxyl groups and the deprotonated imidazole group of histidine, which requires a minimum concentration of these cat ions to maintain these complexes.

At this pH, some binary complexes may exist because lysyl and arginyl residues of the proteins are still positively charged. At high pH the interaction between proteins and phytic acid decreases, arginyl and lysyl groups lose their charge, and therefore its ability to form binary complexes (Thompson, 1991); as well, they may form complexes such as protein-InsP and protein-mineral-InsP, which reduce their bioavailability. Such complexes may affect the protein structure, which may decrease the enzyme activity, function, solubility, absorption and protein digestibility (Cheryan and Rackis, 1980). Particularly, the ability to inhibit proteolytic (pepsin, trypsin, chymotrypsin), amylolytic (amylase) and lipolytic (lipase) enzymes, is responsible of their anti-nutritional properties. This inhibition may be due to the nonspecific nature of InsP-protein interactions and the chelation of calcium ions, which are essential for the activity of trypsin and α -amylase (Cheryan and Rackis, 1980). Furthermore, phytic acid can also bind to starch, either directly via hydrogen bonds or indirectly through the proteins to which it is

associated

(Thompson,

1998).

Figure 4: Inositol phosphate interaction with minerals, protein and starch
(Thompson, 1987)

2.8 Polyunsaturated Fatty Acids

Soybean yields about 18.5% oil in weight (Soyatech, 2008), a characteristic that makes it an important source of vegetable oil. The majority of soybean oil production is used by food processors and food service operators as an ingredient for baked and fried food products, or it is packaged for sale as cooking oil (Soyatech, 2008). The importance of soybean oil in human nutrition can be expressed in numbers; it accounts for about 50% of all the vegetable oil and for about 30% of all oils and fats produced around the world (USDA, 2010).

As the soybean oil is primarily used for human nutrition, constituting an important fraction of the lipids present in the diet of the majority of the population, it raises great economic and scientific interests. It contains an impressive amount of PUFAs. Typically, it contains about 60% polyunsaturated fatty acids (PUFAs), 25% monounsaturated fatty acids (MUFAs) and 15% saturated fatty acids (SFAs). The high content of PUFAs in the soybean oil raises some questions which are the basis of the following discussion.

Lipids are not simply a source of energy in human nutrition as they do exert other important functions. They compose biological membranes, serve as precursors of inter/intracellular signaling molecules, carry hydrophobic molecules in the bloodstream, functionalize biomolecules such as enzymes and receptors,

participate in the digestive process and are involved in several other aspects of the mammalian physiology. Particularly their hydrophobicity was intensively explored in biological evolution and the life as it is known would not be possible in the absence of lipids. Every cell in the human body contains lipids and is sensible for lipid-derived signaling molecules. The majority of the lipids required by the human cells are synthesized by the human body and, as expected for any physiological process, the control of the lipid metabolism is fine-tuned by feedback mechanisms. However, not every kind of lipids needed for the physiological processes to work properly is totally synthesized by the human cells.

Some lipids cannot be synthesized by the human cells by a *de novo* process, i.e., they are not synthesized by the cells from simple and freely available substrates. In this case, the dietary intake of this kind of lipid is not only recommended but in fact essentially necessary. A nutrient that cannot be synthesized from simple substrates and then should be obtained by means of dietary intake is called “essential nutrient”, a designation that summarizes the importance of including this nutrient in a diet. There are classical essential lipids, which are the ω 3 and ω 6 PUFAs. These fatty acids contain carbon-carbon double bonds (unsaturation) at the extremity of the acyl hydrocarbon chain – the first unsaturations at the third and at the sixth carbon atom counting from the methyl extremity, respectively – that cannot be achieved with the enzymes of the human

cells. Although the human cells are not able to synthesize these lipids from simple substrates such as acetyl-CoA, they are necessary for several physiological processes, and this is the reason why these PUFAs are essential nutrients.

An example of a process dependent on essential lipids is the synthesis of the eicosanoids, a group of signaling molecules that participate in several physiological processes such as immunity, digestion, reproduction and neurotransmission. When the cell consumes the ω 3 and ω 6 PUFAs, restoration of the supply of these lipids must be done by means of the dietary intake. For example, when the synthesis of an eicosanoid is activated in a cell, the long chain ω 3 and/or ω 6 PUFAs are consumed. These lipids cannot be restored by the human cell by a *de novo* synthetic pathway. Instead, the cell must receive new ω 3 or ω 6 PUFAs from the diet. Therefore, if an individual consume little or no food containing all the essential lipids, the cell is not able to exert its proper function and this can lead to a physiological malfunction. Besides this, not only the quantity is important but also the dietary ω 3-to- ω 6 PUFAs ratio. These two kinds of lipids can be used in the same metabolic pathways but the products obtained may present quite different actions in some cases (James, et al., 2000). Moreover, the human cells incorporate not only PUFAs but also MUFAs and SFAs, and the diet is an important determinant for the lipid composition of the cellular structures, which affect several cellular processes as discussed here (Bourre *et al.*, 1989; Rapoport *et*

al., 2007). Since the diet is the only source of these essential nutrients, this dietary imbalance can lead to physiological malfunction and exert health-deleterious effects.

As some lipids are provided only or mainly by the diet and cells are specialized in taking up these lipids, the diet profoundly affects the lipid profile of biological structures (James, *et al.*, 2000; Pan & Storlien, 1993). The relative excess intake of PUFAs – and not only the most discussed imbalanced intake of $\omega 3$ and $\omega 6$ PUFAs can exert important health-deleterious effects in humans and this fact is closely related to both the essential nature of these lipids and to their higher susceptibility to oxidation. When PUFAs are oxidized, the pathogenesis and the natural course of an inflammatory disease can be affected. Therefore, this review shows that some facts point to the need of a rational consumption of the PUFAs-containing aliments, such as the soybean oil.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

All glass and plastic wares used in these experiments were washed and rinsed several times with distilled deionized water and dried. The reagents used were of analytical grade obtained from the Basic Laboratory Department of the National Research Institute of Chemical Technology Bassawa, Zaria, Kaduna.

3.1.1 Reagents

The reagents used were: Hydrogen Chloride, ammonium thiocyanide solution, iron chloride, tetraoxosulphate (VI) acid, potassiumtetraoxomanganate (VII) and methanol.

3.1.2 Equipment and Apparatus

The equipment used were:- Gas chromatography-mass spectrometer QP2010 (SHIMADZU) Japan, electrical weighing balance , water bath, electric blender (Kenwood-) , conical Flask, spatula , test tubes, beakers, measuring cylinder, thermometer , stirrer, wash bottle and filter papers .

3.1.3 Samples

Four varieties of soybean seeds were used as samples namely:

- TGX-1936-3F
- TGX-1987-10F
- TGX-1904-6F
- TGX-1951-4F

Samples of four different varieties of soybeans seeds each weighing 50g were obtained from the seed technology store. The seeds were hand cleaned, free from broken and damaged seeds, from dust and other external factors. The soybean seeds were dehulled, winnowed, ground into fine powder using an electric grinder and packaged in bags which were clearly labeled.

3.2 Procedure for Estimation of Phytate

Phytic acid was determined using the method described by Lucas and Markakas (1975). Exactly 2.0 g of each sample powder was weighed into 250 ml conical flask; 100ml of 2 % hydrochloric acid was used to soak each sample in a conical flask for 3hrs and then filtered through a double layer of Harden filter paper. 50 ml of each filtrate was measured into 250 ml beaker and 107 ml of distilled water was added to each solution as an indicator. This was titrated with

standard iron (iii) Chloride solution which contains 1.95 mg of iron/ml. The endpoint was brownish in color persisting for 5 minutes.

The percentage (%) of phytic acid was calculated using the formula

$$\% \text{ phytic acid} = \frac{Y * 1.19 * 100}{\text{Sample weight}}$$

Where Y is the titre value obtained for each sample

3.3 Procedure for Estimating Oxalate

The titration method described by Dey and Underwood (1996) was used to determine the oxalate content. 1 g of the sample was weighed into 100 ml conical flask and 75 ml of 3 N tetraoxosulphate (VI) acid was added and stirred for 1 hour. It was then filtered using Whatman No. 1 filter paper, 25 ml of each filtrate was taken and titrated while hot (80 – 90°C) against 0.1 N Potassiumtetraoxomanganate (VII) solutions, until a faint pink color appeared which persisted for at least 30 seconds.

$$\text{Oxalate (mg/100 g)} = \frac{T * V_{me} * D.F * 100}{M_E * M_S (g)}$$

Where T is the titer value of KMNO_4 (ml)

V_{me} is the volume mass equivalent (1cm^3 of 0.05M KMNO_4) Solution is equivalent to 0.00225 anhydrous oxalic acid

D.F is total dilution factor ($V_t/A = 75/25 = 3$)

Where V_t is the total volume of titrate (75ml) and A is the aliquot used (25ml).

M_E is molar equivalent of KMNO_4 and

M_s is the mass of the sample used.

3.4 Procedure for Polyunsaturated Fatty Acid Determination

1g of the powdered sample of each soybean variety was weighed using an electrical weighing balance and then dissolved in 2ml of methanol and shaken vigorously.

The mixture of methanol and soybean was filtered and the filtrate was subjected to GC-MS-QP2010 (SHIMADZU) with a column oven temperature of 80°C , Injection temperature of 250°C with a scan range of 0.5s at $40\text{-}600\text{m/z}$. Helium was used as the carrier gas at pressure of 108.0 kPa with high pressure injection on.

Percentage composition of polyunsaturated fatty acids were calculated using the Formula:

$$\% \text{ composition} = \frac{\text{peak area}}{\text{Total sum of peak areas}} \times 100$$

CHAPTER FOUR

4.1 RESULTS

The results obtained are as illustrated in the tables below.

They include:

- The % composition of phytate in the soybean varieties.
- The oxalate content of the soybean varieties.
- The % composition of polyunsaturated fatty acids in the soybean varieties.

There is considerable variation among the soybean varieties used in this present study. The oxalate composition of the four varieties range from 36.45 to 60.75 mg/100g of soybean varieties. The phytate content of the varieties range from 0.79 to 1.04 % per g of soybean sample. The variety TGX 1951-4F has the lowest and TGX 1936-3F has the highest phytate content. Conversely, TGX 1951-4F has the highest oxalate composition of 60.75 mg/100g. The % phytate composition of TGX-1951-4F is lowest and its oxalate content significantly higher than those of other soybean varieties (Table 1).

Table 1: The oxalate content and percentage (%) composition of phytate of the soybean varieties

Varieties(soybeans)	Oxalate(mg/100g)	Phytate (%)
TGX-1936-3F	49.28±9.50	1.04±0.11
TGX-1987-10F	54.00±11.22	0.93±0.10
TGX-1904-6F	36.45±14.03	1.02±0.13
TGX-1951-4F	60.75	0.79

Table 2 shows the values for the linoleic and linolenic contents of the soybean varieties under study. A considerable amount of variations was also observed among these varieties especially for linoleic acid content ranging from 10.47 to 15.30 %. The linolenic content range from 1.20 to 2.50±0.54 % with an exception of TGX 1987-10F which has no peak.

Table 2: The percentage (%) composition of polyunsaturated fatty acids in the soybean varieties

Varieties (Soybeans)	Linoleic Acid (%)	Linolenic Acid (%)
TGX-1936-3F	11.6±2.00	2.5±0.59
TGX-1987-10F	10.47±2.33	-
TGX-1904-6F	11.2±2.37	2.03±0.48
TGX-1951-4F	15.30	1.2

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CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 DISCUSSION

This study was carried out to evaluate four soybean varieties (TGX-1936-3F, TGX-1987-10F, TGX-1904-6F and TGX-1951-4F) for their levels of polyunsaturated fatty acids and some antinutritional components. The values of phytate content obtained from the soybean varieties evaluated ($0.79-1.04 \pm 0.11$ %) are in agreement with the result obtained by Sachi *et al*, (1986) on the composition of phytates of 1.0-1.7 % in winged bean varieties, Liu (1997) with phytate content ranging from 1.0-1.5 % in soybeans and within the range given by Reddy and Sathe (2001) with phytate contents ranging from 1.0-2.22 % in soybean varieties. The importance of phytic acid concentration is related to its antioxidant function, especially in maintaining the iron in Fe (III) oxidation state and obstructing generation of hydroxyl radicals (Graf and Empson, 1987). Among cooking treatments, boiling appears effective in reducing the phytate level, which could be reduced to as low as 20 % phytate (Bhandari and Kawabata, 2004). Therefore, the phytate levels of these soybean varieties analyzed are within the safe and acceptable limits for consumption.

The oxalate content varies across the varieties used in the present study. TGX-1951-4F (60.75 mg/100g) has the highest oxalate content and the variety, TGX-1904-6F (36.45±14.03 mg/100g) has the least oxalate content. The oxalate content obtained in all the varieties under study is low compared to that reported in pigeon pea (310.50 mg/100g) as reported by Oloyo (2002).

Individuals susceptible to kidney stone infection are advised to limit their intake of oxalate to 50-60 mg per day (Massey. *et al.*, 2001). Therefore such patients should avoid foods high in oxalate such as spinach, beets (roots and leaves), rhubarb, chocolate, bran concentrates and cereals, and legumes (beans, peanuts, soybeans and soy foods) (Massey and Sutton, 1993). The differences in oxalate content of soybeans can be attributed to biological variation such as cultivar, growing conditions and time of harvest (Rahman and Kawamura, 2011). The value of oxalate changes during processing, soaking and cooking of foodstuffs high in oxalate content by leaching. Boiling may cause considerable seed rupture, and facilitate the leakage of soluble oxalate into cooking water, this may be the possible reason observed in high reduction of oxalate level upon boiling (Bhandari and Kawabatu, 2004). In this present study, the oxalate content of three of the varieties (TGX-1936-3F, TGX-1987-10F, TGX-1951-4F) is high and not within safe limits for consumption by patients suffering from kidney stone.

The fatty acids composition of a vegetable oil is a major determinant of its quality especially its percentage composition of unsaturated fatty acids. Based on the result obtained, the most abundant polyunsaturated fatty acids in these soybeans are the linoleic acid (10.47 ± 2.33 - 15.30 %) and linolenic acid (1.20 - 2.50 ± 0.54 %). The polyunsaturated fatty acid composition of sesame with respect to linoleic acid ranges from 37.7 - 41.2 % which is higher than that of the result obtained and linolenic acid which was absent in sesame oil cake (Yasothai, 2014).

The average percentage composition of linoleic acid in soybean oil as reported by Stella *et al* (2013) was 50% and linolenic acids in amount between 5-6% which is higher when compared to the results obtained in this work which ranged from 1.20 - 2.50 %. This discrepancy could partly be accounted for by the form of sample used. TGX-1951-4F had the highest composition of linoleic acid while TGX-1987-10F had the least composition of linoleic acid. TGX-1987-3F had the highest composition of linolenic acid while there was no definite peak in TGX-1987-10F. The presence of high concentration of polyunsaturated fatty acids (PUFA) especially linoleic acids is responsible for the auto-oxidative instability and off flavor associated with soybean oil (Laubli and Bruttel, 1987). To curb this effect, soybean oil is hydrogenated to reduce the proportion of PUFA in order to improve the shelf life and stability at high

temperatures used in deep frying. This process converts many of the cis double bonds in the fatty acids to trans double bonds which produces an undesirable effect leading to higher incidence of cardiovascular disease and possibly increases the body's inflammatory response (Ferh, 2007). The composition of polyunsaturated fatty acids in these soybean cultivars are low thereby limiting the phenomenon of auto-oxidation associated with soybean oil.

5.2 Conclusion

Various studies have been carried out on the composition of phytate, and polyunsaturated fatty acids in soybeans while very limited information is available on oxalate composition of soybean seeds. Due to the great potential of soybean in the global market with its attendant importance of edible cum-therapeutic oil to man and livestock as well as its valuable usage in industries, all available information both qualitative and quantitative should be used in making decisions about the food value of these soybean varieties. The findings indicated significant levels of linoleic and linolenic acid with the exception of TGX-1987-10F with no peak in the result.

The phytate composition of these soybean varieties are safe while the oxalate levels could pose a threat to human health particularly individuals diagnosed of kidney stones or hyperoxaluria. The oil obtained from these soybean cultivars

are also less prone to auto-oxidation that is characteristic of most soybean oil due to high composition of polyunsaturated fatty acids which causes rancidity and off flavor thereby lowering their shelf life.

5.3 Recommendation

1. The oxalate contents of the soybean cultivars evaluated were high, more than the required serving per day. As a result, additional studies with larger population size need to be conducted to determine the range of variation in oxalate content among available cultivars of soybean, then those cultivars with the lowest oxalate content be utilized in human feeding studies to determine whether increase in urine oxalate levels remain below an acceptable level. There are no known low oxalate cultivars at the present time.
2. The variety TGX-1904-6F is recommended based on its low levels of oxalate and phytate.
3. Although some other attributes such as yield, largely affects large scale production for industrial use, all the varieties used in this study are recommended as a good source of vegetable oil.

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