KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ENGINEERING

DEPARTMENT OF AGRICULTURAL ENGINEERING

A PROJECT REPORT ON:

EFFECT OF HEATING TIME ON YIELD AND QUALITY OF SOYBEAN MEAL AND OIL

BY

AVEYIRE EVELYN AVEDEWEH

BSc. AGRICULTURAL ENGINEERING

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A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING

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AUGUST, 2014

DECLARATION

I hereby declare that, except for references to other peoples' work which have been duly acknowledged, this report is the result of my own research work and has not, in part or whole, been presented for the award of a degree or diploma in any institution.

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DEDICATION

I dedicate this work to the Almighty God who gave me the strength to complete this work. My parents, Mr. Joseph Aveyire and Mrs. Mary Aveyire played an important role in this work.

ACKNOWLEDGEMENT

Glory, honour and praise to the Lord God Almighty for his goodness and mercies in my life throughout my studies on campus.

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ABSTRACT

The effect of pre-heating time and number of presses of soybean on the percentage yield and quality of soybean oil and cake were investigated in this study. Pre-heat treatment does not only reduce or denature some anti nutritional factors but it also helps in the process of oil extraction. Pre-heat treatment increased the levels of protein and minerals which can be used in diets to prevent some mineral deficiencies. Roasting is one of the common ways used to pre-heat soybeans before extraction.

The soybean oil extraction parameters examined were percentage yield, free fatty acid (FFA), acid value, peroxide, saponification and ester value. Proximate analysis and percentage cake yield of soybean cake were also studied.

The cold pressed (control) single pressed soybean cake (SPSC) had the highest cake yield of 87.17% followed by 86.25%, 85.85%, 84.52% and 82.50% which were pre-heated for 20, 35, 45 and 55 minutes respectively. The corresponding double pressed soybean cakes (DPSCs) had lower yields than their single pressed soybean cakes (SPSCs). Single pressed soybean oil obtained after pre-heating for 35 minutes had an oil yield of 11.35%.

Acid value, FFA, ester value, peroxide value and saponification values increased as heating time increased. Double pressed soybean oils (DPSOs) had higher parameters than single pressed soybean oils (SPSOs) of the same pre-heated soybean sample.

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CHAPTER ONE

INTRODUCTION

1.1 Background

According to Ibrahim and Onwualu (2005) agricultural oil-bearing products are classified into oilseeds, oil nuts and mesocarpsor fruits. Cotton, castor, sunflower, soybean and moringa are seeds; coconut, groundnut and shea-nut are nuts. Oil palm isagood example of oilmesocarp/fruit. However, there has been an increase of oil crop production globally (Murphy, 1994). Groundnuts (pea nuts), oil palm, shea-nut and soybean are some oil crops that are mostly grown in Ghana. Jatropha and moringa are the other ones that are still under investigation. Just as the name suggests, oilseeds contain some appreciable amount of oil. According toFAO (2013) palm kernel nuts,groundnuts, cotton seed and soybean seed contain about46-57%, 35-50%, 15-25% and 20% oil respectively.

In Africa,crude vegetable oil is mainly extracted in the traditional/conventional way. The low efficiency of oil extracted has birthed methods that are improvements on the traditional/conventional methods. Traditional/conventional methods of extraction are known to be laborious and ineffective. Improved methods like mechanical extraction, gas assisted mechanical extraction, supercritical extraction (pressure and temperature are increased beyond the critical values) and solvent extraction methods mentioned by Willems (2007)have been used in the process of crude vegetable oil extraction. However, all these methods have their limitations such as cost of operation, efficiency, complexity of management and safety of workers. But these limitations could be minimised or even eliminated, if some parameters like temperature, heating time, moisture content, and type of solvent and extraction machine settings are carefully studied and optimised.

The qualities of products are affected by the parameters and type of extraction processes as mentioned. If the quality of the crude oil is below the recommended standard, the processor has to spend more money and time to refine such oils. Moreover, animals do not get the required nutrients, if they are fed with substandard cake/meal.

There has been a steady rise in the demand of vegetable oil for domestic and industrial purposes in most developing countries (Ibrahim and Onwualu, 2005). The world market for oils and fats is approaching 400 million metric tonnes of seed production per year, resulting in a total amount of oil around 100 million tonnes (USDA, 2006 as cited by Willems, 2007). The crude vegetable oils are used as biodiesel. These crude vegetable oils can be used directly by engines or blended with other oils. Some oils that have been used as biofuel are jatropha, yellow mustard, linseed, sunflower, canola and others. Biodiesel has helped to reduce the stress on fossil fuels which are not renewable. Recently the cotton and moringa seeds are under serious investigation, because of their medicinal importance. However, soybean cannot be ignored since it has gained so much attention because of its high nutritional value and its peculiar properties as a biofuel.

In 2003, the world production of soybean was estimated to be 187.49 million metric tonnes out of the 317.89 million metric tonne total for vegetable oil crops, making soybean the world's largest oilseed crop, rivalled only by oil palm (USDA, 2002 as cited by Hammond *et al.,* 2005).

Soybean meal is used as feed because it is the world's most valuable source of protein (Guy, 2009). It contains about 40% crude protein as compared to fish which a crude protein content of 18% (Abbey *et al.,* 2001). Soybean oil is used as salad oil, but it is usually hydrogenated or used as margarine stock or frying oil (Hammond *et al.,* 2005). It also has industrial uses such

as soap making, production of paint and lubricants and also used as raw material in cosmetic and pharmaceutical products.

1.2 Problem Statement

The processing of oil bearing crops is mainly achieved by traditional/conventional and improved techniques. Oil processing techniques have not changed much over the years as the bulk of this trade is still in the hands of rural women who employ traditional/conventional techniques (Ibrahim and Onwualu, 2005).Theefficiency of traditional/conventionaltechniques of extracting soya bean oil is low (less than 50%), labour intensive, time consuming and possibly compromising quality and safety standards (Grace*et al*., 2008 as cited by Dari, 2009).

According to Mrema and McNulty (1985) as cited by Dari (2009), mechanical pressing of oilseeds is the most common method used for edible oil extraction in the world. However, mechanicalpresses do not have high extraction efficiencies as compared to the solvent extraction.

Apart from the quality of the seed that varies depending on the climate, variety and storage of the oilseed; processing methods also have impact on the quality and yield of oil and cake/meal. A pre- treatment such as heating is a way to improve the yield of oil expelled. However, pre heating is an extra cost that is not well accepted by the processors, because they are not aware of some of the set-backs of cold-pressed soybean meal. Unfortunately, the anti-nutritional factors in soybean can cause stunted growth and in some cases even death of poultry. These factors can be denatured by the application of heat before oil expulsion.

1.3 Importance of Study

Soybean is known to be high in protein; therefore, it is essential in the diets of humans and animals. Soybean meal is commonly used as a source of protein for poultry and swine feeds.Soybean meal constitutes about 67% of the animal feed market in the world (Pettigrew *et al.,* 2002).The use of vegetable protein is becoming increasingly important as fish stocks decline and concerns increase over the possibility of disease transmission from animal protein meal to animals (Swick, 2002). This can be a possible contributing factor to the rise in the demand for soybean in the feed industry.

A report prepared by the High Quest Partners for the United States Soybean Export Council (2011) stated that, soybean oil importation into Ghana was 3600 metric tonnes in 2010. Another report by MoFAand CSIR(2005) also mentioned that the domestic demand of soybean in Ghana is twice its production. This clearly shows that the soybean produced is insufficient. Increasing the production is one way to decrease importation of soybean meal and oil into the country; but another way is to make sure that the oil and meal yield and quality are improved or maximised.

Mechanical extraction is the most common method of oilseed extraction used in Africa especially Ghana. The main reason for this is that itprovides a non-contaminated, protein-rich, low-fat defatted cake,an important by-product in many developing nationsata relatively lowcost (Dari, 2009).Hydraulic press and screw press machines are used to extract oil from oilseeds mechanically. Screw press machines are preferred to hydraulic press; becausehydraulic press processed oil seeds in batches whiles the screw press does that continuously. Most of the soybean processors in Kumasi use the mechanical screw press; because it is easy to operate, repair and maintain.

Pre-treatment of the raw material is very crucial. Oil in oilseeds can be displaced by increasing the moisture content before processing. Application of heat does not only allow the oil in the cells to flow but also destroys some anti-nutritional factors that are undesirable in the meal. Protein content is influenced by heat. It is therefore, imperative for processors to have an idea of the optimum heating time to enhance the quality of their products. Oilseeds are subjected to heat treatment in order to lower the viscosity of the oil to be extracted, coagulate the protein in the meal and also adjust the moisture content of the meal to the optimum level for oil extraction. Under-heating and over-heating can give undesirable quality of products. When soybeans are undertreated, anti-nutritional factors will hamper the growth of birds and also reduce oil yield during processing. Over-heating on the other hand; destroys protein and some essential amino acids and also gives the meal an unusual colour. Hence, processors must know the optimum temperature that will give them high yield products without compromising onquality.

Data from this project will help processors to have a fair idea on the quantity of cake/meal and oil they can obtain after mechanical extraction coupled with pre-heat treatment. This study will also determine whether it is necessary to pre-heat and do double pressing or not.

The products of oil-bearing seeds have contributed to the economic development of many countries especially the West African countries where the products are grown for commercial purposes (Ibrahim and Onwualu, 2005). With this information the processors can produce high quality soybean oil and soybean meal/cake. Importation of soybean oil and soybean meal/cake will reduce when Ghana is able to produce high quality soybean cake/meal. Hence, soybean will have the ability to contribute to the nation's Gross Domestic Product (GDP).

1.4 Objective

The main objective of this study was to determine the effect of heating time, single and double press on the quality and yield of soybean products (oil and cake/meal).

1.5 Specific Objectives of Study

This study was to investigate specifically into the effect of heating time, single and double presson the;

1. Oil and meal yields of soybeans.
2. Moisture, crude protein, fat, fibre, and carbohydrate content of the soy cake.
3. Free fatty acid, acid, peroxide and saponification value of the crude soybean oil.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soybeans

Soybean (*Glycine max* L Merrill) is an important global legume that grows in the tropical, subtropical and temperate climates; like peas, beans, lentils and peanuts, belonging to the leguminosae family (Osman, 2011).

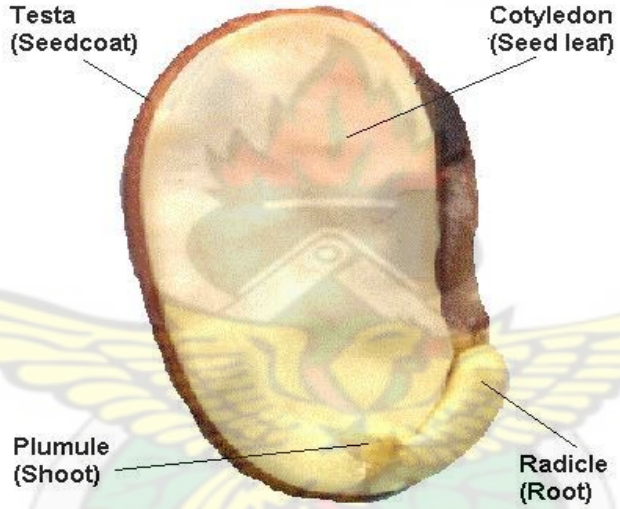

Figure 1: Structure of soybean seed
(Source: TNAU Agritech Portal, 2013)

Figure 1, represents the internal structure of the soybean seed. Soybeans have about 8% seed coat or hull, 90% cotyledon and 2% germ (USDA, 2009). Figure 2a is a picture of the soybean plant. It is an annual herbaceous erect plant with a height of 30cm to 183 cm; the stem, leaves and pods are covered with fine brown or grey hairs, this may vary a little bit depending on the variety (Ngeze, 1993). The leaves have 3 to 4 leaflets per leaf (trifoliate); the pod which is 5-8cm long and usually contains 2 to 4 seeds and grows in clusters of 3 to 4 (Rienke and Joke, 2005) as shown in Figure 2b. The seeds vary in size and colour; the seed coat ranges from cream, black, brown, yellow to mottle as shown in Figure 2c; the hull of the

matured bean is hard, water resistant and protects the cotyledons and hypocotyls from damage (Osman, 2011).

Figure 2a: Soybean Plant
(Source: grain farmers of Ontario, 2013)

Figure 2b: Soybean in its Pod
(Source: Ariskan, 2013)

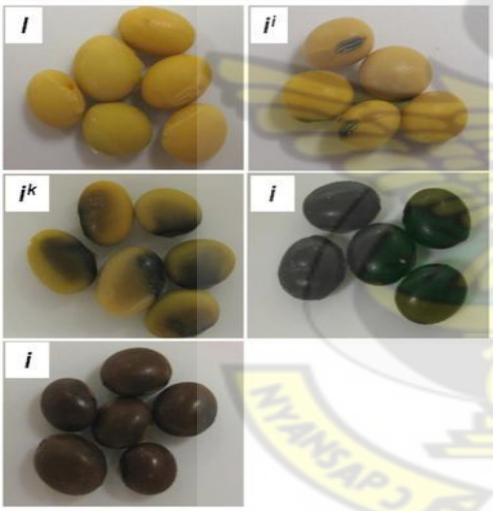

Figure 2c: Different Colours of Soybean
(Source: Hernandez-Garcia, 2013)

In the tropics, the growth duration of adapted genotypes is commonly 90-110 days, and up to 140 days for the late maturing ones (Osafo, 1997). Soybean is mostly grown in Bimbila, Nakpanduri, Karaga, Tilli and Bawku in the northern sector of Ghana (Plahar, 2006). Ejurais also known to produce soybean in the southern sector of Ghana. Soybean is an example of crops that is tolerant to a wide range of soil conditions. Addo-Quaye*et al.*(1993) stated that

soybean does best in warm, moist, and well drained fertile loamy soil; they concluded that the loamy soil provided adequate nutrients and good contact between the seed and the soil for rapid germination and growth. Ngeze (1993) found that, soybean also does well in fertile sandy soils with pH of between 5.5 and 7.0, and that the crop can tolerate acidic soils more than other legumes but does not do well in water logged, alkaline and saline soils. The optimum rainfall for soybean is about 350mm and 750mm which is well distributed throughout the growth cycle (Ngeze, 1993). The same author also mentioned that most legumes require an optimum temperature of 17.5°C to 27.5°C for growth; but soybean has a wider range from 10°C to 40°C, with 22°C being the optimum (Osman, 2011). However, Addo-Quaye *et al.*(1993) suggested the optimum temperature for growth is between 23°C and 25°C.

The leading producer, United States of America produces about 40% of the world's output of soybean; followed closely by China and Brazil (Govindarao, 2010). After its introduction in 1910 to Ghana (Plahar, 2006), soybean was hardly known as a traditional crop in Africa (Tweneboah, 2000). But the story changed a little bit; after serious attempts made to establish its production in the early 1970's (Osman, 2011). This was as a result of collaborative breeding efforts by Ghana's Ministry of Agriculture (MoFA) and the International Institute of Tropical Agriculture (IITA) (Twenboah, 2000). Production of soybean in Ghana was 15000 metric tonnes in 2005, 113000 metric tonnes in 2009 and 145000 metric tonnes in 2010 (MoFA and CSIR, 2005. The production of soybean is expected to increase tremendously to meet the 27135000, 30325000 and 33399000 projected population of Ghana in 2015, 2020 and 2025 respectively (United Nations, 2010 as cited by High Quest Partners, 2011). If these targets are not met, importation of soybean and its products will increase. Ghana already experienced a situation like that in 2004, where the annual production was half the domestic demand (CSIR and MoFA, 2005). The increasing demand for soybean and soybean products

is as a result of its versatility and high nutritional value. That is why the High Quest Partners (2011) marked West, East and Southern Africa as the highest potential areas to receive US Soybean Complex exports.

2.2 Importance and Uses of Soybeans

Osman (2011) mentioned that soybean can be classified as an oilseed, containing significant amounts of all the essential amino acids minerals and vitamins for nutrition. Soybean is therefore an important source of animal and human dietary protein with an average of 40% content, 30% carbohydrate and 20% oil (MoFA and CSIR, 2005). Soybean meal is used as food for human, feed for animals (livestock) and ingredients of some pharmaceutical products. The oil can be used as vegetable oil for cooking, as biodiesel, to produce paint, cosmetics, soap, pharmaceuticals and many other industrial purposes. Soybean oil contains essential fatty acids that are required for the human body to produce prostaglandins (Ayoola and Adeyeye, 2010).Prostaglandins are long-chain fatty acid derivatives synthesized by most cells in the body and affect many of the vital physiological functionssuch as regulating the contraction and relaxation of smooth muscle tissue (Nelson, 2005). Vitamin E (tocopherol) is important for the human body to sustain cardiovascular health (Ayoola and Adeyeye, 2010). Soybean oil contains more Vitamin E than any other commonly consumed vegetable oil which serves as an effective deterrent to prostate cancer for elder males (Ayoola and Adeyeye, 2010). Soybean oil contains VitaminK1 which plays an important role in blood coagulation and bone metabolism (Hammond *et al*., 2005).

In crop rotation, oilseeds are known to reduce pest, disease, weed and nematodes infestation (Jaeger and Siegel, 2008). Osman (2011) also mentioned that soybean is beneficial in the management of *Strigahemonthica*, an endemic parasitic weed of cereal crops in the savannah zone of Ghana, which causes severe losses in crop yield of up to 70-100% of millet, sorghum

and maize. Apart from the mentioned importance, soybean as legume also fixes nitrogen into the soil which in turn fertilizes the soil.

2.3 Soybean Meal

Full-fat soybean meal is the meal that is acquired through size reduction only. Defatted soybean meal involves the removal of some amount of oil from the beans/meal. Due to the presence of extra oil, full-fat soybean contains significantly more energy than defatted soybean meal. Some users limit the use of full-fat soybean in poultry diets due to the high unsaturated oil content as poultry deposits the fat they consume with little or no modification, which reduces the meat quality (CIGI, 2010). As mentioned earlier, soybean is high in protein and is therefore, consumed by humans and livestock alike. Locally it is processed into *dawadawa*, a spice that is used in preparing some Ghanaian delicacies; it also has some medicinal uses. The vegetarians also use it to substitute meat, which is commonly called soybean kebab. Food scientist and nutritionist have suggested to food processors to incorporate soybean in various porridge formulations, for the preparation of soups and stews. Soymilk is also one of the products that is catching the attention of many Ghanaian consumers. In China, soybean is used for *tofu*, cheese, yoghurt and other local Chinese dishes.

2.3.1 Quality of Soybean Meal

The quality of soybean meal can be measured by the metabolising energy present in the meal. The metabolising energy is calculated by the percentage crude protein, carbohydrate, fibre, ash, moisture and fat content of the meal. The quality of meal therefore depends on the following parameters.

2.3.1.1 Crude Protein and Amino Acids

The soybean seed contains the highest crude protein (about 40%) and the best amino acids compared to other legume seeds (Dozeir and Hess, 2011; Coussens, 2009). Soybean protein provides all the essential amino acids needed to fulfil human nutritional requirements for growth, maintenance and physical stress (Robert and Nemat, 1998). Coussens (2009) also mentioned that protein is the building block for muscle, organs, feathers and eggs. Furthermore, hestated that 10 amino acids are essential in the daily diet of birds. But this was contrary to the statement of Thakur and Hurbrugh (2007). They said that lysine, methionine, theronine, cysteine and tryptophan are the 5 key amino acids that are essential for pig and poultry nutrition. In the 12th Soybean Australian Conference, Willis (2013) mentioned that soybean meal has the highest lysine digestibility (91%); it also ranks high in methionine, cysteine and theronine digestibility.According to Neutkens (2005), these 5 amino acids are limiting, because they are present in the lowest amounts in a feed relative to their requirements by the animal and can be easily destroyed by overheating.

2.3.1.2 Crude Carbohydrate Content

Soybean is not only a good source of protein but also rich in carbohydrates (Choct*et al.,* 2010). Carbohydrate is an energy source for poultry and is converted to glucose, which is used for growth and egg production. Willis (2013) explained that the carbohydrate components (hulls, sugars and non-starch polysaccharides) are poorly digested by monogastric animals. Macrae*et al*. (1993) stated that the carbohydrates in soybean consist of approximately 10% free sugars (5% sucrose, 4% stchyyose and 1% raffinose) as cited by Choct*et al.*(2010). Monogastric animals do not have the enzymes to hydrolyze these carbohydrates, and thus their digestion occurs by means of bacterial fermentation (Choct*et al.,* 2010). The main two types of non-starch polysaccharides are insoluble non-starch

polysaccharides (cellulose) and soluble non-starch polysaccharides (polymers that are partially soluble in water). In poultry, insoluble non-starch polysaccharides (cellulose) can reduce the digestibility of nutrients and depress growth performance. When oil is extracted, soybean meals must contain 35-40% carbohydrates(Dersjant-Li, 2010).

2.3.1.3 Crude Fat Content

In a sample, the crude mixture of fat-soluble materials is referred to as crude fat (Aurand*et al*., 1987 as cited by Dari, 2009). Ether extract is also referred to as the crude fat content. Fat contains more than twice the calories in carbohydrate and protein; it is therefore, an excellent source of energy. Fatty acids help to maintain the feather and skin quality and are important component in eggs. However, in soybean meal for poultry a high crude fat content is not desirable (CIGI, 2010). High crude fat content in feed can reduce the quality of the meat of poultry (CIGI, 2010). Organic solvent extraction methods are mostly used to determine crude fat content in food (Nielsen, 1994).

2.3.1.4 Crude Fibre Content

A measure of the quantity of indigestible cellulose, pentosans, lignin and other similar components found in food is the crude fibre (Aurand*et al*., 1987 as cited by Dari, 2009).Hemicellulose, cellulose and lignin make up the crude fibre (Dari, 2009). It is the organic residue of insoluble and combustible matter after the treatment of a sample. There are various ways of determining the crude fibre content in a sample. One of the treatments is to remove all protein and carbohydrates from the sample; this involves dissolving the sample with petroleum, boiling sample with dilute sulphuric acid and boiling with dilute sodium hydroxide (Kirk and Sawyer, 1991).

Content of crude fibre in soybean is about 6% which is lower than other feed which is desirable (Coussens, 2009).

2.3.1.5 Ash Content

When the organic matter of food material is burnt, the inorganic residue remaining is the ash content. The ash composition is not considered the same as the mineral content but it may provide an estimate of the quality of the food product, since high levels may indicate contamination (Dari, 2009). The ash content must be low. This reduces caking during storage.

2.3.1.6 Moisture Content

Moisture content is very important in food storage and processing. Moisture affects the shelf life and nutritionof food products. Soybean meal must have a low moisture content to avoid contamination by mycotoxins and fungus.

2.3.1.7 Mycotoxins

Mycotoxins are secondary metabolites produced by microfungi that are capable of causing disease and death in humans and other animals (Bennett and Klich, 2003). According to the NOPA (2006), the important mycotoxins in soybean are *vomitoxin*, T2, *fusarochromanone*and *zeralenone* produced by fungal genus *Fausarium*. The fungus grows in infected whole grain and meal during storage. These mycotoxins cause great problems for animal producers; *vomitoxin* and T2 cause vomiting in pigs and lesion of the upper digestive tract in poultry, *zeralenone*causes reproductive problems. Mycotoxins contaminants can be

minimised by drying beans immediately after harvesting (NOPA, 2006).Mycotoxins contamination can also be avoided by storing soybean in a dry place.

2.3.1.8 Antioxidants

Antioxidants slow down oxidation which extends the shelf life of fats, oils and food products. Synthetic antioxidants have toxicological effects (Jing *et al*., 2011); therefore, more attention has been drawn to natural antioxidants. Tocopherol is a natural antioxidant found in soybean. It serves to retard soybean oil oxidative degradation (Ayoola and Adeyeye, 2010).

Temperature, availability of oxygen and the chemical nature and physical state of the fat are the conditions that influence the role of tocopherols as inhibitors of lipid oxidation (Lampi*et al*., 1999). During oil processing, tocopherol level is reduced. According to Frankel (1996), the levels of tocopherol left may be sufficient to protect the oil from oxidation under ambient conditions as cited by Van der Merwe(2003).

2.3.1.9 Anti-Nutritional Factors

Unfortunately, it has been discovered that raw soybean contain some anti-nutritional components which hamper the ability of monogastric animals like poultry and pigs to digest feed (CIGI, 2010).

The two most important anti-nutritional components are trypsin and lectinsinhibitors (CIGI, 2010). Trypsin causes stunted growth, reduces feed efficiency and pancreatic hypertrophy in animals; lectins causes damage to the lining of digestive tract of poultry and can only be removed by soaking and denatured by proper heat treatment (Rienke and Joke, 2005). Another method of decreasing these anti-nutritional components is the development of high-lysine, high-oleic, or low-phytic acid varieties (CIGI, 2010).

The enzyme lipase results in the liberation of free fatty acids from the oil present in the soybeans which can only be deactivated at temperatures greater than 79°C; lixopase promotes oxidative rancidity or peroxide formation which is also destroyed at temperatures exceeding 49°C(Blattner, 2005). Raw soybeans also contain the enzyme called urease. Urease hydrolyzes ammonia from urea, so when there is too much nitrogen present in the ration compared to ammonia then a drop in the dry matter intake can occur. Saponins are also present in raw soybeans. This compound gives a bitter taste and impact nutrient absorption, but the concentration is too low that it is not usually considered to be of any practical significance (Ishaaya*et al.*, 1969 as cited by CIGI, 2010).

Poultry feeds are suppose to contain all the protein, energy, vitamins, minerals and other nutrients necessary for proper growth, egg production and health of the birds. According to the NOPA (2006) the recommended quality measurements for soybean meal are mentioned in Table 1.

Table 1: Quality of Soybean Meal

QUALITY	LIMITS
Ash	Less than 7.5%
Acid insoluble ash (silica)	Less than 1%
Lysine	More than 2.9%
Protein soluble index 0.2% KOH	73-85% (or more if the urease is within specification)
Protein dispersibility index	15-40%
Urease activity	0.02-.30pH unit rise
Trypsin inhibitor	< 4mg/g of meal
Bulk density	57-64g/100cc
Screen analysis	95% through #10 mesh, 40-50% through #20 mesh, 6% max through #80 mesh
Texture	Homogenous, free flowing, no lumps or cakes, not dusty
Colour	Uniform particle colours of light tan to light brown
Odour	Fresh, not musty, not sour, not like ammonia, not burned
Taste	Bland
Contaminants	Free of urea, ammonia, mycotoxins and mould

(Source: National Oil Processors Association (NOPA), 2006)

2.4 Soybean Oil

Fats and oils contain a glycerol molecule (a type of alcohol) bonded to 3 fatty-acid chains, a structure commonly called triglyceride (Hammond *et al.*, 2005). Oils tend to be liquid at room temperature and fats are solid at room temperature. Soybean oil is one of the major

products after both mechanical and solvent extraction. Among the various components in soybean, oil is much more variable than protein from year to year (Hammond *et al.*, 2005). Hence, the oil content is affected by the variety of seed, amount of moisture that tends to display the oil during processing, the heat treatment used (temperature and heating time) and the method of oil extraction. Even though soybean is known to have relatively low oil content as compared to cotton seed, palm kernel and groundnuts, it contributed 27% to the global vegetable oil production in 2011 as shown in Figure 3. This is because soybean oil has special and unique properties which make it standout amongst all the other vegetable oils.

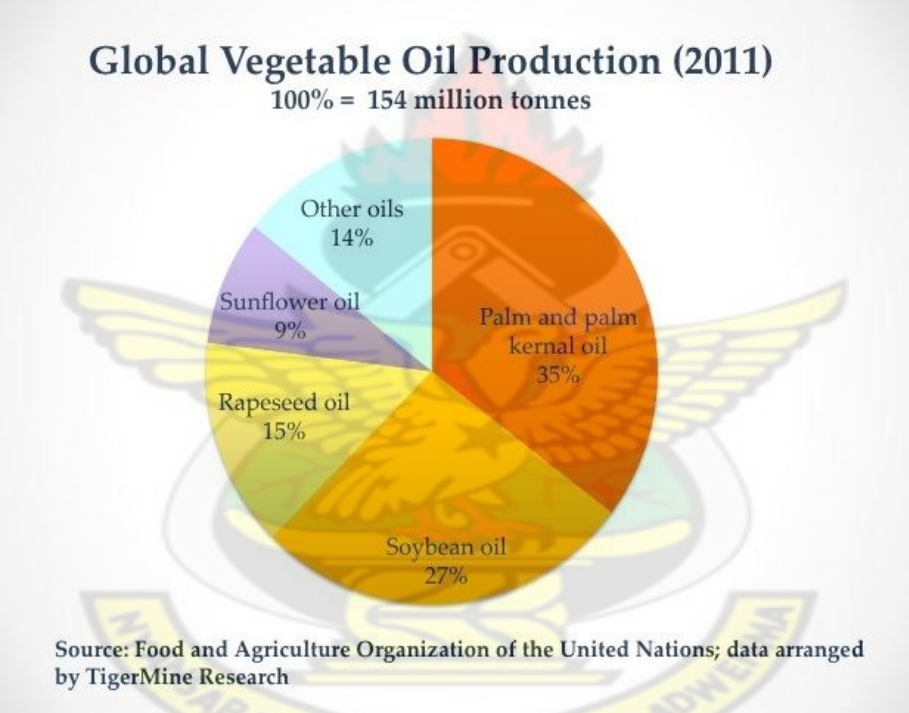

Figure 3: Global Vegetable Oil Production (2011)

2.4.1 Biodiesel

Biodieselis a non-toxic and biodegradable renewable fuel. Biodiesel is environmental friendly because it does not contain sulphur and has a low content of carbon monoxide emissions, particulate matter and unburnt products (Tascano and Maldini, 2007). More over it has similar properties to the traditional fossil diesel fuel and can easily substitute diesel fuel with none or very minor engine modification (Ma and Hanna, 1999 as cited by Mahajan*et al.*, 2011). Soybean, cotton seed, sunflower, rapeseed, safflower, peanut, agal oil and other

oilseed are the best candidates as emergency fuel (Spolaore*et al.*, 2006). An experiment that was carried out by Mahajan*et al.* (2011) concluded that soybean oil is the closest to biodiesel when it properties were compared to groundnuts and rapeseed. Soybean oil properties fall into standard values of biodiesel as in Table 2. Jaeger and Siegel (2008) buttressed the conclusion of Mahajan*et al.* (2011) by stating that the melting point and oxidative stability are concerns in biodiesel. Palm oil, canola oil and soybean oil melt at 95°F, 14°F and 3.2°F respectively (Jaeger and Siegel, 2008).

Table 2: Standard Values of Properties of Biodiesel

PROPERTY	**LIMITS**	**UNITS**
Flash point	130 min	°C
Water and sediment	0.05	% volume
Kinematic viscosity	1.9-6.0	mm^2/sec
Sulphated ash	0.02 max	% mass
Sulphur	0.05 max	% mass
Cloud point	-3-12	°C
Free glycerene	0.02 max	% mass
Pour point	-15 to 16	°C

(Source: Mahajan*et al.*, 2011)

2.4.2 Crude and Refined Oil

Most crude vegetable oils are conventionally obtained from oilseeds by either mechanical pressing or solvent extraction methods. Crude vegetable oils are mostly refined by physical or chemical processes. The objective of refining is to eliminate impurities with the least possible effect on desirable components present in the crude vegetable oils in order to obtain an odourless, bland and oxidatively stable refined vegetable oil that is acceptable to

consumers**.**Acceptable oil quality characteristics of crude vegetable oils processed by refining methods are of crucial importance in order to obtain refined vegetable oils.

2.5 Traditional Methods of Oil Extraction

All the improved methods of oil extraction have their basis from the traditional methods of oil extraction. According to Dari (2009), traditional oil extraction can be grouped into two. These ways are the wet and water assisted extraction methods. These methods are used locally in the developing countries; even though, it is time consuming and tedious.

The wet assisted extraction method involves the use of relatively large amounts of water to suspend the oilseeds such that the extracted oil floats on the top of the suspended oilseeds (Dari, 2009). The water assisted method involves the addition of small quantities of water to the slurry before the oil is extracted by manual kneading (Dari, 2009). After the slurry has boiled for some time, the oil then floats on the surface and is scooped.

Some seeds such as cotton, sunflower and castor are ground to paste without dehusking. Heat is then applied to the paste and then with boiling water; the mixture is stirred to its boiling point. After boiling, the mixture is cooled and the oil that settled at the top and is scooped off. Nuts like shea are roasted slightly and the skin removed. The nuts are the pounded with mortar and pestle or ground to paste using a grinding stone to a smooth paste. The paste is kneaded and pressed by hand to remove the oil-water mixture. Then the oil-water mixture is fried to remove most of the water.

2.6 New Methods of Oil Extraction

As mentioned in Section 2.4, all improved methods have their basis from the traditional methods of extraction. Most of the improved methods are more mechanised, hence less

labour intensive. To maximise the efficiency of oil extraction, some of the following basic steps are used.

2.6.1 Cleaning

Inprocessing, after the selection of raw materials the next stage that is critical is cleaning. Good quality oleaginous materials (oil bearing crops) will contain about 2% foreign materials (Kemper, 2005). Sticks,pods, dust, soil, sand, stones, unwanted seeds and pieces of metal are some of the common foreign material to be removed. If the cleaning is not done well it will not only reduce the quality of products but destroy the machines, increasing the repair and maintenance cost. Cleaning can be done by various means. Sticks, pods and dust are lighter than the oil crops and can be blown away mechanically. Stones can be separated by the sieves depending on the size and weight. Metals can be removed by metal detectors. Even though, cleaning may be time consuming and add to the production cost, its benefits far outweigh its costs.

2.6.2 Increasing Moisture Content

Moisture content of food products is manipulated to the advantage of processing and storage. Reducing the moisture content can increase the shelf life and protect the produce during storage. In other cases the moisture content must be increased for easy flow of the crop produce for processing. As the moisture content of soybean increased from 7.37% to 15.80% (db) angle of repose was found to increase from 26.35º to 30.96º (Wandkar*et al*., 2012). The angle between the surface of a heap and the floor is the angle of repose (Natural Resource Institute, 1999). The angle of repose will determine whether grains will flow or remain stable on a particular surface. However, for a machine to be completely efficient it also depends on how the grains flow for processing. The relationship between moisture content of kernel seed

and extraction ability of the expeller reduces when moisture content of kernel seeds is increases above the optimum moisture content(Samuel and Alabi, 2012).

Moisture content is also increased in order to displace the oil present in oil bearing crops. This makes the oil easily accessible for extraction.

2.6.3 Heat Treatment

Heat treatment does not only reduce or denature some anti nutritional factors but it also helps in the process of oil extraction. When oil bearing seeds are heated the walls of the oil bearing cells are broken which allows the oils to be extracted. Oil yields at 100°C are always higher than at 40°C for sesame and linseed (Willems, 2007). Tunde-Akintunde*et al*. (2001) performed an experiment and found out that the yield of soybean oil increased from a heating temperature of 70°C to 80°C and a heating time of 15 to 30 minutes. Moringa seeds that were heated at 100°C had the highest percentage yield of 33.7% as compared to the higher temperatures and the control (Tunde-Akintunde*et al*., 2001).This can be attributed to increased cell wall permeability, coagulation of seed protein above 80°C.Ghafoor*et al*, (2011) mentioned that, heating in the range of 60-70°C enhances the quality raw materials for further processing. Digestibility and bioavailability of nutrients are also increased by thermal processing (Slavin*et al.,* 2000).A commercial soybean meal was placed in an autoclave for up to 40 minutes at 121°C; the result was a significant reduction in the analytical concentration of lysine and cystine as well as a reduction in the digestibility of lysine and cystine (Dudley-Cash, 2003). There are various methods of heat application. But the method to be used is usually determined by the intended use of product, scale and cost of production.

2.6.3.1 Microwave Treatment

Heating is a way of denaturing some anti nutritional factors in the soybean before processing; excessive heating denatures the protein which results in the reduction of feed and food value. Therefore, using mild heat (microwave treatment) in the processing of soybean is also a good option. A research carried out by Nosenko (2013) revealed that, microwave treatment yielded 7% more oil than the traditional method of heating. Furthermore, the oil obtained had a lower peroxide value (0.86mM $\frac{1}{2}$O/kg) as compared to the control which had a value of 2.89mM $\frac{1}{2}$O/kg which could be due to the reduction of microwave heating time relatively to the traditional heating. Nosenko (2013)also detected that the deactivation time for urease and trypsin inhibitors was 20 minutes, which was lower than the traditional heating.

Snyder *et al.* (1991) heat treated soybeans for storage. They concluded that treatment of soybeans with microwave energy for longer periods, such as 8-10 minutes can damage oil and meal quality.

But the use of microwave energy is always reconsidered because of the high cost of electricity, maintenance and repair. Hence in Ghana, the use of microwave treatment may be reconsidered by many processors.

2.6.3.2 Micronisation

Micronisation is a specific heat treatment in which the layer of grain on the conveyor belt is continuously carried under ceramic radiators emitting radiation with wavelength in the near infrared region ranging from 1.8 to 3.4 mcm (Puvača*et al.,* 2013). Puvača*et al.*,(2013) mentioned that the conveyor belt within the microniser can oscillate in order to tumble the grain and expose all the surfaces of the grain to the wave's effect. The most important

parameters of this treatment are the speed of the conveyor belt, thickness of product layer, space between the product and the radiation source and certainly the achieved temperature (Puvača*et al.*, 2013).

According to results obtained by Puvača*et al.*,(2013), it can be concluded that the application of the micronisation process led to the increase of the digestibility coefficient in relation to digestibility of dry matter of fresh grain.

2.6.3.3 Roasting

Materials with high protein content must usually be cooked before pressing (Wiess, 1983). The heat coagulates the protein and also frees the oil for efficient pressing. Roasting does not lead to reduction in the levels of mineral elements but rather increases the levels of protein and minerals which can be used in diets to prevent some mineral deficiencies (Ayoola and Adeyeye, 2010). According to the Cambridge International Dictionary, roasting is to cook in an oven or over fire. Soybeans are roasted by exposure to high temperatures for short periods. This is usually done by passing the beans through a flame in a continuous flow system so that the beans are rapidly heated in the process. Another way is to suspend the beans in a hot stream of air (fluidized bed drying). Soybeans passed through a drum roaster can produce fairly consistent product.

The proximate composition of soybean will definitely change after it is heated at different temperatures (Dozier and Hess, 2011). Faldet and Satter (1991) roasted soybeans in a direct fire roaster at 146°C. The protein quality did not reduce and it was not also over cooked. Meanwhile, the crude protein content of *Nigella sativa* meal increased as the temperature increased, with its highest content at 100°C and lowest at 60°C (Silvia *et al.*, 2012).This suggests that heating can also improve the quality of meal. However, Piper and Boote (1999)

also found that the crude protein of soybean meal to increase with increasing temperature. Nonetheless, over-heating decreases the protein and amino acid content thus, reduces amino acid digestibility especially lysine (Jahan-Mihan*et al.*, 2011) and also giving the meal an unusual colour. Moreover, over-heating also increases processing cost. Therefore, processing temperature must be controlled to ensure that the beans are heated sufficiently.

2.6.4 Methods of Extraction

Mechanical extraction method, solvent extraction method and the rendering method are three major methods of extracting oil from agricultural seed apart from the traditional methods (Adejumo*et al*., 2013).

2.6.4.1 Solvent Extraction

The use of volatile organic solvent to leach out insoluble solid structure of oil seeds is referred to as solvent extraction (Obikili, 2010). It involves the washing of oil from soybean flakes with a solvent. Organic and supercritical solvents are the two types of solvents used to extract oil from oilseeds. Solubility, cost and safety are the factors that determine the choice of solvent to be used. However, solubility of oil in solvent is increased with increase in extraction temperature (Sargolzaei *et al.*, 2013).

According to Dari (2009) solvent extraction has an efficiency of over 98%. Sargolzaei *et al*., (2013) mentioned it as the most efficient method of extraction to recover oil from oilseeds. Even though, the chemical residue in the solvent extraction is not harmful, processors and poultry farmers are not ready to take any risk because some solvents could be toxic. Solvent are highly inflammable therefore they must be handled with extreme care. Organic solvents

such ashexane, petroleum ether and alcohols are used commercially because of their low boiling points permitting essentially complete desolventisation of the oil.The extraction of oil from *Treculiaafricana*with hexane gave highest oil yield as compared to isopropanol, butanol and acetone in an experiment carried out by Nwabueze and Okocha (2008). But theuse of such oils extracted with hexane, has been questioned in terms of safety (Nwabueze and Okocha, 2008); however, they recommended it above other physical and chemical properties for use in industries other than food. Soybean meal retains residual levels of solvents that are safe in animal feeds but less desirable in food-grade soy flours and meals(Nwabueze and Okocha, 2008).

A supercritical solvent is an alternative for the organic solvents. The supercritical carbon dioxide technique, which utilizes carbon dioxide above its critical pressure (7.3 MPa) and temperature (31°C) as solvent, has been the choice for the majority of edible applications (Sargolzaei *et al.,* 2013). Sargolzaei *et al*., (2013) also mentioned that when pressure is released from the system, carbon dioxide returns to the gas phase and oil precipitates out from CO_2oil mixture. Hence, the carbon dioxide is recycled; CO_2 released from the system is not an environmental issue.

Solvent oil extraction is usually applied to seeds with low oil content (< 20%), such as soybeans (Azadmard-Damirchi*et al*., 2010). However, when the soybean is pre-pressed prior to solvent extraction, the efficiency is further improved (Oyinlola*et al.,* 2004).Solvent extraction of the oil from the pre-pressed meal can reduce the residual oil content in the meal to less than 1% (Zaher, 2004).

The three major steps in solvent extraction are oilseed preparation, oilseed extraction and desolventising of the oil and meal (Wang, 2002).Solvent extraction equipment is generally expensive to acquire; the chemicals used are toxic and highly inflammable. Therefore

operating it is difficult. On the other hand, mechanical pressing is simple and the equipmentare relatively cheap. Even though, mechanical press method gives the lowest yield it is the most common method of extraction used in the world (Mrema and McNulty, 1985 as cited by Dari, 2009).

2.6.5 Mechanical Extraction

Mechanical oil extraction (expression) is a solid-liquid phase seperation method which is applied to seeds(Gümüşkesen and Yemişçioğlu, 2011**)**. Mechanical method involves the direct application of forces to the materials in other to get out oil from the seed. It is usually done in two ways, either hydraulic or uni-axial/screw press which is also called an expeller. Mechanical method is the oldest method used in extracting oil from seeds (Willems, 2007). Mechanical extraction can be done by two main approaches which are cold pressing and hot pressing. Cold pressing is done when the seeds are not heated before pressing, and when heat is applied before pressing it is referred to as hot pressing.

Expellers are preferred to the hydraulic press because; it is able to process continuously while the hydraulic press process in batches. Efficiency of oil expulsion actually depends on the preparation of seed; according to Shukla*et al.*(1992) a single press has an efficiency of 6-7%. They also mentioned that the cake obtained contained a fat content of 4% after a double press. To recover the maximum amount of good quality oil is the main objective of oilseed processing. Therefore, the choice of double press depends on the economics of the process, oilseed and type and end use of the cake. However, the excessive use of pressure in the single or double press affects the quality of the oil and cake (Shukla*et al.,* 1992). Linseeds are pressed more than once; they are pressed twice or thrice for maximum yield. Kasote*et al*. (2012) mentioned that, the percentage yield of linseed increased as the number of presses also

increased. The difference between the single and double press was great, but the difference between the double and the third press very small (Kasote*et al*., 2012).

2.7 Chemical Properties of Oil

Chemical properties of oil are affected by factors like temperature, availability of oxygen and light. According to Kasote*et al*., (2013) the chemical properties of linseed oil varied with the number of mechanical presses.

2.7.1 Peroxide Value

Peroxide value test is one of the most widely used to test for oxidative rancidity; peroxide value is a measure of the concentration of peroxides and hydroperoxides formed in the initial stages of oxidation rancidity of fats and oils (O'Brien, 1998). The method used is based on an iodometric titration with standardised sodium thiosulphate which measures the iodine liberated from potassium iodine by peroxides present in the oil (Rossell, 1994). Milliequivalents of peroxide per kg of fat are measured by titration with iodide ion. High peroxide values are a definite indication of a rancid fat, but moderate values may be the result of depletion of peroxides after reaching high concentrations.

According to Abdulkarim*et al*., (2007), the amount of peroxides in oil cannot be used to estimate the extent of oil deterioration because peroxides are unstable as deterioration continues the hydroperoxides decomposes. Therefore it is important to use other parameters other than peroxide value alone.

The peroxide value decreased with increasing temperature in moringa seed oil (Tunde-Akintunde*et al.*, 2001); the lower peroxide value indicates its resistance to rancidity. An experiment by Kasote*et al.*,(2013) showed that the peroxide value of linseed oil from the

second press was higher than the peroxide value of the single pressed oil.Peroxide values of hazel nut were 0.89 meqO_2/kg oil and 0.92 meq O_2/kg oil for untreated seeds and microwaved pretreated seeds, respectively (Uquiche*et al.*, 2008).

2.7.2 Iodine Value

Iodine value is the measure of unsaturated acid present in the oil. A lower value indicates a lower degree of unsaturated acid. An experiment carried out by Tunde-Akintunde*et al.* (2001) found out that, the higher the temperature of moringa seeds the lower the iodine value of the extracted oil. But then the iodine value of oil extracted from single pressed oil was higher than that which was extracted after the second and third press (Kasote*et al.*, 2013).

2.7.3 Free Fatty Acid and Acid Value

Free fatty acid (FFA) is the percentage by weight of a specified fatty acid (e.g. % oleic acid) (Nielsen, 1994). The extent to which glycerides in oil are decomposed by lipase action is measured by the FFA value. FFA also has a pro-oxidant effect (Frega*et al.*, 1999). Pro-oxidants in oil have detrimental effect on oil stability. Metals act as pro-oxidants, they liberate radicals from fatty acids or hydroperoxides (Van der Merwe, 2003); two of the most active metals are iron and copper (Van der Merwe, 2003). Rancidity is a result of FFA formation. Hence, the FFA present in oil determines its shelf life.

FFA is also affected by temperature. In 2001, Tunde-Akintunde*et al.* performed an experiment on heat-treated moringa seeds; they found out that the higher the temperature the lower the free fatty acid value.Heating time also has an effect on the FFA. FFA content increased from 0.336 to 0.339 when castor seeds were microwaved at 280W to 280W for 120 seconds (Mgudu*et al.*, 2012).The number of mechanical presses can also affect the free fatty

acid value. The free fatty acid value increased from 0.98 to 1.48 when linseed was pressed for the second time (Kasote*et al.,* 2013).

In crude oil, FFA estimates the amount of oil that will be lost during refining (Kirk and Sawyer, 1991). High FFA values mean more oil loss during refining. The smoke point of oil is lowered when the free fatty acid value is extremely high.

When used as a biodiesel, FFA form salts with the metal and may damage the engine or the tanks at high temperatures (Toscano and Maldini, 2007). Fatty acids have some advantages. A monounsaturated fatty acid called oleic acid, reduces the risk of high blood pressure, fights cholesterol by reducing bad cholesterol, demonstrates preventive impact on cardiovascular diseases, reduces insulin needs of diabetic patients, and it has prevents cancer (Mecit*et al*., 2005).

On the other hand acid value is the number of milligrammes of potassium hydroxide necessary to neutralize the free acids in one gram of oil sample. Acidvaluecanbeusedforapuritycheckofoilandmayhavealreadystarted decomposition reactions.Acid value may be directly converted into Free fatty acid value by multiplying the by a factor of 1.989.According to Tunde- Akintunde*et al*., (2001) higher temperatures gave lower acid values, which imply that oils from moringa seeds that were heated-treated at 100°C, 130°C and 150°C are edible.

2.7.4 Saponification Value

Saponification is the reaction between ester and alkali in the presence of heat. Saponification literally means "soap making". Saponification is the hydrolysis of fats or oils under basic conditions to produce glycerol and the salt of the corresponding fatty acid. Moringa seeds that were heated from 100°C to 150°C, the saponification value of the oil decreased with

increasing temperature (Tunde-Akintunde*etal*., 2001). Ayoola and Adeyeye (2010) conducted an experiment on groundnut had values of 170 to 201 Mg/KOH/g. They suggested that these values were very high and made the oil from groundnuts not attractive as raw material because of its economic and nutritive implications; but very useful in soap making industry. Another experiment conducted on effect of mechanical press on the saponification value showed that the value increased from 146.1 to 183.07 and to 196.27 at single, double and triple press respectively (Kasote*et al.*, 2013).

2.7.5 Unsaponified matter

Unsaponifiable matter in oils and fats are the substances that are not saponifiable by alkali hydroxides but are soluble in the ordinary fat solvents and to products of saponification that are soluble in such solvents. Hydrocarbons, alcohols and sterols, and non-fatty constituents like mineral oil make up the unsaponified matter (Boekenoogen, 1964 as cited by Dari, 2009). At least 2% of unsaponifiable matter can be found in pure fats and oils (Dari, 2009). However, high values of unsaponifiable matter may indicate adulteration and contamination (Kirk and Sawyer, 1991).

2.7.6 Ester value

Ester value is the number of milligrams of potassium hydroxide required to saponify the esters in 1.0g of the substance. It can also be determined by calculating the difference between the saponification and acid value.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The materials, machines and devices that are discussed in the following subsections were used in the study.

3.1.1 Digital Thermometer

Temperature reading was taken by a multi-meter. The multi meter can be used to measure a lot of other parameters such as resistance, current and potential difference. A probe was connected to the multi-meter and inserted into the heated soybean. The reading was recorded when the temperature was stable.

3.1.2 Drum Roaster

The drum was powered by a 10 horse powerelectric motor and fuelled by Liquefied Petroleum Gas (LPG). The drum has beaters which help in turning the soybeans as there are heated. The drum rotates at 17 turns per minute. It also has a maximum capacity of 250kg. The roaster also allows dirt to fall out through the openings at one end as shown in Figure 4a.

Figure 4a: Holes that aid in cleaning

Figure 4b: Outlet of roasting

Figure 4c:Inlet or hopper of the roaster

Figure 4d: Gas hoses connected to the stoves

3.0.1 Screw Expeller

The screw press is a 6YL-100 model powered by a 20 horse power motor. The main parts of the expeller are the seed feeder, cone shaped cage, adjustable cone for press-cake outlet and a worm. As the soybean enters the barrel and falls on the helical pressure. The material is subjected to further pressure as it moves through the barrell.The cage is made of a number of special steel bars which allows the oil to pass through. The oil passes between the bars andflows out of the cage. Figures 5a and 5b show the front and side veiw of the screw expeller.

Figure 5a: Front View of Screw Expeller

Figure 5b: Side View of Screw Expeller

3.1.3 Soybeans

Soybeans were acquired from the Tamale market. Conditioning of the soybeans before roasting was done by first calculating the moisture content. The required amount of moisture was added before roasting. The adequate moisture content for maximum oil yield must be about between 14% wb.

3.1.4 Other Instruments

The electronic balance is used to measure the mass of samples. It is able to measure even very small masses like 0.01g. A weighing scale was also used to measure masses above 10kg.

Other instruments such as measuring cylinder, pipette, burette, was used to measure the volumes of chemicals. And a reflux condenser was used to perform various qualitative analyses.

3.2 Methods

The methods and procedures that are discussed in the following subsections were used in the study.

3.2.1 Conditioning of Soybeans

Moisture has to be added to the soybean to allow more oil to be expelled during the extractionprocess. However, the moisture was increased to about 14%wb. Equation 1 was used to determine the moisture content of the soybean and the amount of moisture that was required for processing.

$$\textbf{Moisture content} = \frac{\textbf{initial weight} - \textbf{final weight}}{\textbf{initial weight}} \times 100 \quad \textbf{.....Equation 1}$$

3.2.2 Oil and Meal Yield

A density bottle was used to find the densityof the oil sample. The weight of the oil sample was then calculated using equation 2:

$$\text{Weight of extracted oil} = \text{density of extracted oil} \times \text{volume} \quad \textbf{.....Equation 2}$$

Percentage oil and meal yield were calculated using equations 3 and 4:

$$\text{Percentage oil yield} = \frac{\text{weight of extracted oil}}{\text{total weight of sample}} \times 100 \quad \textbf{.....Equation 3}$$

$$\text{Percentage meal yield} = \frac{\text{weight of meal}}{\text{total weight of sample}} \times 100 \quad \textbf{.....Equation 4}$$

3.2.3 Standardising Sodium Hydroxide WithOxylic Acid

The 50ml burette was filled with oxylic acid. Then 10ml of sodium hydroxide was put in a conical flask and mixed with one drop of phenolphthalein. The oxylic acid was titratedagainst the sodium hydroxide until there was a colour change. This was replicated and the average titre value was calculated. The concentration of the sodiumhydroxide was calculated using equation 5.

$$\mathbf{C_1V_1 = C_2V_2} \quad \textbf{.....Equation 5}$$

Where, $C_1 =$ Concentration of oxylic acid

$C_2 =$ Concentration of NaOH

$V_1 =$ Volume of oxylic acid

$V_2 =$ Volume of NaOH

3.2.4 Standardising with hydrogen chloride

The burette filled with HCl was titrated against the 10ml of NaOH in a conical flask and drop of phenolphthaleinwere added till there was a colour change. Equation 5 was used to determine the concentration of HCl.

Where, $C_1 =$ Concentration of Hydrochloric acid

$C_2 =$ Concentration of NaOH

$V_1 =$ Volume of hydrochloric acid

$V_2 =$ Volume of NaOH

3.2.5 Acid Value

5g of the oil was dissolved in 50mL of a mixture of equal volumes of ethanol and diethyl ether which has been neutralized with 0.1 NaOH. 5mL of phenolphthalein was added and titrated with NaOH until the solution remains pink after shaking for 30seconds. The acid

value or the volume of 0.1 alkali required to neutralize 5g of the oil sample was recorded for each replicate and the average was found.

3.2.6 Saponification Value

1g of oil was dissolved in 30ml of equal volume mixture of ethanol and diethyl ether. 25ml of 0.5M alcoholic KOH was added and reflux condenser was set up. Another reflux condenser was set up as a blank. Both flasks were heated on a boiling water bath or 30 min. Samples were allowed to cool to room temperature. Samples were then titrated with 0.5M HCl and phenolphthalein indicator. The difference between the blank and test readings gave the volume of 0.5M KOH required to saponify 1gram of oil.

3.2.7 Peroxide Value

5g of oil was put in a conical flask. 30ml of a mixture of glacial acetic acid and chloroform (3:2)added and shakenwhich dissolved the oil sample. 0.5ml of saturated potassium iodide solution was dropped into the sample and shakenfor about a minute. 30ml of water was added to the sample and titrated slowly with 0.01N sodium or thiosulphate. 0.5ml of starch was added and titration continued, shaken vigorously until the blue colour was discharged. A blank was also carried out under the same conditions. The difference between the actual test and the blank, multiplied by 10 and divided by the weight in grams of each sample taken is the peroxide value.

3.2.8 Moisture Content Determination of Meal

2 g of the milled sample was weighed using an electronic balance, placed in a crucible and dried in an oven at 105°C for 5hours. The sample was removed and placed in a desiccator and

cooled to room temperature. The sample and crucible were weighed repeatedly until a constant weight was obtained. Loss in weight of the sample was reported as moisture content.

$$\%\ \text{Moisture content of meal} = \frac{\text{loss of meal weight}}{\text{weight of initial meal sample}} \times 100 \quad \textbf{.....Equation 6}$$

3.2.9 Ash Content Determination

2g of the milled sample was transferred into a previously ignited and weighed crucible and placed in a furnace (preheated to 600°C) for 2hours. The sample with the crucible was transferred directly from the furnace into a desiccator, and allowed to cool and the weight taken.

$$\%\ \text{ash} = \frac{\text{weight of ash}}{\text{weight of sample}} \times 100 \quad \textbf{.....Equation 7}$$

3.2.10 Crude Protein Determination

2 g of the milled sample, half of selenium based catalyst tablet and a few anti-bumping agents were placed into a digestion flask. 25 ml of concentrated sulphuric acid (H_2SO_4) was added to the sample and the flask shaken, a wet and well mixed mixture was obtained. The mixture was heated slowly till boiling stopped and a clear solution was obtained. The solution was cooled to room temperature and the digested sample put in a volumetric flask. For distillation of the sample, the apparatus was flushed out before use. 25 ml of 2% boric acid was put into a conical flask and 2 drops of mixed indicator added. Liquid was drained from the steam trap while leaving the stop cork which drains the steam trap opened. The conical flask with its content was placed under the condenser in a position where the tip of the condenser was completely immersed in the solution. 10 ml of the digested sample was measured and added to the decomposition flask. 40% of NaOH (about 20 ml) was also added to the decomposition flask. Distillation was allowed to continue for about 5 minutes and the burner removed from

the steam generator. The sample was titrated with 0.1N Hydrochloric Acid (HCl) solution until the sample solution became colourless.

3.2.11 Crude Fat Determination

Moisture determined samples were transferred into a paper, sealed and placed into a thimble with cotton wool to prevent loss of the sample. An anti-bumping granule and 150 ml petroleum spirit was measured into a 250 ml round bottom flask and fluxed for 4 hours on high heat. The flask was removed and evaporated on a steam bath and the oil dried for 30 minutes in an oven at 103°C and weighed. The oil was cooled to room temperature

$$\% \text{ fat} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100 \quad \textbf{.....Equation 8}$$

3.2.12 Crude Fibre Determination

The defatted sample for crude fat determination was transferred into a 750 ml flask and half gram of asbestos added. 200 ml of boiling 1.25%$H_2SO_4$was added and the flask immediately set up on a hot plate and connected to a condenser. The content started boiling after a minute and agitated frequently until the sample was thoroughly wetted. The flask was removed in 30 minutes and the sample filtered through a linen cloth in a funnel. The boiled sample was washed continuously until there was no indication of the presence of an acid in the sample. The charge and asbestos were washed into a flask using 200 ml boiling 1.25% sodium hydroxide (NaOH) solution $H_2SO_4$was and the condenser connected and set back on the hot plate. At the end of 30 min the content was filtered through a linen cloth and thoroughly washed with boiling water. The residue was transferred into a crucible and washed with approximately 15 ml alcohol. The content was dried in an oven at 100°C for an hour; the content was transferred into a desiccator and weighed. The crucible with content was ignited

in a furnace between 500°C - 600°C for 30 min cooled and weighed; the crude fibre is the loss in weight.

3.2.13 Statistical analysis

Each sample was replicated trice; the results were expressed as means and standard deviation (SD).Significant differences between means of two oil samples were assessed with Student's *t* test. Significant differences between means of same sample were determined by Duncan's multiple range test using SPSS 11.5 software package. At $P < 0.05$ differences were considered statistically significant. The results of the proximate analysis were not represented as means. The percentage quantity yield was analysed using the formulae.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Quantitative Analysis

In this project quantitative analysis were measured in percentage mass yield. It is one of the common methods used for measuring yield.

4.1.1 Percentage Cake Yield

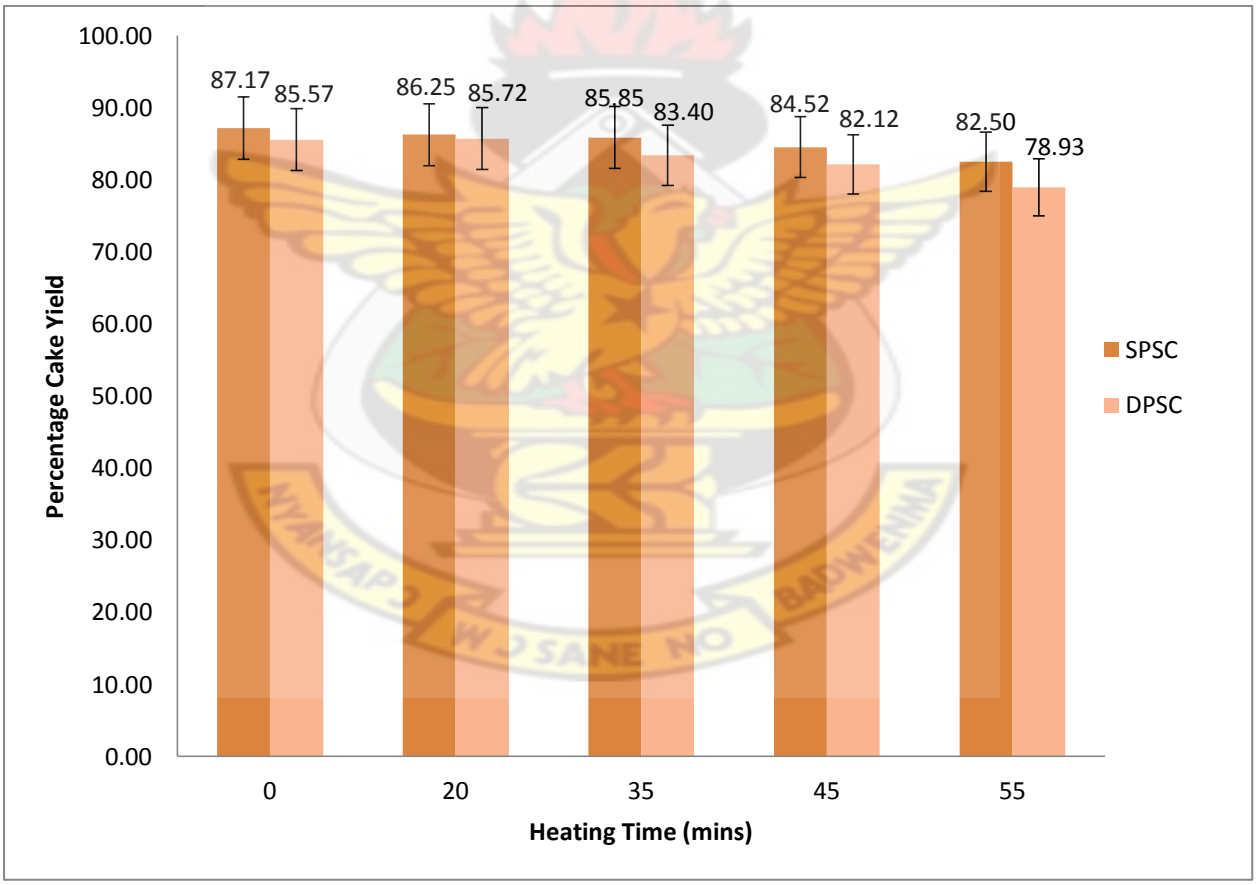

Figure 6: Percentage Cake Yield against Heating Time

Figure 6 represents the percentage cake yield. Figure 6 shows that percentage cake yields decreased with increase in heating time. There was a significant difference ($p < 0.05$)

between Single Pressed Soybean Cakes (SPSCs) and their corresponding Double Pressed Soybean Cakes (DPSCs); the control was the only exception. This was due to further expulsion of oil and other losses (sludge and grits) during the double press, hence reducing the percentage cake yield for DPSCs.

The percentage cake yield for the control SPSC was significantly different from the all the other SPSCs. The control SPSC had the highest yield of 87.17% followed by 86.25%, 85.85%, 84.52% and 82.50% which were heated for 20, 35,45 and 55 minutes respectively. As more oil is expelled as heating time increases, percentage cake yield decreases. However, heating a sample for 35 minutes did not give a significantly($p < 0.05$) higher percentage cake yield than the sample that was heated for 20 minutes.

4.1.2 Percentage Oil Yield

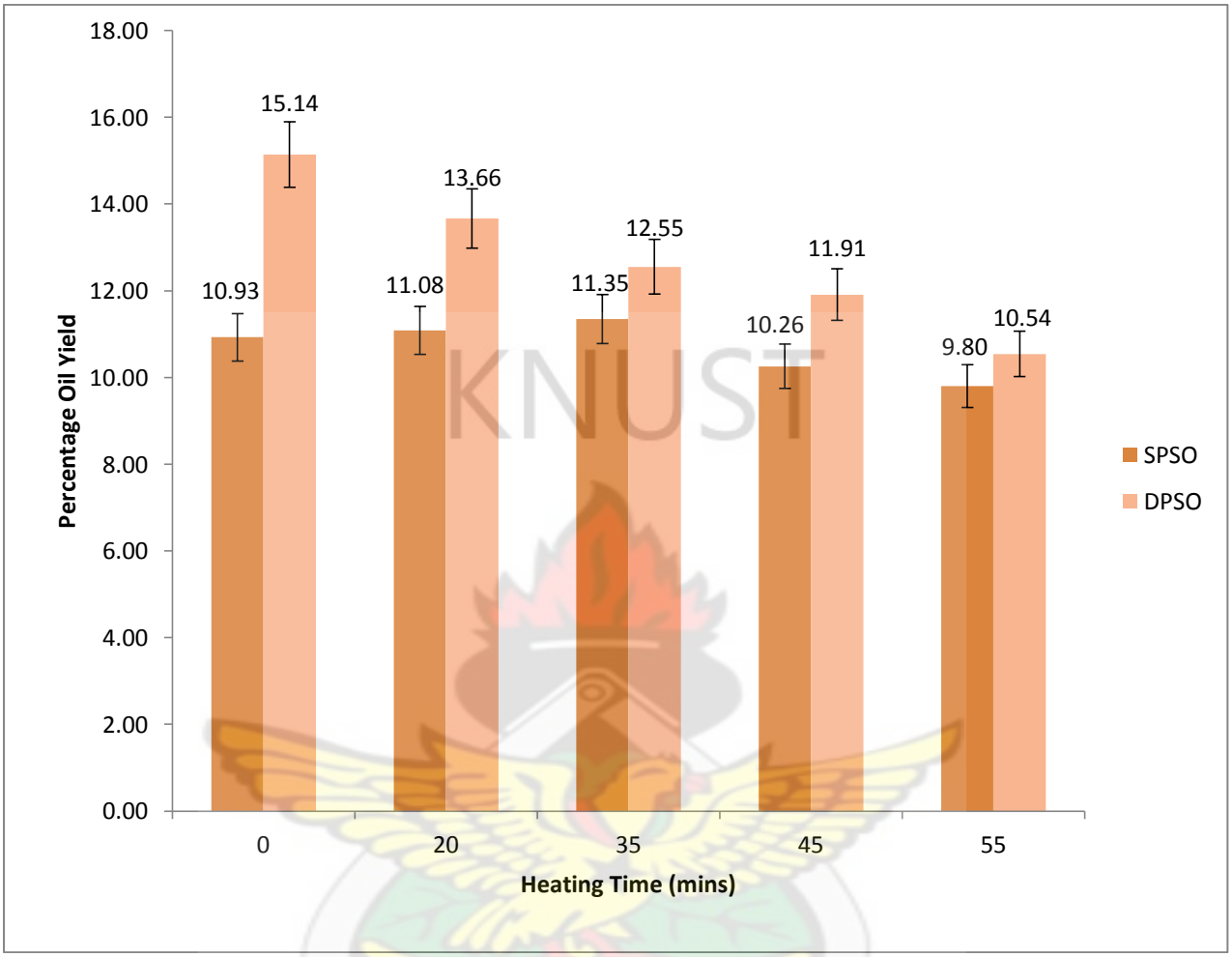

Figure 7: Percentage Oil Yield against Heating Time

As shown in Figure 7, the percentage oil yield forSingle Pressed Soybean Oils (SPSOs) increased gradually and started reducing gently withheating time. For the single press, the sample that was heated for 35 minutes had the highest yield of 11.35%.The increase in oil yield as the heating time increased to 35 minutes can be attributed to breaking of the walls of the oil bearing cells which allows the oil to be expelled easily. A similar result was obtained by Tunde-Akintunde*et al*. (2001); they found that the yield of soybean oil increased from a heating time of 15 to 30 minutes. Nonetheless, in biological materials there are always limits. Above a heating time of 35 minutes, oil yield decreased. This may be due to the further

decrease (removal of excess) in the moisture content and volatility of oil during roasting. This point is buttressed by an experiment carried out by Adejumo*et al.* (2013); their reults showed that oil yeild of moringa seed decreased when it was heated above 100°C for 30 minutes. They stated that the procesing method, variety of seed and soil condition could have caused the variation.

There wasa significant difference at $p< 0.05$ between the control SPSO and the SPSO obtained after 35 minutes of heating. There was also no significant difference between the SPSOs which were obtained after 20 and 35 minutes of heating. However, the percentage Double Pressed Soybean Oils (DPSOs) yield weresignificantly ($p< 0.05$) higher than their corresponding SPSOs samples. The DPSO oil yield was the sum of the SPSO oil and the oil derived from the second press. This explains why the DPSO had the highest oil yield. This means that oil yield can only be optimised in the control by pressing it twice. A similar result was obtained by Williams and Rathod (1974) when DPSO increased to 8% from 5% of SPSO. This is where the cost of production might be considered and the quality of the meal might also be compromised. Since anti-nutritional components can cause harm to livestock.

4.2 Qualitative Analysis

Quality is subjective to the end use of a product. This means that what might be of good quality to one may be of bad quality to another. Quality of oil may be grouped into two main categories; they are chemical and physical properties. In this project only some of the chemical properties were considered.

4.2.1 Acid Value and Free Fatty Acid

The acid values obtained were far lower as compared to the value obtained byAbitogun*et al*., (2009)who had an acid value of 2.72mgKOH/g oil. This could be due to the difference in variety and method of extraction.According to the CODEX-STAN 210 acid value of crude oil must not be more than4.0 mg KOH/g oil. The acid for all samples was less than 1 which was even lower than the 0.6 mg KOH/g for refined vegetable oils as stated by CODEX-STAN 210. This explains why soybean oil is widely used because of its low acid value.

Free fatty acid is just a multiple of 1.989 by the acid value so acid value and free fatty acid have the same effect. The acid value of the samples that were pressed once decreased with increasing heating time. This agrees with the findings of Adejumo*et al*. (2013); they found out that the acid value in moringaolifera seeds decreased with increase in temperature. At the same heating time, SPSOs were significantly lower at $p< 0.05$ than their corresponding DPSOs.This agrees with the findings ofKasote*et al.*(2013).They found out that the acid value of linseed increased when it was pressed twice. As shown in the Table3, the corresponding DPSO of SPSO obtained after 20 minutes of heating had the highest acid value followed by the corresponding control DPSO and DPSOsof SPSO obtained after 45 minutes, 35 minutes and 55 minutes of heating respectively.

Suitable oils for industrial purposes must have low acid values especially for the petroleum industry as high acid values cause destruction to the sump of engines at high temperatures (Tascano and Maldini, 2007). The acid value from the analysis gave soya bean oil an added advantage for use in the petroleum industry, just as in Table 2. All the samples can be used as biofuel for low and high speed engines.

4.2.2 Saponification Value and Ester Value

Saponification values decreased with increase in heating time for SPSOs as shown in Table 3.Adejumo*et al*. (2013) also had the similar trend of decreasing saponification value with increase in temperature. In the control SPSO had the highest value of 239.35±10.58and the SPSOs obtained after 55minutes heating had the lowest value of168.49±1.85. Apart from the SPSO that was obtained after 20 minutesof heating and its corresponding DPSO, there was no significant difference at $p< 0.05$ between SPSOs and their correspondingDPSOs.

SPSOs which were obtained after 20 and 35 minutes of heatingperfectly fit into the range recommended by CODEX STAN 210-1999 of 189-195 for crude soybean oil. However, SPSO obtained after 45 minutes of heating was not far from the FAO/WHO (2009) recommendation which is 181±2.60 for cooking.

DPSOs had relatively higher values compared to their corresponding SPSOs; even though the differences not significant at $p< 0.05$, except for the SPSO obtained after 20 minutes of heating and its corresponding DPSO. As shown in Table3, value of sample heated for 35 minutes reduced drastically to 205.65±4.60 closely followed by samples heated for 45 and 55 minutes.

Oil samples with higher saponification value (above 195) are not attractive as raw material for the edible oil, because of cost of refining. However, they are best used as raw materials in the soap industry because the greater the saponification value, the better the soap making ability of the oil (Nielsen, 1994).

Ester value is related to the saponification value. Therefore, all that is applicable to saponification is likened to the ester value. As shown in the Table3, the ester value takes the same pattern as the saponification value.

4.2.3 Peroxide Value

All the samples fell within the standard specified by CODEX-STAN 210 oil which is below 15m/mol/kg. 2.67, 2.24, 2.17, 2.17 and 2.14 are the peroxide values of oil obtained from the first press respectively. The values for the DPSOs are 3.47, 3.04, 2.67, 2.54 and 2.34 respectively. In both cases, the peroxide values decreased with increasing heating time. The peroxide values of the DPSOs were significantly higher than their corresponding SPSOs. Only SPSO that was obtained after 55 minutes of heating and its corresponding DPSO were not significantly different. There was also a significant difference between the control and the other samples. However, SPSOs obtained from increasing the heating time from 20 to 55 minutes did not give a significant increase in the peroxide values for the single pressed oil as shown in Table 3.

Lower peroxide values in the soybean oil indicate its resistance to rancidity. Therefore, all samples were resistant to rancidity.

Table 3: Chemical characteristics of extracted soybean oil

Parameter	Heating time (min)	SPSO	DPSO
Acid value	0 (Control)	0.47±0.06*A*	0.50±0.11*A*
	20	0.28±0.06*B*	0.55±0.07*A**
	35	0.27±0.02*B*	0.35±0.04*B**
	45	0.22±0.02*C*	0.38±0.02*B**
	55	0.17±0.02*C*	0.28±0.06*C**
Free fatty acid	0 (Control)	0.93±0.12*A*	0.99±0.22*A*
	20	0.56±0.12*B*	1.09±0.14*A**
	35	0.54±0.04*B*	0.70±0.08*B**
	45	0.44±0.04*C*	0.76±0.04*B**
	55	0.34±0.04*C*	0.56±0.12*C**
Saponification	0 (Control)	239.35±10.58*A*	261.65±46.32*A*
	20	194.75±1.21*B*	264.62±46.82*A**
	35	193.26±6.42*B*	205.65±4.60*B*
	45	185.34±4.26*B*	194.75±16.82*B*
	55	168.49±1.85*C*	173.94±37.04*C*
Peroxide value	0 (Control)	2.67±0.08*A*	3.47±0.22*A**
	20	2.24±0.06*B*	3.04±0.23*B**
	35	2.17±0.06*B*	2.67±0.29*C**
	45	2.17±0.02*B*	2.54±0.07*C**
	55	2.14±0.00*B*	2.34±0.04*D*
Ester value	0 (Control)	238.88±10.52*A*	261.15±46.21*A*
	20	194.47±1.15*B*	264.07±46.75*A**
	35	193.00±6.36*B*	205.30±4.58*B*
	45	185.12±4.24*B*	194.37±16.80*B*
	55	168.32±1.85*C*	173.65±36.98*C*

Each value in the table represents the mean of three replicates ±SD
Values in column with the same upper cases are not significantly different at p<0.05
***for the same heating time, acid value, free fatty acid, peroxide value saponification value and ester value were significantly different from that of SPSO**

Table 4: Proximate Analysis of the Raw Material

Parameter	(%)
Moisture content	9.00
Crude fat	15.50
Crude protein	43.20
Crude fibre	16.77
Carbohydrate	9.53
Ash content	6.00

4.2.4 Moisture Content

Moisture content of the cake decreased with increase in heating time. However, moisture content of DPSCs had lower moisture contents than their corresponding SPSCs. The control had the highest as shown in Table 5; the second press of the control was lower as expected. The reduction in moisture content within a column in Table 5 could be due to the evaporation of moisture from the soybean during roasting (heating). More of the moisture could have also found its way into the crude oil that was extracted. According to Feedstuffs Ingredient Analysis Table (2012) as shown in the appendix A, the required moisture content for soybean that has gone through an expeller is about 11%. This means that all the samples are not likely to be easily contaminated by mycotoxins and fungus, if the meal is stored in a dry place.

4.2.5 Crude Fat

The crude fat content of all the samples agrees with the percentage oil yield in section 4.0.2. High percentage oil yield means a low fat content of the cake. The DPSC of the corresponding SPSC obtained from the sample that was heated for 35 minutes had the lowest moisture content of 2.5%; which was a little lower than 3.5% recommended by theFeedstuffs Ingredient Analysis Table (2012) as shown in Appendix A. This difference could be due to

difference in variety and method used for the extraction of oil. High fat contents are not desirable for poultry as mentioned in Chapter 2. The highest fat content was 11.38%. This could be related to its corresponding moisture content. Thus, low moisture content of beans is likely to give a low oil yield and hence a high crude fat content for that meal.

4.2.6 Crude Protein

As shown in Table 5, the protein content increased after the samples were heated up to 35 minutes and then started decreasing afterwards. This shows that heating soybean increases the protein content of the meal. Hence, over heating also destroys the protein leading to the reduction of the protein. From the Table 5, both the SPSCs and the DPSCs had the rise-fall trend. SPSC obtained after heating the soybean for 35 minutes and its corresponding DPSC had the best crude protein content.

4.2.7 Crude Carbohydrate

For the SPSC obtained after heating the soybeans for 55 minutes had the highest crude carbohydrate content of30.66%. Comparatively, the DPSCs hadsignificant higher carbohydrate content than their corresponding SPSCs. According to the Feedstuffs Ingredient Analysis Table (2012) as shown in Appendix A, carbohydrate should be about 36.4%. However, the raw soybean had a carbohydrate content of 9.53% before heating. It is likely that heating increased the carbohydrate content. But this was not confirmed by any literature. The increase could also be related to the changes in other parameters such as protein and/or fibre content.

4.2.8 Crude Fibre

As discussed in the Section 4.1.7, there could be a relationship between fibre content and carbohydrate content. Lower fibre content gave corresponding higher carbohydrate content. According to the Feedstuffs Ingredient Analysis Table (2012) as shown in Appendix A, the fibre content must be about 6.5%; this corresponds to *Coussens (2009)* recommendation. Therefore, the samples with fibre content lower than 6% may not be desirable as feed.

Table 5: Proximate analysis after extraction

Parameter (%)	Heating time (min)	SPSC	DPSC
Moisture content	0 (Control)	11.20*B*	7.09*C**
	20	11.64*A*	10.86*A**
	35	11.50*A*	9.75*B**
	45	9.67*C*	6.36*D**
	55	6.33*D*	5.47*E**
Crude fat	0 (Control)	11.00*B*	8.56*A**
	20	9.74*C*	7.32*C**
	35	8.00*D*	2.50*E**
	45	11.05*B*	6.00*D**
	55	11.38*A*	7.98*B**
Crude protein	0 (Control)	44.90*C*	45.08*B**
	20	43.45*D*	44.24*C**
	35	46.10*A*	47.03*A**
	45	45.03*B*	44.41*C**
	55	43.72*E*	43.63*D*
Crude fibre	0 (Control)	6.98*A*	6.48*A**
	20	5.47*B*	5.00*B**
	35	6.33*B*	6.34*A*
	45	3.07*D*	2.89*D*
	55	3.68*C*	3.22*C*
Crude carbohydrate	0 (Control)	20.25*E*	27.34*E**
	20	24.90*C*	27.86*D**
	35	23.07*D*	28.98*C**
	45	26.59*B*	36.26*A**
	55	30.66*A*	35.25*B**

Each value in the table represents the mean of three replicates
Values in column with the same upper cases are not significantly different at p<0.05
***for the same heating time, moisture content, crude fat, crude protein, crude fibre and crude carbohydrate were significantly different from that of SPSC**

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the percentage yield results, heating time had an influence on the percentage yield of both oil and cake. 35 minutes was the optimum heating time for obtaining SPSO for a high percentage oil yield (11.35%). Further heating after the optimum heating time reduced the percentage yield of the oil.

As the heating time increased percentage cake yield decreased. But one must also have in mind that some mechanical losses also occurred during the extraction process.

The meal quality depends on the end use of the meal. The main parameters that are considered by many retailers and farmers are low fat content and high protein content. Therefore, heating the soybean for 35minutes was the optimum heating time. However, double pressing this same sample increased the protein content to 47.03%. Therefore, pressing soybean meal for the second time increased the protein content.

The corresponding DPSC of SPSC that was obtained after 35 minutes of heating gave the highest crude protein, low moisture and crude fat content which agrees with the Feedstuffs Ingredient Analysis Table (2012) as shown in Appendix A.

All samples of crude soybean oil obtained can be used for cooking if refined and other industrial uses. The acid value, saponification value, free fatty acid and peroxide values were all affected by heating time and number of presses (single and double presses). Acid value decreased with increasing heating time. The second pressed oil acid value was higher than the single pressed oil. All the samples saponification values also decreased with increasing heating time. The double press did not affect the saponification number except the sample

that was heated for 20 minutes. The second pressed oils had a higher peroxide values than the single pressed oils.

5.2 Recommendations

This project did not consider certain parameters such as using different extraction methods like solvent extraction and physical properties of the extracted oil. It is therefore suggested that:

1. Future study should consider when the anti-nutritional factors (trypsin and lectins) are denatured.
2. Amino acids like lysine, methionine, theronine, cysteine and tryptophan should also be investigated.
3. Future study should consider comparing the solvent and mechanical extraction methods.
4. Physiochemical properties of extracted oil such as refractive index, density and viscosity should be considered in future work.

REFERENCES

1. Abbey, T.K., Alhassan, A., Ameyibor, K., Essiah, J.W., Fometu, E., and Wiredu, M.B.(2001). *Integrated Science for Senior Secondary Schools* (1st edn), Unimax Macmillan Ltd., Accra North,pp 75-76.
2. Abdulkarim, S.M., Long, K., Lai, O.M., Muhammad, S.K.S. and Ghazali, H.M.(2007). Frying Quality and Stability of High-Oleic *MoringaOleifera* Seed Oil in Comparison with other Vegetable Oils. *Food Chemistry*Vol 105 (4), pp1382-1389.
3. Abitogun A.S., Alademeyin O.J., Oloye D.A. (2009). Extraction and characterization of Castor Seed Oil. Internet J. Nutr. Wellness 8(2).
4. Addo-Quaye, A.A., Saah, M.K.,Tachie-Menson, C.K.B., Adam, I.,Tetteh, J.P.,Rockson-AkorlyV.K. and J. E. Kitso (1993). *General Agriculture for Senior Secondary Schools*. MOE. 191-194.
5. Adejumo B.A, Alakowe A.T. and Obi D.E. (2013) Effect of heat treatment on the characteristics and oil yield of moringaoleifera seeds. *International Journal of Engineering and Science (IJES),*Vol2(1): 232-239
6. African Development Foundation (ADF) (2004). e-news. Bosbel vegetables oil project. Cited on the 13th December, 2013.
7. Aurand, L.W., Wood, A.E., Wells, M.R. (1987). Food composition and analysis. Van Nostrand Reinhold, New York, pp. 20-33, 181-220.
8. Ayoola P.B. and Adeyeye A.(2010). Effect of Heating on the Chemical Composition and Physico – Chemical Properties of *Arachis hypogea* (Groundnut) Seed Flour and Oil, *Pakistan Journal of Nutrition*Vol 9 (8): 751-754
9. Azadmard-Damirchi S., Habibi-Nodeh F., Hesari J., Nemati M., Achachlouei B.F. (2010). Effect of Pretreatment with Microwaves on Oxidative Stability and Nutraceuticals Content of Oil from Rapeseed. *Food Chem*. Vol121:1211– 1215.

10. Bennett, J.W. and Klich, M. (2003). Mycotoxins.*ClinMicrobiol Rev*. Vol 16(3): 497–516. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC164220/ cited on 13th January, 2014.
11. Blattner, C. (2005). Boicatlysis Using Lipase Immobilised in Organoels in Supercritical Carbon Dioxide. Unpublished Doctorate Thesis, University of Regensburg. http://epub.uni-regensburg.de/10431/1/Dissertation_Blattner.pdf cited on 23rd February, 2014.
12. Canadian International Grain Institute (CIGI)(2010). Soyabean feed industry guide, 1st Edition. http://cigi.ca/wp-content/uploads/2011/12/2010-Soybean-Feed-Industry-Guide.pdf cited on the 4th of November, 2013.
13. Choct, M., Dersjant-Li, Y., McLeish, J. And Peisker, M. (2010). Review: Digestion, Nutritive and Anti- Nutritive Effects in Pigs and Poultry. *Asian-Australasian Journal, Animal Science*,Vol 23(10):1386-1398.
14. Coussens, I.(2009). Poultry Nutrition. https://extension.arizona.edu/4h/sites/extension.arizona.edu.4h/files/resourcefile/resource/icoussens/Poultry-Nutrition.pdf cited on the 14 of August, 2013.
15. Dari, L. (2009). Effect of Different Solvents on the Extraction of Soya Bean Oil. Unpublished Master's Thesis, Kwame Nkrumah University of Science and Technology, Kumasi.
16. Dersjant-Li, Y.(2010).Reviewing Soybean Carbohydrates.http://www. Prepared foods.com/articles/reviewing-soybean-carbohydratescited on the 26th June, 2014.
17. Dozeir, W.A. and Hess, J.B.(2011). Soybean Meal Quality and Analytical Techniques. http://www.intechopen.com/books/soybean-meal-quality-and-analytical-techniques cited on 3rd March, 2014.

18. Dudley-Cash, W.A.(2003) Soybean Meal Quality. American Soybean Association, Brussels, Belgium. http://www.asa-europe.org/pdf/sbm_qual.pdf cited on June 29th, 2013.

19. Faldet, M. A. and Satter, L. D.(1991). Feeding heat-treated full fat soybeans to cows in early lactation. *J. Dairy Sci*., 74: 3047-3054**.** http://dx.doi.org/10.3168/jds.S0022-0302(91)78490-7 cited on 13thMay, 2014.

20. Food and Agricultural Organisation (FAO)(2013). Small scale food processing- a guide for appropriate equipment. Chapter 8 (vegetables). http://www.fao.org/wairdocs/x5434e/x5434e0c.htm cited on 3rd October, 2013.

21. Food and Agriculture Organization/World Health Organization (FAO/WHO) (2009) http://www.who.int/nutrition/publications/nutrientrequirements/anm_fatsandfattyacids_human_nut/en/index.html cited on the 3rd of November, 2013.

22. Frankel, E.N.(1996). Antioxidants in Lipid Foods and Their Impact on Food Quality. *Food Chem*. Vol.57: 51-55.http://www.sciencedirect.com/ science/ journal/03088146/57/1 cited on 3rd December, 2013.

23. Frega, N., Mozzon, M. and Lercker, G. (1999). Effects of free fatty acids on oxidative stability of Vegetable Oil. *J.AOCS vol76* (3),p325-329http://lib3.dss.go.th/fulltext/Journal/J.AOCS/J.AOCS/1999/no.3/mar1999,vol76,no3,p325-329.pdf cited 3rd May, 2014.

24. Ghafoor, K., AL-Juhaimi,F.Y.I. and Park,J. (2011). High Pressure Treatments of Soybean and Soybean Products, Recent Trends for Enhancing the Diversity and Quality of Soybean Products, InTech, Available from: http://www.intechopen.com/books/recent-trends-for-enhancing-the-diversity-and-quality-of-soybean-products/high-pressure-treatments-of-soybean-and-soybean-products cited on 4th December, 2013.

25. Govindarao, C.N. (2010). Characterisation of Soybean (*Glycine max (L) Merrill*) Varieties through Morphological, Chemical, Molecular Markers and Image Analyzer. University of Agricultural Sciences, Dharwad.
26. Grace, O.M., Borus, D.J., Bosch, C.H. (2008). Vegetable Oils of Tropical Africa: Conclusions and Recommendations based on PROTA 14. Nairobi, Kenya, pp.31
27. Gümüşkesen, A. S and Yemişçioğlu, F.(2011). Crude Oil Production, Oil and fat technology lectures. http://orbit.dtu.dk/fedora/objects/orbit:65586 /datastreams/ file_5825090/content cited on the 3rd May, 2014.
28. Guy, E.(2009). Baseline Data on the Nutrient Content and Physiochemical Properties of Selected Varieties of Soybean, Groundnut and Rice for the Development of Nutritious, Energy-Dense Diets. Unpublished Master's Thesis, Kwame Nkrumah University of Science and Technology, Kumasi.
29. Hammond, E.G., Johnson, L.A., Su, C., Wang, T. and White, P.J.(2005). Soybean Oil, Chapter 13 page 577-653. Bailey's Industrial Oil and Fat Products, 6th edition, sixth volume.
30. High Quest Partners, (2011). Market Potential of Sub-Sahara Africa. http://www. unitedsoybean.org/wp-content/uploads/ MarketPotential_ SubSaharan Africa 2.pdf cited on 14th November, 2013.
31. Ibrahim, A. and Onwualu, A.P.(2005). Technologies for extracting oil from oil-bearing agricultural products: review. *Journal of Agricultural Engineering and Technology (JAET),*Vol 13:59-89.
32. Ishaaya, I., Birk, Y.,Bondi, A. and Tencer,Y. (1969). Soybean Saponins. IX. Studies of Their Effect on Birds, Mammals, and Cold-Blooded Organisms. *J. Sci. Food Agric*. 20:433-436.

33. Jahan-Mihan, A., Luhovyy B.L., El Khoury, D. and Anderson G. H.(2011). Dietary Proteins as Determinants of Metabolic and Physiologic Functions of the Gastrointestinal Tract. http://www.scribd.com/doc/226087552/Dietary-Proteins-and-Physiological-Function cited on 30th January, 2014.

34. Jeager, W. and Siegel, R. (2008). Economics of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley. http://ir.library.oregonstate. edu/xmlui/bitstream/handle/1957/8503/SR_no.1081_ocr.pdf cited on the 3rd January, 2014.

35. Jing, J., Li, D., Wang, X., Ma, Y., Li, H. and Sun L. (2011). Determination of Quinestrol in Animal Food by RP-HPLC Method. http://impascience.eu/CIGR/510_proceedings/043_Posters-ChineseDelegation-part2.pdf cited on 15th February, 2013.

36. Kasote D. M., Badhe Y.S. and Hegde M.V.(2012). Effect of mechanical press oil extraction processing on quality of linseed. Industrial Crops and Products 42 (2013) 10– 13. http: //www.elsevier.com/locate/indcropcited on the 3rd October, 2013.

37. Kemper, T.G. (2004). Bailey's Industrial Oil and Fat Products, chapter 2, (6thedn.) Vol 6: 57-97. John Wiley & Sons, Inc.

38. Kirk, R. S. and Sawyer, R. (1991). Pearson's Composition and Analysis of Foods, 9th edition. Addison Wesley Longman Ltd., England, pp. 9-29, 608-640.

39. Lampi, A. M., Kataja, L., Kamal-Eldin, A., and Vieno, P. (1999). Antioxidant Activity of Alpha- and Gamma-Tocopherols in the Oxidation of Rape Seed Oil Triacylglycerols,*J. Am. Oil Chem. Soc.*Vol. 76:749-755.

40. Ma F. and M.A Hanna (1999). Biodiesel Production, *BioresourceTechnology,*Vol70:1-15.

41. Macrae, R., Robinson, R. K. and Sadler, M.J. (1993). Soya Beans. Food Technology and Nutrition. Academic Press; London. 1993:4215-4218.

42. Mahajan, A., Ahluwalia, A.S., and Mahajan, P. (2011). Properties of Biodiesel from Various Oilseeds. *International Journal of Research in Environmental Science and Technology*, Vol 1(4) pp 26-29.

43. Mecit, H. O., Serpil, S., Gulum, S. (2005). Optimization of microwave frying of potato slices by using Taguchi technique. *Journal of Food Engineering* 79: 83-91.

44. Mgudu, L., Muzenda, E., Kabuba, J. and Belaid, M. (2012). Microwave –Assisted Extraction of Castor Oil. International Conference on Nanotechnology and Chemical Engineering (ICNCS'2012) December 21-22, 2012 Bangkok (Thailand). http://psrcentre.org/images/extraimages/1312551.pdf cited on 15th November, 2013.

45. MoFA and CSIR (2005). Soybean Production Guide. Food crops development project.Ghana's Ministry of Food and Agriculture. 38pp.

46. Mrema, G.C. and McNulty, P.B. (1985). Mathematical model of mechanical oil expression from oilseeds. *Journal of Agricultural Engineering Research*, Vol 31(5): 361-370.

47. Murphy, D. J. (1994). Designer Oil Crops. VCH Press, Weinheim, pp 604-698

48. National Oil Processors Association (NOPA) (2006). Specifications for Soybean Meal. http://www.nopa/soybeanspecifocations/pdf cited on the 3rd November 2013.

49. Natural Resource Institute (1999). Grain storage management PG Dip/MSc Computer Mediated Distance Learing, course 1, storage and handling volume 1. Chapter 1 page 6.

50. Nelson, R.F. (2005). *An introduction to behavioral endocrinology* (3rd ed.). Sunderland, Mass: Sinauer Associates. p.100. ISBN 0-87893-617-3.

51. Neutkens, D.(2005). Amino Acids and Their Limitations. http://nationalhog farmer.com/mag/farming_amino_acids_limitations cited 3rd November, 2013.

52. Ngeze, P. B. (1993). Learn How to Grow Soybean. Nairobi, Kenya. CTA Publ. 21pp.

53. Nielson, S.S.(1994). Introduction to the chemical analysis of foods. Chapman and Hall, New York, pp. 93-207.

54. Nosenko, T.T. (2013). Using of Microwave Heat Treatment in Soybean Processing. http://www.eurofedlipid.org/meetings/archive/gothenburg/5870/5870_0108.pdf cited on 5th, December, 2013.

55. Nwabueze T.U. and Okocha K.S. (2008). Extraction Performance of Polar and Non-polar Solvents on The Physical and Chemical Indices of African Breadfruit (*Treculiaafricana*) Seed Oil. African Journal of Food Science Vol 2 pp. 119-125. http://www.academicjournals.org/ajfs cited on the 15th October 2013.

56. Obikili, C. M. (2010): Evaluation Of The Effect of Methods of Oil Extraction On Physico-Chemical Properties of Oil From African Breadfruit Seeds, (*Treculiaafricana*) And Cashew Nuts (*AnarcardiumOccidentale*) Unpublished Undergraduate Project. Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State. Page 12-18.

57. O'Brien, R.D. (1998). *Fats and Oils: Formulating and Processing for Applications*. Lancaster, PA: Technomic Publishing Co., Inc. ISBN 0-8493-1599-9.

58. Osafo, D. M. (1997). Effect of Population Density on the Soybean Varieties in Ghana's Forest Zone. *Exp. Agric*. Vol13: 235-340

59. Osman, M. (2011). Growth and Yield Response of Early and Medium Maturity of Soybean (*Glycine max (L) merrill*) Varieties to Row Spacing. Unpublished thesis, Kwame Nkrumah University of Science and Technology, Kumasi.

60. Oyinlola A, Ojo A, Adekoya LO. (2004). Development of a laboratory model screw pres for peanut oil expression. *J. Food Eng*. Vol64: 221–227.

61. Pettigrew, J. E., Soltwedel, K. T., Miguel, J. C., Palacios, M. F.(2002). Soybean Use-Swine. Soybean Meal Information Center Fact Sheet. The Soybean Meal Information Center, United Soybean Board.

62. Pipper, E.L., and Boote, K.J. (1999). Temperature and Cultivar Effects on Soybean Oil and Protein Concentrations. *Journal of America Oil Chemists' Society* Vol. 76: 1233-1241.

63. Plahar, W.A. (2006). Overview of the Soybean Industry in Ghana, Workshop on Soybean Protein for Human Nutrition and Health, Accra, Ghana-28thSeptember, 2006. Available online: http://www.wishh.org/workshops/intl/ghana/ghana06/plahar-06.pdf.

64. Puvača,N., Stanaćev,V., Glamočić, D., Lević, J., Stanaćev V., Milić, D., Vukelić, N. and Ljubojević D.(2013). Application of the Process of Extrusion and Micronisation and Their Influence on Nutritive Value of Feedstuffs. http://semenarska.rs/UNS-PSU/radovi/2/40%20Application%20197-202.pdf on the 27th June, 2013.

65. Rienke, N. And Joke, N. (2005). Cultivation of Soya and Other Legumes. Agrodok-series No.10.Agromisa. CTA publication. 69 pages

66. Robert, B.D. and Nemat, A.N. (1998). Soybeans in Egypt: Research, Production, Economics, Nutrient and Health. ISBN: 1883053-641 pp. 143-161.

67. Rossell, F. B. (1994). Measurement of Rancidity. In J. C. Allen and R. J. Hamilton (Eds.), Rancidity in foods (3rd ed., pp. 27 – 30). London: Chapman and Hall.

68. Samuel, O.D. and Alabi, A.G.F. (2012). Problems and Solutions Involved In Oil Processing From Kernel Seeds. *The Pacific Journal of Science and Technology*,Vol 13 (1) 372-382.

69. Sargolzaei, J., Asl, M.H. and Moghaddam A.H. (2013). Prediction of Super Critical Oil Extraction Yield Using Single and Combined Intelligent Systems, *Global*

*Perspectives on Artificial Intelligence (GPAI)*Volume 1 Issue 2, April 2013. www.seipub.org/GPAI/Download.aspx?ID=2790cited on the 3rd December, 2013.

70. Shukla, B.D., Srivastava, P.K. and Gupta, R.K. (1992). Oilseeds processing technology. Central Institute of Agricultural Engineering, India. http://idl-bnc.idrc.ca/dspace/bitstream/10625/11596/1/95811.pdf cited on 24th December, 2014.
71. Silvia, D., Masturah, M.F., Aris, Y.T., Nadiah, W.A.W and Bhat, R. (2012). The Effects of Different Extraction Temperatures of the Screw Press on Proximate Compositions, Amino Acid Contents and Mineral Contents of *Nigella sativa* Meal. *American Journal of Food Technology*, Vol. 7: 180-191.http://scialert.net/abstract/?doi=ajft.2012.180.191 cited on the 3rd October, 2013.
72. Slavin, J.L., Jacobs, D., Marquart, L. (2000). Grain Processing and Nutrition.*Crit. Rev. Food Sci. Nutr.*Vol40:309-326.
73. Snyder J.M., Mounts, Y.L. and Holloway, R.K.(1991). Volatiles from Microwave-Treated, Stored Soybeans. Food Quality and Safety Research, Notional Center for Agricultural Utilization Research, Agricultural Research Service, U.S.Department of Agriculture, Peoria, *IL 61604 JAOCS*, Vol. 68(10):744-747.
74. Spolaore, P., Joannis-Cassan,C., Duran, E. and Isam-bert,A. (2006). Commercial Application of Microalgae. *Journal of Bioscience and Bioengineering*Vol101: 87–96.
75. Swick, R.A. (2002). Soybean Meal Quality. Assessing the Characteristics of a Major Aquatic Feed Ingredient. http://pdf.gaalliance.org/pdf/GAA-Swick-Apr02.pdf Cited on the 2nd December, 2013.
76. Tascano,G. and Maldini, E. (2007). Analysis of the Physical and Chemical Characteristics of Vegetable Oil as Fuel. *Journal of Agricultural Engineering*, Vol 3: 39-47.

77. Thakur, M. and HurbrughC.R. (2007). Quality of US Soybean Meal Compared to the Quality of Soybean Meal form Other Origins. *Journal American Oil Chemists Society*, Vol 84:835-843.

78. Tunde-Akintunde T.Y., Akintunde B.O., and Igbeka J.C. (2001). Effect of Processing Factors on Yield and Quality of Mechanically Expressed Soybeans Oil. *J. Agric. Eng. Tech*Vol.55: 86-92

79. Tweneboah, C.K. (2000). Modern Agriculture in the Tropics with Special Reference to Ghana. Co-Wood Publishers, Accra, Ghana.

80. Uquiche, E., Jeréz, M. and Ortíz, J. (2008). Effect of Pretreatment with Microwaves on Mechanical Extraction Yield and Quality of Vegetable Oil from Chilean Hazelnuts (*GevuinaavellanaMol*). http://www.captura.uchile.cl/bitstream/ handle/2250/7278/ Uquiche_Edgar.pdf?sequence=1 cited on the 3rd of April, 2013.

81. Van der Merwe, G.H. (2003). Chapter Two, Literature Review Oxidation and Rancidity of Fats and Oils. University of Pretoria. http://upetd.up.ac.za/ thesis/submitted/etd-09022005-123035/unrestricted/02chapter2.pdf cited on 15th December, 2013.

82. Wandkar, S.V., Ukey, P.D. and Pawar, D. A.(2012). Determination of Physical Characteristics of Soybean at Different Moisture Levels. *AgricEng Int. CIGR Journal*, 14(2): Manuscript No. 2081.

83. Wang T. (2002). Soybean Oil. *Vegetable Oils in Food Technology: Composition, Properties and Uses*, Blackwell Scientific Publications Inc., Oxford, UK., pp. 24–25

84. Wiess, M.G., Weber C.R., Williams L.F. and Probst A.H. (1983). Correlation of Agronomic Characteristics and Temperature with Seed Compositional Characteristics in Soybeans, as Influenced by Variety and Time of Planting. *Crop Sci*. 44: 289-297.

85. Willems, P.(2007). Gas Assisted Mechanical Expression of Oilseeds, Proefschift, UniversiteitTwente, Nederland. http://www.crowniron.com/technologies/_spx_hple.cfm, cited on the 3rd January 2014

86. Williams, S.W. and Rathod, K.L. (1974). A Case Study of Expeller Production of Soybean Flour in India. http://pdf.usaid.gov/pdf_docs/pnaaa649.pdf cited on the 14th May, 2013.

87. Willis, S. (2013). The use of Soybean Meal and Full Fat Soybean Meal by the Animal Feed Industry. 12th Australian Soybean Conference. http://www.australianoilseeds.com/__data/assets/file/0019/1198/Sarah_Willis-The_Use_of_Soybean_Meal_and_Full_Fat_Soybean_Meal_by_the_Animal_Feed_Industry.pdf cited on 30th October, 2013.

88. Zaher F.A., El Kinawy O.S. and El Haron D.E.(2004). Solvent extraction of jojoba oil from pre-pressed jojoba meal. Grasas y Aceites Vol. 55. Fasc. 2 (2004), 129-134

APPENDICES

Appendix A: Soybean Meal Composition Standard Definition

	Soybean Meal Solvent	Dehulled Solvent	Expeller	Full-fat
Dry Matter (%)	90	88.0	89	90
Crude Protein (%)	44.0	47.8	42.0	38.0
Ether Extract (%)	0.5	1.0	3.5	18.0
Crude Fibre (%)	7.0	3.0	6.5	5.0
Ash (%)	6.0	6.0	0.6	0.59
Ruminant Dig, Protein (%)	37.5	46.6	35.5	34.1
Ruminant TDN (%)	78	79.0	78	85
Metabolizable Energy, Poultry (Kcal/#)	1020	1115.0	1100	1520
Metabolizable Energy, Swine (kcal/#)	1405	1425	1360	1610

(Source**:** Feedstuffs Ingredient Analysis Table, 2012)

Appendix B: Heating Temperature of Soybean before Single Press

Heating time (minutes)	Average temperature (°C)
20	51.47
35	64.13
45	73.29
55	78.01

Appendix C: Soybean Meal Yield

Heating Time (Minutes)	Average Yield for Single Press (kg)	Average Yield for Double Press (kg)
Control	18.10	17.11
20	17.88	17.14
35	17.30	16.68
45	17.75	16.42
55	18.11	16.71

Appendix D: Soybean Oil Yield and Density

Heating Time (minutes)	Single Pressed Oil		Double Pressed Oil	
	Average Yield (mL)	Density	Average Yield (mL)	Density
control	2325.00	0.94	3221.17	0.94
20	2463.00	0.9	3036.33	0.9
35	2608.33	0.87	2885.83	0.87
45	2471.50	0.83	2869.50	0.83
55	2362.00	0.83	2540.51	0.83

Appendix E: Standardizing Sodium Hydroxide with Oxylic Acid

Readings	1st Trial	2nd Trial	3rd Trial
Final	10.40	20.20	31.00
Initial	0.00	10.40	20.20
Titre	10.40	9.80	10.80

$$\text{average} = \frac{10.4 + 10.8}{2} = 10.6\text{ml}$$

$C_1V_1 = C_2V_2$

$0.05 \times 10.6 = C_2 \times 10$

$C_1 = \text{Concentrationofoxylicacid}$

$C_2 = \text{ConcentrationofNaOH}$

$V_1 = \text{Volumeofoxylicacid}$

$V_2 = \text{VolumeofNaOH}$

$C_2 = 0.053$

Ratio= 2:1

Therefore, $C_2 = 2 \times 0.053 = 0.106 \approx 0.1\text{M}$

Appendix F: Standardising with Hydrogen Chloride

Readings	1st Trial	2nd Trial	3rd Trial
Final Reading	4.80	6.70	8.80
Initial Reading	2.80	4.80	6.70
Titre	2.00	1.90	2.10

$$\text{average reading} = \frac{2 + 1.9 + 2.1}{3} = 2\text{ml}$$

$C_1V_1 = C_2V_2$

$C_1 \times 2 = 0.106 \times 10$

$C_1 = \text{Concentration of Hydrochloric acid}$

$C_2 = \text{Concentration of NaOH}$

$V_1 = \text{Volume of hydrochloric acid}$

$V_2 = \text{Volume of NaOH}$

$C_2 = 0.53$

Appendix G: Analysis of Variance

Source of variation	df	ss	ms	vr
Heating time	**4**	**6675**	**6675**	**198**
Number of presses	**1**	**36357.77**	**36357.77**	**90**
total	**5**	**43032.77**		

Appendix H: Least significant difference of means (5% level)

	Heating time	Number of presses
rep	**30**	**30**
lsd	**0.98**	**0.98**