

Quality Parameters and Extraction Percentage of the Seed-oils of Groundnut, Sunflower and Sesame Samples**Extracted by Different Solvents**

Elrasheid E M. Ali; Mutaman A. A. Kehail; Salma A. A. Abdalla; Maha A. I. Hashim and Yasir M. Abdelrahim

University of Gezira, Biosciences and Biotechnology Center

E-mail: k.mutaman@yahoo.com**Abstract**

Oils and fats are recognized as essential nutrients in both human and animal diets. They carriers fat soluble vitamins, and are present in varying amounts in many foods. The aim of this study is to evaluate the quality parameters (physical and chemical properties) and extraction percentage of the seed-oils of Groundnut, Sunflower and Sesame samples extracted by using centrifugation method and different solvents (Chloroform, Hexane and Petroleum ether). Samples of Sunflower seeds (*Helianthus annuus*), Groundnut seeds (*Arachis hypogaea*) and Sesame seeds (*Sesamum indicum* L.) were brought from Agricultural Research Corporation, Wad Medani, Gezira State, Sudan. Each of the seed samples were extracted using Centrifuge (model; 80-1, made in China). A commercial samples (controls) of oils was also brought from the local market. Some physical and chemical tests were run for the extracted oils in addition to controls samples. The results proved that, the percentage oil content was significantly affected by the solvent used. Petroleum ether solvent was the best solvent for extraction of oils, followed by Hexane solvent and lastly Chloroform solvent. The best solvent to be used to extract oil with good quality from Groundnut seeds, Sesame seeds and Sunflower seeds samples was Hexane solvent. The physical and chemical properties of oil extracted by using centrifuge and different solvents were statistically similar to their standards. The study recommends improving the centrifugation method to be applied at field (oil industries) and at Laboratory level (experimental work).

Acknowledgments: Thanks are extended to all staff members of Food Analysis Laboratory, Faculty of Engineering and Technology, University of Gezira.

Dedication: We dedicate this work to our families.

Table of Contents

| Subject | Page |
|---------------------------------------|------|
| Acknowledgments | i |
| Dedication | i |
| Table of Contents | ii |
| List of Tables | iv |
| CHAPTER ONE: INTRODUCTION | 1 |
| CHAPTER TWO: LITERATURE REVIEW | 3 |
| 2.1 Oils | 3 |
| 2.1.1. Physical properties | 3 |
| 2.1.1.1 Refractive index: | 3 |

| | |
|-------------------------------------------------|----|
| 2.1.1.2 Density: | 3 |
| 2.1.1.3 Viscosity: | 4 |
| 2.1.1.4 Flash point: | 4 |
| 2.1.1.5 Smoke point: | 4 |
| 2.1.2 Chemical properties of oil | 5 |
| 2.1.2.1 Saponification value: | 5 |
| 2.1.2.2 Iodine value: | 5 |
| 2.1.2.3 Free fatty acids (FFA) and acidity: | 5 |
| 2.1.2.4 Peroxide value: | 6 |
| 2.2 Groundnut | 6 |
| 2.2.1 Scientific classification: | 7 |
| 2.2.2 Description | 7 |
| 2.3 Sesame | 7 |
| 2.3.1 Scientific classification: | 7 |
| 2.3.2 Description | 9 |
| 2.4 Sunflower | 9 |
| 2.4.1 Scientific classification: | 9 |
| 2.4.2 Description | 11 |
| 2.4 Solvents | 11 |
| 2.4.1 Hexane: | 11 |
| 2.4.2 Chloroform | 13 |
| 2.4.3 Petroleum ether | 14 |
| 2.5 Extraction of essential oils | 16 |
| 2.5.1 Distillation | 16 |
| 2.5.2 Expression: | 16 |
| 2.5.3 Cold extraction: | 17 |
| 2.6 Centrifuge: | 17 |
| 2.6.1 Types | 17 |
| 2.6.2 Uses | 17 |
| 2.6.3 Advantages: | 18 |
| 2.7 Thin layer chromatography (TLC) | 19 |
| CHAPTER THREE: MATERIALS AND METHODS | 20 |
| 3.1 Materials: | 20 |
| 3.2 Preparation of seed samples for extraction: | 20 |
| 3.3 Quality parameter for the extracted oils | 20 |

| | |
|----------------------------------------------------------------------------------------------------------------------|----|
| 3.3.1 Physical characteristics | 20 |
| 3.3.1.1 Determination of refractive index: | 20 |
| 3.3.1.2 Determination of density and specific gravity | 20 |
| 3.3.2 Chemical characteristics | 21 |
| 3.3.2.1 Determination of saponification value: | 21 |
| 3.3.2.2 Determination of iodine value (IV): | 21 |
| 3.3.2.3 Determination of free fatty acids (FFA): | 22 |
| 3.3.2.4 Determination of peroxide value: | 22 |
| 3.4 Statistical analysis | 23 |
| CHAPTER FOUR: RESULTS AND DISCUSSION | 24 |
| 4.1 The efficiency of different solvents in extraction of Groundnut, Sunflower and Sesame seed-oils using centrifuge | 24 |
| 4.2 Quality parameters of the extracted seed-oils | 26 |
| 4.2.1 Physical properties | 26 |
| 4.2.1.1 Groundnut oil | 26 |
| 4.2.1.2 Sesame oil | 28 |
| 4.2.1.3 Sunflower oil | 30 |
| 4.2.2 Chemical properties | 32 |
| 4.2.2.1 Groundnut oil | 32 |
| 4.2.2.2 Sesame oil | 34 |
| 4.2.2.3 Sunflower oil | 36 |
| CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS | 38 |
| 5.1. Conclusions | 38 |
| 5.2. Recommendations | 38 |
| References | 39 |

List of Tables

| Table No. | Title | Page |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2.1 | Nutritional Contents in Ground nut seeds | 8 |
| 2.2 | Nutritional Contents in Sesame seeds | 10 |
| 2.3 | Nutritional Contents in Sunflower seeds | 12 |
| 4.1 | Mean percentage of oil extracted from Groundnut, Sunflower and Sesame seeds by using centrifuge device (for 30 minutes) and different solvents | 25 |

| | | |
|------------|--------------------------------------------------------------------------------------------|-----------|
| 4.2 | Some physical properties of Groundnut oil extracted by centrifuge using different solvents | 27 |
| 4.3 | Some physical properties of Sesame oil extracted by centrifuge using different solvents | 29 |
| 4.4 | Some physical properties of Sunflower oil extracted by centrifuge using different solvents | 31 |
| 4.5 | Some chemical properties of Groundnut oil extracted by centrifuge using different solvents | 33 |
| 4.6 | Some chemical properties of Sesame oil extracted by centrifuge using different solvents | 35 |
| 4.7 | Some chemical properties of Sunflower oil extracted by centrifuge using different solvents | 37 |

Chapter One: Introduction

Oils and fats are recognized as essential nutrients in both human and animal diets. They provide the most concentrated source of energy of any foodstuff, supply essential fatty acids (which are precursors for important hormones, prostaglandins), carriers fat soluble vitamins, and serve to make foods more palatable. Fats and oils are present in varying amounts in many foods. The common physical properties of such oils and fats are that they float on water but are not soluble in it; they are greasy to the touch, and have lubricating properties; they are not readily volatile; and may be burned without leaving any residue (Fediol, 2015).

Groundnut oil also known as Peanut oil or arachis oil, is a mild-tasting vegetable oil derived from peanuts. The oil is available latter with a strong peanut flavor and aroma, analogous to sesame oil (Liu *et al.*, 2011). Groundnut oil has a high smoke point relative to many other cooking oils, so is commonly used for frying foods. Its major component fatty acids are oleic acid (46.8% as olein), linoleic acid (33.4% as linolein), and palmitic acid (10.0% as palmitin) (USDA, 2011). The oil also contains some stearic acid, arachidic acid, behenic acid, lignoceric acid and other fatty acids (Anyasor *et al.*, 2009).

Sesame oil is an edible vegetable oil derived from sesame seeds. The oil from the nutrient-rich seed is popular in alternative medicine, from traditional massages and treatments to the modern day. Sesame oil is one of the more stable natural oils, but can still benefit from refrigeration and limited exposure to light and high temperatures during extraction, processing and storage in order to minimize nutrient loss through oxidation and rancidity. Storage in amber-colored bottles can help to minimize light exposure (USDA, 2015). Sesame oil is composed of the following fatty acids: linoleic acid (41% of total), oleic acid (39%), palmitic acid (8%), stearic acid (5%) and others in small amounts (Kamal-Eldin *et al.*, 2012).

Sunflower oil is the non-volatile oil compressed from sunflower (*Helianthus annuus*) seeds. Sunflower oil is commonly used in food as a frying oil, and in cosmetic formulations as an emollient (Christov, 2012). Sunflower oil is a monounsaturated (MUFA)/polyunsaturated (PUFA) mixture of mostly oleic acid (omega-9)-linoleic acid (omega-6) group of oils. The oil content of the seed ranges from 22 to 36% (average, 28%): the kernel contains 45–55% oil. The expressed oil is of light amber color with a mild and pleasant flavor; refined oil is pale yellow. Refining losses are low and the oil has good keeping qualities with light tendency for flavor reversion. The oil contains appreciable quantities of vitamin E, sterols, squalene, and other aliphatic hydrocarbons (National Sunflower Association, 2013).

Objective:

The aim of this study is to evaluate the quality parameters (physical and chemical properties) and extraction percentage of the seed-oils of Groundnut, Sunflower and Sesame samples using centrifugation method and different solvents.

Chapter Two: Literature Review

2.1 Oils

An oil is any neutral, nonpolar chemical substance that is a viscous liquid at ambient temperatures and is both hydrophobic (immiscible with water, literally "water fearing") and lipophilic (miscible with other oils, or fat loving). Oils have a high carbon and hydrogen content and are usually flammable and slippery. The general definition of oil includes classes of chemical compounds that may be otherwise unrelated in structure, properties, and uses. Oils may be animal, vegetable, or petrochemical in origin, and may be volatile or non-volatile (Oxford English Dictionary, 2005). The composition of oil varies with the source and depends on factors such as climatic conditions, soil type, maturity of plant and variety. The physicochemical properties of oils are directly related to their lipids and glyceride composition (Rahman et al., 2007)

2.1.1. Physical properties

2.1.1.1 Refractive index:

In optics the refractive index or index of refraction of an optical medium is a dimensionless number that describes how light, or any other radiation, propagates through that medium (Hecht, 2002).

2.1.1.2 Density:

The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume. Mathematically, density is defined as mass divided by volume. For a pure substance the density has the same numerical value as its mass concentration. Different materials usually have different densities, and density may be relevant to buoyancy, purity and packaging. Osmium and iridium are the densest known elements at standard conditions for temperature and pressure but certain chemical compounds may be denser. To simplify comparisons of density across different systems of units, it is sometimes replaced by the dimensionless quantity relative density or specific gravity, i.e. the ratio of the density of the material to that of a standard material, usually water. Thus a relative density less than one means that the substance floats in water. The density of a material varies with temperature and pressure (Oilglossary.com, 2010).

2.1.1.3 Viscosity:

The word "viscosity" is derived from viscous glue (birdlime) made from mistletoe berries and applied to twigs to catch birds. The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress (Etymonline.com, 2010). A fluid that has no resistance to shear stress is known as an ideal or in viscid fluid. Zero viscosity is observed only at very low temperatures in super fluids. Otherwise, all fluids have positive viscosity, and are technically said to be viscous or viscid. In common parlance however, a liquid is said to be viscous if its viscosity is substantially greater than that of water; and may be described as mobile if the viscosity is noticeably less than water. A fluid with a relatively high viscosity, for example, pitch, may appear to be a solid (Streeter et al., 1998).

2.1.1.4 Flash point:

The flash point of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a flash point requires an ignition source. The flash point is not to be confused with the auto-ignition temperature (which does not require an ignition source) or with the fire point (the temperature at which the vapor

continues to burn after being ignited). Neither the flash point nor the fire point is dependent on the temperature of the ignition source, which is much higher (NFPA30, 2014).

2.1.1.5 Smoke point:

The smoke point of an oil or fat is the temperature at which, under defined conditions, enough volatile compounds emerge when a bluish smoke becomes clearly visible from the oil. At this temperature, volatile compounds, such as free fatty acids, and short-chain degradation products of oxidation come up from the oil. These volatile compounds degrade in air to give soot. The smoke point indicates the temperature limit up to which that cooking oils can be used. The smoke point correlates with the amount of free fatty acid in an oil (Thomas, 2002). It varies widely, depending on origin and refinement (Wolke, 2007). The smoke point of an oil does tend to increase as free fatty acid content decreases and degree of refinement increases (Bockisch, 1998). Heating the oil produces free fatty acid and as this heating time increases, more free fatty acids are produced, thereby decreasing smoke point. It is one reason not to use the same oil to deep fry more than twice (Wolke, 2007).

2.1.2 Chemical properties of oil

2.1.2.1 Saponification value:

Vegetable oils and animal fats are the main materials that are saponified. These greasy materials, triesters called triglycerides, are mixtures derived from diverse fatty acids. The saponification value is the amount of base required to saponify a fat sample. Saponification is a process that produces soap, usually from fats and lye (Schumann and Siekmann, 2005). Saponification can occur in oil paintings over time, causing visible damage and deformation. The ground layer or paint layers of oil paintings commonly contain heavy metals in pigments such as lead white, red lead, or zinc white. If those heavy metals react with free fatty acids in the oil medium that binds the pigments together, soaps may form in a paint layer that can then migrate outward to the painting's surface (Silvia and Dorothy, 2009).

2.1.2.2 Iodine value:

The iodine value (or "iodine adsorption value" or "iodine number" or "iodine index") in chemistry is the mass of iodine in grams that is consumed by 100 grams of a chemical substance. Iodine numbers are often used to determine the amount of unsaturation in fatty acids. This unsaturation is in the form of double bonds, which react with iodine compounds (Thomas, 2002).

2.1.2.3 Free fatty acids (FFA) and acidity

The "acidity" in an oil is the result of the degree of breakdown of the triacyl glycerols, due to a chemical reaction called hydrolysis or lipolysis, in which free fatty acids are formed. The acid value is the number of mg of potassium hydroxide required to neutralize the free fatty acids in 1 g of the fat. The acidity is an expression of the content (in %, m/m; percentage) of free fatty acids as content of dominant or chosen fatty acid. The acid value (AV) is a common parameter in the specification of fats and oils. It is defined as the weight of KOH in mg needed to neutralize the organic acids present in 1g of fat and it is a measure of the free fatty acids (FFA) present in the fat or oil. An increment in the amount of FFA in a sample of oil or fat indicates hydrolysis of triglycerides. Such reaction occurs by the action of lipase enzyme and it is and indicator of inadequate processing and storage conditions (i.e., high temperature and relative humidity, tissue

damage). The source of the enzyme can be the tissue from which the oil or fat was extracted or it can be a contaminant from other cells including microorganisms. Besides FFA, hydrolysis of triglycerides produces glycerol.

FFA is a source of flavors and aromas. The later are more prone to oxidation in their free form and their breakdown products (aldehydes, ketones, alcohols, and organic acids) provide characteristic flavors and aromas. In most cases these flavors and aromas are considered a defect in oils, fats, and foods that contain them. However, there are instances where hydrolysis of triglycerides and oxidation of FFA are key in the development of desirable flavor and aroma in foods. The AOAC method to determine AV in fats and oils is based on a titration in ethanol using phenolphthalein as indicator. Disadvantages of this and similar methods are the use of organic solvents (volume and toxicity), the need for heating the reaction media, incomplete solubility of the oil/fat, the need to pre-neutralize the solvents, use of large amounts of sample, and the possibility of error to detect the color change of the indicator when analyzing colored samples. There are some non-titration methods designed to overcome these disadvantages. However, in spite its drawbacks, the titration method is still the most used due to the fact that it does not require expensive equipment (Kardash and Tur'yan, 2005).

2.1.2.4 Peroxide value:

Detection of peroxide gives the initial evidence of rancidity in unsaturated fats and oils. Other methods are available, but peroxide value is the most widely used. It gives a measure of the extent to which an oil sample has undergone primary oxidation, extent of secondary oxidation may be determined from p-anisidine test. The double bonds found in fats and oils play a role in autoxidation. Oils with a high degree of unsaturation are most susceptible to autoxidation. Peroxide value, concentration of peroxide in an oil or fat, is useful for assessing the extent to which spoilage has advanced (Nielsen, 2003).

2.2 Groundnut

Groundnut also known as peanut or earthnut is a member of the family Fabaceae, the largest and most important of the three subfamilies of leguminosae. The crop originated in South East America (Krapovikas, 1968). Produced in more than 82 countries worldwide. A groundnut is grown as an oil-seed and grain legume crop. It is a major cash crop and widely grown in practically all the tropical and subtropical regions of the world for direct use as food for oil and for the high protein meal produced after oil extraction (Onwueme and Sinha, 1999).

2.2.1 Scientific classification:

Kingdom: Plantae

Division: Tracheophyta

Class: Magnoliopsida

Order: Fabales

Family: Fabaceae

Genus: *Arachis*

Species: *A. hypogaea* Krapovikas (1968).

2.2.2 Description

Groundnut is a self-pollinating, indeterminate, annual, herbaceous legume. Natural cross-pollination occurs at rates of less than 1% to greater than 6% owing to typical flowers or the action of bees. The fruit is a pod with one to five seeds that

develops underground within a needlelike structure called Leaves are alternate and pinnate with four leaflets (two pairs of leaflets per leaf) (Krapovikas, 1968). The nutritional composition of Groundnut was presented in Table (2.1)

2.3 Sesame

Sesame (*Sesamum indicum* L.) is one of the most important oilseed crops worldwide, and a flowering plant in the genus ‘sesamin’. It is used in the making of tahin (sesame butter) and halva, and for the preparation of rolls, crackers, cakes and pastry products in commercial bakeries. There are numerous varieties and ecotypes of sesame adapted to various ecological conditions (Adebowale et al., 2011).

2.3.1 Scientific classification:

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Lamiales

Family: Pedaliaceae

Genus: *Sesamum*

Species: *S. indicum*, Adebowale et al. (2011).

Table (2.1) Nutritional Contents in Ground nut seeds

| Nutritional value per 100 g (3.5 oz) | |
|--------------------------------------|---------------------|
| Energy | 2,385 kJ (570 kcal) |
| Carbohydrates | 21 g |
| Dietary fiber | 9 g |
| Fat | 48 g |
| Saturated | 7 g |
| Monounsaturated | 24 g |
| Polyunsaturated | 16 g |
| Protein | 25 g |
| Vitamins | |
| Thiamine (B1) | (52%) 0.6 mg |
| Riboflavin (B2) | (25%) 0.3 mg |
| Niacin (B3) | (86%) 12.9 mg |
| Pantothenic acid (B5) | (36%) 1.8 mg |

| | |
|---------------------------|--------------|
| Vitamin B6 | (23%) 0.3 mg |
| Folate (B9) | (62%) 246 µg |
| Vitamin C | (0%) 0.0 mg |
| Vitamin E | (44%) 6.6 mg |
| Minerals | |
| Calcium | (6%) 62 mg |
| Iron | (15%) 2 mg |
| Magnesium | (52%) 184 mg |
| Manganese | (95%) 2.0 mg |
| Phosphorus | (48%) 336 mg |
| Potassium | (7%) 332 mg |
| Zinc | (35%) 3.3 mg |
| Other constituents | |
| Water | 4.26 g |

Source: [USDA \(2014\)](#)

2.3.2 Description

It is an annual plant growing 50 to 100 cm (1.6 to 3.3 ft) tall, with opposite leaves 4 to 14 cm (1.6 to 5.5 in) long with an entire margin; they are broad lanceolate, to 5 cm (2 in) broad, at the base of the plant, narrowing to just 1 cm (0.4 in) broad on the flowering stem. The flowers are yellow, tubular, 3 to 5 cm (1.2 to 2.0 in) long, with a four-lobed mouth. The flowers may vary in colour, with some being white, blue, or purple. Sesame fruit is a capsule, normally pubescent, rectangular in section, and typically grooved with a short, triangular beak. The length of the fruit capsule varies from 2 to 8 cm, its width varies between 0.5 and 2 cm, and the number of loculi varies from four to 12. The fruit naturally splits open (dehisces) to release the seeds by splitting along the septa from top to bottom or by means of two apical pores, depending on the varietal cultivar. Sesame seeds are small. Their size, form, and colours vary with the thousands of varieties now known. Typically, the seeds are about 3 to 4 mm long by 2 mm wide and 1 mm thick. The seeds are ovate, slightly flattened, and somewhat thinner at the eye of the seed (hilum) than at the opposite end. The weight of the seeds is between 20 and 40 mg ([Langham, 2008](#)). The nutritional composition of Sesame seeds was presented in Table (2.2).

2.4 Sunflower

The sunflower (*Helianthus annuus*) is an annual plant as crop for its edible oil and edible fruits (commonly called “sunflower seeds”). Sunflower is also used as bird food, as livestock forage (as a mean or silage plant) and in some

industrial applications. The plant was first domesticated in the Americans. Wild *H. annuus* is a widely branched annuals plant with many flower heads (Pope et al., 2001). Average oil content of the seed: 40-50% (Murphy, 1994).

2.4.1 Scientific classification:

Kingdom: Plantae

Division: Angiospermae

Class: Asterids

Order: Asterales

Family: Asteiaceae

Genus: *Helianthus*

Species: *H. annuus* (Pope et al. (2001)).

Table (2.2) Nutritional Contents in Sesame seeds

| Nutritional value per 100 grams | |
|---------------------------------|---------------------|
| Energy | 573 kcal (2,400 kJ) |
| Carbohydrates | 23.4 |
| Dietary fiber | 11.8 |
| Fat | 49.7 |
| Saturated | 7.0 |
| Monounsaturated | 18.8 |
| Polyunsaturated | 21.8 |
| Protein | 17.7 |
| Vitamins | |
| Vitamin A | 9 IU |
| Thiamine (B1) | (69%) 0.79 mg |
| Riboflavin (B2) | (21%) 0.25 mg |
| Niacin (B3) | (30%) 4.52 mg |
| Vitamin B6 | (61%) 0.79 mg |
| Folate (B9) | (24%) 97 µg |

| | |
|------------------------------------|----------------|
| Vitamin E | (2%) 0.25 mg |
| Minerals | |
| Calcium | (98%) 975 mg |
| Iron | (112%) 14.6 mg |
| Magnesium | (99%) 351 mg |
| Phosphorus | (90%) 629 mg |
| Potassium | (10%) 468 mg |
| Sodium | (1%) 11 mg |
| Zinc | (82%) 7.8 mg |
| Other constituents | |
| Water | 4.7 g |
| Source: Ray (2011) | |

2.4.2 Description

Sunflower is an annual native to the Americas, it possesses a large inflorescence (flowering head). The sunflower got its name from its huge, fiery blooms, whose shape and image is often used to depict the sun. The sunflower has a rough, hairy stem, broad, consist of 1000-2000 individual flowers joined together by a receptacle base from the Americas, sunflower seeds were brought to Europe in the 16th century, where, along with sunflower oil, they became widespread cooking ingredient. Sunflower leaves can be used as cattle feed, while the stems contain a fiber which may be used in paper production. What is usually called “the flower” on amateur sunflower is actually a flower head (also known as a “composite flower”) of numerous florets (small flower) crowded together. The outer petal-bearing florets (ray florets) are sterile and can be yellow, red, orange, or other colors. The florets inside the circular head are called disc flowers which mature into seeds, The same seed lot grew almost 8 m (26 ft) at other times and places. Including Madrid in the 20th century, of over 8 m has been achieved in both Netherlands and Ontario, Canada ([Wood, 2002](#)). The nutritional composition of Sunflower seeds was presented in Table (2.3)

2.4 Solvents

2.4.1 Hexane:

Normal hexane (n-hexane) is both an anthropogenic and naturally occurring chemical. n-Hexane is a minor constituent of crude oil and natural gas. Its inclusion in a variety of petroleum products is a consequence of refining operations that separate hydrocarbons within specific ranges of boiling points for such uses as heating oils or automotive fuels. It may also be a metabolic byproduct from certain types of fungi ([Ahearn et al., 1996](#)).

In commercial products prepared from the distillation of petroleum, n-hexane has many uses as a special-purpose solvent and oil extract ant. In a highly purified form, n-hexane is used in chemical laboratories as an extract ant for a wide range of hydrocarbons and non-polar organic compounds. Virtually all n-hexane is obtained from petroleum mixtures through controlled fractional distillation and other refinery-based processes (Speight, 1991).

Table (2.3) Nutritional Contents in Sunflower seeds

| Nutritional value per 100 g (3.5 oz) | |
|---------------------------------------------|---------------------|
| Energy | 2,445 kJ (584 kcal) |
| Carbohydrates | 20 g |
| Dietary fiber | 8.6 g |
| Fat | 51.46 g |
| Protein | 20.78 g |
| Vitamins | |
| Thiamine (B1) | (129%) 1.48 mg |
| Riboflavin (B2) | (30%) 0.355 mg |
| Niacin (B3) | (56%) 8.335 mg |
| Pantothenic acid (B5) | (23%) 1.13 mg |
| Vitamin B6 | (103%) 1.345 mg |
| Folate (B9) | (57%) 227 µg |
| Choline | (11%) 55.1 mg |
| Vitamin C | (2%) 1.4 mg |
| Vitamin E | (234%) 35.17 mg |
| Minerals | |
| Calcium | (8%) 78 mg |
| Iron | (40%) 5.25 mg |
| Magnesium | (92%) 325 mg |

| | |
|---------------------------|---------------|
| Manganese | (93%) 1.95 mg |
| Phosphorus | (94%) 660 mg |
| Potassium | (14%) 645 mg |
| Sodium | (1%) 9 mg |
| Zinc | (53%) 5 mg |
| Other constituents | |
| Water | 4.7 g |

Source: [Science Daily \(2005\)](#)

n-Hexane can also be synthesized from sugar cane wastes using special catalysts ([SUCRON, 1996](#)). This type of synthesis is relatively new and the volume produced is still very limited. The presence of many types of hydrocarbon impurities in many commercial grades of n-hexane, combined with the intentional denaturing of n-hexane preparations to discourage substance abuse, make it difficult to establish odor thresholds for many products containing n-hexane. n-Hexane is used mainly as an edible-oil extractant for a variety of seed crops such as soybeans, cottonseed, rape seed (canola), flax (linseed), mustard seed, peanuts, safflower seed, and corn germ, which are then processed into foods for humans or livestock ([Bhagya and Srinivas, 1992](#)).

While other petroleum-derived solvents (e.g., pentane) or other organic solvents (e.g., chloroform, methanol, ethanol, or ammonia-alcohol mixtures) are currently being studied or are used for certain processes, n-hexane has been widely used since the early part of this century, especially with soybeans, cottonseed, and linseed ([Conkerton et al., 1995](#)). Part of n-hexane's appeal relates to aesthetic properties such as preserving the colors of the original plant materials. Different extractant mixtures can also have significant effects on the levels of materials that can cause bitter tastes (e.g., tannins) and on the degree to which certain flatulence-causing sugars are removed. While other solvents could be used in the initial oil extraction phases, several decades of experience in combining the oil-extraction steps with other procedures to preserve desirable colors and eliminate unwanted tastes or other undesirable food properties have worked to maintain a heavy reliance on n-hexane for edible-oil extraction ([Lawson, 1995](#)).

2.4.2 Chloroform

Chloroform is a solvent in laboratories and in the chemical industry. It is also an inhalation anesthetic agent; however, the medical use is restricted because it is both hepatotoxic and cardiotoxic ([Haddad and Winchester, 1990](#)). It is a clear, colorless, volatile liquid with a characteristic sweet odor. Chloroform is indirectly produced when chlorine reacts with organic compounds. Therefore, a number of water disinfection processes including the chlorination of drinking water, waste water and swimming pools contribute to the formation and release of chloroform into the environment. Disinfection processes at pulp and paper plants are also potential sources of chloroform. mainly used in the production of refrigerant

gases, but is also used in pesticide formulations, as a solvent and as a chemical intermediate. There are present at low levels in air and may also occur in drinking water, sea and ground water. Potential sources of chloroform exposure for the general population include contaminated air and food. Drinking water may also be a source of exposure to trace amounts. Occupational exposure may occur during the production and use of chloroform. It may also occur at drinking-water plants and waste-water treatment sites. Inhalation of chloroform vapors' may lead to symptoms such as shortness of breath and dryness of the mouth and throat. Ingestion of chloroform can cause a burning sensation in the mouth and throat, nausea and vomiting. Skin contact with chloroform may lead to irritation and inflammation of the exposed area. Exposure of the eyes to chloroform vapor may cause a stinging sensation, and eye contact with liquid chloroform can cause immediate pain and inflammation. The International Agency for Research on Cancer (IARC) has classified chloroform as possibly having the ability to cause cancer in humans. Prolonged exposure to high enough levels of chloroform to cause liver damage is thought to be necessary to cause cancer. Chloroform does not have any significant mutagenic properties (HPA, 2007).

2.4.3 Petroleum ether

Petroleum ether is the petroleum fraction consisting of aliphatic hydrocarbons and boiling in the range 35–60 °C; commonly used as a laboratory solvent (David, 2010). It is very lightest, most volatile liquid hydrocarbon solvents that can be bought from laboratory chemical suppliers may also be offered under the name petroleum ether. Petroleum ether consists mainly of aliphatic hydrocarbons and is usually low on aromatics. It is commonly hydrodesulfurized and may be hydrogenated to reduce the amount of aromatic and other unsaturated hydrocarbons. Petroleum ether bears normally a descriptive suffix giving the boiling range. Thus, from the leading international laboratory chemical suppliers it is possible to buy various petroleum ethers with boiling ranges such as 30--80 °C. In the United States, laboratory grade aliphatic hydrocarbon solvents with boiling ranges as high as 100-140 °C may be called petroleum ether, rather than petroleum spirit (Alan, 2007).

It is not advisable to employ a fraction with a wider boiling point range than 20 °C, because of possible loss of the more volatile portion during its use in recrystallisation, etc. and consequent different solubility relations of the higher boiling residue. Most of the unsaturated hydrocarbons may be removed by shaking two or three times with 10 % of the volume of concentrated sulfuric acid; vigorous shaking is then continued with successive portions of a concentrated solution of potassium permanganate in 10 % sulfuric acid until the color of the permanganate remains unchanged. The solvent is then thoroughly washed with sodium carbonate solution and then with water, dried over anhydrous calcium chloride, and distilled. If required perfectly dry, it can be allowed to stand over sodium wire, or calcium hydride (Arthur, 1989).

Ligroin is assigned the CAS Registry Number 8032-32-4, which is also applied to many other products, particularly the lower boiling ones, called petroleum spirit, petroleum ether, and petroleum benzine. "Naphtha" has the CAS Registry Number 8030-30-6, which also covers petroleum benzine and petroleum ether: that is, the lower boiling point non-aromatic hydrocarbon solvents. DIN 51630 provides for petroleum spirit (also called spezialbenzine or petrolether) which is described as "a special boiling-point spirit commonly used in laboratory applications, having high volatility and low aromatics content." Its initial boiling point is above 25 °C, its final boiling point up to 80 °C. Petroleum ethers are extremely volatile, have very low flash points, and present a significant fire hazard (Alan, 2007).

The naphtha mixtures that are distilled at a lower boiling temperature have a higher volatility and, generally speaking, a higher degree of toxicity than the higher boiling fractions (*Stephen, 2005*). Exposure to petroleum ether occurs most commonly by either inhalation or through skin contact. Petroleum ether is metabolized by the liver with a biological half-life of 46–48 h (*Patricia, 2005*).

Inhalation overexposure causes primarily central nervous system (CNS) effects (headaches, dizziness, nausea, fatigue, and incoordination). In general, the toxicity is more pronounced with petroleum ethers containing higher concentrations of aromatic compounds. n-Hexane is known to cause axonal damage in peripheral nerves. Skin contact can cause allergic contact dermatitis (*Patricia, 2005*). Oral ingestion of hydrocarbons often is associated with symptoms of mucous membrane irritation, vomiting, and central nervous system depression. Cyanosis, tachycardia, and tachypnea may appear as a result of aspiration, with subsequent development of chemical pneumonitis. Other clinical findings include albuminuria, hematuria, hepatic enzyme derangement, and cardiac arrhythmias. Doses as low as 10 ml orally have been reported to be potentially fatal, whereas some patients have survived the ingestion of 60 ml of petroleum distillates. A history of coughing or choking in association with vomiting strongly suggests aspiration and hydrocarbon pneumonia. Hydrocarbon pneumonia is an acute hemorrhagic necrotizing disease that can develop within 24 h after the ingestion. Pneumonia may require several weeks for complete resolution (*Shayne, 2005*).

Intravenous administration produces fever and local tissue damage (*Jerrold and Frank, 2008*). Petroleum-derived distillates have not been shown to be carcinogenic in humans (*Stephen, 2005*). Petroleum ether degrades rapidly in soil and water (*Patricia, 2005*).

2.5 Extraction of essential oils

2.5.1 Distillation

Appears to have been practiced throughout ancient times. Based upon the current interpretation Paolo Rovesti's discovery of an earthenware distillation apparatus, the production or extraction of aromatic oils by means of steam distillation, has been known for 5000 years (*Schnaubelt, 2002*).

The three types of distillation (*FAO, 2005*) include:

1. Water Distillation

The plant material comes into direct contact with the water. This method is most often employed with flowers (rose and orange blossoms), as direct steam causes these flowers to clump together making it difficult for steam to pass through.

2. Water and Steam

This method can be employed with herb and leaf material. During this process, the water remains below the plant material, which has been placed on a grate while the steam is introduced from outside the main still (indirect steam).

3. Steam Distillation

This method is the most commonly used. During this process, steam is injected into the still, usually at slightly higher pressures and temperatures than the above two methods.

2.5.2 Expression:

It referred to as cold pressing, is a method of extraction specific to citrus essential oils, such as tangerine, lemon, bergamot, sweet orange, and lime. In older times, expression was done in the form of sponge pressing, which was literally

accomplished by hand. The zest or rind of the citrus would first be soaked in warm water to make the rind more receptive to the pressing process. A sponge would then be used to press the rind, thus breaking the essential oil cavities, and absorb the essential oil. Once the sponge was filled with the extraction, it would then be pressed over a collecting container, and there it would stand to allow for the separation of the essential oil and water/juice. The essential oil would finally be siphoned off (Arctander, 1994).

2.5.3 Cold extraction:

Cold water extraction is the process whereby a substance is extracted from a mixture via cold water. It is a type of fractional crystallization. The process generally involves taking a mixture of substances, dissolving them in warm water, and then rapidly cooling the mixture. The insoluble compounds precipitate out of the water, while the soluble ones stay dissolved. The solution can then be separated by filtration or decantation. This process works by exploiting the differences in solubility (with respect to temperature) of different substances in a mixture. It is commonly used to separate out opiate-derived drugs that have been mixed with common non-opiate-based analgesics, such as that which are found in Codeine/Paracetamol (Acetaminophen) formulations, Zaldiar and Vicodine (Cone, 2006).

2.6 Centrifuge:

A centrifuge is a piece of equipment that puts an object in rotation around a fixed axis (spins it in a circle), applying a potentially strong force perpendicular to the axis of spin (outward). The centrifuge works using the sedimentation principle, where the centripetal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the center. In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low-density substances rise to the top (Susan and Eduardo, 2004).

2.6.1 Types

There are multiple types of centrifuge. Fixed-angle centrifuges are designed to hold the sample containers at a constant angle relative to the central axis. Swinging head (or swinging bucket) centrifuges, in contrast to fixed-angle centrifuges, have a hinge where the sample containers are attached to the central rotor. This allows all of the samples to swing outwards as the centrifuge is spun. Continuous tubular centrifuges do not have individual sample vessels and are used for high volume applications (Cole-Parmer and William, 2012).

2.6.2 Uses

A wide variety of laboratory-scale centrifuges are used in chemistry, biology, biochemistry and clinical medicine for isolating and separating suspensions and immiscible liquids. They vary widely in speed, capacity, temperature control, and other characteristics. Laboratory centrifuges often can accept an range of different fixed-angle and swinging bucket rotors able to carry different numbers of centrifuge tubes and rated for specific maximum speeds. Controls vary from simple electrical timers to programmable models able to control acceleration and deceleration rates, running speeds, and temperature regimes. Ultracentrifuges spin the rotors under vacuum, eliminating air resistance and enabling exact temperature control. Zonal rotors and continuous flow systems are capable of handling bulk and larger sample volumes, respectively, in a laboratory-scale instrument (Susan and Eduardo, 2004).

Geotechnical centrifuge modeling is used for physical testing of models involving soils. Centrifuge acceleration is applied to scale models to scale the gravitational acceleration and enable prototype scale stresses to be obtained in scale models. Problems such as building and bridge foundations, earth dams, tunnels, and slope stability, including effects such as blast loading and earthquake shaking (Ng *et al.*, 2006).

2.6.3 Advantages:

- Decanter centrifuges have a clean appearance and have little to no odor problems.
- Not only is the device easy to install and fast at starting up and shutting down, but also only requires a small area for operation compared to other competitive processes.
- The decanter centrifuge is versatile as different lengths of the cylindrical bowl section and the cone angle can be selected for different applications. Also the system can be pre-programmed with various design curves to predict the sludge type, while some competitive processes, such as a belt filter press, cannot change the belt type to operate for different sludge types (Havrin, 2013). Its versatility allows the machine to have various functions such as operating for thickening or dewatering.
- The machine can operate with a higher throughput capacity than smaller machines (Genck *et al.*, 2008). This also reduces the number of units required.
- The device is simple to optimise and operate as it has few major variables and reliable feedback information (Havrin, 2013).
- The decanter centrifuge has reduced labour costs compared to other processes, as it requires low continuous maintenance and operator attention.
- Compared to some competitive process such as the belt filter process, the decanter centrifuge has more process flexibility and higher levels of performance.

2.7 Thin layer chromatography (TLC)

Thin layer chromatography (TLC) is a chromatography technique used to separate non-volatile mixtures (Harry *et al.*, 1989). Thin-layer chromatography is performed on a sheet of glass, plastic, or aluminum foil, which is coated with a thin layer of adsorbent material, usually silica gel, aluminum oxide, or cellulose. This layer of adsorbent is known as the stationary phase. After the sample has been applied on the plate, a solvent or solvent mixture (known as the mobile phase) is drawn up the plate via capillary action. Because different analytes ascend the TLC plate at different rates, separation is achieved (Vogel *et al.*, 2003). Thin-layer chromatography can be used to monitor the progress of a reaction, identify compounds present in a given mixture, and determine the purity of a substance. Specific examples of these applications include: analyzing ceramides and fatty acids, detection of pesticides or insecticides in food and water, analyzing the dye composition of fibers in forensics, assaying the radiochemical purity of radiopharmaceuticals, or identification of medicinal plants and their constituents (Reich and Schibli, 2007).

Chapter Three: Materials And Methods

3.1 Materials:

Samples of Sunflower seeds (*Helianthus annuus*), Groundnut seeds (*Arachis hypogaea*) and Sesame seeds (*Sesamum indicum* L.) were brought from Agricultural Research Corporation, Wad Medani, Gezira State, Sudan. About 30 ml oil from each seed samples were extracted using Centrifuge (model; 80-1, made in China). A commercial samples (controls) of oils was also brought from the local market.

3.2 Preparation of seed samples for extraction:

The seed samples (Sunflower, Groundnut and Sesame) were prepared in 2 g for each and were rolled carefully in filter papers. The medium speed of the device (2000 rpm) was used. The extraction was run following the method described by Kehail *et al.*, (2016). The total time for extraction was 30 minutes for each sample. The estimation of the oil content was depended on the weight of the sample before and after the extraction.

3.3 Quality parameter for the extracted oils

Some physical and chemical tests were run for the samples of Groundnut, Sesame and Sunflower seeds oils extracted by centrifuge using deferent solvents (chloroform, hexane and petroleum ether) in addition to controls samples.

3.3.1 Physical characteristics

3.3.1.1 Determination of refractive index:

Was measured by using Refractometer (Model ABBE60) in the laboratory of Food analysis, Faculty of Engineering and Technology, University of Gezira.

3.3.1.2 Determination of density and specific gravity

According to (John, 2003), 10 ml of the oil (V) was measured in a pre-weighed measuring cylinder (W). The weight of the cylinder and oil were measured (W₁). The density of the water and the oil was then obtained as follow:

$$\text{Density of water} = W_1 - W / V$$

Where:

W₁ = weight of measuring cylinder + water

W = weight of empty measuring cylinder

V = volume of water used

$$\text{Density of oil sample} = W_1 - W / V$$

Where:

W₁ = weight of measuring cylinder + oil sample

W = weight of empty measuring cylinder

V = volume of oil sample used

Therefore: **Specific gravity** = Density of water / Density of oil sample

3.3.2 Chemical characteristics

3.3.2.1 Determination of saponification value:

According to (Jimoh *et al.*, 2006), about 2 g of the oil sample were added to a flask with 30 ml of ethanolic KOH and were then attached to a condenser for 30 minutes to ensure the sample were fully dissolved. After sample had cooled, 1 ml of phenolphthalein was added and titrated with 0.5M HCl until a pink end point has reached. Saponification value was calculated from the equation:

$$\text{Saponification value} = (S - B) \times M \times 56.1 / \text{sample weight}$$

Where :

S = sample titer value

B = blank titer value

M= morality of the HCl

56.1 = molecular weight of KOH

3.3.2.2 Determination of iodine value (IV):

According to Jimoh *et al.* (2006), 0.4 g of sample oil were weighed into a conical flask and 20 ml of carbon tetrachloride were added to dissolve the sample. Then 25 ml of Wijs reagent were added to the flask using a safety pipette in fume chamber. Stopper was then inserted and the content of the flask was vigorously swirled. The flask was then placed in the dark for 2 hours and 30 minutes. At the end of this period, 20 ml of 10% aqueous potassium iodide and 125 ml of water were added using a measuring cylinder. The content was titrated with 0.1M sodium thiosulphate solution until the yellow color almost disappeared. Few drops of 1% starch indicator was added and the titration continued by adding thiosulphate drop wise until blue coloration disappeared after vigorous shaking. The same procedure was used for blank test and other sample. The iodine value (IV) is given by the expression:

$$\text{Iodine Value} = 12.69 C (V_1 - V_2) / M$$

Where:

C = Concentration of sodium

V_1 = Volume of sodium thiosulphate used for blank

V_2 = Volume of sodium thiosulphate used for determination

M = Weight of the sample

3.3.2.3 Determination of free fatty acids (FFA):

According to Chopra and Kanwar (1991), 2.0 g of sample were measured into 250 ml Erlenmeyer flask, 100 ml of ethanol were added and followed by 2 ml of phenolphthalein indicator. The mixture was shaken and titrated against 0.1M NaOH with continuously shaking until the endpoint is reached, which is indicated by a slight pink color that persists for 30 seconds, the free fatty acids is expressed as:

$$\text{FFA\%} = V \times N \times 282 \times 100 / W$$

Where :

FFA% = Percent of free fatty acid (g/100g)

V = Volume of NaOH (ml)

N = Morality of NaOH

282 = Molecular weight of oleic acid

W = Weight of oil sample

3.3.2.4 Determination of peroxide value:

According to Nielsen (2003), 2.0 g of oil sample were added to 22 ml of a solution mixture of 12 ml chloroform and 10 ml acetic acid. 0.5 ml of saturated potassium iodide was added to the flask. The flask was corked and allowed to stay with occasional shaking for 1 minute. 30 ml of distilled water were then added to the mixture and titrated against 0.1M of $\text{Na}_2\text{S}_2\text{O}_3$ until yellow color is almost gone. 0.5 ml of starch indicator was quickly added and titration continued until blue color just disappeared. A blank titration was also carried out at the same condition.

$$\text{Peroxide Value} = (S - B) \times N \times 1000/W$$

Where:

Peroxide Value = Meq peroxide per 100g of sample

S = Volume of titrate for sample

B = Volume of titrate for blank

N = Morality of $\text{Na}_2\text{S}_2\text{O}_3$ solution

W = Weight of sample

3.4 Statistical analysis

Microsoft office, excel program, 2007, was used to present and analyze the obtained data. Simple descriptive statistics and ANOVA two factor were also used to clear the differences observed in the values of the physical and chemical parameters of all the oil samples (Groundnut seeds (roasted and non roasted), Sesame seed and Sunflower seeds) and the commercials samples.

Chapter Four: Results And Discussion

4.1 The efficiency of different solvents in extraction of Groundnut, Sunflower and Sesame seed-oils using centrifuge

Table (4.1) showed the efficiency of using different solvents and centrifuge on the extraction of Groundnut, Sunflower and Sesame seeds. Petroleum ether extracted relatively more amount of Groundnut oil (mean= 41.6%), followed by Hexane (mean =38.6%). The lowest amount of oil content (mean= 36%) was extracted by Chloroform.

Oil content of Sudanese varieties of groundnut seeds ranged between 44.8%-51.7% (mean= 48%) **Arabi (2014)**. The results obtained in this study showed that, the extraction efficiency of Petroleum ether was 86.7% (41.6/48) using centrifuge within 30 minutes, while that of Hexane was 80.4% and of Chloroform was 75% of Ground nut seed oil.

Concerning Sunflower, Petroleum ether extracted more oil (mean= 42%), than Hexane (mean =40.6%). The lowest amount of oil content (mean= 36.6%) was extracted by Chloroform.

Ahmed (2013) found that, oil contents in Sunflower seeds ranged between 39%-45% (mean 41.7). The results showed that, the extraction efficiency of Petroleum ether was about 100% (referring to the minimal value), while that of Hexane was 97.3% and that of Chloroform was 87.7% of Sunflower seed oil using centrifuge within 30 minutes.

Table (4.1) also showed that, Petroleum ether extracted relatively highest level of Sesame oil (mean= 42.67%), followed by Hexane (mean =39.67%), then Chloroform (mean= 33.67%).

Sesame seed contains 49.7% oil (**Ray, 2011**). It was clear that, the extraction efficiency of Petroleum ether was 85.8%, while that of Hexane was 79.8% and that of Chloroform was 67.7% of Sesame seed oil using centrifuge within 30 minutes.

The statistical analysis revealed that, Petroleum ether extracted a mean of 42.09% from all seed samples, followed by Hexane (39.62%) and then Chloroform (35.42%). There was a significant difference ($f=25.99$; $f\text{-crit}= 6.94$) in the columns level (solvents), i.e. some solvents are better (e.g. Petroleum ether) than the others.

Table (4.1) Mean percentage of oil extracted from Groundnut, Sunflower and Sesame seeds by using centrifuge device (for 30 minutes) and different solvents

| Type | Petroleum ether | Hexane | Chloroform |
|-----------|-----------------|--------|------------|
| Groundnut | 41.6 | 38.6 | 36 |
| Sunflower | 42 | 40.6 | 36.6 |
| Sesame | 42.67 | 39.67 | 33.67 |

| SUMMARY | Count | Sum | Average | Variance |
|-----------|-------|--------|---------|----------|
| Groundnut | 3 | 116.2 | 38.73 | 7.85 |
| Sunflower | 3 | 119.2 | 39.73 | 7.85 |
| Sesame | 3 | 116.01 | 38.67 | 21 |

| | | | | |
|-----------------|---|--------|-------|------|
| Petroleum ether | 3 | 126.27 | 42.09 | 0.29 |
| Hexane | 3 | 118.87 | 39.62 | 1.00 |
| Chloroform | 3 | 106.27 | 35.42 | 2.40 |

ANOVA

| Source | SS | df | MS | F | P-value | F crit |
|---------|-------|----|-------|-------|----------|--------|
| Rows | 2.13 | 2 | 1.07 | 0.81 | 0.505113 | 6.94 |
| Columns | 68.17 | 2 | 34.08 | 25.99 | 0.005103 | 6.94 |
| Error | 5.244 | 4 | 1.311 | | | |
| Total | 75.55 | 8 | | | | |

4.2 Quality parameters of the extracted seed-oils

4.2.1 Physical properties

4.2.1.1 Groundnut oil

Table (4.2) showed some physical properties (the density, refractive index and the specific gravity) of Groundnut oil extracted from the seeds by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The density of Groundnut oil extracted by Chloroform, Hexane and Petroleum ether solvents were 0.81, 0.83 and 0.85, respectively, which were not fall within the **CoDEX-STAN210 (1999)** standard (0.912–0.920), therefore, Groundnut oil extracted by Petroleum ether solvent has good quality.

The refractive index of Groundnut oil extracted by Chloroform, Hexane and Petroleum ether were 1.4670, 1.4660 and 1.4678, respectively, and it did not fall within the **CoDEX-STAN210 (1999)** standard (1.460-1.465), therefore, Groundnut oil extracted by Hexane solvent has good quality, while the refractive index of control was 1.4650.

The specific gravity of Groundnut oil extracted by Chloroform, Hexane and Petroleum ether solvents were 0.99, 0.93 and 0.94, respectively, were not fall within the **CoDEX-STAN210 (1999)** standard (0.910-0.915), therefore, Groundnut oil extracted by hexane solvent has good quality, while in control, the specific gravity was (0.93).

ANOVA analysis revealed that, the differences in the physical properties of Groundnut oil extracted by centrifuge using different solvents were not significant (f= 0.16; f-crit= 3.84), therefore, and according to the density, refractive index and specific gravity of the oil, Hexane is relatively the best solvent to be used for extraction of Groundnut oil followed by Petroleum ether solvent and at the last Chloroform solvent.

Concerning density, refractive index and specific gravity of Groundnut oil, the centrifuge method using different solvent led to yield oil with competent quality.

Table (4.2) Some physical properties of Groundnut oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210, (1999) |
|------------------|---------|--------------|--------|-----------------|-----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Density | 0.86 | 0.81 | 0.83 | 0.85 | 0.912-0.920 |
| Refractive index | 1.4650 | 1.4670 | 1.4660 | 1.4678 | 1.460-1.465 |
| Specific gravity | 0.93 | 0.99 | 0.93 | 0.94 | 0.910-0.915 |

| SUMMARY | Count | Sum | Average | Variance |
|------------------|-------|------|---------|----------|
| Density | 5 | 4.27 | 0.85 | 0.002 |
| Refractive index | 5 | 7.33 | 1.46 | 4.23E-06 |
| Specific gravity | 5 | 4.70 | 0.94 | 0.0008 |
| Control | 3 | 3.26 | 1.09 | 0.109 |
| Chloroform | 3 | 3.27 | 1.09 | 0.115 |
| Hexane | 3 | 3.23 | 1.07 | 0.117 |
| Petroleum ether | 3 | 3.26 | 1.09 | 0.111 |
| Standard | 3 | 3.29 | 1.09 | 0.100 |

| Source | SS | Df | MS | F | P-value | F crit |
|---------|-------|----|--------|--------|----------|--------|
| Rows | 1.10 | 2 | 0.55 | 480.04 | 4.66E-09 | 4.46 |
| Columns | 0.001 | 4 | 0.0001 | 0.16 | 0.9528 | 3.84 |
| Error | 0.01 | 8 | 0.001 | | | |
| Total | 1.11 | 14 | | | | |

4.2.1.2 Sesame oil

Table (4.3) showed some physical properties (density, refractive index and specific gravity) of Sesame oil samples extracted by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The densities of Sesame oils extracted by Chloroform, Hexane and Petroleum ether solvents were 0.82, 0.88 and 0.96, respectively, while the CoDEX-STAN210 (1999) standards ranged between 0.915–0.924, whereas the density in control was (0.86), therefore, sesame oil extracted (specially by Hexane solvent) has good quality.

The refractive index of Sesame oil extracted by Chloroform, Hexane and Petroleum ether solvents were 1.468, 1.468 and 1.467, respectively, which were near to the CoDEX-STAN210 (1999) standards ranged between (1.470-1.474), while the refractive index in control was (1.467).

The specific gravity of Sesame oil extracted by Chloroform, Hexane and Petroleum ether solvents were 0.98, 0.91 and 0.83, respectively, while that of the CoDEX-STAN210 (1999) standards ranged between (0.916-0.921). The specific gravity in control sample was (0.93).

It was noticed that, the oil extracted by Hexane and Petroleum ether solvents had physical properties matched with the CoDEX-STAN210 (1999) standards, unlike the oil extracted by Chloroform solvent which is far from the same standards, therefore, and according to the physical properties of the tested oils, Hexane is the best solvent to be used for extraction of Sesame oil followed by Petroleum ether solvent and at the last Chloroform solvent.

ANOVA analysis revealed that, the differences in the physical properties of Sesame oil extracted by centrifuge and different solvents were not significant ($f= 0.07$; $f\text{-crit}= 3.84$), i.e. density, refractive index and specific gravity of Sesame oil the centrifuge method using different solvent led to yield oil with competent quality.

Table (4.3) Some physical properties of Sesame oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210, (1999) |
|------------------|---------|--------------|--------|-----------------|-----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Density | 0.86 | 0.82 | 0.88 | 0.96 | 0.915-0.924 |
| Refractive index | 1.4671 | 1.4689 | 1.4680 | 1.4670 | 1.469-1.479 |
| Specific gravity | 0.93 | 0.98 | 0.91 | 0.83 | 0.916-0.921 |

| <i>SUMMARY</i> | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|------------------|--------------|------------|----------------|-----------------|
| Density | 5 | 4.44 | 0.89 | 0.003 |
| Refractive index | 5 | 7.35 | 1.47 | 8.4E-06 |
| Specific gravity | 5 | 4.57 | 0.91 | 0.003 |
| Control | 3 | 3.26 | 1.08 | 0.11 |
| Chloroform | 3 | 3.27 | 1.09 | 0.11 |
| Hexane | 3 | 3.26 | 1.09 | 0.11 |
| Petroleum ether | 3 | 3.26 | 1.08 | 0.11 |
| Standard | 3 | 3.31 | 1.10 | 0.10 |

| <i>Source</i> | <i>SS</i> | <i>Df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|---------------|-----------|-----------|-----------|----------|----------------|---------------|
| Rows | 1.08 | 2 | 0.54 | 190.45 | 1.79E-07 | 4.46 |
| Columns | 0.001 | 4 | 0.0002 | 0.07 | 0.99 | 3.84 |
| Error | 0.023 | 8 | 0.003 | | | |
| Total | 1.10 | 14 | | | | |

4.2.1.3 Sunflower oil

Table (4.4) showed some physical properties (density, refractive index and specific gravity) of Sunflower oil samples extracted by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The density of Sunflower oil extracted by Chloroform, Hexane and Petroleum ether solvents were 0.82, 0.88 and 0.80, respectively, and were not far from the CoDEX-STAN210 (1999) standards (0.918–0.923), while the density in control was (0.82).

The refractive index of Sunflower oil extracted by Chloroform, Hexane and Petroleum ether solvents were 1.4651, 1.4699 and 1.4697, respectively, and were fall within the CoDEX-STAN210 (1999) standards (1.461-1.468). The refractive index in control was (1.4699).

The specific gravity of Sunflower oil extracted by Chloroform, Hexane and Petroleum ether solvents were 0.98, 0.91 and 1.0, respectively, which were not far from the CoDEX-STAN210 (1999) standards (0.915-0.919). The specific gravity in control sample was (0.98).

ANOVA analysis revealed that, the differences in the physical properties of Sunflower oil extracted by centrifuge and different solvents were not significant ($f= 0.06$; $f\text{-crit}= 3.84$), i.e. density, refractive index and specific gravity of Sunflower oil the centrifuge method using different solvent led to yield oil with competent quality.

Table (4.4) Some physical properties of Sunflower oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210 (1999) |
|------------------|---------|--------------|--------|-----------------|----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Density | 0.84 | 0.82 | 0.88 | 0.80 | 0.918-0.923 |
| Refractive index | 1.4699 | 1.4651 | 1.4699 | 1.4679 | 1.461-1.468 |
| Specific gravity | 0.98 | 0.98 | 0.91 | 1.0 | 0.915-0.919 |

| SUMMARY | Count | Sum | Average | Variance |
|------------------|-------|------|---------|----------|
| Density | 5 | 4.26 | 0.85 | 0.002 |
| Refractive index | 5 | 7.34 | 1.47 | 6.61E-06 |
| Specific gravity | 5 | 4.79 | 0.96 | 0.002 |
| Control | 3 | 3.29 | 1.09 | 0.11 |
| Chloroform | 3 | 3.26 | 1.09 | 0.11 |
| Hexane | 3 | 3.26 | 1.09 | 0.11 |
| Petroleum ether | 3 | 3.27 | 1.09 | 0.12 |
| Standard | 3 | 3.30 | 1.10 | 0.09 |

| Source | SS | Df | MS | F | P-value | F crit |
|--------|------|----|------|--------|----------|--------|
| Rows | 1.08 | 2 | 0.54 | 276.79 | 4.12E-08 | 4.46 |

| | | | | | | |
|---------|--------|----|--------|------|------|------|
| Columns | 0.0004 | 4 | 0.0001 | 0.06 | 0.99 | 3.84 |
| Error | 0.02 | 8 | 0.002 | | | |
| Total | 1.09 | 14 | | | | |

4.2.2 Chemical properties

4.2.2.1 Groundnut oil

Table (4.5) showed some chemical properties (saponification value, iodine value, peroxide value and free fatty acid) of Groundnut oil samples extracted by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The results showed that, the saponification values were (168, 165, 168 and 159), while the iodine values were (86.3, 84.0, 85.0 and 83.2), free fatty acids (FFA) values were (0.80, 0.84, 0.74 and 0.86) and the peroxide values were (1.0, 1.0, 0.5 and 1.0) in the control and the samples extracted by Chloroform, Hexane and Petroleum ether solvents, respectively.

The standard chemical properties of Groundnut oil of **CoDEX-STAN210 (1999)** were: saponification (187-196), iodine value (86-107), Free Fatty Acid (0.6 max), and peroxide (1-10%).

It was noticed that, Hexane solvent is the best solvent to be used for extraction of Groundnut oil followed by Petroleum ether solvent and at the last Chloroform solvent.

ANOVA analysis revealed that, the differences in the chemical properties of Groundnut oil extracted by centrifuge and different solvents were not significant ($f= 3.10$; $f\text{-crit}= 3.26$), i.e. the extracted oils have chemical characteristics with competent quality.

Table (4.5) Some chemical properties of Groundnut oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210, (1999) |
|-----------------|---------|--------------|--------|-----------------|-----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Saponification | 168 | 165 | 168 | 159 | 187-196 |
| Iodine value | 86.3 | 84.0 | 85.0 | 83.2 | 86-107 |
| Free fatty acid | 0.84 | 0.84 | 0.74 | 0.86 | 0.6 max |
| Peroxide | 1.0 | 1.0 | 0.5 | 1.0 | 1-10% |

| SUMMARY | Count | Sum | Average | Variance |
|-----------------|-------|--------|---------|----------|
| Saponification | 5 | 851.5 | 170.3 | 153.95 |
| Iodine value | 5 | 435 | 87 | 29.55 |
| Free fatty acid | 5 | 3.58 | 0.716 | 0.06 |
| Peroxide | 5 | 9 | 1.8 | 4.33 |
| Control | 4 | 256.14 | 64.04 | 6423.8 |
| Chloroform | 4 | 250.84 | 62.71 | 6184.2 |

| | | | | |
|-----------------|---|--------|--------|--------|
| Hexane | 4 | 254.24 | 63.56 | 6430.1 |
| Petroleum ether | 4 | 244.06 | 61.015 | 5771.2 |
| Standard | 4 | 293.8 | 73.45 | 8145.1 |

| Source | SS | df | MS | F | P-value | F crit |
|---------|----------|----|----------|---------|----------|--------|
| Rows | 98493.77 | 3 | 32831.26 | 1066.47 | 7.97E-15 | 3.49 |
| Columns | 382.08 | 4 | 95.52 | 3.10 | 0.06 | 3.26 |
| Error | 369.42 | 12 | 30.78 | | | |
| Total | 99245.28 | 19 | | | | |

4.2.2.2 Sesame oil

Table (4.6) showed some chemical properties (saponification value, iodine value, peroxide value and free fatty acid) of Sesame oil samples extracted by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The results showed that, the saponification values were (190, 182, 186 and 193), while the iodine values were (82.5, 82.5, 86.3 and 81.2), free fatty acid were (0.84, 0.88, 0.84 and 0.98) and the peroxide value were (0.5, 0.5, 0.5 and 0.5) in the control and the samples extracted by Chloroform, Hexane and Petroleum ether solvents, respectively.

The standard chemical properties of Sesame oil of **CoDEX-STAN210 (1999)** were: Saponification value (186-195), Iodine value (86-105), Free Fatty Acid 0.6 max), and Peroxide (1-10%).

It was clear that, Hexane is the best solvent to be used for extraction of Sesame oil followed by Petroleum ether solvent and at the last Chloroform solvent.

ANOVA analysis revealed that, the differences in the chemical properties of Sesame oil extracted by centrifuge and different solvents were not significant (f= 1.63; f-crit= 3.26).

Table (4.6) Some chemical properties of Sesame oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210, (1999) |
|-----------------|---------|--------------|--------|-----------------|-----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Saponification | 190 | 182 | 186 | 193 | 186-195 |
| Iodine value | 82.5 | 82.5 | 86.3 | 81.2 | 104-120 |
| Free fatty acid | 0.84 | 0.98 | 0.84 | 0.98 | 0.6 max |
| Peroxide | 0.5 | 0.5 | 0.5 | 0.5 | 1-10% |

| SUMMARY | Count | Sum | Average | Variance |
|----------------|-------|-------|---------|----------|
| Saponification | 5 | 941.5 | 188.3 | 18.7 |
| Iodine value | 5 | 444.5 | 88.9 | 170.39 |

| | | | | |
|-----------------|---|--------|-------|---------|
| Free fatty acid | 5 | 3.94 | 0.79 | 0.08 |
| Peroxide | 5 | 7.5 | 1.5 | 5 |
| Control | 4 | 273.84 | 68.46 | 8053.37 |
| Chloroform | 4 | 265.98 | 66.49 | 7415.04 |
| Hexane | 4 | 273.64 | 68.41 | 7774.98 |
| Petroleum ether | 4 | 275.68 | 68.92 | 8281.26 |
| Standard | 4 | 308.3 | 77.08 | 8367.46 |

| Source | SS | df | MS | F | P-value | F crit |
|---------|----------|----|----------|--------|----------|--------|
| Rows | 119172.9 | 3 | 39724.31 | 946.95 | 1.62E-14 | 3.49 |
| Columns | 273.30 | 4 | 68.32 | 1.63 | 0.230 | 3.26 |
| Error | 503.39 | 12 | 41.95 | | | |
| Total | 119949.6 | 19 | | | | |

4.2.2.3 Sunflower oil

Table (4.7) showed some chemical properties (saponification value, iodine value, peroxide value and free fatty acid) of Sunflower oil samples extracted by using centrifuge and different solvents (Chloroform, Hexane and Petroleum ether).

The results showed that, the saponification values were (190, 182, 190 and 184), while the iodine values were (81.2, 83.3, 86.3 and 82.5), free fatty acid were (0.98, 0.70, 0.70 and 0.98) and the peroxide value were (1.0, 0.5, 0.5 and 0.5) in the control and the samples extracted by Chloroform, Hexane and Petroleum ether solvents, respectively.

The standard chemical properties of Sunflower oil of **CoDEX-STAN210 (1999)** were: saponification (188-194), iodine value (118-141), free fatty acids (0.6 max), and peroxide (1-10%).

It was clear that, Hexane is the best solvent to be used for extraction of Sunflower oil followed by Petroleum ether solvent and at the last Chloroform solvent.

ANOVA analysis revealed that, the differences in the chemical properties of Sunflower oil extracted by centrifuge and different solvents were not significant (f= 1.58; f-crit= 3.26).

Table (4.7) Some chemical properties of Sunflower oil extracted by centrifuge using different solvents

| Property | Control | Solvent used | | | CoDEX-STAN210, (1999) |
|-----------------|---------|--------------|--------|-----------------|-----------------------|
| | | Chloroform | Hexane | Petroleum ether | |
| Saponification | 190 | 182 | 190 | 184 | 188-194 |
| Iodine value | 81.2 | 83.3 | 86.3 | 82.5 | 118-141 |
| Free fatty acid | 0.98 | 0.71 | 0.70 | 0.98 | 0.6 max |
| Peroxide | 1.0 | 0.5 | 0.5 | 0.5 | 1-10% |

| <i>SUMMARY</i> | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|-----------------|--------------|------------|----------------|-----------------|
| Saponification | 5 | 937 | 187.4 | 16.8 |
| Iodine value | 5 | 462.8 | 92.56 | 429.94 |
| Free fatty acid | 5 | 3.67 | 0.73 | 0.08 |
| Peroxide | 5 | 8 | 1.6 | 4.8 |
| Control | 4 | 273.18 | 68.29 | 8012.86 |
| Chloroform | 4 | 266.51 | 66.63 | 7435.58 |
| Hexane | 4 | 277.5 | 69.38 | 8098.96 |
| Petroleum ether | 4 | 267.98 | 66.99 | 7570.05 |
| Standard | 4 | 326.3 | 81.58 | 8887.89 |

| <i>Source</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|---------------|-----------|-----------|-----------|----------|----------------|---------------|
| Rows | 118833.7 | 3 | 39611.23 | 402.04 | 2.67E-12 | 3.49 |
| Columns | 624.15 | 4 | 156.04 | 1.58 | 0.2415 | 3.26 |
| Error | 1182.31 | 12 | 98.53 | | | |
| Total | 120640.1 | 19 | | | | |

Chapter Five: Conclusions and Recommendations

5.1. Conclusions

- The percentage oil content was affected by the solvent used
- Petroleum ether solvent was the best solvent for extraction of oils, followed by Hexane solvent and lastly Chloroform solvent.
- Centrifuge device can be adopted to be used for oil extract in all oil-seeds.
- The best solvent to be used to extract oil with good quality from Groundnut seeds, Sesame seeds and Sunflower seeds samples was Hexane solvent.
- The physical and chemical properties of oil extracted by using centrifuge and different solvents were statistically similar to their standards.

5.2. Recommendations

- Improvement of centrifugation method to be applied at field (oil industries) and at Laboratory level (experimental work).
- For relatively high amount of oils, Petroleum ether and Hexane solvents should be used to extract Groundnut, Sunflower and Sesame oils from their seeds
- For extracting oils with high quality, Hexane solvents should be used.

References

- Adebowale, A. A.; Sanni, S. A. and Falore, O. A. (2011).** Varietal differences in the physical properties and proximate composition of elite sesame seeds. *World Journal of Agricultural Sciences*, 7(1): 42-46.
- Ahearn, D. G.; Crow, S. A. and Simmons, R. B. (1996).** Fungal colonization of fiberglass insulation in the air distribution system of a multi-story office building: VOC production and possible relationship to a sick building syndrome. *J. Ind. Microbiol.*, 16:280-285
- Ahmed, T. (2013).** The Effect of X-rays on some Physical and Chemical Characteristic of First Generation (F₁) Sesame (*Sesamum indicum* L.) and Sunflower (*Helianthus annuus* L.) Seeds. M.Sc. Thesis, University of Gezira.
- Alan, P. (2007).** *Generic Hydrocarbon Solvents: a Guide to Nomenclature.* WAAC Newsletter, 29 (2).
- Anyasor, G. N.; Ogunwenmo, K. O.; Oyelana, O. A.; Ajayi, D. and Dangana, J. (2009).** Chemical Analyses of Groundnut (*Arachis hypogaea*) Oil. *Pakistan Journal of Nutrition*, 8 (3): 269–272.
- Arabi, H. N. (2014).** Effect of X-rays, Gamma rays and Ultra Violet light on some Morphological characteristics and nutritional contents of the first generation groundnut (*Arachis hypogaea* L.) seeds. M.Sc. thesis, University of Gezira.
- Arctander, S. (1994).** *Perfume and Flavor Materials of Natural Origin.* Carol Stream, Illinois: Allured Publishing Corporation.

- Arthur, I. V. (1989). *Practical Organic Chemistry (5th ed.)*, Longman, p. 397-398
- Bhagya, S. and Srinivas, H. (1992). Extraction of soybean with hexane-acetic acid: Effect on oil quality. *Food Chem.*, 44:123-125.
- Bockisch, M. (1998). *Fats and Oils Handbook*. Champaign, IL: AOCS Press. pp. 95–6. ISBN 0-935315-82-9.
- Chopra, S. L. and Kanwar, J. S. (1991). *Analytical Agricultural Chemistry*, 4th Edition, New Delhi, Kalyami publishers, Pp 12-15.
- Christov, M. (2012). Contribution of interspecific hybridization to sunflower breeding. *Helia.*, 35(57): 37- 46.
- CoDEX-STAN210 (1999). Codex standard for named vegetable oils, (FAO).
- Cole-Parmer, P. and William, A. (2012). Basics of Centrifugation. Retrieved 11 March 2012.
- Cone, E. J. (2006). Ephemeral profiles of prescription drug and formulation tampering: evolving pseudoscience on the internet. *Drug Alcohol Depend.*, 83 (1): 31–39.
- Conkerton, E. J.; Wan, P. J. and Richard, O. A. (1995). Hexane and heptane as extraction solvents for cottonseed: A laboratory-scale study. *J. Am. Oil Chem. Soc.*, 72:963-965.
- David, R. L. (2010). *CRC Handbook of Chemistry and Physics (90th ed.)*, CRC Press, p. 2-60
- Etymonline.com. (2010). "The Online Etymology Dictionary". Retrieved 2010-09-14.
- FAO, Food and Agriculture Organization of the United Nations (2005). Basic Principles of Steam Distillation. Retrieved August 18, 2005.
- Fediol (2015). Sitemap - Disclaimer - CMS by Antalya.
- Genck, W. J.; Dickey, D. S.; Baczek, F. A.; Bedell, D. C.; Brown, K.; Chen, W.; Ellis, D. E.; Harriott, P.; Li, W.; Mcgillicuddy, J. K.; McNulty, T. P.; Oldshue, J. Y.; Schoenbrunn, F.; Smith, J. C.; Taylor, D. C. and Wells, D. R. (2008). *Perry's chemical engineers' handbook*, 8th edition, the McGraw-hill companies, inc., United States of America.
- Haddad, L. M. and Winchester, J. F. (1990). *Clinical Management of Poisoning and Drug Overdose*. 2nd ed., pp. 1173-114. W.B. Saunders Company.
- Harry, W.; Lewis, A. and Christopher, J. M. (1989). *Experimental Organic Chemistry: Principles and Practice (Illustrated ed.)*. Wiley Blackwell. pp. 159–173. ISBN 978-0-632-02017-1.
- Havrin, R. G. (2013). The comparison and selection of separations equipment for the municipal industry (centrifuges versus belt filters) (pdf), CentriSys Corporation, Retrieved 2013-11-04.
- Hecht, E. (2002). *Optics*. Addison-Wesley. ISBN 0-321-18878-0.
- HPA (2007). Chloroform-toxicological overview. Prepared by K Foxall Chapd HQ, HPA, Version 1.
- Jerrold, B. L. and Frank, P. P. (2008). "Petroleum Distillates - Naphtha", *Poisoning and*

Toxicology Handbook (4th ed.), Informa, pp. 836–837.

- Jimoh, D.; Mohammed, A. D. and Akpan, U. (2006).** Extraction Characterization and Modification of castor seeds oil Leonardo. *J. of Science*, 8: 43-52.
- John, K. (2003).** Analytical Chemistry for Technicians, 3rd Edition, Lewis Publishers, Kalyani Publisher, New Delhi, India, Pp 347-349.
- Kamal-Eldin, A.; Appelqvist, A. and Lars, Å. (2012).** "The effects of extraction methods on sesame oil stability". *Journal of the American Oil Chemists' Society*, 72 (8): 967–969.
- Kardash, E. and Tur'yan, Y. I. (2005).** Acid Value Determination in Vegetable Oils by Indirect Titration in Aqueous-alcohol Media. *Croat. Chem. Acta*, 78:1:99-103.
- Kehail, M. A.; Mohamed, R. A.; Abdelrahim, Y. M. and Ibrahim, N. I. (2016).** Extraction Rates of Oils of Some Seeds by using Different Speeds of the Centrifuge. *Asian Journal of Applied Sciences*: 04(6):1267-1273
- Krapovikas, A. (1968).** Origin variability. Diffusion del mani (*Arachis hypogaea*). Actasy Memories, cong-lint. *American Ensiles-Bs. Aires*, 2:517-534.
- Langham, A. (2008).** "Growth and Development of Sesame" (Pdf). American Sesame Growers Association.
- Lawson, H. (1995).** Food oils and fats: Technology, utilization, and nutrition. New York, NY: Chapman Jz Hall.
- Liu, X.; Jin, Q.; Liu, Y.; Huang, J.; Wang, X.; Mao, W. and Wang, S. (2011).** Changes in Volatile Compounds of Peanut Oil during the Roasting Process for Production of Aromatic Roasted Peanut Oil". *J. Food Science*, 76 (3): 404–412.
- Murphy, D. J. (1994).** Designer Oil Crops, Breeding, Processing and Biotechnology. VCH Verlagsgesellschaft mbH, Weinheim, Germany.
- National Sunflower Association (2013).** "Sunflower Oil - Your Healthy Choice". Retrieved 26 June 2013.
- NFPA30 (2014).** Flammable and Combustible Liquids, Code Edition. Retrieved January 4, 2014.
- Ng, C. W. W.; Wang, Y. H. and Zhang, L. M. (2006).** Physical Modeling in Geo-techniques: proceedings of the Sixth International Conference on Physical Modeling in . Taylor and Francis. p. 135. *Geo-techniques*. ISBN 0-415-41586-1.
- Nielsen, S. (2003).** Food analysis, laboratory manual 3rd Edition, Kluwer academic Premium Publishers, London. Pp 88-89.
- Oilglossary.com (2010).** "Density definition in Oil Gas Glossary". Archived from the original on August 5, 2010. Retrieved September 14, 2010.
- Onwueme I. C. and Sinha, T. A. (1999).** Field crop production in tropical Africa. Technical Center for Agricultural and Rural Co-operation, Pp 324-327.

- Oxford English Dictionary (2005)**. 3rd ed., Oxford University Press. oil (Subscription or UK public library membership required).
- Patricia, J. B. (2005)**. "Petroleum Ether", *Encyclopedia of Toxicology*, 3 (2nd ed.), Elsevier, pp. 375–376
- Pope, K.; Pohl, M. E. D.; Johnes, J. G.; Lentz, D. L.; Von Nagy, C.; Vega, F. J. and Quitmyer, I. R. (2001)**. "Origin and Environmental Setting of Ancient Agriculture in the Lowlands of Mesoamerica," *Science*, 292(5520): 1370-1373.
- Rahman, M. S.; Hossain, M. A.; Ahmed, G. M. and Uddin, M. M. (2007)**. Studies on the characterization, lipids and glyceride compositions of Sesame (*Sesamum indicum* linn.) Seed Oil. *Bangladesh J. Sci. Ind. Res.*, 42: 67-74.
- Ray, H. (2011)**. "Sesame profile". Agricultural Marketing Resource Center.
- Reich, E. and Schibli, A. (2007)**. High-performance thin-layer chromatography for the analysis of medicinal plants (Illustrated ed.). New York: Thieme. ISBN 3-13-141601-7.
- Schnaubelt, K. (2002)**. Biology of Essential Oils. San Rafael, CA: Terra LindaScent.Surrey.ac.uk./Personal/R.Knott/Fibonacci/fibant.Retriev 2011-01-31.
- Schumann, K. and Siekmann, K. (2005)**. "Soaps" in Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH, Weinheim.
- Science Daily (2005)**. "Sunflower Seeds, Pistachios Among Top Nuts For Lowering Cholesterol". Retrieved 2011-03-27.
- Shayne, C. G. (2005)**. "Petroleum Hydrocarbons", *Encyclopedia of Toxicology*, 3 (2nd ed.), Elsevier, pp. 377–379
- Silvia, A. C. and Dorothy, M. (2009)**. The Chemistry of Aging in Oil Paintings: Metal Soaps and Visual Changes. The Metropolitan Museum of Art Bulletin'', Summer 2009, pp. 12–19.
- Speight, J. G. (1991)**. Classification. The chemistry and technology of petroleum. Second edition, 197-527.
- Stephen, R .C. (2005)**. "Petroleum Distillates", *Encyclopedia of Toxicology*, 3 (2nd ed.), Elsevier, pp. 372–375
- Streeter, V. L.; Wylie, E. B. and Bedford, K. W. (1998)**. Fluid Mechanics, McGraw-Hill, ISBN 0-07-062537-9.
- SUCRON (1996)**. The SUCRON wood and cane to gasoline and hydrogen process. Clinton, LA: SUCRON, Inc.
- Susan, R. M. and Eduardo, C. (2004)**. Bioanalytical Chemistry, Ch. 13. Centrifugation Methods. John Wiley and Sons, Mar 4, 2004, pp. 247-267.
- Thomas, A. (2002)**. Fats and Fatty Oils. Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH. doi:10.1002/14356007.a10_173.

- USDA (2011).** National Nutrient Database for Standard Reference. [www.ars.usda.gov/ Services docs. Htm? Docid=8964](http://www.ars.usda.gov/Services/docs.Htm?Docid=8964).
- USDA (2015).** Nutrition Facts for sesame oil per 100 g, analysis of fats and fatty acids". Conde Nast for the USDA National Nutrient Database, version SR-21. 2014. Retrieved 11 July 2015.
- USDA, National Nutrient Database (2014).** "Nutrition facts for peanuts, all types, raw, USDA Nutrient Data". Conde Nast, version SR-21. 2014.
- Vogel, A. R.; Tatchell, B. S.; Furnis, A.; Hannaford, A. J. and Smith, P. W. G. (2003).** Vogel's Textbook of Practical Organic Chemistry (5th ed.) 2003. ISBN 0-582-46236-3.
- Wolke, R. L. (2007).** "Where There's Smoke, There's a Fryer". The Washington Post. Retrieved March 5, 2011.
- Wood, M. (2002).** Sunflower Rubber Agricultural Research, USDA. Available at: www.ars.usda.gov/is/AR/archive/jun02/rubber0602.ht. Retrieved 2011-01-31.