ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTER FOR FOOD SCIENCE AND NUTRITION

Physicochemical characteristics and shelf life stability of Soya bean oil-based Shortening

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A Thesis Submitted to Center for Food Science and Nutrition as partial fulfillment for Master degree in Food Science and Nutrition

November ,2019

Addis Ababa, Ethiopia

Declaration

I, the undersigned, declare that this is original work and has never been presented in this or any other University, as well as research center previously and all the sources materials used for this thesis, have been fully acknowledged.

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List of Abbreviations

AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of Variance
AOCS	American Oil Chemist Society
CIE	Chemical Interesterification
CRD	Completely Randomized Design
EIE	Enzyme Interesterification
ESA	Ethiopian Standard Agency
FAC	Fatty Acid Composition
FAO	Food and Agricultural Organization
FAs	Fatty Acids
FFA	Free Fatty Acid
HDL	High Density Lipoprotein
IE	Interesterification
ISO	International Standard Organization
IV	Iodine Value
LDL	Low Density Lipoprotein
LSD	List Significance Difference
PO	Palm Oil
Pos	Palm Stearin

PUFA	Polyunsaturated Fatty Acid
PV	Peroxide Value
RBDSBO	Refined, Bleached and Deodorized Soya bean oil
RSO	Rape Seed Oil
SBO	Soya Bean Oil
SFO	Sunflower Oil
SMP	Slip Melting Point
SV	Saponification value
TAG	Triacylglycerol
TGs	Triglycerol
WHO	World Health Organization

Acknowledgments

I would like to express my deepest appreciationto my advisors, Mr. KelbeasaUrga and Mr. Alemu Bezabih for their invaluable support, assistance and giving constructive comment and feedback from proposal writing up to thesis preparation. I would like to acknowledge Southern Agricultural Research Institute for giving me chance for MSc study.My special thank goes to Kunifera Agro - processing PLC for financial and material support and alsothe School of Graduate Studies of Addis Ababa University is acknowledged for giving me the opportunity for this MSc. study and its financial support.I would also like to express my heartfelt gratitude to all Addis Ababa University, Center for Food science and Nutrition academic staffs member and lab technicians for their kind technical support and assistance during laboratory work. I would like to extend my gratitude to my families as I would not be standing where I am today without their unconditional support. Lastly, I would like to thank AFHA food processing plant for providing the chance to produce soya-based shortening and material support.

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Abstract

Fats and oils enhance the foods we eat by providing texture and mouthfeel, imparting flavor, and contributing to the feeling of satiety after eating. Most edible oils have limited application in food products in the original form. Hence, modification techniques are applied to extend and increase their use in food formulations. Shortening is a fat product that incorporates tenderness in the food (e.g., bakery products) in which it is used. Palm stearin is theoretically a potential to be used as raw material for shortening manufacturing because of its triacylglycerols composition. The restriction of some religions and beliefs and also limited supply of animal shortening, efforts have been made to develop the technology to substitute animal fat with vegetable fat. The aim of this study was to develop semisolid fats (shortening) from soybean oil and palm stearin formulations. It was produced by formulating a blend, solidifying and plasticizing the blend, and packing the final shortening product. Physicochemical property and stability of the processed shortening were determined and homemade cookies were prepared for sensory acceptability test. Stability tests of the processed shortening were determined for 6-months every two months interval. Three types of vegetable shortening were tested: (i) shortening with 60% palm stearin (S60), shortening with 70% palm stearin (S70) and (iii) commercial shortening (C). The results obtained from this work showed that the acidity, peroxide value and free fatty acid values were increased with storage time and storage temperature. The physicochemical properties of the samples were within the requirements of the food domain except commercial shortening at 6-month storage. The samples stored at 37 °C exhibited the highest acid, peroxide, and free fatty acid values throughout storage time. In conclusion, shortening produced from 60% palm stearin (S60) and stored at room temperature has shown a good physicochemical characteristic and well accepted for different sensory attributes.

1. Introduction

1.1. Background

Oils and fats are the highest energy sources in comparison to carbohydrates and proteins. Oils and fats are used as, carriers for oil soluble vitamins, and many contain fatty acids essential for health that are not synthesized by the human body (O'Brien, 2009). Vegetable oils are substances derived from oil plants; they are composed of triglycerides which contain primarily monounsaturated polyunsaturated and fatty acids. Vegetable oils are the most important source of fat in the human diet.

At present, soybean oil is the world's leading vegetable oil in terms of both production and consumption. Soybean oil represents 53% of total oilseed production in the world and is the second most-consumed with 28% (karasulu *et al.*, 2011).Soybean production begins only recently in Africa, during the second half of 20^{th} century is believed introduced to Ethiopia in the 1950's. It is the leading oil crop, next to palm with over 250 million metric ton production in 2013. It isrich sources of protein 38-46% and 18-20% oil (Mesfin & Abush, 2018).

Soybean oil is also somewhat unique among the edible vegetable oils in its fatty acid composition (FAC), having a relatively high content of linolenic acid. Soybean oil is very popular with the rich value of Omega- 3 and Omega- 6 fatty acids. These fatty acids regulate lipid and cholesterol metabolism and prevent the narrowing of artery veins. Soybean oil accounts for 75% of vegetable oil used in commercial and consumer cooking and is the primary ingredient in many processed foods such as salad dressings, sandwich spreads, margarine, bread, mayonnaise, non-dairy coffee creamers and snack foods, including dairy product substitutes. Hardening of fats is produced by the addition of hydrogen to double bonds in the chains of fatty acids in triacylglycerols (Hamm, 2005). This process has a vital role in the fats and oils industry because it achieves two main goals. In the first place, it permits the transformation of liquid oils into semisolid fats more indicated for specific applications, as in the case of margarine and shortenings. Secondly, it results in materials with improved stability (Pollock, 2004; ISEO, 2006).

Hydrogenation, interesterification, and crystallization are distinct processes that can be applied to modify the physical or chemical properties of fats and oils to improve their usefulness. By combining hydrogenation and interesterification with a simple blending of native and modified oils, it is possible to modify the characteristics of fats and oils for specific applications. Crystallization is the process of forming solid material from a liquid solution or melt, where the solid material formed has crystalline (as opposed to amorphous) structure.

Oxidation stability is one of the most important quality parameters of edible vegetable oils. It determines their usefulness in technological processes as well as shelf life. Chemical quality of the oils was also determined by determining the acid value (AV), the peroxide value (PV), and the fatty acids composition (Maszewska *et al.*, 2018). Oxidation of unsaturated fatty acids is one of the major causes in the development of off-flavor compounds and the reduction of the nutritional value of food products (Hemalatha & Ghafoorunissa, 2007).

Fats and oils add flavor, lubricity, and texture to foods and contribute to the feeling of satiety upon consumption. After extraction and refining, they can be processed into products such as margarine, shortening, salad, and frying oils. Processed fats and oils are important functional ingredients in foods. The prime objective of modification is the production of some novel products (Krishna & Dahyabhai, 2010). According to Agriculture Statistics 2000 (USDA- NASS, 2000), margarine, shortening and salad /cooking oils accounted for 12, 31, and 41% of total domestic consumption of oils and fats in the US in 1998. Soybean oil was used to produce 95% of total margarine and 83% of total shortening. Shortening can be produced by formulating a blend, solidifying and plasticizing the blend, and packing and tempering (Gunstone, 2002). As per our knowledge, there are two vegetable shortening processing companies (AFHA food processing plant and Mojjo edible oil factory) in Ethiopia, especially soya shortening are not produced.

Therefore, the current study was intended to produce soya, shortening by the blending of soybean oil with palm stearin. Finally, physicochemical properties, product stability and consumer acceptability of soya shortening were evaluated with a baked product.

1.2. Statement of the Problem

Several studies reported that saturated fatty acids increase blood cholesterol levels, while mono and polyunsaturated fatty acids decrease blood cholesterol levels. Soybean oil is widely accepted as a healthy oil, low in saturated acids and rich in polyunsaturated acids, especially linoleic acid. However, these oils are also easily oxidized, leading to rancidity and quality deterioration (Chen *et al.*, 2011; Waraho *et al.*, 2011). Since vegetable oils are liquid at room temperature, their use in foods particularly in bakeries is limited (Karabulut *et al.*, 2003). The restriction of some religions and beliefs has been an issue towards the use of animal fat for shortening purposes. Due to the limited supply of animal shortening, efforts have been made to develop the technology to substitute animal fat with vegetable fat. Hydrogenated oils are also more stable than saturated products, such as butter.

Although hydrogenation is the most common method for shortening production, it has a high amount of trans fatty acid in the final product which several studies linked to some medical complications (Buana *et al.*, 2002). Nowadays there is a concern regarding trans fats consumption, which are formed during hydrogenation, the industry needs to find an alternative to hydrogenated fats (Muhammad *et al.*, 2012). Thus, it is advisable to replace by another method like interesterification or crystallization. Other studies have shown that dietary *trans* fats can increase levels of "bad" LDL (Low-Density Lipoprotein) cholesterol and decrease levels of "good" HDL (High-Density Lipoprotein) cholesterol. It can also increase triglyceride and lipoprotein levels which are risk factors for cardiovascular diseases (AHA, 2006).

Currently, the number of bakery industries and food processing companies increasing with time, but the production and consumption of this vegetable shortening has found very limited especially, soya-based shortening is not available in Ethiopia. Therefore, the main goal of the present study was to produce low or trans-free soya shortening.

1.3. Objectives

1.3.1. General objective

- The general objective of the study was to develop soya bean oil shortening with a combinations of palm stearin through the crystallization process;

1.3.2. Specific objectives

- To determine the physicochemical properties of the processed shortening;
- To evaluate the sensory acceptability of products and to improve texture, flavor, mouth feel and eating qualities of the baked product;
- To evaluate oxidative stability and shelf life of this shortening.

1.4. Significance of the study

The significance of this study was providing information to the oil-producing industries, consumers, policymakers, and researchers to find the most economical oil blends, with high nutrition as well as desirable physicochemical properties with the low or trans-free fat product since trans fats have adverse health effects in terms of developing chronic and other non-communicable diseases. Besides, it also found a blend with oxidatively stable palm stearin and with low melting point by the addition of soybean oil which is a high degree of unsaturation and avoiding the presence of *trans*-fatty acid and increases shelf life and quality enhancement of the product. It also provides brief information in terms of shelf-life stability and storage temperature on the physico-chemical property and product acceptability for the processed shortening.

2. Literature Review

2.1. Worldwide soya bean oil production

Soya bean oil is a vegetable oil that is extracted from soybeans, which is scientifically known as *Glycine max*. It is one of the most widely used vegetable oils in the world, possibly because soybeans are some of the most widely cultivated and utilized plants, particularly in recent decades. Soybean is native to East Asia and is considered a legume, however, despite its limited origin; it is highly prized for its edibility. Reference

Most soybean oil is refined, blended, and sometimes hydrogenated and it can be graded into different levels and strengths depending on the desired application. Soybean is the world's largest oilseed crop, with about 13 million tons of oil produced per year (Patterson, 1989). Soybean oil has gained popularity in the manufacture of margarine, shortenings, soaps, insecticides, and disinfectants (Erickson *et al.*, 1980). Soybean oil accounted for 80-90% of total edible oil consumption in the US (USDA-NASS) in 1998 because of its availability &its many desirable characteristics, including compositional &functional properties. Soya bean oil is the predominant vegetable oil produced in the world with palm oil being the second (Gnstone, 2002)

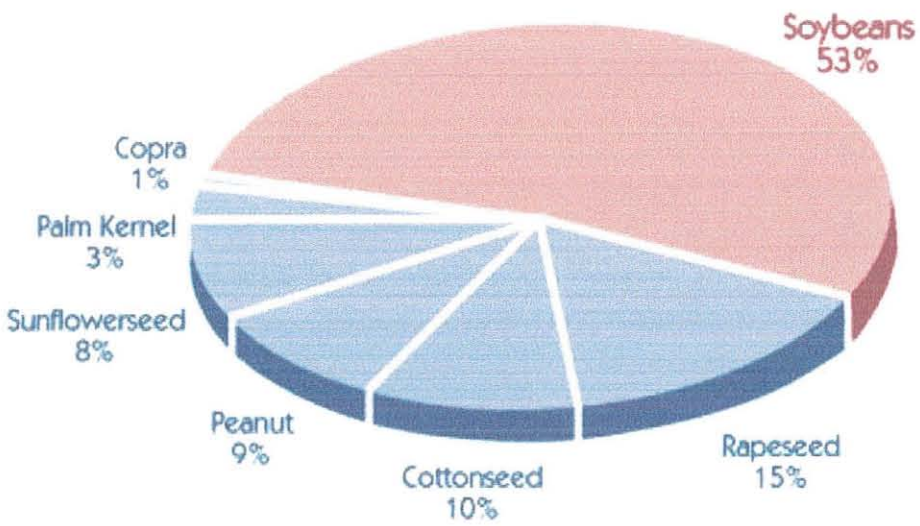

Fig.1. Worldwide oilseed production of 2009 (Karasulu *et al.*, 2011)

2.2. Worldwide Soya bean oil consumption

Soya bean production, about 24 million metric tons of oils are extracted and largely utilized for human food each year. With a fatty acid composition of 61% polyunsaturated and only 15.5% saturated, soybean oil can be utilized in a broad array of products. The neutralized-bleached-deodorized soybean oil is usually used as a salad oil, cooking oil, baking fats, confectionary fats, ingredient for margarine and mayonnaise, heavy-duty frying oil if blended with high stability oil like cottonseed or palm oil. The lightly, lightly too moderately, moderately, moderately too highly and highly-hydrogenated oil is used as a frying oil, ingredient for margarine, shortening, confectionery fat and stabilizer applications (Karasulu *et al.*, 2011).

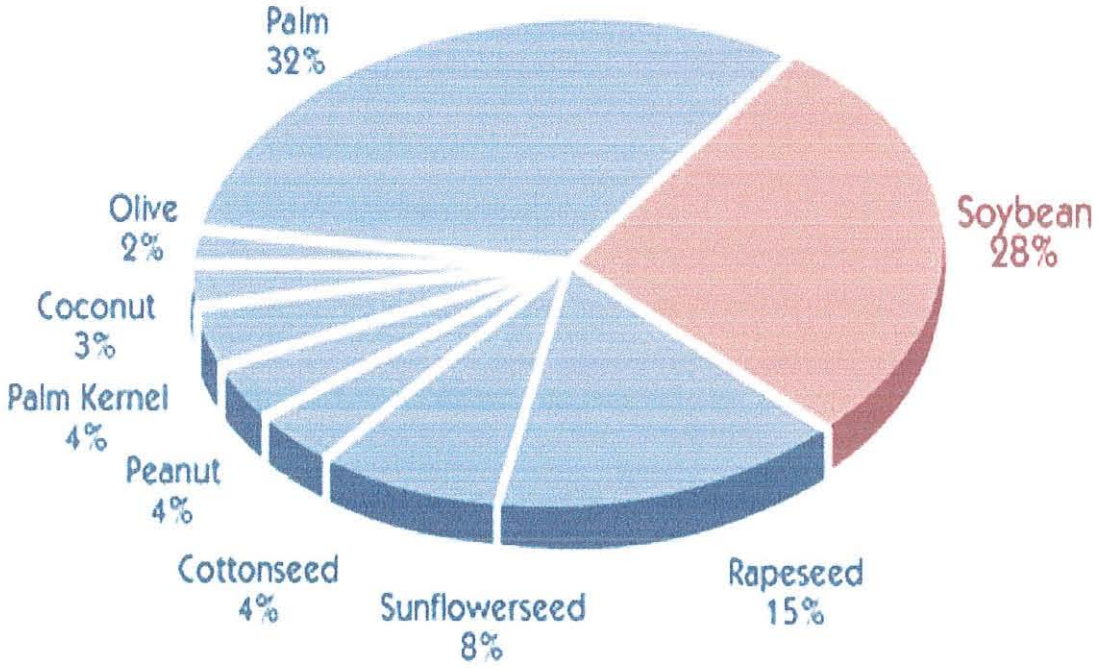

Fig.2. World vegetable oil consumption of 2009 (Karasulu *et al.*, 2011).

2. 3. Nutritional benefits and usage of soybean oil

The dietary fat consumption for about 70% of the population averages 62,5% of the recommended amount for good health. Soya bean oil is one of the most preferred oils for a healthy life. The oil content of soybeans is around 20% dry bases. Soybean is in high demand due to its high protein and oil content (Erickson *et al.*, 1980). Soy oil is characterized by relatively large amounts of the polyunsaturated fatty acids (PUFA), *i.e.*, ~55% linoleic acid and ~8% α-linolenic acid, of total fatty acids (Messina, 1997). Linoleic acid in soy oil is an essential fatty acid (EFA) belonging to the ω-6 family of PUFAs, which exerts important nutritional and physiological functions. Even the α-linolenic acid is also an EFA belonging to the ω-3 fatty acid family and plays an important role in the regulation of several metabolic pathways. However, due to the presence of lipoxygenases in soya bean, linoleic acid renders the soya bean oil-prone to rancidification (Liu, 1997). Essential fatty acids are required for the human body to produce prostaglandins. Prostaglandins are long-chain fatty acid derivatives synthesized by most cells in the body and affect many of the vital physiological functions.

Soybean containing 2.5 times the protein contents of wheat and four times the protein contents of maize. This is especially true for vegetable soybean, due to its high protein, dietary fiber, health promoting phytochemicals and easy cooking; it is an attractive crop for alleviating protein malnutrition. Because it also contains cholesterol free fat it is an excellent vehicle for the absorption of vitamin A (Mesfin & Abush 2018). In the USA, the Federal Food and Drug Administration allows foods containing 5g of soybean protein per serving to be labeled as reducing heart disease (Ash *et al.*, 2006).Vitamin E (tocopherol) is important for the human body to sustain cardiovascular health. For older males, vitamin E serves as an effective deterrent to prostate cancer. Soybean oil contains more Vitamin E than any other commonly consumed vegetable oil. Tocopherol is a natural anti-oxidant which serves to retard soybean oil oxidative degradation (Karasulu*et al.*, 2011). The minor components of crude soybean oil are phospholipids, collectively called lecithin, as well as phytosterols, and tocopherols.

Phytosterols: -Soybean oil contains about 300 to 400 mg of plant sterols per 100 g. The major components of soy sterols are β-sitosterol (53 to 56%), campesterol (20 to 23%), and stigmasterol (17 to 21%).

Phospholipids: -Soybean oil contains 1-3% phospholipids (Liu,1997, Sugano.,2006), of which~35% phosphatidylcholine, ~25% phosphatidylethanolamine, ~15%phosphatidylinositol, ~5-10% phosphatidic acid. The phospholipids are removed from the oil mainly during the 'degumming' process and are used as a natural food emulsifier. They are polar lipids and contribute to the structure of the cell membrane.

The composition of soybean oil in terms of fatty acids content is as follows: Lauric acid 0.2%, myristic acid 0.1%, palmitic acid 9.8%, stearic acid 2.4%, arachidic acid 0.9%, oleic acid 28.9%, linoleic acid 50.7%, linolenic acid 6.5%, and hexadecenoic acid 0.4%. Commodity soybean oils composed of five fatty acids: palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1), linoleic acid (18:2), and linolenic acid (18:3). The percentage of these five fatty acids in soybean oil averages 10%, 4%, 18%, 55%, and 13%, respectively.

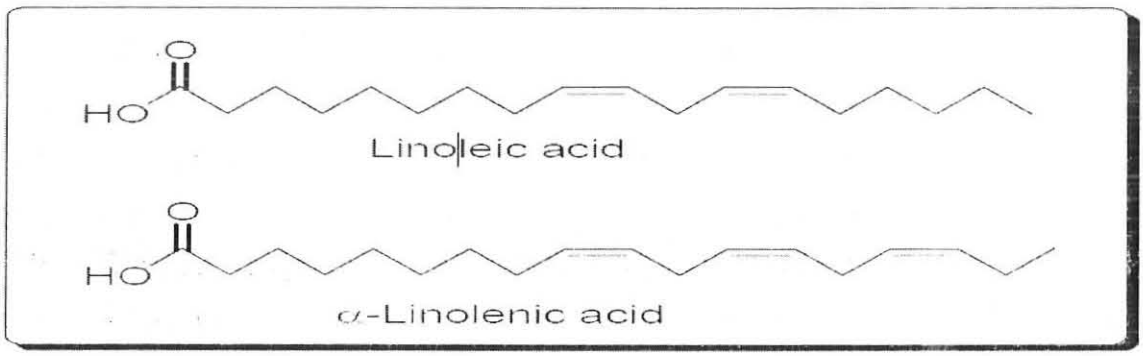

Fig. 3. Two EFAs present in soya bean oil.

Soya bean oil has different applications and benefits. Among the most benefits the following are included.

- Boosts immune system
- Promote healthy skin and eyes
- Helps to regulate cholesterol levels
- Prevents atherosclerosis and heart disease
- Aids in improving symptoms of Alzheimer's diseases and
- Protects skin cell membranes from damage and infections.

2.4. Chemical and physical properties of soybean oil

Soybean is the dominant oilseed produced in the world, because of its favorable ergonomic characteristics, its high-quality protein, and its valuable edible oil. It contributes 47% of all oilseeds produced worldwide in 2008/09 (Gunstone, 2011). Soybean oil, palm oil, and low-erucic acid rapeseed oil are the main vegetable oils used in industrial shortening (Danthine & Deroanne, 2003). Soybean oil contains (12-15) % saturated fatty acids which is mostly palmitic and 85%–88% unsaturated fatty acids which is mostly oleic, linoleic, and linolenic (Ribeiro *et al.*, 2009).

Table 1. Soybean oil composition and physical properties.

Characteristics	Typical	Range
Specific gravity, 25/25 ^{0}C	0.9175	0.917 to 0.921
Refractive index 25 ^{0}C	1.4728	1.470 to 1.276
Iodine value	131	123 to 139
Saponification number	192	189 to 195
Unsaponifiable matter %	0.6	0.6 to 1.6
Fatty acid composition, %		
C-14:0 Myristic	0.1	<0.2
C-16:0 Palmitic	10.6	8.0 to 13.3
C-16:1 Palmitoleic	0.1	<0.2
C-17:0 Margaric	0.1	
C-18:0 Stearic	4	2.4 to 5.4
C-18:1 Oleic	23.3	
C-18:2 Linoleic	53.7	
C-18:3 Linolenic	7.6	
C-20:0 Arachidic	0.3	
C-20:1 Gadoleic		
C-22:0 Behenic	0.3	
C-22:1 Erucic		
C-24:0		
Triglyceride composition,%		
SSS Trisaturated	0.1	
SUS Disaturated	5.6	6.6 to 9.6
SUS Disaturated		5.2 to 9.3
SUU Monosaturated	35.7	14.0 to 32.4
UUU Triunsaturated	58.4	55.2 to 80.3

Source: O'Brien, (2009).

2.5. Oxidative stability of soybean oil

Polyunsaturated fatty acid-rich oils are more prone to oxidative changes, and hence promote oxidation in both food and nonfood products, although important from a health point of view. Soybean oil a polyunsaturated or linoleic type of oil that is highly susceptible to lipid oxidation. The rate of lipid oxidation depends on primary on fatty acid composition &only secondary on the stereospecific distribution of the fatty acyl groups (Gustone, 2002).

Soya bean oil is rich in protein but direct use of soybean oil has some limitations as it contains linolenic acid and it becomes unstable even under ambient conditions. Typical soybean oil with about 7 to 8% linolenic acid (18:3) is known to be oxidatively unstable, especially during frying (Man &Moh, 1998, Zhang & Lee, 1997). Linolenic acid is oxidized twice as quickly as linoleic acid and produces short-chain aldehydes with flavor that are even stronger and less acceptable than those produced from linoleic acid, due to this odor of oil change. To increase the stability of soya bean oil linolenic acid content must reduce it can be done by changing fatty acid composition this is possible by blending with more stable oils compare to soybean oil. The oxidative stability of soybean oil is affected by its composition, handling of beans before extraction, processing conditions, and additives. Important compositional factors in soybean oil stability include its fatty acid composition and the presence of free fatty acids, phospholipids, natural antioxidants, and pigments (Su, 2003).

2.6. Palm Stearin

Refined, Bleached and Deodorized Palm Stearin is a very useful source of fully natural hard fat component for products such as shortening and pastry and bakery margarine. Palm stearin, the cheaper high-melting fraction from palm oil, can be used as a source of a fully natural hard component in the manufacture of solid fat products such as shortenings, margarine and fat spreads. However, because of its high melting point (44 °C–56 °C), palm stearin poses problems in the manufacture of the solid fat products as it confers low plasticity to the products and does not completely melt at body temperature (Pantzaris & Mohammed, 2000). Palm stearin, the more saturated fraction of palm oil, is more viable in composition and thus physical characteristics

The wide range in solid fat content is consistent with the wide range in iodine value for this fraction (Gunstone, 2011).

Table 2.**Fractionated palm oil characterstics.**

Characterstics	Palm oil fraction		
	Whole	Olein	Stearin
Density at 50/25 ^{0}C	0.892- 0.893		
Density at 60/25 ^{0}C		0.909 -0.903	0.882 – 891
Iodine value	51- 55	51- 61	22-49
Saponification value	190-202	194-202	193-206
Cloud point, ^{0}C		6-12	
Unsaponifiable matter, %			0.1-1
Fatty acid composition %			
C-14:0 Myristic	1-1.5	1-1.5	1-2
C-16:0 Palmitic	42-47	38-42	47-74
C-18:0 Stearic	4-5	4-5	4-6
C-18:1 Oleic	37-41	40-44	16-37
C-18:2 Linoleic	9-11	10-13	3-10
Triglyceride composition, %	0.8-9.0		
SSS Trisaturated	38.5-50.3	0.1-0.3	22.2
SUS Disaturated	31.8-44.4	37.6-46.1	43.9
SUU Monosaturated	4.8-9.8	41.3-49.1	25.6
UUU Triunsaturated		6.4-8.4	3.9

Notes: S= saturated, U=unsaturated: (O`Brien, 2009).

2.7. Properties of fats and oils

The physicochemical properties of oils are directly related to the profile triacylglycerol and fatty acids as well as the distribution of fatty acid in glycerol moiety. A change in any of these leads to the alteration in the physical and chemical properties of the mother oil (Krishna & Dahyabhai, 2010).So that those are an important factor that determines the overall quality and stability of a food system. Density, saponification value, iodine value, acid value, peroxide value, is some of the important characteristics of vegetable oil.

Saponification value: Saponification value is the amount of alkali necessary to saponify a definite quantity of the sample (oil). It is expressed as the number of milligrams of potassium hydroxide (KOH) required for saponifying 1 g of the sample. It is based on the oil sample saponification by refluxing with a known excess of alcoholic potassium hydroxide solution. The smaller the saponification number, the larger the average molecular weight of the triacylglycerol present in the oil (Akinola *et al.*, 2010).

Acid value: The acid value is the number of milligrams of the potassium hydroxide necessary to neutralize the free acid in 1 g sample. The acid value is often a good measure of the breakdown of the triacylglycerol into free fatty acids, which hurts the quality of many fats (Akinola *et al.*,2010).

Iodine value: The iodine value of an oil or fat is defined as the weight of iodine absorbed by 100 g of the oil or fat. The glycerides of the unsaturated fatty acids (particularly of the oleic acid series) unite with a definite amount of halogen and the iodine value is, therefore, a measure of the degree of unsaturation. It is consistent for particular oil or fat, however, the exact figure obtained depends on the particular technique employed. The greater the degree of unsaturation (i.e. the higher the iodine value), the greater the likelihood that the oil or fat will become rancid by oxidation (Akinola *et al.*,2010).

Peroxide value:- Peroxide value (PV) measures the milliequivalents of oxygen (hydroperoxides) per 1000 grams of oil. The peroxide value is a measure of the concentration of substances that oxidize potassium iodide to iodine.

Fatty acid composition (FAC):-The fatty acid composition result provides a large quantity of information with one analysis, such as identification of individual fatty acids and quantities, saturate/unsaturated levels (calculated iodine value), identification of the unsaturated fatty acid isomers (*cis, trans*, conjugated, positional), provide data to determine the source oil proportions and processing of a blended product, and it applies equally well to refined and unrefined oils (O'Brien, 2009). The gas-liquid chromatography fatty acid composition analysis provides a rapid and accurate means of determining the fatty acid distribution of fats and oils products.

Triacylglycerols (TAG): - The characteristics of triacylglycerols depend on the position that each fatty acid occupies on the glycerol molecules (O'Brien, 2009). In general, fats and oils are composed of mixed acylglycerols rather than mixtures of simple acylglycerols. Mixed triacylglycerol has two or three different fatty acids joined to glycerol.

Solid fat content (SFC): -Solid fat content is the number of fat crystals in a fat or fat blend. It has a great influence on the suitability of the fat or fat blend for a particular application. The solid fat content is responsible for many product characteristics in margarine, shortenings and fat spreads, including their general appearance, ease of packing, spreadability, oil exudation and organoleptic properties (Dian *et al.*, 2007). The solid fat content profile reflects the fraction of the fat phase that is solidified at a particular temperature and strongly influences the sensory attributes and the physical stability of the fatty food.

Slip Melting Point (SMP): - The softening point (open tube melting point) or slip melting point is often used to characterize oils and fats and is related to their physical properties, such as hardness and solidification or melting behavior (Goh & Ker, 1991). The melting points of triacylglycerols are related to the fatty acid present. For a fatty acid, it's melting point depends on the chain length and number and position of double bonds. It increases with increasing chain length and decreases with increasing *cis* unsaturation. As fats and oils are complex mixtures of compounds, they have no definite melting point and pass through gradually softening before becoming liquid (Pomeranz &Meloan, 2003).

Unsaponifiable matter: - Unsaponifiable matter is defined as the substances soluble in the oil, which after saponification are insoluble in water but soluble in the solvent used for the determination.

It includes lipids of natural origin such as sterols, higher aliphatic alcohols, pigments, vitamins, and hydrocarbons as well as any foreign organic matter non-volatile at 100°C e.g. mineral oil (AOAC 17th ed, 2000).

Table 3. Physical and chemical characteristics of edible fats and oils.

No.	Characteristics	Requirement	Test method
1	Fat content, % by mass, min.	99.5	ISO 17189
2	Acid value, mg KOH/g, maxes.	Non-virgin 0.6 Virgin 4	ISO 660
3	Peroxide value, meq. Peroxide oxygen/kg, max.	Non-virgin 10 Virgin 15	ISO 3960

Source: (Edible fats and oils Specification: 2016)

2.8. Oils and fat processing

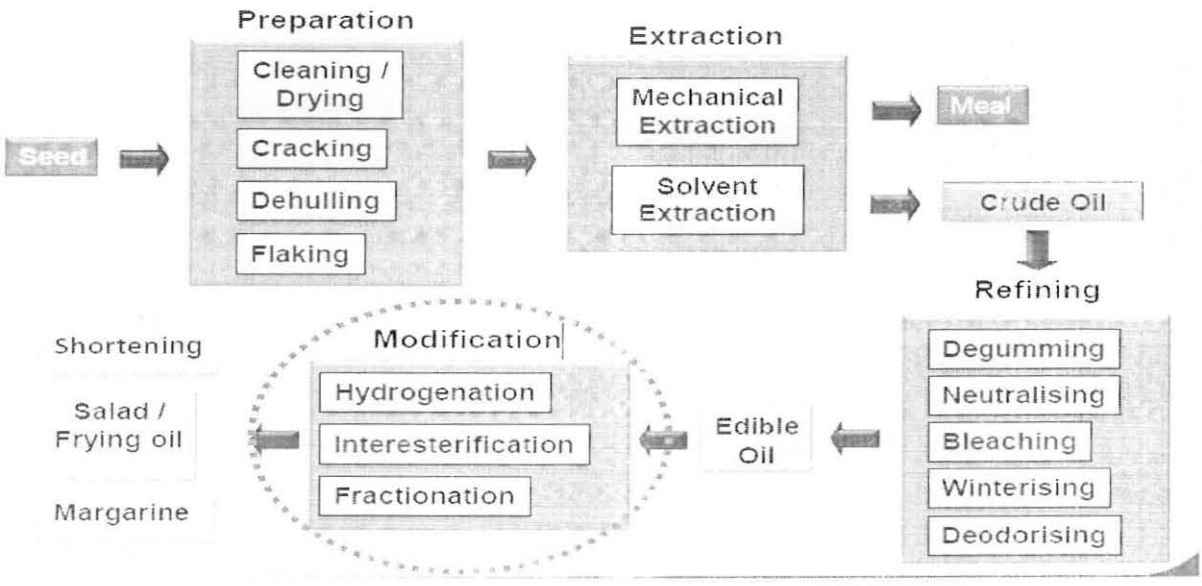

Fig.4. Fat and oil processing (De Kock &Wim Degrey, 2014).

2.9. Quality of oils and fats

Vegetable oils are important in human nutrition as they provide energy, essential fatty acids and facilitate the absorption of fat-soluble vitamins (Grace *et al.*, 2008). Oil quality and its stability are therefore very important for the consumer's desirable use usually as cooking ingredients (Jambunathan, & Reddy, 1991). The quality of any oil is indicated by some physicochemical properties which indicate both the nutritive and physical quality of the oil. These properties include iodine value, peroxide value, saponification value, free fatty acid, color, appearance, etc.

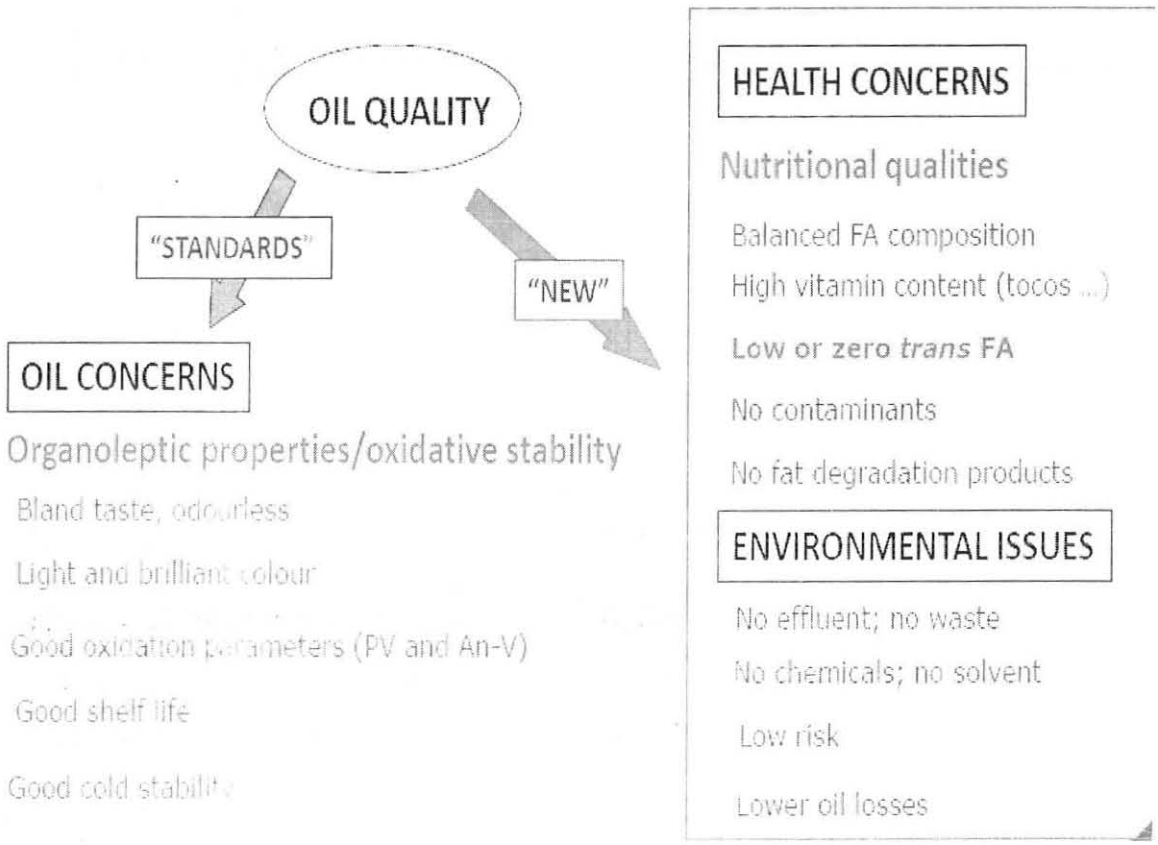

Fig.5. Oil &Fat quality criteria (Jan De Kock & Wim Degrey, 2014).

2.10. Oils modifications

Most edible oils have limited application as functional ingredients in food products in the original form. Modification techniques are applied to extend and increase their use in food formulations. This is achieved by physical or chemical modifications of the triacylglycerol composition. Historically, this was mostly done by partial and selective hydrogenation. Now a day, hydrogenation products are more and more replaced by low or non-trans products (De Kock & Wim Degrey, 2014)

2.11. Vegetable oil modification techniques

Several chemical processes are employed for the modification of native vegetable oils to improve their functional performances, such as plasticity, tractility and shortening property, to meet the specifications for certain food applications. Hydrogenation and interesterification are the commonly used methods available to tailor the physicochemical properties of food oils, but the hydrogenation method can generate larger amounts of *trans* fatty acids (FAs).

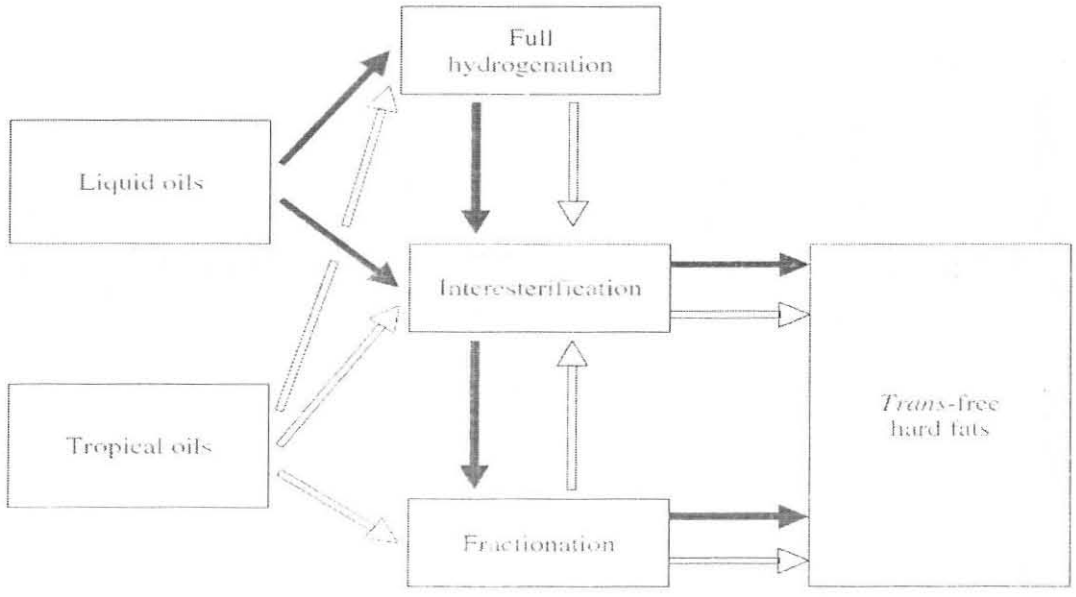

Fig.6. Virtual trans-free modification techniques (Hamm, et al, 2013).

2.11.1. Hydrogenation

Hydrogenation is a chemical process where hydrogen reacts to an organic compound. The hydrogenation process removes those kinks and makes the fatty acids straight, either by making them fully saturated or altering them to trans fatty acids. It involves the addition of hydrogen atoms across the unsaturated double bonds of the particular triacylglycerols. The fundamental importance enables the production of solid and semi-solid fats (Wassell & Young, 2007). The most common oils that undergo hydrogenation processing are soy (about 60% of hydrogenated oils), sunflower, safflower, peanut, palm, cottonseed, and corn. It may undergo full hydrogenation or partial hydrogenation process.

Full hydrogenation (full saturation): -The full hydrogenation process saturates all carbon atoms with the maximum possible number of hydrogen atoms, making the oil fully saturated (no more hydrogen atoms can be attached and also no trans fatty acids exist. The process of full saturation transforms unsaturated into fully saturated fatty acids. Fully hydrogenated oils are hard and not very practical in some food preparation methods, they are usually mixed with unsaturated oils. Most of these oils are genetically modified (e.g. soybean oils) or maybe even partially hydrogenated. A fully saturated product would not sound good. That is why the process of hydrogenation usually doesn't go all the way through. It retains a large portion of unsaturated fats to preserve the supposedly "healthy" properties.

Partial hydrogenation (partial saturation): -Partial hydrogenation is an incomplete process, the hydrogenation process stopped before completing a full saturation of carbons with hydrogen atoms. Some of these double bonds are of "cis" configuration (normal configuration characteristic for unsaturated fatty acids) and some have been damaged in the process forming a "trans" configuration, where one of the hydrogens at the carbon double bond has been removed and another placed on the opposite side of the chain. The purpose of partial hydrogenation of oils is to make their properties optimal for food preparation. The biggest problem with partially hydrogenated oils is the damage to the fat molecules that occurs during the process. The damaged molecules are called Trans-Fats or Trans Fatty Acids.

Trans fat increases the "bad" low-density lipoprotein cholesterol, or LDL, and decreases the "good" high-density lipoprotein cholesterol, or HDL. High HDL levels tend to have cardioprotective effects, whereas high LDL levels are an increased risk factor for heart disease. Trans fat seems to be as detrimental to heart health as saturated fat, which may be because trans fat is difficult to digest so your body processes it as saturated fat. Oils used during the partial hydrogenation process contain polyunsaturated fats omega 6, which cause inflammation if consumed in high omega-6 to omega-3 proportions. Our diets today already provide us with a high ratio of omega-6 to omega-3 and partially hydrogenated oils only increase that ratio.

Intake Recommendations: -"Trans fat" will appear on the Nutrition Facts panel under saturated fat if the product contains any, and the ingredient list will include "partially hydrogenated" oil. The American Heart Association recommends consuming no more than 2 grams of trans fat per day for a 2,000-calorie diet, or less than 1 percent of your daily calorie intake. Fully hydrogenated fats do not contain trans fat and are less risky for your health.

2.11.2. Interesterification

Another process used by oil processors is interesterification which causes a redistribution of the fatty acids on the glycerol fragment of the molecule. This rearrangement process does not change the composition of the fatty acids from the starting materials. The fatty acid interchanges resulting from interesterification lead to changes in the physical characteristics of oils and fats because in nature fatty acid is not randomly distributed between the triacylglycerols present. It is conveniently achieved by on alkali methoxide- catalyzed reaction with a mild temperature (20-100 ^{0}c) (Gunstone, 2002). In its most commonly used form, interesterification produces a truly random distribution of fatty acid that leads to the oils and fats, such as melting and crystallization behavior.

The rearrangement process does not change the degree of unsaturation or the isomeric state of the fatty acid as they shift from one position to another (Nor Aini *et al.*, 2002). Interesterification (IE) has received much interest in the edible oil industry as an alternative method to improve the physical properties of fats and oils.Unlike hydrogenation, interesterification neither affects the degree of saturation nor cause isomerization of the fatty-acid double bond. The stability of oils and fats also remains essentially unchanged (Rousseau *et al.*, 1996). It may be accomplished by chemical or enzymatic processes (Denke, 2006). Chemical interesterification is one of the major reactions used for the modification of natural fats and oils. Chemical interesterification is preferred over enzymatic interesterification because of the lower investment and production costs of the finished products (Nor Aini *et al.*, 2002).

It is used industrially to produce modified edible fats and oils for shortenings, confectionery fats, margarine and spreads, reduced-calorie fats and oils and infant formula. Industrially, the CIE process is usually conducted by homogeneous base catalysts to produce distributed FA residues among TAG molecules, in which sodium alkoxide and sodium hydroxide are the most preferred choice of catalysts for the CIE processes (Gibon & Kellens, 2014, Rodríguez *et al,* 2009). The second process is the enzymatic interesterification. This process rearranges the fatty acids (can be position-specific) on the glycerol backbone of the triglyceride through the use of an enzyme. Enzymatic interesterification (EIE) can provide several benefits such as mild reaction conditions, low side reactions and ease of product recovery (Jeyarani & Reddy, 2010). Higher temperatures will result in the inactivation of the enzyme. After interesterification, the oil is deodorized to make finished oil products (Tarrago-Trani *et al.*, 2006).

2.11.3. Blending of palm oil and palm products with other oils

Blending is one of the methods used to modify oils and fats for specific applications. Blending helps extend the range of applications of oils and fats. Blending of vegetable oils and fats has emerged as an economical way of modifying the physicochemical characteristics of vegetable oils and fats besides enhancement in oxidative stability (Chu & Kung, 1997). Direct blending of fats is the method of choice as it has been considered to be a cheap and nondestructive technique (Nor Hayati *et al.*, 2009).

Blending of polyunsaturated oils with highly saturated oils reduces the content of linoleic and linolenic acids to the desirable level where the effect is similar to partial hydrogenation without worrying about the formation of trans fatty acid isomers (Hoffmann *et al.*, 2002; Naghshineh & Mirhosseini,2010; Tiwari *et al.*, 2014). The fatty acid composition of the single oil or the blend remains unchanged and does not interact with triacylglycerols as they are of similar chemical composition (Benjumea *et al.*, 2008; Christie & Han, 2010). Palm oil and palm products have a good opportunity to be processed for a healthy shortening. The blending of palm stearin and soybean oil at different ratios could able to modify the properties of natural fats. Blending can change the natural physical and chemical characteristics of a fat or oil; thus, it offers greater functionality for a large number of product formulations. Palm stearin obtained from palm oil by fractionation has limited use due to its high melting point.

One of the potential oils that can be blended with palm stearin is soybean oil (Hadi, 2013). The high melting palm stearin fraction with a melting point of about 58 °C cannot be used as such in fat-based edible products due to its high melting point (Ghosh &Bhattacharyya, 1997). The triacylglycerol composition of palm oil makes the physical form of palm oil to be semi-solid so that no hydrogenation is needed when it is used for shortening. Furthermore addition, palm oil contains minor components such as tocopherol and tocotrienol (Vitamin E) as well as β- carotene which are needed by the human body (Ismail *et al.*, 2002).

Palm oil is high in palmitic acid (C16:0) and forms small β'crystals which are essential for smooth texture and functionality. Thus, it is an advantage to blend other oils and fats with the palm oil to get the desirable properties of the β'containing palm oil. The fat crystals in shortenings and margarine can exist in two polymorphic forms, β' and β. The β'crystals are more desirable than β crystals (Nor Aini *et al.*, 2002). The oxidative stability of palm oil in a blend is principally due to its high saturation and heavy presence of natural antioxidants, especially γ-tocotrienol (Bansal *et al.*, & Neo, 2010; De Leonardis & Macciola, 2012; De Marco *et al.*, 2007). PO contains only traces of the unstable linolenic acid (C18:3) but contains a moderate amount of the more stable linoleic acid (C18:2) (10%-12%). The presence of vitamin E (380-890 ppm) acts as an effective natural antioxidant (Gapor, 1994).

Vanaspati or vegetable ghee is a major commodity in countries such as India, Pakistan, Egypt, Saudi Arabia, Iraq, and Iran. Palm oil has similar physical characteristics to Vanaspati in terms of melting point, melting profile and consistency at ambient temperature.Trans-free Vanaspati can be produced easily by a direct blending of POs with other liquid oils (Idris *et al.*, 1997). Vanaspati based on 60% palm stearin (POs) and 40% other liquid oils such as soya bean (SBO), rapeseed oil and SFO were of good characteristics and superior to products containing 80% or 40% POs. To maximize the use of POs in the formulation, the process of interesterification could be employed. Much POs (80%) could be incorporated and showed good properties.

Table 4. Formulation and observation of Vanaspati based on direct blending of palm stearin (POs) With soybean (SBO), rapeseed (RSO) and sunflower (SFO) oils.

Sample composition	Appearance	Consistency	Oil separation
POs: SBO			
40:60	Oily, granular	Too soft	Yes
60:40	Granular	Soft	No
80:20	Dry, granular	Slightly firm	No
POs: RSO			
40:60	Oily, granular	Too soft	Yes
60:40	Granular	Soft	No
80:20	Granular	Slightly soft	No
POs: SFO			
40:60	Oily, granular	Too soft	Yes
60:40	Granular	Soft	No
80:20	Oily, granular	Slightly soft	No

Source: (Nor Aini *et al., 2002*)

2.11.4. Fractionation

Fractionation is the economical and second important way of fat modification technique. Solid fats contain either already precipitated or still dissolved solid triacylglycerols, which under controlled conditions of cooling can be induced to full or partial crystallization. The physicochemical characteristic of edible oils and fats are closely linked to their triacylglycerol composition.

Edible fats and oils are fractionated to provide new materials more useful than natural products (Hadi,2013). Separation of fat or oil into fractions can also provide two or more useful functional products from the same original product (O'Brien, 2009). Fractionation (solvent or dry) leads to the separation of fats and oils into two or more fractions with different melting points. Also, it could be used to remove an undesirable minor component such as waxes in oils during dewaxing and winterization processes to produce salad oil. Fractional crystallization is a reversible modification process, carried out in 2 stages; crystallization and followed by separation (Kellens *et al.*, 2007), done through dry-fractionation. Dry fractionation has gained popularity because of its cheaper process and greener technology. Also, there is no harmful effluent, no chemical used and no loss in yield. The dry fractionation process is simply a controlled crystallization of the melted oil, followed by separation of solid from liquid fraction. Three steps are involved in the crystallization process; supercooling of the melt, nucleation and crystal growth (Zaliha *et al., 2004*). The entrapment of the liquid fat is due to occlusion within crystallized particles or aggregates as well as retention between particles (Hamm, 1995). The formations of mixed crystals in the form of agglomerated spherulites, which adsorb liquid within crystals, and depend to a considerable extent to the crystallization conditions employed (Patience *et al.*, 1999).

Today, the most important oil in terms of fractionation is palm because it has a unique fat profile that can be broken down into individual fractions and sub-fractions thereof (Wassell & Young, 2007). Dry fractionation of palm oil is efficient in producing fractions enriched in saturated fatty acids and could be used to produce different fat products (structured fats, spreads), or as an intermediate step in the production of high-melting-point stearin appropriate for confectionery fat formulation (Bootello *et al.*, 2011). Fats tend to crystallize in various forms having different melting points.

Each of these crystalline forms with their respective melting points is called polymorphs and the phenomenon is called polymorphism. The triglycerides exhibit, with some exceptions, three basic crystalline forms designated alpha (α), beta prime (β '), and beta (β). Apart from a few types of shortening the β 'crystals are the most desirable. They are relatively small and can incorporate a larger amount of liquid oil in the crystal network. β 'crystals result in a glossy surface and a smooth texture.

It is possible to crystallize all types of fats in the β 'form if the fats are shock chilled with subsequent intensive kneading without cooling. The general rule is that fats with a low content of palmitic acid (approx. 10%) will crystallize in the β form if they are not exposed to shock chilling. Fats that tend to crystallize in β'usually have a double amount of palmitic acid, however, the position of the palmitic acid on the glycerol molecule does additionally affect the crystallization habit. Sunflower oil (SFO) and soybean oil (SBO) have a good nutritional profile, with poor oxidative stability and are, accordingly, prone to flavor deterioration because of their high proportion of unsaturated fatty acids, especially, linolenic acid in SBO (White, 2000).

2.12. Vegetable shortening

Vegetable shortening was developed in the early 1900s as a more economical and nutritional alternative to animal fat. It also provided a vegetable-based fat that vegetarians and people with religious dietary restrictions could use in cooking and baking. Itis a semisolid fat that is mostly solid at room temperature. It is named for the "short" or crumbly texture that it produces in cooking and baking applications, particularly in shortbread, piecrusts, and puff pastry.Vegetable shortening inhibits the formation of long, tough strands of gluten in the dough and contributes a light texture. It is typically made from hydrogenated and partially hydrogenated vegetable oils, such as corn, cottonseed or soybean. It has a higher smoke point than butter and margarine and is 100 percent fat results in a very tender baked good. (compared to butter and margarine that contain milk solids). Shortening seems to get its name from the fact that it shortens gluten strands in wheat by adding fat. Shortening, like margarine, is a food ingredient commonly used in baked goods such as biscuits and pie crusts, foods readily consumed by those at risk of obesity and cardiovascular disease.

Therefore, the oils and fats used to produce shortenings will have a significant effect on product quality.Shortening is made by a process called hydrogenation, which involves adding extra hydrogen atoms to the aforementioned vegetable fats and turns them into solids, rather than liquids. This process of turning the previously unhydrogenated oil into a partially hydrogenated fat with trans fatty acids. Shortening can be melted or softened and creamed into a mixture.

The fat content of vegetable shortening makes it useful for frying and for recipes that require pure fat. It is more economical than butter or lard; it does not require refrigeration (it may last up to one year in an airtight container) and can extend the shelf life of some foods and baked goods. Some vegetable shortening contains tiny bubbles filled with nitrogen. These bubbles are useful in recipes that require leavening. These vegetable shortenings may also contain emulsifiers that help stabilize the gas-filled bubbles and disperse the fat. When vegetable shortening is used in cookies instead of butter, the cookies may have a fluffy texture but lack flavor. If half butter and half vegetable shortening are used, both texture and flavor may improve (Marcus, 2013).

2.13. Characteristics of modified fat products

Fat blends formulated by blending palm oil (PO) with sunflower oil (SFO) and soybean oil (SBO) in different ratios were subjected to chemical interesterification (CIE) reactions using sodium methoxide (NaOMe) as a catalyst. Interesterified blends of 80-90% PO and 10 to 20% SFO: SBO had higher slip melting point(SMP) and Solid fat content (SFC) than their respective non-interesterified blends. The interesterified blends with 80-90% PO and 10-20% SFO: SBO had SFC in the range of all-purpose type shortenings. (Muhammad *et al.*, 2012). He also stated that Fat/oil blends, formulated by mixing fully hydrogenated palm oil stearin or palm oil stearin with vegetable oils (canola oil and cottonseed oil) were interesterified in different ratios from 30:70 to 70:30 (w/w %). SMPs of interesterified blends were decreased compared to starting blends because of extensive rearrangement of FAs among triacylglycerols. SFCs of the interesterified blends also decreased concerning the starting blends, and the interesterified products were softer than starting blends.

Based on PV, AV and reaction rate constants, the oxidative stability of interesterified oils was higher than their non-interesterified counterparts (Basturk *et al.*, 2007). The process of interesterification results in changes in triacylglycerol (TAG) structure and is used to increase the melting point of dietary fats. CIE facilitated the formation of the beta polymorphic form (Mayamol *et al.*, 2008).

Table 5. Physicochemical characteristics of palm stearin, soybean oil and PS: SBO binary blends.

PS: SBO	Iodine Value (IV)	Slip Melting point (SMP)	Hardness index (HI)
100 :0	37.21 ± 0.06^{e}	49.16 ± 0.05^{a}	36.20 ± 4.55^{a}
70:30	51.08 ± 0.56^{d}	43.20 ± 0.20^{b}	11.87 ± 0.66^{b}
50:50	72.47 ± 1.06^{c}	35.07 ± 0.12^{c}	5.12 ± 0.34^{c}
30:70	93.05 ± 1.12^{b}	28.03 ± 0.05^{d}	3.26 ± 0.04^{c}
0:100	129.97 ± 2.66^{a}	-	2.56 ± 0.03^{c}

Note: Means within column followed by different superscripts are significantly different at $p<0.05$. ((Hadi,2013). (PS = Palm stearin; SBO = Soya Bean Oil)

The author suggested that according to his result obtained from the above table, the increasing of the amount unsaturated oils which is SBO into the PS blends had caused the increase of the IV, whereas the solid fat content (SFC), slip melting point (SMP) and the hardness index (HI) decreased. The blends 50:50 PS: SBO has product stability and resistance to oiling out, with a good melting point below body temperature suitable for a product such as margarine that must be melted in the mouth with minimum waxiness to have a good oral-melt.

Table 6. Physicochemical characteristics of three different commercial shortenings (SO1, SO2, SO3) (Mean + SD).

Parameters	SO1	SO2	SO3	Recommended (FAO/WHO)
Density, 60^0C(g/ml)	0.877± 0.007	0.881±0.002	0.882±0.008	0.851-0.899
Melting point (^{0}C)	44.7 ±0.1	44.9±0.1	44.1±0.2	41-51
Refractive index, 60^0C	1.469±0.002	1.469±0.002	1.468±0.001	1.46-1.47
Free fatty acids (%as oleic acid)Peroxide value (mEq/kg)	0.089±0.01	0.099±0.004	0.064±0.002	<0.3
Saponification value (mg KOH/g)	8.99±0.02	9.91±0.02	9.14±0.02	<10
Iodine value (g I/100g)	191.01±0.04	192.24±0.1	192.07±0.2	185-200
	46.98±0.02	46.33±0.01	47.16±0.01	42-55

Source: (Eshetu Gizaw, 2007)

2.14. Application of shortening

Shortenings perform two chief functions in baked goods: leavening and creaming, and lubricating. Shortening delays starch gelatinization and allows the dough to expand more before the structure is set and added to baked goods to shorten or tenderize them by interrupting the gluten structure. Large quantities of shortenings are used in frying, by deep fat and by pan and grill methods. Fats play a dual role by aiding in the transfer of heat to the food being fried and by being partially absorbed by the food contributing to the nutritive value and flavor and texture. They also improve mouthfeel and eating qualities, add lubricity, improve dough-handling properties, contribute flavor and structure, and promote desirable crumb grain and texture (Stauffer, 1996). Shortening and tenderizing effects are especially important in cakes, pie crusts, pastries, cookies, and crackers.

Generally, solid fat indices that change little with temperature are desired for most shortening applications. Typical shortening levels are 2–5% in bread, 5–25% in cake, 20–30% in sweet goods, 30–40% in puff pastry, and 20–35% in piecrusts.

2.15. Nutritional value of shortening

One tablespoon of vegetable shortening has about 113 calories, 12.7 grams of total fat, 3.2 grams of saturated fat, 8.9 grams of unsaturated and 0 milligrams of cholesterol. Some vegetable shortening contains 2 grams of trans fats (Marcus, 2013). Unlike butter or margarine, which contain approximately 80% fat, shortening is 100% fat. Therefore, it is very high in calories and contains neither crabs nor protein. It also contains very few vitamins and minerals. A 1-tablespoon serving of vegetable shortening contains 0.78 milligrams of vitamin E. That's about 5 percent of the 15 milligrams you should aim to get in your daily diet. Vitamin E is an antioxidant that helps protect your cells from damage by free radicals. This essential vitamin plays a role in the production of red blood cells and aids your body in making proper use of vitamin K. One tablespoon of vegetable shortening provides 6.8 micrograms of vitamin K. That translates to about 8 percent of the 90 micrograms of vitamin K women need each day and about 6 percent of the 120 micrograms men need on a daily basis. Vitamin K is most notable for its role in properly clotting blood, but it has a small part in keeping bones healthy, as well. A vitamin K deficiency can cause excessive bleeding, but this type of deficiency is quite rare in developed countries

2.16. Handling, storage and shelf life

The oxidative stability of lipids has been evaluated by a variety of methods under a wide range of conditions. Temperature is the most important factor to consider in oxidation stability determination because the rate of oxidation is exponentially related to temperature increase. Therefore, the shelf life of a lipid decreases logarithmically with increasing temperature (Gunstone, 2002).

In some cases where the shortening oil blend includes very slowly crystallizing oils (f. ex. palm oil), it can be necessary to store the produced product in a storage room with a temperature of approx. 25°C for a period of max. 48 hours. The tempering is necessary to ensure the stability of the β 'crystal structure. The stability is achieved by holding the processed shortening in the quiescent state at a temperature just below the melting point of the lowest melting crystals i.e. triglycerides. Care must be taken during storage and shipment to avoid damaging the flavor. Shortening, no matter how carefully packaged, will pick up flavors if stored near items giving off strong odors. The suggested storage is at room temperature.

The shelf life of shortening depends on the type of product that it is, but shortening does expire; for example, unopened cans and shortening sticks have a shelf life that is about 2 years from the manufacturing date, while an opened can of shortening will last about a year, but shortening sticks will only last about 6 months. Key indicators of shortening are color, smell, and taste. If any of these are off, the shortening has likely gone bad and should be discarded.To ensure a shortening's shelf life, store it in a cool, dry place, such as a kitchen pantry.

3. Materials and methods

3.1. Study area and sample collection

The study was conducted at Addis Ababa University, Center for Food Science and Nutrition Laboratory. Refined, Bleached and Deodorized Soya bean Oil (RBDSBO) samples were collected from KUNIFIRA Agro-Processing PLC, supermarkets, shops and retailers in Addis Ababa. The palm stearin was obtained from AFHA Food Processing Plant. The collected oil samples were coded and preserved in a dry and cool place in food science and nutrition laboratory. Commercial shortening (as a control) was obtained from shortening processing industries.

3.2. Chemicals and reagents

Chloroform, potassium iodide, iodine, glacial acetic acid, bromine water, potassium hydroxide, phenolphthalein, sodium thiosulfate, hydrochloric acid, starch, calcium oxide, alcohol. All reagents used in this were analytical grade.

3.3. Sample preparation

Before shortening processing, each of the collected oil samples were mixed and homogenized and the palm stearin was melted at 90 °C before use. Fat blends were formulated by mixing a highly saturated fat (palm stearin) with native vegetable oil (soybean oil) in varying proportions as indicated table 7 below. The blended sample was processed into vegetable fat (shortening) at AFHA food processing plant by crystallization process with continuous mixing. After the mixing process was completed, the blended sample was left at least 24 hrs at 13-14^{0}C for settling purposes. Finally, vegetable shortening was found.

Table 7.Mixing ratio (%wt/wt) for palm stearin and soybean oil

Ratio (%wt/wt)	
Palm stearin	Soybean oil
20	80
40	60
50	50
60	40
70	30
80	20

Based on the above formulations, six samples were produced, but the desired physical quality or characteristics of the processed shortening was not displayed for (20:80, 40:60 and 50:50) Ps and SBO formulations respectively. Thus, these products could not form crystals or expected shortening for further applications. Therefore, vegetable shortening was prepared by a combination of 60 % and 70% palm stearin and 40% and 30% soya bean oil respectively, because these products exhibited the desired physicochemical characteristics of vegetable shortening. The result was reported by Hadi, 2013 and stated that the blends 50:50 PS: SBO has product stability and suitable for margarine production.

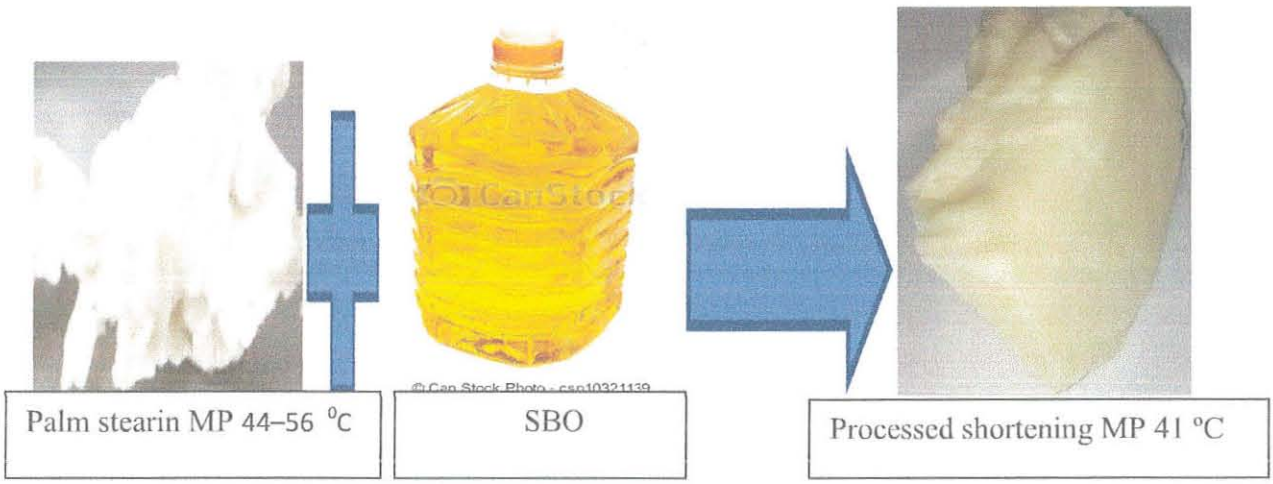

Fig.7. Shortening processing.

3, 4. Overall experimental design and data collection

3.4.1. Experimental design

A laboratory-based experimental study was carried out using shortening samples under a Completely Randomized Design (CRD). Figure 3.1 shows the overall experimental frame work of the study and physicochemical properties of the product that has been analyzed during this study.

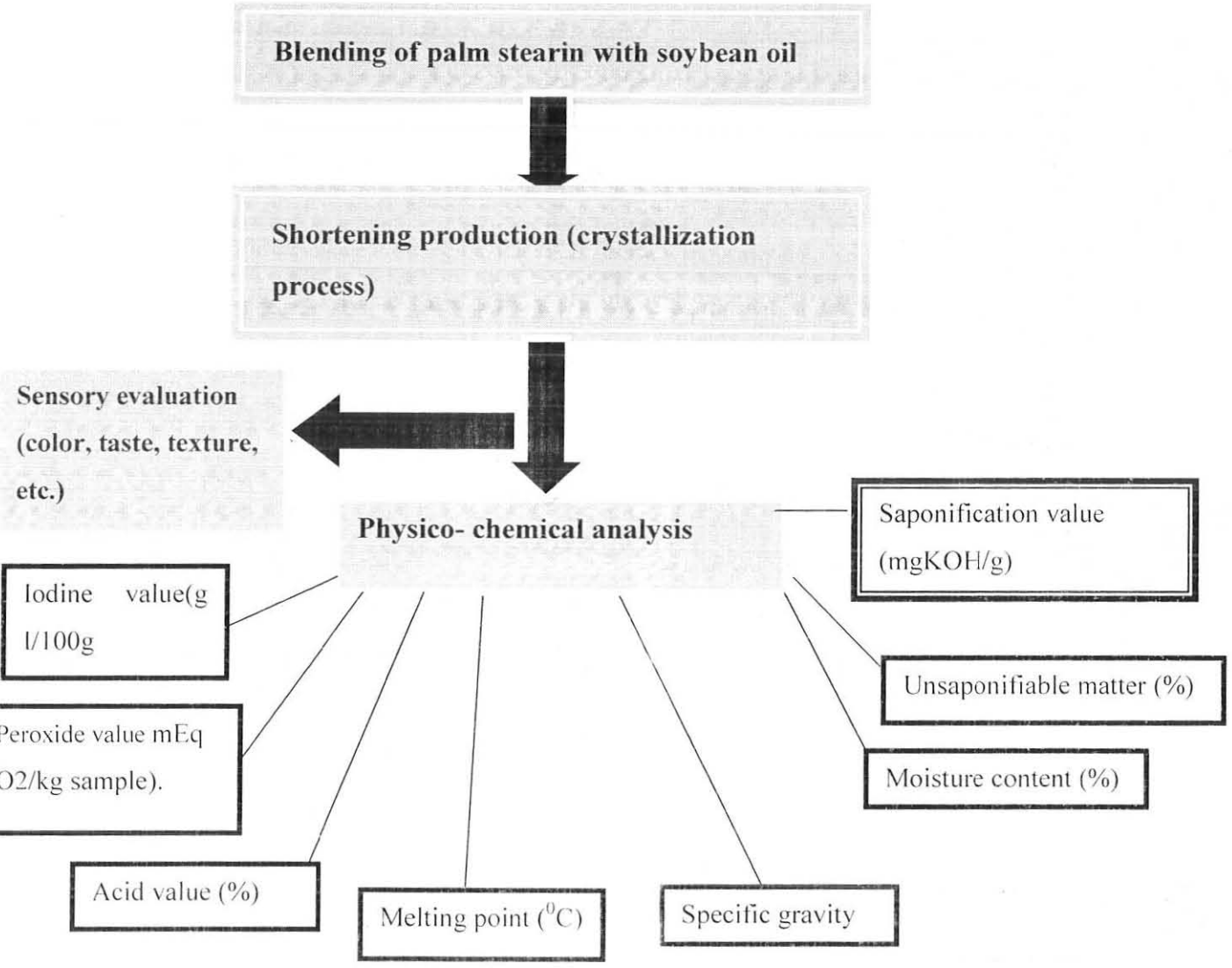

Fig.8. Overall experimental frame-work

3.4.2. Physicochemical analysis

After sample preparation was done, physicochemical measurements like, Moisture content, Acid value, Free fatty acid, Peroxide value, Saponification value, Unsaponifiable matter, and Iodine value and sensory evaluation test were carried out.

3.4.2.1 Moisture determination

The moisture content of shortenings was determined by oven drying method based on AOCS Official Method Ca 2b-38. Drying metal dish was cleaned and driedin drying oven at 105 ± 1°C for 1hour, and cooled in desiccators and weighed (W1). About 5gm of the sample (W2) was placed in a previously dried and weighed dish and heat, in an oven at 105±1°C for 2 hours. Then, cooled in a desiccator containing phosphorus pentoxide or equivalent desiccant and measured (W3). This process was repeated until the change in weight between two successive observations does not exceed 1 mg. The determination was carried out in duplicate.

$$\text{Moisture and volatile matter (\%)} = \frac{W3-W1}{W2-W1} * 100 \quad \text{---------- Eq}^{n}\text{ (1)}$$

Where,

W1 = weight of (gm) of the metal dish

W2 = Weight of the sample (gm) and

W3 = weight of dried sample and metal dish

3.4.2.2. Determination of specific gravity

Specific gravity is the ratio of the density of a sample to the density of a reference substance (mostly water); equivalently, it is the ratio of the mass of a sample to the mass of a reference substance for the same given volume.

An empty bottle was cleaned, dried, and weighed. About 10ml of the sample was filled in a cleaned and dried empty bottle and weighed. then, the density of the sample was calculated. The same procedure was used for the density of clean water (Akinola, et al., 2010).

Specific gravity was calculated as follows.

$$\text{Specific gravity} = \frac{w1/v}{w2/v} = \frac{w1}{w2} \quad \text{---------- Eq}^{n}\ (2)$$

Where, W1= weight of sample

W2 = weight of water

3.4.2.3. Determination of melting point

The melting point of the product was determined by (ISO 6321: 1997). A portion of the test sample was melted as rapidly as possible to at least 5^0C, but not more than 10^0C above which is completely melted. Then cooled the melted test sample with occasional stirring until its temperature is 32 to 34^0C and then stirred continuously with stirrer allowing the fat to cooled until the first signs of cloudiness have appeared. Stirring was continued by hand until the fat had a pasty consistency and then transferred the fat to a 100 ml beaker at room temperature. The fat was stored at this temperature for a minimum of 24 hours. Four capillary tubes pushed into the conditioned fat until the column of fat 10 mm +2 mm long was obtained in each tube and removed any fat adhering to the outer surfaces of the tubes and the temperature was adjusted so that it could raise 10C/minute. The capillary tubes were put in the apparatus with adjusted temperature. Lastly, the temperature was taken at which the first fat droplet was observed and reported the average of the capillary tubes as one determination.

3.4.2.4. Determination of acid value and free fatty acid

The oil or melted fat was mixed thoroughly before weighing. The mass of the test sample has been taken based on the color and expected acid value.

Table 8. Mass of test portion and expected acid value.

Expected Acid Value	Mass of Test portion (gm)	Accuracy of weighing of test portion (gm)
<1	20	0.05
1 to 4	10	0.02
4 to 15	2.5	0.01
15 to 75	0.5	0.001
>75	0.1	0.0002

Source: Manual of methods of analysis of foods (oils and fats; 2016)

The acid value was determined byusing an official method of AOCS Ca 5a-40. The mass of test sample was based on the expected acid value of the product as shown on table 8 above. Based on (ISO,660) the expected maximum acid value for edible oils and fats must be less than 0.6. Thus, about 20gm of sample was placed in 250ml conical flask. Then 50ml of hot ethanol with 0.5ml of 1% phenolphthalein was added and mixed. Lastly, the sample was titrated with 0.1N potassium hydroxide solution, until light pink color was appeared.

The acid value was calculated with the equation:

$$\mathbf{AV} = \frac{56.1 * V * N}{m} \quad \text{---------- Eq}^{n}\ (3)$$

Where, AV represents acid value, V - volume of standard potassium hydroxide solution, (mL) (volume of KOH solution used for sample – blank reagent); N - normality of the potassium hydroxide solution; m - weight of the test sample (gm).

Determination of Free Fatty Acids (FFA): -The acidity is frequently expressed as the percentage of FFA in the sample

The percentage of FFA in most oils and fats is calculated on the basis of oleic acid; although in coconut oil and palm kernel oil it is often calculated as lauric acid, in castor oil in terms of ricinoleic acid and in palm oil in terms of palmitic acid. Based on table 9 below FFA expressed as the following equation:

$$\textbf{\%FFA value (as oleic acid)} = \frac{28.2*V*N}{W} \qquad \text{---------- Eq}^{\underline{n}}\ (4)$$

Where, V: volume of the standard KOH solution,

N: normality of KOH

W: weight of sample

Table 9. The calculations in terms of different oils

Free fatty acid as oleic acid % by weight =	$\frac{28.2 * V * N}{w}$
Free fatty acid as lauric acid % by weight =	$\frac{20 * V * N}{w}$
Free fatty acid as ricinolic acid % by weight =	$\frac{29.8 * V * N}{w}$
Free fatty acid as palmitic acid % by weight =	$\frac{25.6 * V * N}{w}$

Source: Manual of methods of analysis of foods (oils and fats; 2016)

3.4.2.6. Determination of Iodine value

Iodine value was determined according to AOAC (2000) and 0.25gm of sample was placed into 250ml conical flask. Then 10ml of chloroform and 30ml of Hanus reagent (18.2gm of iodine

dissolved in 1L of glacial acetic acid with 3ml of bromine water) were added. Then, the solution was placed in dark thorough mixingfor 30min. At the end of the specified time, 10ml of potassium iodide (15%) was added and diluted with 100ml of distilled water to prevent loss of the free iodine. Then the solution was titrated with 0.1 N sodium thiosulfate, and 2-3 drops of starch solution where blue solutions formed and then continued with titration till the blue color was disappeared.

The iodine value was calculated with the equation:

$$IV = \frac{(B-S)*0.127*N*100}{m} \quad \text{---------- Eq}^{n}\ (5)$$

Where,

IV represents iodine value, (g I2/100 g sample);

0.127 - number of grams of iodine corresponding to 1mL of sodium thiosulfate solution, (g);

B - volume of sodium thiosulfate solution used for the blank reagent, (mL);

S- volume of sodium thiosulfate solution used for the sample, (mL);

N- concentration of sodium thiosulfate solution; m – mass of sample (gm).

3.4.2.7. Determination of peroxide value

Peroxide value was determined by AOAC (2000). About 5gm of sample was placed in 250ml conical flask. Then, 30ml of glacial acetic acid-chloroform solution (3:2) and 0.5ml of saturated potassium iodide (KI) solution were added and left for a minute in a dark at ambient temperature. Then, 30ml of distilled water was added to stop the reaction and to prevent free iodine loss. 2ml of saturated starch solution was used as indicator and the mixture formed dark blue color and titrated with standardized 0.01N sodium thiosulfate solution until the color of the mixture was disappeared.

The peroxide value was calculated with the equation: -

$$\text{Peroxide value (mEq } O_2\text{/kg of sample)} = \frac{(V2-V1)*N*1000}{m} \quad \text{---------- Eqn (5)}$$

Where,

PV:Represents peroxide value, (m Eq O_2/kg sample);
V1:Volume of standard sodium thiosulfate solution used for the blank reagent, (mL);
V2: Volume of standard sodium thiosulfate solution used for the sample, (mL);
m: Weight of the sample (gm).

3.4.2.8. Determination of saponification value

Saponification value was determined by AOAC (920.160) method. About 2gm of filtered sample was put on 250ml Erlenmeyer flask. Then,25 ml of alcoholic KOH (mixture of 40gm KOH and 45gm CaO dissolved in 1L of ethanol) solution was added into the flask.

The flask was connected with the condenser and boiled until the fat was completely saponified for 1hr. After a specified time, the sample was cooled and titrated with 0.5M HCL (dilute 42.5 ml of 37% HCL with distilled water) phenolphthalein was used as an indicator.

The saponification value was calculated with the equation:

$$\mathbf{SV}= \frac{56.1*M*(V2-V1)}{m} \quad \text{---------- Eq}^{\text{n}}\text{ (6)}$$

Where,

SV represents saponification value, (mg KOH/ g sample); 56.1-molecular weight of HCL; M-exact concentration of HCL used for titration;V1 - volume of standard hydrochloric acid required for the sample, (mL);V2 - volume of standard hydrochloric acid required for blank reagent, (mL);m - weight of the oil sample (gm).

3.4.2.9. Determination of unsaponifiable matter

Unsaponifiable matter was determined according to ISO 3596:2000. About 5.0 gram of sample was weighed into a flask and 50ml of ethanolic KOH solution was added. Then boiled gently under reflux condenser for 1hrs. After the saponification was completed, 100 mL of distilled water was added.

After cooling the solution was transferred into 500ml of separating funnel and then the flask was rinsed several times with 100 ml diethyl ether and poured into separating funnel the solution was vortexed vigorously for 1 min and released the pressure.The solution was left until complete separation of two phases formed and run off the lower layer completely and transferred into the second separating funnel. Ethanolic soap solution was extracted twice more with 100 ml of diethyl ether and ether extracts were collected into another separating funnel containing 40ml of distilled water. The combined extracts was rotated and allowed to separate the layer then draw off the lower aqueous layer. The ethereal solution was washed twice more with 40ml water, shaked vigorously and discarded the lower aqueous layer after separation. The ethereal solution was washed successively with 40ml KOH solution (0.5M), 40ml water and again with 40ml KOH solution and then at least twice more with 40 ml of water. Washing was continued until the washing no longer gives a pink color on the addition of a drop of phenolphthalein solution. Ethereal solution was transferred quantitively into 250ml flask previously dried at $103^0C \pm 2^0C$ in the oven, cooled and weighed to the nearest 0.1mg. The solvent was evaporated on boiling water bath, then 5ml of acetone was added and volatile solvent was evaporated. The residue was dried in the oven at $103^0C \pm 2^0C$ for 15 minutes, then cooled in the desiccators and weighed to the nearest 0.1mg. The drying was repeated until the difference between two successive weighing was less than 1.5mg. The residue was dissolved in 4ml of diethyl ether and then 20ml of ethanol and titrated with 0.1M ethanolic KOH solution to calculate the mass of the free fatty acid as oleic acid (m_3), g

$$= 0.28VC. \quad \text{---------- Eq}^{n} (7)$$

Where, V= volume of the standard volumetric solution of KOH

C= conc., moles per liter of the standard volumetric solution of KOH

Calculation,

Unsaponifiable matter, expressed as a percentage by mass of the sample

$$= \frac{100*(m1-m2-m3)}{m0} \quad \text{---------- Eq}^{n}\ (8)$$

Where, m_0= mass of test portion, gm

m_1= mass of residue, gm

m_2= mass of residue from the blank.gm

m_3= mass of free fatty acid (if any), gm

3.4.3. Sensory analysis

There are widely divergent opinions on the number of judges required for sensory descriptive analysis (DA) with some authors saying 6 and others up to 15. As Singh-Ackbarali & Maharaj, (2014) reported that the minimum requirement for sensory acceptance panel number was 20.

Sensory acceptability of the product was evaluated after 6th month storage at room temperature. Homemade cookies were used as a baked product (Granny, 2007) and those cookies were processed as follows.Two cups all-purpose wheat flour was mixed with 1 tablespoon baking powder, 1/2 teaspoon salt, 2 tablespoons sugar and 1/4 cup of shortening and the process was show in fig 3.1 below.After baking process was completed twenty Food Science and Nutrition students were participated for sensory acceptance test of the product by using 9-point hedonic scale. Different sensory attributes like, color, crispiness/texture, taste, and flavor and over all acceptability of the product were evaluated. Finally, sensory evaluation data were recorded on score sheet paper.

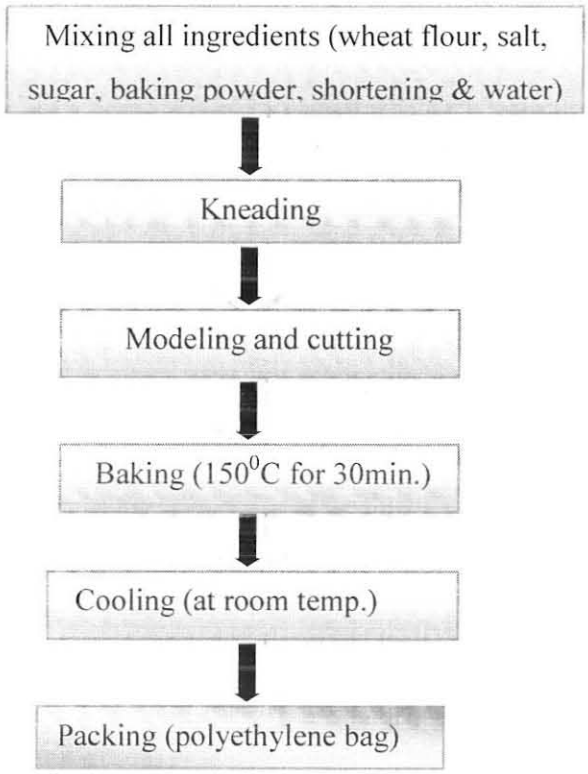

Fig.9. Homemade cookies processing (Granny, 2007).

3.5 Data analysis

The data obtained from the experiment were subjected to analysis using statistical software, SPSS (Statistical Package for Social Sciences) version 20. Accordingly, ANOVA, mean comparison and significance were set at 5% level.

4. Results and discussion

Physicochemical characteristics were determined for all processed shortening (S60 & S70) and commercial shortening as indicated in table 10.

Table 10. Physico-chemical characteristics of processed shortening at 0-month storage (Mean + SD).

Parameter	S60	S70	C
Specific gravity	0.88 ± 0.01^{a}	0.88 ± 0.02^{a}	0.88 ± 0.02^{a}
Melting point(^{0}C)	41.33 ± 0.58^{b}	44.67 ± 0.58^{a}	40.00 ± 1.00^{b}
Moisture %	0.10 ± 0.01^{b}	0.10 ± 0.02^{b}	0.15 ± 0.05^{a}
Acid value	0.14 ± 0.01^{a}	0.14 ± 0.10^{a}	0.22 ± 0.01^{a}
FFA (%as oleic acid)	0.07 ± 0.01^{b}	0.09 ± 0.01^{a}	0.11 ± 0.01^{a}
Peroxide ((mEq O_2/kg))	2.20 ± 0.10^{c}	2.47 ± 0.10^{b}	3.30 ± 0.10^{a}
Iodine (g I/100g)	49.70 ± 0.10^{a}	45.00 ± 0.50^{c}	48.70 ± 0.10^{b}
Sapon.value(mgKOH/g)	190.10 ± 0.10^{c}	190.70 ± 0.20^{b}	194.35 ± 0.05^{a}
Unsaponifable matter	0.96 ± 0.01^{a}	0.84 ± 0.02^{c}	0.87 ± 0.01^{b}

Note: Means within row followed by different superscripts are significantly different at $p<0.05$. S60 = shortening produced from 60% palm stearin and 40% soybean oil, S70 = shortening produced from 70% palm stearin and 30% soybean oil and C = commercial shortening used as control.

From Table 10, shortening processed from 70% palm stearin had the highest melting point (44. 7^{0}C) means, melting point decreases when more of SBO blended with PS. The same report was reported by Hadi (2013).

Melting point changes with the chain length of fatty acids, unsaturation ratios, *trans* fatty` acid content and the position of the fatty acids in the glycerol backbone (Karabulut *et al.*, 2003; Hadi, 2013). The same experiment was done by Siddique *et al,* (2010) and results showed a substantial decrease in the melting point of the palm olein when blended with other oils. The higher portion of the other low melting point oils blended with palm olein resulted in a further decrease in the melting point of the blends.

The iodine value of the product was decreased from 49.7 to 45 when the amount of palm stearin increased in the fat blends from 60% to 70% respectively. Soybean oil has higher IV than PS due to the high degree of unsaturation, thus become more vulnerable to oxidation (Siddique *et al.*, 2010). The iodine values for the blends increased significantly ($p<0.05$) with the increasing amount of SBO in the blends because increasing amount of unsaturated fatty acids in SBO which are linoleic acid and oleic acid.

Commercial shortening was found to have the highest peroxide value and saponification value followed by shortening produced from 70% palm stearin, while shortening containing 60% palm stearin had the lowest PV and SV. But there is no significance difference in terms of density, specific gravity and acid value (Table10). On the other hand, FFA, peroxide value and saponification value of the product was increased when the percent of palm stearin was increased during processing. FAO/WHO Joint Committee standard for shortenings products indicated that peroxide value should not exceed 10 mEq/kg; the free fatty acid should also be less than 0.3% and the melting point between 41 to 51^0C (Eshetu, 2016).Based on the above table the finding of this study also agreed with FAO/WHO standard.

4.1. Oxidative stability tests

Oxidation stability is one of the most important quality parameters of edible vegetable oils and fats. It determines their usefulness in technological processes as well as shelf life. Many methods are used to determine oxidative stability. Among most frequently used methods, determinations of peroxide value (PV) and acid value (AV) are included (Maszewska et al, 2018).

Shortenings and vegetable ghee relatively contain no water which makes them to have better stability during storage. They can undergo autoxidation and hydrolytic rancidity due to poor raw materials, processing, packaging and storage conditions (Teklit, 2015, Zhang *et al.*, 2005).

Table 11. Physicochemical changes of the product at 0, 3 & 6-month storage with different storage temperature.

Products	Parameters			
	MC	**AV**	**FFA**	**PV**
S60 1st	0.1±0.01^{b}	0.14±0.01^{g}	0.07±0.01^{g}	2.2±0.1^{k}
S60 RT 3rd	0.1±0.01^{b}	0.14±0.01^{g}	0.07±0.01^{g}	2.43±0.10^{j}
S60 37 3rd	0.1±0.02^{b}	0.18±0.01^{efg}	0.08±0.01^{fg}	4.57±0.12^{f}
S60 RT 6th	0.1±0.01^{b}	0.16±0.01^{fg}	0.14±0.01^{d}	3.40.±0.03^{h}
S60 37 6th	0.1±0.02^{b}	0.21±0.10^{def}	0.18±0.01^{b}	6..60±0.05^{d}
S70 1st	0.1±0.02^{b}	0.14±0.01^{g}	0.09±0.01^{efg}	2.47±0.10^{j}
S70 RT 3rd	0.1±0.01^{b}	0.20±0.10^{def}	0.10±0.01^{ef}	3.10±0.76^{i}
S70 37 3rd	0.1±0.02^{b}	0.29±0.02^{e}	0.15±0.01^{cd}	4.25±0.06^{g}
S70 RT 6th	0.1±0.01^{b}	0.18±0.02^{efg}	0.14±0.02^{d}	5.5±0.02^{e}
S70 37 6th	0.1±0.02^{b}	0.37±0.01^{a}	0.26±0.02^{a}	6.7±0.05^{d}
C 1st	0.15±0.01^{a}	0.22±0.01^{de}	0.11±0.01^{e}	3.3±0.10^{h}
C RT 3rd	0.1±0.01^{b}	0.21±0.01^{def}	0.11±0.01^{e}	6.63±0.03^{d}
C 37 3rd	0.1±0.03^{b}	0.24±0.01^{d}	0.16±0.01^{bc}	9.68±0.10^{c}
C RT 6th	0.1±0.01^{b}	0.32±0.02^{bc}	0.18±0.01^{b}	11.5±0.03^{b}
C 37 6th	0.1±0.02^{b}	0.36±0.02^{ab}	0.25±0.02^{a}	12.3±0.01^{a}

Note: Means within a column followed by different superscripts are significantly different at $p<0.05$. Where, $S60^{1st}$, $S60^{3rd}$, $S60^{6th}$ = 60% palm stearin and 40% soybean oil, $S70^{1st}$, $S70^{3rd}$, $S70^{6th}$ = 70% palm stearin and 30% soybean oil, C^{1st}, C^{3rd}, and C^{6th} = commercial shortening, at 0^{th}, 3^{th} - and 6^{th} month storage respectively.

Table 11, showed the comparison of chemical property of shortening during 0, 3 and 6 - month storage. The result indicated that, the moisture content of commercial shortening was higher at initial time (0-month storage) but there was no significant difference with storage time and temperature changes. The acidity, FFA and PV were increased significantly when the storage time and storage temperature was increases for all products. The acidity, free fatty acid and peroxide value was higher when the products were stored at 37^0C.

The lowest acid value was found in all (0 ,3 and 6) month storage for S60 stored at room temperature, while in both 3^{rd}& 6^{th} month storage the highest acid value was found for S70 at 37 ^{0}C storage temperature. The lowest free fatty acid was found in all (the 1^{st} ,3^{rd} and 6^{th}) month storage for S60 stored at room temperature, but in the 3^{rd} month storage the highest FFA value was found for commercial shortening,while in 6^{th} month storage S70 was the highest at 37 ^{0}C storage temperature. Peroxide was found the highest in commercial shortening, while the lowest in S60 for all storage months in both storage condition.Peroxide are the primary oxidation product and peroxide concentration may fluctuate over time since peroxide turn to other oxidation product with time (Thomaidis &Georgiou, 2000). Bukola, *et al.*, 2015 also reported that peroxide value and acid value were increased with storage time for different vegetable oils. However, the acid value, peroxide value and free fatty acid values were increased during storage for processed shortening (S60 &S70) after 6 months of storage, none of the tested samples exceeded the maximum permissible values as recommended by WFP (World Food Program), but peroxide value of commercial shortening at 6-month storage was above the recommended level.

4.2. Sensory test

Sensory acceptance test of the product was done by homemade cookies. Food Science and Nutrition MSc. students were the panelists and a 9-point hedonic scale was used (where 1= like extremely& 9= dislike extremely) and some sensory attributes like color, flavor, texture, taste and overall acceptance test were evaluated as indicated in the table below.

Table12. Sensory acceptability test result for baked cookies made by shortening stored at room temperature.

Sensory attributes	Product		
	S60	S70	Control
Color	2.07±0.73[a]	2.43±1.60[a]	2.57±1.22[a]
Texture	2.21±0.97[a]	2.57±1.34[a]	2.5±1.09[a]
Flavor	2.71±1.44[a]	2.43±1.34[a]	2.34±1.008[a]
Taste	2.43±1.6[a]	2.57±1.4[a]	2.64±1.08[a]
Overall acceptability	2.43±1.09[a]	2.5±1.16[a]	2.5±0.76[a]

Note: Means within row followed by the same superscript are not significantly different at $p<0.05$. Where, S60 = 60% PS and 40% SBO, S70 = 70% PS and 30% SBO, C = commercial shortening at sixth month storage &stored at room temperature respectively.

Results showed that there was no significant difference for all sensory attributes between the processed products (S60 and S70) and commercial shortening which indicates the processed products has equal sensory acceptance by the consumers with that of commercial shortening.

5. Conclusions and Recommendations

5.1 Conclusions

The technology for production of shortening using palm stearin and soya bean oil as raw material using crystallization process reveals that it is possible to develop products with the desired quality. In this study, palm stearin used in shortening manufacturing is the natural oil with *cis* molecule configuration. A blend of palm stearin and soybean oils were used as raw materials in the target shortening processing. It requires great effort and motivation as well as legal background for the control of some of these products.

The study also assessed the shelf-life stability of processed shortening on the physicochemical properties for a period of six (6) month at different storage temperatures. During the storage period, changes took place in the values of quality parameters. The physicochemical properties of the product were within the requirements of food domain, but the peroxide value of commercial shortening was above the requirement during 6-month storage in both storage temperatures. From the results obtained it can be deduced that all shortenings have no significantly different in moisture content until six- month storage. All these vegetable shortening can exist as semi solid at room temperature. Products stored at 37 ^{0}C have poor physicochemical characteristics than that of stored at room temperature especially the peroxide value and acid value were increased with storage temperature and storage time. All shortening products had equal sensory acceptance for different sensory attributes. The physicochemical property and oxidative stability of S60was good compared with S70 and commercial shortening. Therefore, shortening produced from 60% palm stearin and 40% soya bean oil was found preferable product for its preferredquality.

5.2. Recommendations

Recommendation drawn from this study is that shortenings used for baking should be stored at room temperature because the acid and peroxide values obtained from such shortenings were the lowest compared with stored at 37 ^{0} C.

S60 the most suitable shortening for consumption as they maintain their quality with increase in storage time and also it will increase cost effectiveness because the amount of palm stearin was lower than S70 since palm stearin is imported product so, cost benefit analysis and nutritional content of the product will increase because SBO contains polyunsaturated essential fatty acids (Linoleic acid(ω-6 family of PUFAs) and α-linolenic(ω-3 fatty acid family), which exerts important nutritional and physiological functions and regulate number of metabolic pathways respectively. Researchers and food processing industries (especially bakery industries)should be focused on the development ofshortening processing with the desire product quality, because the demand and supply is not compatible because and vegetable shorteningsprocessing companies are few in number.

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