Palestine Polytechnic University

College of Engineering

Recycling of Waste Cooking Oil to Produce Soaps and Detergents: Technical and Economic Feasibility Study

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Submitted to the College of Engineering In partial fulfillment of the requirements for the Bachelor degree in Environmental Technology Engineering

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Abstract

Waste cooking oils (WCO), mainly oils used in the frying process are considered impair for both environment and the sewer system. This project aims at recycling these oils using alkali material and other ingredients to convert them into sellable product (soaps and detergents) in order to make a feasibility study for a project establishment. A preliminary investigation using a questionnaire indicated that large quantities of used frying oils, mainly corn oil with a percent of 64% followed by sunflower and soybean oils are disposed without any proper treatment. Literature review indicated the capability of converting these oils into soaps by the saponification reaction. Information about availability, types and quantities of these waste cooking oils was done by a questionnaire which was distributed randomly in Hebron city. Both liquid and bar soaps were formulated from WCO using alkaline materials and surfactants with the addition of dyes and fragrances which approves the technical feasibility of the project. A preliminary economic feasibility study was accomplished showing a payback period of 2.909 years with a return for the cash flow of 21.26% per year which approves the economic feasibility of the project.

الإهداء

بسم الله الرحمن الرحيم

(قل إعملوا فسيرى الله عملكم ورسوله والمؤمنون)
صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولايطيب النهار إلا بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك

إلى من كلله الله بالهيبة والوقار .. إلى من علمني العطاء بدون انتظار .. إلى من أحمل أسمه بكل افتخار ..
أرجو من الله أن يمد في عمرك لترى ثماراً قد حان قطافها بعد طول انتظار وستبقى كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد
..
والدي العزيز

إلى ملاكي في الحياة .. إلى معنى الحب وإلى معنى الحنان والتفاني .. إلى بسمة الحياة وسر الوجود
إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب
..
أمي الحبيبة

الى كل من علمني حرفا في جامعة بوليتكنك فلسطين

إلى الأصدقاء الاعزاء
إلى طلبة هندسة تكنولوجيا البيئة
إلى كل من سقط من قلمي سهوا

أهدي هذا العمل

الشكر

الحمد لله الذي بفضله تتم النعم والصالحات .. الحمد لله الذي انار قلوبنا وعقولنا

الشكر لله .. واهب عقلنا .. رازقنا نعمه .. الشكر لله أولاً وأخيرا على حسن توفيقه وكرم عونه

الشكر لكل من علمنا حرفا .. لكل من أنار دربنا ولم يبخل علينا بعلم

الشكر لوالدينا الأعزاء .. شكرا لثقتكم ودعمكم

الشكر الجزيل لمشرفنا .. لمن زرع ثقته فينا وزرعنا ثقتنا به .. الشكر للدكتور ماهر الجعبري

الشكر للدكتور حسن صوالحة

الشكر للمهندسة هبة سليمية

الشكر لكل طاقم هندسة تكنولوجيا البيئة بكل طاقمه التدريسي

الشكر لطلاب هندسة تكنولوجيا البيئة

الشكر لزملائنا .. خليل .. وئام .. مصعب .. جبر

الشكر لكل من مد لنا يد العون .. ممن لم تسعفنا الذاكرة بشكرهم .. جزاكم الله عنا خير الجزاء

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Chapter One

Research Proposal

1.1 Introduction

Cooking oil is plant, animal, or synthetic fat used in frying, baking, and other types of cooking. Their status is typically a liquid at room temperature, although some oils that contain saturated fat, such as coconut oil and palm oil are solid. There are a wide variety of cooking oils from plant sources such as olive oil, palm oil, soybean oil, sunflower oil, corn oil, peanut oil and other vegetable oils, as well as animal-based oils like butter.

A large quantity of used vegetable oil is produced and recycled, mainly from industrial deep fryers in potato processing plants, snack food factories, households and fast food restaurants. Deep frying (also referred to as deep fat frying) is a cooking method in which food is submerged in hot fat, most commonly oil [1]. Waste cooking oil (WCO) must not be poured down in the drains or the sewer system because this results in several operation and maintenance problems to the system [2].

WCO solidifies and accumulates inside the drainage system which prevents the sewage from flowing freely to the wastewater treatment plant or sewage chamber. Once sewage is blocked, it causes sewer backups and overflows into surrounding environment, which could result in potential environmental health hazards and an extra costs being required for clean-up efforts [3].

Another thing is that WCO must not be disposed of with the rest of the kitchen waste because it may cause spillages, leading to odor and ground pollution [4]. Recycled oil has numerous uses, including use as a direct fuel, as well as in the production of biodiesel, soap, animal feed, pet food, detergent, and cosmetics.

In Palestine, many of these oils are poured into the sewer system or in an open area without paying attention to their adverse effects for both human and environment. The problem caused by a waste such as frying oils can be solved by converting this waste into a useful product such as detergents. This can be done by using different chemicals so that it can be used for cleaning purposes.

WCO management aims at preventing the general environmental and health effects associated with its improper disposal. It entails any legal and practical measures employed in ensuring that WCO is handled in a manner that don't affect the environmental and human welfare.

This project attempts to increase the knowledge about converting WCO into useful products such as detergents and soaps in order to conserve both human and environmental aspects. This is done by adding alkali material to the used oil with the addition of other ingredients such as fragrances, dyes and many other components which will be detailed in the next chapters.

1.2 Scientific Background

Vegetable oils are esters of carboxylic acids; they have a high molecular weight. Chemically, these oils are called triglycerides. The principal acids in vegetable oils can be prepared from the natural triglycerides by alkaline hydrolysis (saponification). See figure 1.1.

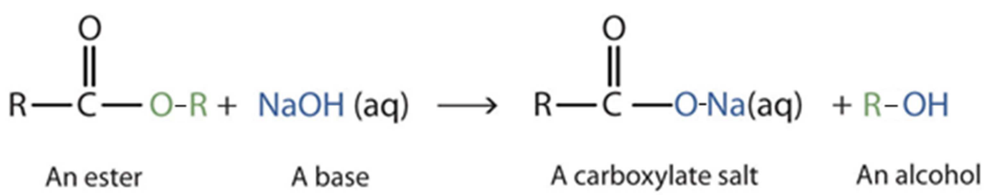

Figure 1.1: Saponification reaction [5].

Detergents are structurally similar to soaps, but differ in the water-soluble portion. The reaction in making soap and detergents (saponification) is a base (usually NaOH or KOH) hydrolysis of triglycerides to make three salts (soap) and glycerol. The molecules crystallize differently depending on the base used. NaOH produces a harder bar while KOH is used more frequently for liquid soaps [6].

The cleaning action of both soaps and detergents results from their ability to emulsify or disperse water-insoluble materials (dirt, oil, grease, etc.) and hold them in emulsion in water. This ability comes from the molecular structure of soaps and detergents. When a soap or detergent is added to water that contains oil or other water-insoluble materials, the soap or detergent molecules surround the oil droplets [7].

The oil or grease is dissolved in the alkyl groups of the soap molecules while the ionic end allows the micelle to dissolve in water. As a result, the oil droplets are dispersed throughout the water (this is referred to as emulsification) and can be rinsed away.

The two most commonly used methods to make soap are called the cold process and the hot process. Both require a heat source and careful mass balance calculations to ensure that no caustic base is left unreacted in the soap. The hot process uses heat to speed the reaction resulting in fully saponified soap. The cold process uses just enough heat to ensure that all the fat is melted prior to reacting it with the base [8].

1.3 Problem Statement

The main problem of this research is investigating the technical and economic feasibility of recycling WCO in soap/detergents manufacturing in Hebron city.

Sub problems:

- Is it technical (chemically) feasible to produce detergents/soaps from WCO?
- What are the types and amounts of available WCO in the study area?
- How to collect WCO from their sources?
- What type of detergents/soaps that can be produced (solid, liquid, powder) from the available WCO?
- What are the effects of operation parameters on detergent/soap quality (stirring time, stirring rate, temperature, alkali concentration)?
- What is the economic feasibility of establishing a local factory for producing soap/detergents from WCO?

1.4 Goal and Objectives

Main Goal

The main goal of this project is to produce products (soaps and detergents) that are technically and economically feasible by using WCO as a resource in the process of manufacturing.

Objectives

- To study the amounts of WCO available of making detergents.
- To study the reactions and requirements in the making process, for optimizing detergents recipe.
- To evaluate the final product's conditions and properties in term of usability.
- To identify the field (cleaning application) which the product will be used in.
- To find environmental friendly alternatives for the process components.
- To evaluate the feasibility of recycling WCO in Hebron city.

1.5 Research Importance

This project responds to environmental problems associated with improper disposal of WCO. It contributes in reducing the environmental impacts of WCO through converting the waste into a resource for soaps/detergents manufacturing.

Another importance came from the project role in encouraging the traders to make benefit of recycling expired oils instead of selling them causing serious public health problems.

1.6 Research Methodology

This project will be implemented through literature review, field survey and experimental work. Then ended with preparing an economic feasibility study.

Reviewing scientific publications including books about detergents/soaps manufacturing is another approach in research accomplishment to describe it.

Samples of usable product will be prepared and tested as an experimental approach to measure their characteristics and effectiveness. Cleaning properties, pH, NaCl concentration, oil emulsification and hard water test will be used as technical feasibility measures for the final product quality. The effect of various experimental parameters on soap quality will be investigated.

Field survey of availability, quantities and types of WCO in the study area will be accomplished using questionnaires and personal interviews. Full feasibility study will be accomplished.

1.7 Materials and Equipment

The following materials and equipment will be used:

- Various types of WCO.
- Chemicals including alkali materials (NaOH and KOH), surfactants and additives (fragrances and coloring).
- Laboratory apparatus including beakers, stirrers and pH meter.

1.8 Experimental Procedures

To reach to a usable product the following procedure must be followed:

Due to the presence of food remaining within the used oil, a preliminary filtering of oil is done; the oil is then poured into beaker and heated to an acceptable level. Chemicals including alkali material dissolved into water, dyes, and fragrances are added to the oil with different concentration depending on the oil used. The solution is then stirred and mixed until the reaction is completed; the resulted output is then poured into mold and left for a period of time (2-4 weeks) until it becomes usable. The final step is to Measure the characteristics of the final output in terms of pH, foamability and cleaning properties.

Concentrations and quantities of the recipe components will be measured and changed according to the output results until reaching an optimum usable recipe.

1.9 Budget

The total estimated budget for this project is 400 NIS. It is detailed in Table 1.1.

Table 1.1: Estimated costs of the proposed project.

Task/Item	Cost (NIS)
Chemicals	100
Transportation	100
Apparatus	200
Total	400

1.10 Action plan

The plan of actions for the first semester is shown Table 1.2.

Table 1.2: Plan of actions for the first semester.

Week / Task	1st Wk	2nd Wk	3rd Wk	4th Wk	5th Wk	6th Wk	7th Wk	8th Wk	9th Wk	10th Wk	11th Wk	12th Wk	14th Wk	15th Wk	16th Wk
Project identification															
Establishing a general scientific background															
Preparing research proposal															
Preliminary experiments															
Preliminary market survey															
Report preparation and presentation															

The plan of actions for the second semester is shown in Table 1.3;

Table 1.3: Plan of actions for the first semester.

Week / Task	1st Wk	2nd Wk	3rd Wk	4th Wk	5th Wk	6th Wk	7th Wk	8th Wk	9th Wk	10th Wk	11th Wk	12th Wk	14th Wk	15th Wk	16th Wk
Selection of ingredients for soap /detergent production															
Experimental work															
Economic feasibility study															
File final preparation & presentation															

Chapter Two

Scientific Background about Cooking Oils and Soap and Detergents Industry

2.1 Introduction

Scientifically, detergents is a term that covers both soap and synthetic detergents, but it is widely used to indicate synthetic cleaning compounds as distinguished from soap [9].

This chapter summarizes the required scientific background about the oils and ingredients used in soap and detergents industry. It also provides information about trends and previous studies in recycling WCO.

2.2 Chemistry of Detergents and Soap

To understand what is needed to achieve effective cleaning, it is helpful to have a basic knowledge of soap and detergent chemistry.

2.2.1 Cleaning Action

Water, has a property called surface tension. Which means that every molecule in the body of the water is surrounded and attracted by other water molecules [10]. A tension (see figure 2.1) is created as the water molecules at the surface are pulled into the body of the water. This tension causes water to bead up on surfaces, which slows wetting of the surface and inhibits the cleaning process.

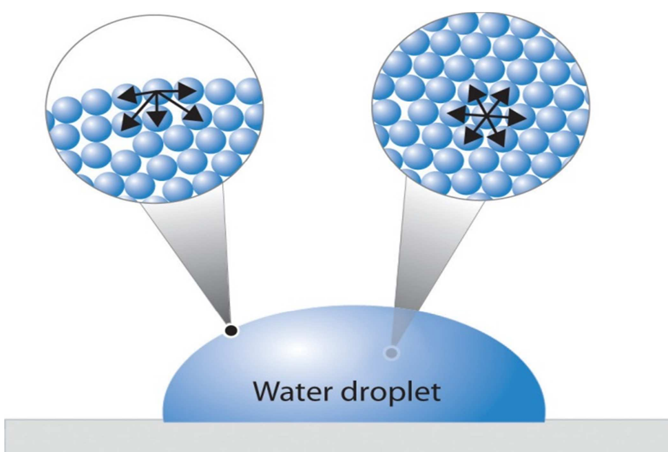

Figure 2.1: Surface tension of a water droplet [11].

For the cleaning process to be accomplished, surface tension must be reduced so water can spread and wet surfaces [12]. This work is done by adding chemicals that are called surface active agents, or surfactants.

Other various functions of surfactants in cleaning process includes loosening, emulsifying and holding soils and oils in suspension so it can be rinsed away [13]. Surfactants can also provide alkalinity, which is useful in removing acidic soils.

The cleaning effectiveness of soaps is affected by the presence of mineral salts such as calcium (Ca), magnesium (Mg), iron (Fe) and manganese (Mn), when those minerals present in water with high concentration, the water becomes hard. This inhabitant is caused when mineral salts react with soap to form soap film or scum which is an insoluble precipitate [14]. The problem of this film comes from that this film is not easily rinsed away.

There are four classifications of surfactants based on their electrical charge (ionic) properties in water and those are: negative charge (anionic), no charge (nonionic), positive charge (cationic) and amphoteric (either positive or negative charge) [13, 15].

2.2.2 Soaps

Soap is basically an anionic surfactant. Other anionic as well as nonionic surfactants are the core ingredients in today's detergents [15]. Soaps are water-soluble sodium or potassium salts of fatty acids. Soaps are made from fats and oils, or their fatty acids, by treating them chemically with a strong alkali.

When triglycerides in fats or oils react with an aqueous alkali material (mainly $NaOH$ and KOH), they are converted into soap and a byproduct called glycerol. This is called alkaline hydrolysis of esters. The resulted reaction is called the **Saponification** reaction since this reaction leads to the formation of soap [16]. The saponification chemical reaction is shown in figure 2.2.

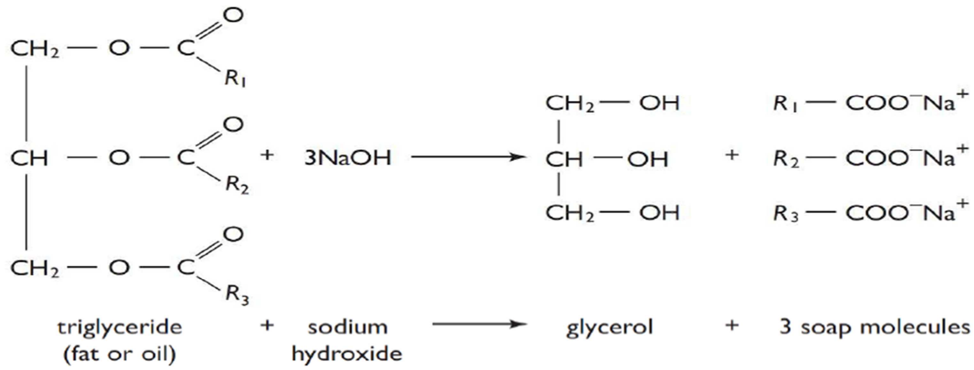

Figure 2.2: Saponification reaction [17].

One molecule of soap is mainly consisting of two parts: a polar group (-COO^-Na^+) which is called the head and a non-polar group (R-hydrocarbon part) which is called the tail. Thus, the soap molecule has a polar head and a non-polar hydrocarbon tail. While the polar head is water loving (hydrophilic) in nature, the non-polar tail is water repelling (hydrophobic) [16].

The fats and oils used in soap making industry come from plant or animal sources. Both fats and oils are made up from a mixture of many different triglycerides. In a triglyceride molecule, three fatty acid molecules are attached to one molecule of glycerine. There are many types of triglycerides; each type consists of its own particular combination of fatty acids [18].

Fatty acids are merely carboxylic acids consisting of a long hydrocarbon chain at one end and a carboxyl group (-COOH) at the other end. They are generally represented as RCOOH. They are an important component of plants, animals and other microorganisms. They are found in various parts of the body, such as cell membranes, the nervous system and as lung surfactant. There are two groups of fatty acids: saturated fatty acids and unsaturated fatty acids [16].

Saturated fatty acids lack double bonds between the individual carbon atoms, while in unsaturated fatty acids there is at least one double bond in the fatty acid chain. Saturated fats are solid at room temperature, while unsaturated fats are liquid.

2.3 Soap Making Processes

The most used method in soap making process is the saponification of fats and oils. It starts with heating of fats and oils then reacting them with a liquid alkali to produce soap [19].

Another major soap making-process is the neutralization of fatty acids with an alkali. At first fats and oils are split (hydrolyzed) using a steam with a high pressure to separate crude fatty acids and glycerine. The fatty acids then purified using distillation and neutralized with an alkali to produce soap and water (neat soap) [19].

In general, a hard soap is produced when sodium hydroxide alkali is used. In the other hand, using potassium hydroxide gives softer soap which is found in liquid hand soaps. Experiments showed a capability of making hard soap by reacting NaOH with waste corn oil, while the reacting with KOH gave 3 layers of unknown components.

Fatty acids and their resulting soap characteristics are shown in Table 2.1.

Table 2.1: Fatty acids and their resulting soap characteristics [20].

Lauric Acid	Hard bar, excellent cleansing, lots of fluffy lather, can be drying to skin
Linoleic Acid	Conditioning, silky feel
Myristic Acid	Hard bar, cleansing, fluffy lather
Oleic Acid	Conditioning, slippery feel, stingy lather, kind to skin
Palmitic Acid	Hard bar, cleansing, stable lather
Ricinoleic Acid	Softer bar, conditioning, moisturizing, lots of fluffy, stable lather, kind to skin
Stearic Acid	Hard, long lasting bar, stable lather

The fatty acids composition is an indicative of the properties of soaps made from that oil. Each oil will also have a percentage of "non saponifiable" components that do not become soap themselves, but rather remain in the soap and add their own characteristics to that soap. These include non-oil plant materials, vitamins, minerals, etc.

Oils in Table 2.2 can have a fairly wide range of percentages of any constituent fatty acid and can be somewhat different from different sources.

Table 2.2: Vegetable oils and their composition of fatty acids [20].

Oil Name	Fatty Acids	Oil Name	Fatty Acids	Oil Name	Fatty Acids
Canola Oil	Oleic 32-62% Linoleic 15-22% Alpha Linoleic 10% Palmitic 1-4%	**Soybean Oil**	Linoleic 46-54% Oleic 22-27% Palmitic 9-12% Alpha Linoleic 7% Stearic 4-6%	**Palm Oil**	Palmitic 43-45% Oleic 38-40% Linoleic 9-11% Stearic 4-5%
Castor Oil	Ricinoleic 90% Linoleic 3-4% Oleic 3-4%	**Neem Oil**	Oleic 50% Palmitic 18% Stearic 15% Linoleic 13%	**Sunflower Oil**	Linoleic 68-70% Oleic 16-19% Palmitic 7% Stearic 4-5%
Corn Oil	Linoleic 45-58% Oleic 28-37% Palmitic 11-14% Stearic 2-3%	**Olive Oil**	Oleic 63-81% Palmitic 7-14% Linoleic 5-15% Stearic 3-5%	**Palm Oil**	Palmitic 43-45% Oleic 38-40% Linoleic 9-11% Stearic 4-5% Myristic 1%

Detergents

Detergents molecules are amphipathic which contains two parts; the first one is a polar (COO-) group, while the other side is a hydrophobic (R) group. The general formula of detergents is shared with soaps which is RCOOX. Components of today's detergents mainly consist of surfactants [21, 22]. Others are builders and co-builders, bleach and bleach activator, and special additives [23]. Extended information of their functions is shown in Table 2.3.

The effective cleaning action of detergents is mainly done by surfactants; this is mainly caused by their chemical makeup. What makes detergents more effective is their ability to work well under many conditions, especially their ability to work with hard water with a less sensitive than soaps, which means a film or scum will not be formed [9].

What led to the invention of detergents surfactants is the shortage of fats provided by animal and vegetable oils. Moreover, a need for a resistive material to hard water was another main reason to create the detergents products. Today, these surfactants are derived from petroleum sources (petrochemicals) and fats and oils (oleochemicals).

Chemicals, such as sulfur trioxide, sulfuric acid and ethylene oxide, are used to produce the water-loving end of the surfactant molecule. As in soap making, an alkali is used to make detergent surfactants. Sodium and potassium hydroxides are the most common alkalis.

Anionic and Nonionic Surfactants

When chemicals react with hydrocarbons that are derived from fats and oils they produce a new acid which is identical to fatty acids. A second reaction is the addition of alkali to the resulted acids to produce anionic surfactant molecule [14].

Nonionic surfactants result from converting the hydrocarbons to an alcohol and then reacting them with ethylene oxide. In addition, anionic surfactants can be produced by reacting the nonionic surfactant with sulfur-containing acids [14].

Table 2.3 summarizes the ingredients used in soap/detergents manufacturing and their functions.

Table 2.3: Ingredients used in soap and detergents manufacturing [24].

Ingredient	Primary Functions	Typical Examples
Abrasives	Supply smoothing, scrubbing and/or polishing action	Calcite, Feldspar, Quartz, Sand
Acids	Neutralize or adjust alkalinity of other ingredients	Acetic acid, Citric acid Hydrochloric acid Phosphoric acid Sulfuric acid
Alkalis	Neutralize or adjust acidity of other ingredients Make surfactants and builders more efficient	Ammonium Sodium carbonate Sodium hydroxide

	Increase alkalinity	Sodium silicate Potassium hydroxide
Antimicrobial agents	Kill or inhibit growth of microorganisms that cause diseases and/or odor	Pine oil Sodium hypochlorite Triclocarban Triclosan
Anti redeposition agents	Prevent soil from resettling after removal during washing	Carboxymethyl cellulose Polycarbonates Polyethylene glycol Sodium silicate
Bleaches	Help whiten, brighten and remove stains	
Chlorine bleach	Disinfection	Sodium hypochlorite
Oxygen bleach	In some products, may be combined with bleach activator for better performance in lower water temperatures.	Sodium perborate Sodium percarbonate
Colorants	Provide special identity to product Provide bluing action	Pigments or dyes
Corrosion inhibitors	Protect metal machine parts and finishes, china patterns and metal utensils	Sodium silicate
Enzymes	Proteins classified by the type of soil they break down to simpler forms for removal by detergent Cellulase reduces pilling and greying of fabrics containing cotton and helps remove particulate soils.	Amylase (starch soils) Lipase (fatty and oily soils) Protease (protein soils) Cellulase
Fabric softening agents	Impart softness and control static electricity in fabrics	Quaternary ammonium compounds
Fluorescent whitening agents	Attach to fabrics to create whitening or brightening effect when exposed to daylight	Colorless fluorescing compounds
Fragrances	Mask base odor of ingredients and package Cover odors of soil Provide special identity to product Provide pleasant odor to clothes and rooms	Fragrance blends

Hydrotropes	Prevent liquid products from separating into layers Ensure product homogeneity	Cumene sulfonates Ethyl alcohol Toluene sulfonates Xylene sulfonates
Opacifiers	Reduce transparency or make product opaque Provide a special effect	Polymers Titanium dioxide
Preservatives	Protect against natural effects of product aging, e.g., decay, discoloration, oxidation and bacterial attack	Butylated hydroxytoluene Ethylene diamine tetraacetic acid Glutaraldehyde
Processing aids	Provide important physical characteristics, e.g., proper pour or flow, viscosity, solubility, stability and uniform density Assist in manufacturing	Clays Polymers Sodium silicate Sodium sulfate Solvents
Solvents	Prevent separation or deterioration of ingredients in liquid products Dissolve organic soils Clean without leaving residue	Ethanol Isopropanol Propylene glycol

2.4 Cooking Oils

An oil is called cooking oil when used for frying, baking and other methods of cooking. They are mainly a plant, animal, or synthetic fat. Therefore they are called edible oils [18].

According to the United States Department of Agriculture, approximately 180 million metric tons of vegetable oils are estimated to be produced globally in the year of 2016. Worlds vegetable oil production has increased over the past decades, especially the production of palm oil, corn oil, soybean oil, canola oil and sunflower oil [25].

Main cooking oils used in Palestinian kitchen are shown in Table 2.4, where these oils are mainly used in the frying process (except for olive oil).

Table 2.4: Various vegetable oils, description and cooking uses [26].

Oil	Description	Cooking Uses	Smoke Point (°C)
Corn Oil	A mild medium-yellow color refined oil. Made from the germ of the corn kernel.	Frying, deep frying, salad dressings, shortening.	232
Olive Oil	Oils varying weight and may be pale yellow to deep green depending on fruit used and processing.	Cooking, salad dressings, sear, stir fry, grill, broil, baking	160 216 238 242
Soybean Oil	Fairly heavy oil with a pronounced flavor and aroma.	Frying, deep frying, salad dressings, shortening	232
Sunflower Oil	Light odorless and nearly flavorless oil pressed from sunflower seeds. Pale yellow.	Cooking, Frying, deep frying, margarine, salad dressings, shortening	232

Smoke point refers to the temperature at which an oil starts to burn and smoke

Corn Oil

Corn oil is extracted from the germ of corn (maize). Its high smoke point makes it ideal for the frying process. It is generally less expensive than most other types of vegetable oils. Corn oil is also feedstock used for biodiesel.

Other industrial uses for corn oil include soap, salve, paint, rustproofing for metal surfaces, inks, textiles, nitroglycerin, and insecticides. It is sometimes used as a carrier for drug molecules in pharmaceutical preparations [18].

Sunflower Oil

Sunflower oil is the non-volatile oil compressed from the seeds of sunflower . Refined sunflower oil is used for low-to-extremely-high-temperature cooking. As frying oil, it behaves as a typical vegetable triglyceride. Sunflower oil is of light amber color with a mild and pleasant flavor; refined oil is pale yellow [18].

Table 2.5: Composition and Chemical and Physical values of Corn and sunflower Oils [18].

Parameter	**Corn oil**	**Sunflower oil**
Weight (all is fats)	100 g	100 g
Moisture	None	None
Protein	None	None
Fats (Triglycerides)	98.8 g	98.3 g
Unsaponifiable Matter	**1.2 g**	**1.7 g**
Carbohydrates	None	None
Ash	None	None
Sodium	None	None
Saponification value (mg KOH/ g oil)	189-195	188-194
Smoke point	229-238 °C	232 °C

2.5 Waste Cooking Oils

Huge quantities of waste cooking oils are available throughout the world. Management of such oils and fats pose a significant challenge because of their disposal problems and possible contamination of the water and land resources. Even though some of this waste cooking oil is used for soap production, a major part of it is discharged into the environment.

2.5.1 Sources

The main source of WCO comes from industrial deep fryers in potato processing plants, snack food factories, households and fast food restaurants.

2.5.2 Characteristics

Globally, Frying is the most used culinary method for both domestic and industrial food preparation procedure. Properties of fried food products must have its own characteristics, such as juicy taste, nice flavor, crispy texture and brownish color.

When cooking oils used in the frying process, it exposed to a very high temperature with the presence of moisture and air. These conditions lead to complex chemical reactions, resulting in a loss of quality and nutritional values of the used cooking oil. Fats are then modified with the repeated frying process by many chemical reactions including oxidation, hydrolysis and polymerization [27].

Excessive reuse of cooking oil is then result in enhanced foaming, converting the oil into a darker color, increase viscosity and decreasing pH value. Moreover, repeated heating lead to a chemical and physical degradation [27].

Three main chemical reactions occurs while deep frying of food at high temperatures [27, 28], and those are:

1. Hydrolysis – Moisture from the food being fried vaporizes and hydrolyses triglycerides (TGs) in the frying oil to glycerol, free fatty acids (FFAs), monoglycerides (MGs) and diglycerides (DGs).

2. Oxidation– Triglyceride molecules in the frying oil undergo primary oxidation to unstable lipid species called “hydro peroxides” which cleave to form secondary oxidation products which comprise non-volatile and volatile compounds. Some of these secondary products polymerize (tertiary oxidation), increasing the oil viscosity, cause browning on the surface, and darken the oil.

3. Thermal Polymerization – High temperatures of the frying operation produce high molecular cyclic fatty acid (FA) monomers, and TG dimers and oligomers.

The following Table shows the changes in chemical and physical characteristics for both corn and sunflower oils after repeated batch potato frying. The results show that the red and yellow units of color value of oils increase with frying period. Viscosity of oils increased significantly during frying and was influenced by repeated frying. The value of pH decreased for both oils during frying. The saponification values were 190.7, and 191.5 mg KOH/g for sunflower oil, and corn oil, respectively [29].

Higher saponification value (mg KOH/ g oil) means a higher required alkali for the completion of the saponification reaction where saponification value is a measure of the total free and combined acids available in fats.

Table 2.6: Changes in characteristics of corn and sunflower oil during potato frying at 175°C [29].

Determination	**Corn Oil**		**Sunflower Oil**	
	Before Frying	After Frying	Before Frying	After Frying
Average Molecular Weight (g/ mol)	877.25	769.5	880.6	785.5
pH	6.455	4.464	6.7	4.8
Free Fatty Acid (% as oleic acid)	0.11	0.628	0.080	0.328
Saponification Value (mg KOH/ g oil)	191.5	218.3	190.7	213.8
Color (red/yellow)	2.1/20	4.5 /54	1.1/11	2.6 /35

2.6 Environmental Impacts of Improper Disposal of WCO [2, 30, 31]

When used cooking oil is disposed down the sinks and drains or onto the environment or even in the garbage, then it’s called improper disposal. This results in various environmental impacts.

The problem of disposing the liquefied oil or grease down the sink is that it can cling the inside of the pipes and the sewer system. Repeated such an action will lead to the buildup of WCO and eventually blocking the pipes completely. This will lead to a problem where wastewater will not go through pipes causing series problems and damages that can be expensive to repair.

Another problem is caused by sealing the soil pores when WCO is poured on the ground, this will lead to prevent air and water to go through soil and eventually killing earth worms and bacteria necessary for regeneration of plants.

When used cooking oil is poured down the house drains, some of the drain systems will lead to the rivers, streams or ponds. This oil will be dumped into it and causes a disastrous effect on any kind of life forms in the rivers, streams or ponds such as killing fishes and water plants. Oil is poisonous to birds and kills them. It sticks to their feathers which preventing them from flying and keeping their body warm.

2.7 WCO Recycling Efforts

WCO has been recycled in producing various useful products. These include production of biodiesel, soaps, animal feedstock and as Lubricating oil.

2.7.1 Biodiesel

WCO, which is very much cheaper than pure vegetable oil, is a promising alternative to vegetable oil for biodiesel production. Biodiesel can be produced by transesterification using alkaline, acidic, and enzymatic catalysts [32]. A significant benefit is that biofuels derived from recycled cooking oil typically burn clean.

Vegetable oils and their derivatives as diesel engine fuels lead to substantial reductions in sulfur, carbon monoxide, polycyclic aromatic hydrocarbons, smoke and particulate emissions. Vegetable oils have comparable energy density, cetane number, heat of vaporization, and stoichiometric air/fuel ratio to that of mineral diesel [33].

Biodiesel esters are characterized by their physical and fuel properties including density, viscosity, iodine value, acid value, cloud point, pure point, gross heat of combustion, and volatility. Biodiesel fuels produce slightly lower power and torque and consume more fuel than diesel fuel. Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content, and biodegradability [3, 33].

Currently, biodiesel is produced from different crops such as, Jojoba oil, palm oil, soybean oil, canola, rice bran, sunflower, coconut, rapeseed, soybean and sunflower oil [34, 35]. Many experiments were done to measure the effectiveness of the produced biodiesel from WCO, and the results were good [36].

2.7.2 Soaps and Detergents

A few research were done about using WCO into detergents manufacturing [2], a biodetergent has been successfully restored from waste cooking oil using alkaline hydrolysis technology. Ingredients used in the production are shown in Table 2.7.

Table 2.7: Ingredients used in the preparation of biodetergent using alkaline hydrolysis technique [2].

Ingredients used	**WCO**	**NaOH**	**Sulfuric acid**	**Hydrogen peroxide**	**Sodium chloride**
Quantity used	10 ml	--	5 ml at 3M	5 ml	Used for washing

Tests of resulted biodetergents showed impressive results compared to other biosurfactant sources as shown in Table 2.8.

Table 2.8: Waste cooking oil biodetergent compared to ASTM D-460 [2].

WCO biodetergents	**Sample 1**	**Sample 2**	**Sample 3**	**ASTM D-460 (commercialized detergent)**
pH	8	9	8	8
Foam height (cm)	1	0.5	2.5	1.8
Oil emulsification	D	D	D	D
Hard water test	Layer	1.2	Layer	Layer
Biodetergent yield	81.23	84.46	90	-

Chapter Three

Market Survey of WCO

3.1 Introduction

The process of frying foods in vegetable oils are considered as the main food preparation method in Palestine, sources of used frying oil comes from industrial deep fryers in potato processing plants, snack food factories, households and fast food restaurants. Used frying oil is then either sold or disposed in the sewer system causing serious problems to the sewage network, decreasing its efficiency and increasing cost of repairing it.

We as environmental engineers look at things differently, for what people see as a waste; we look at it as a resource, and this is exactly what we do in this project.

Recycling these oils by converting them into a useful product such as soaps and detergents is one of the main solutions to such a problem, every type of oil needs different percentages of ingredients, as a result, the needed information about types, quantities and quality of available used oils is required.

Study area

Hebron Governorate is the largest among the other Palestinians governorates; it forms 13.5% of the volume of the Palestinian population in the West Bank and Gaza Strip and one-third of the populations in West Bank.

Business owners in the areas of production, distribution and trade in the various economic sectors at the local level (medium, small and micro businesses, formal and informal, and cooperatives) in the following sectors: agriculture and food industries, other manufacturing industries, traditional crafts, mining, quarrying, construction, commerce, **restaurants**, hotels, information technology, communications, education, health, services and other branches

3.2 Market Survey

Methodology used

The main methodology used in market survey is by using a questionnaire (appendix A) and personal interviews to get information about:

1. Type of used frying oil.
2. Amounts of disposed used oils.
3. Fate of unwanted used oil.
4. Price of used frying oil.

Sampling and Data Collection

In December of 2016, random data were collected using structured questionnaire among 30 restaurants in Hebron city, Bani Na'im and Yatta. The highest percentage of samples was drawn from the center of the city itself due to the large number of present fast food restaurants there.

The questionnaires were completed by the heads of the restaurants or the workers there with the assistance of the survey team. The questionnaire used for this research was designed by the researchers and then checked and corrected by Dr. Zohdi Salhab, a scientific research methods teacher at PPU University.

3.3 Results of Field Survey

All questionnaires were accepted because of that they were filled by the presence of the researchers, and the results were as follow:

Results of types of the used oils are shown in figure 3.1; it revealed that the most used oil was the corn oil with a percentage of 64%, followed by sunflower oil then soybean oil with percentages of 23% and 13% respectively.

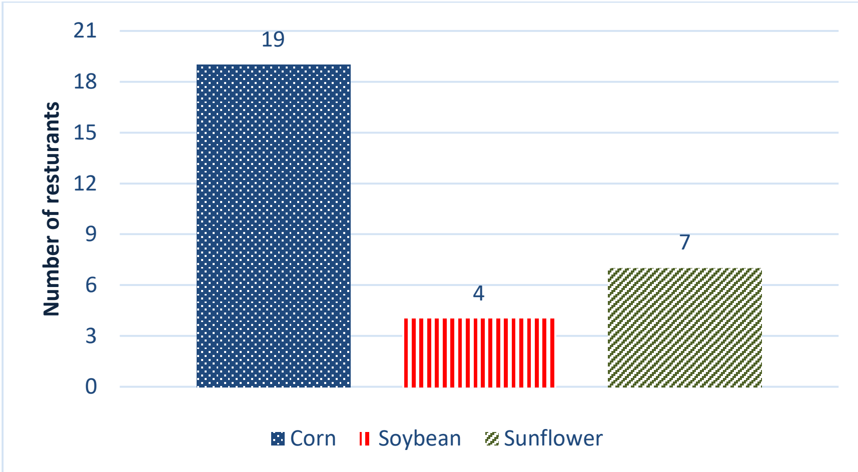

Figure 3.1: Types of used frying oils.

The results also showed that most of the WCO is disposed, where 23 restaurants dispose this oil, mainly in the sink, while only 7 restaurants sell them with an average price of 2 NIS per liter.

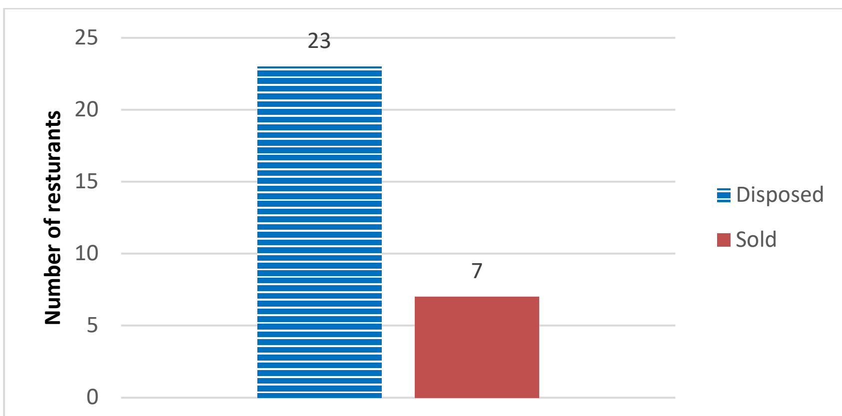

Figure 3.2: Fate of WCO after being used in the frying process.

The sold WCO in the study area is then used in various uses; these uses are shown in Table 3.1.

Table 3.1: Sold WCO end use.

Usage	Soap industry	Animal feedstock	Lubricating
No. samples	1	1	5

Restaurants in the study area are mainly fast food restaurants that uses less than 15 liter of frying oil per day, results are shown in figure 3.3.

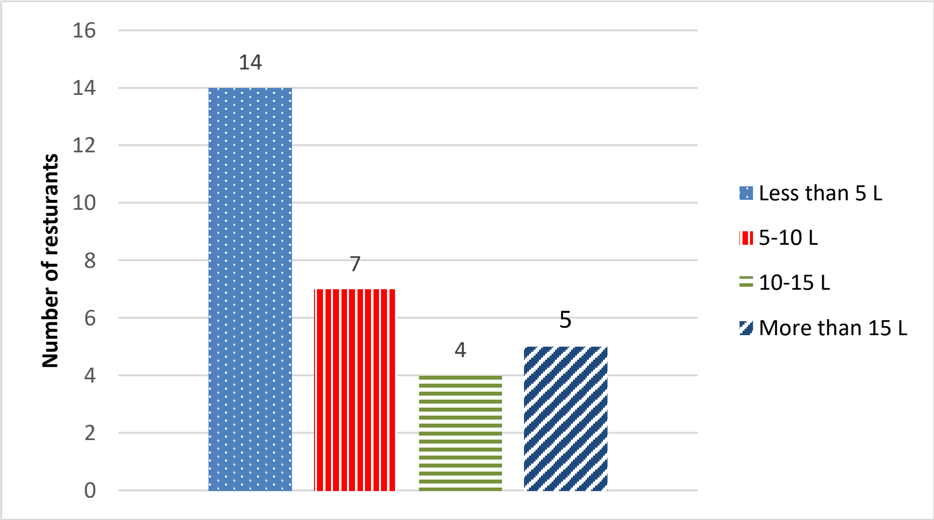

Figure 3.3: Quantities of daily disposed oil per restaurant.

The final result shows that approximately Two-thirds of the used oil is disposed without any consideration for the negative results that could be caused by the improper disposal of WCO.

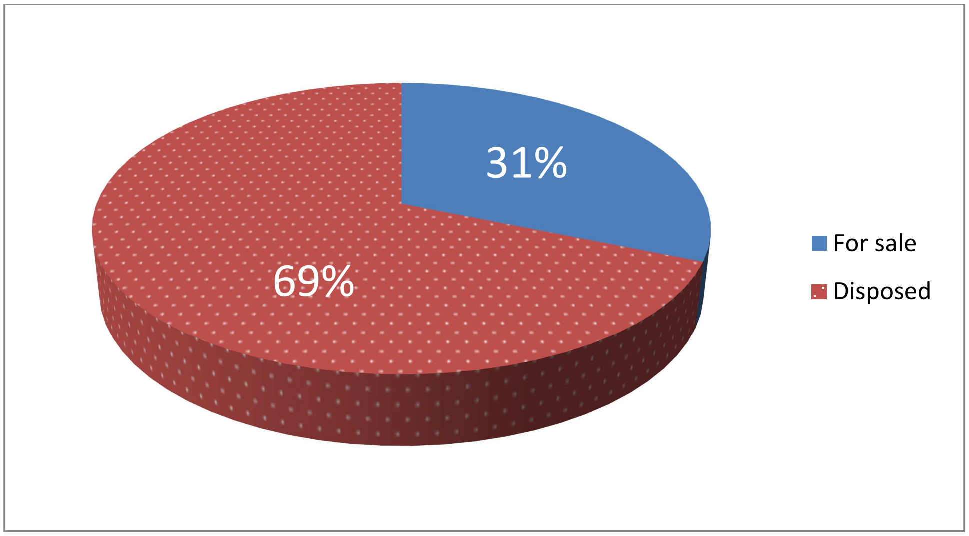

Figure 3.4: Fate of WCO.

3.4 Scaling Up

As noted, almost 70% of the used frying oil in the study area is disposed without getting any benefit of it, the amount of disposed oil from the studied 30 restaurants is equal to 275 liters/day, and according to the Palestinian Central Bureau of Statistics there are about 49 official restaurants and more than 200 fast food restaurants and booths in the city only, while there are about 100 restaurants and booths in Yatta city.

With an average of 10 liters per restaurant, and 350 restaurants, there will be 3500 of daily WCO; 2450 liters are disposed from these restaurants only.

Chapter Four

Experimental Work

4.1 Introduction

This chapter summarizes the methods and procedures used to carry out experiments performed in order to study the technical feasibility of recycling WCO to produce soap. Both hard and liquid soap were formulated from WCO using alkaline materials and surfactants with the addition of dyes and fragrances. The research presented in this chapter includes the following works:

1. Production of hard soap.
2. Production of liquid soap.

4.2 Materials and Equipment

Soap was prepared using WCO, Tween 20, Alkali material (NaOH and KOH), Fragrances and Dyes shown in figure 4.1 below.

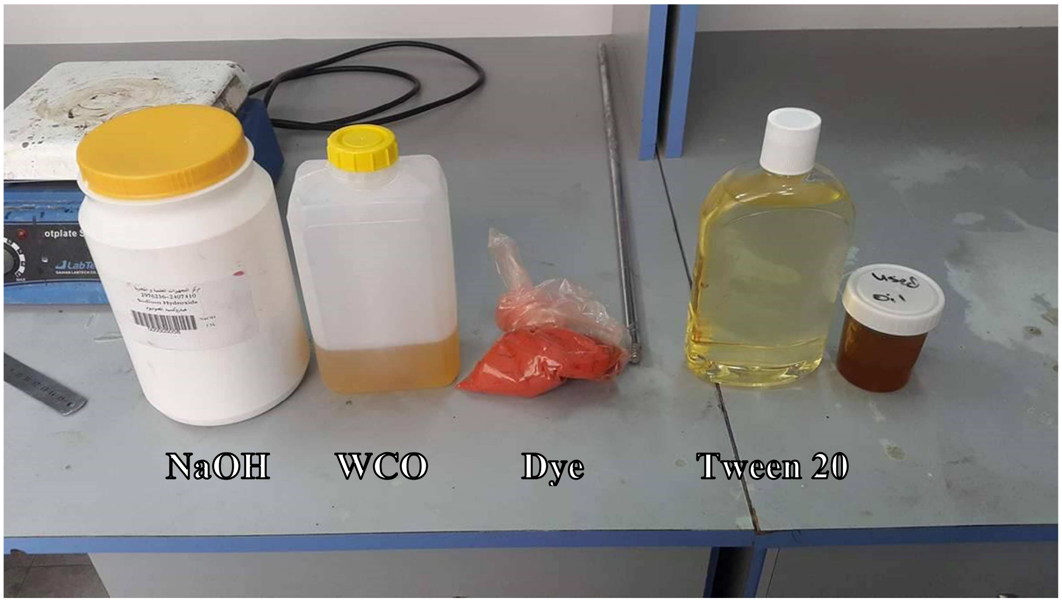

Figure 4.1: Materials used in soap production.

WCO was brought from many sources including the university cafeteria, houses and falafel restaurants. While tween 20, fragrances and dyes were brought from Spartex factory for soap and detergent industry in Hebron city. The alkali materials were available in the university lap. WCO and alkali material are the main components of the soap, while fragrances and dyes were used for improvement of the resulted product.

4.3 Production of Hard Soap

Both corn and sunflower oils were converted into soap using the formulas listed in Table 4.1.

Table 4.1: Hard soap production formulas from WCO.

	Oil percent (%)	NaOH (%)	Water (%)	Fragrances (%)	Dyes (%)
Corn oil	68.5	8.85	22.6	> 0.1	> 0.05
Sunflower (30%) + corn oil (70%)	68.5	8.85	22.6	> 0.1	> 0.05

These formulas were obtained from Bramble Berry website (A website specialized in providing soap making ingredients), those formulas are then developed to suit WCO soap production.

At first, WCO was filtered using a cloth to remove food remaining and then placed into a beaker at room temperature, and then the diluted NaOH solution was added to the beaker gradually with continuous mixing for 10 minutes. Dyes and fragrances were added while mixing the solution, soap is then poured into molds and left for 1-2 days, and then the soap bars are left for 2-4 weeks to be fully cured. Figure 4.2 shows the produced soap using the two formulas were formula 1 is the one with 100% corn oil.

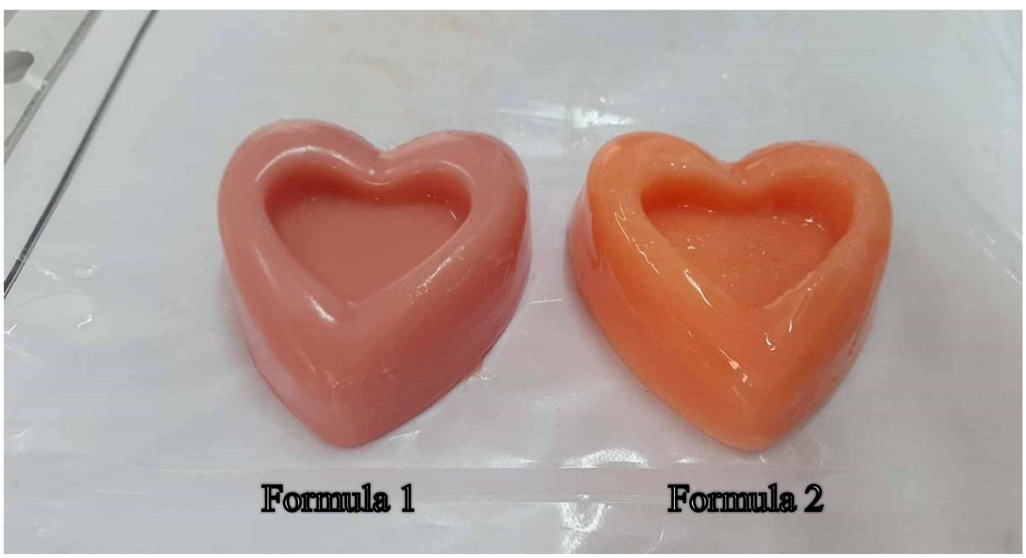

Figure 4.2: Produced bar soap using WCO.

Produced hard soap specifications and comparison

pH value

pH of soap is an important indicator that the soap is safe to use. Soap must have a pH value between 7-10. This is the range that is considered safe to use. For the produced soap, pH value was measured by dissolving 2 grams of soap into 20 ml of distilled water and then measured using pH meter. It was measured to be 9.5 while it was measured to be 9.3 for a commercial bar soap which indicated that the produced soap is safe to be used in term of pH value.

Foamability

The prepared soap showed an impressive results in term of foamability compared to another commercial hard soap, figure 4.3 shows foamability results. Figure 4.4 shows the foam level (sample 1) compared to a commercial soap (sample 2).

Figure 4.3: Foamability results.

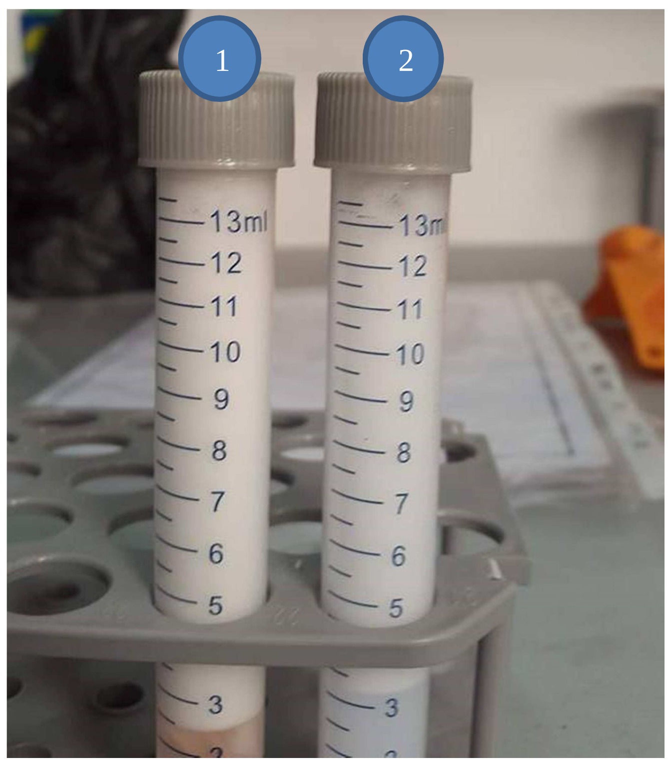

Figure 4.4: Foam level compared to a commercial soap

4.4 Production of liquid soap

Many tests were performed in order to get a liquid soap from WCO, different percentages of tween 20 were used as emulsifying agent for the preparation of stable oil-in-water emulsion. KOH was used for the completion of saponification reaction. The mixture was mixed for 10 minutes using Shaker rotator, Table 4.2 shows the experiment components.

Table 4.2: Liquid soap production formulas from WCO.

Sample No.	Corn Oil weight (g)	Tween 20 weight(g)	KOH weight (g)	Water weight (g)
1	10	1	2	6
2	10	3	2	6
3	10	5	2	6
4	10	7	2	6
5	10	9	2	6

Results showed success with sample No. 5 in term of stability while other samples failed due to insufficient amount of emulsifier (Tween 20); figure 4.5 shows the produced samples.

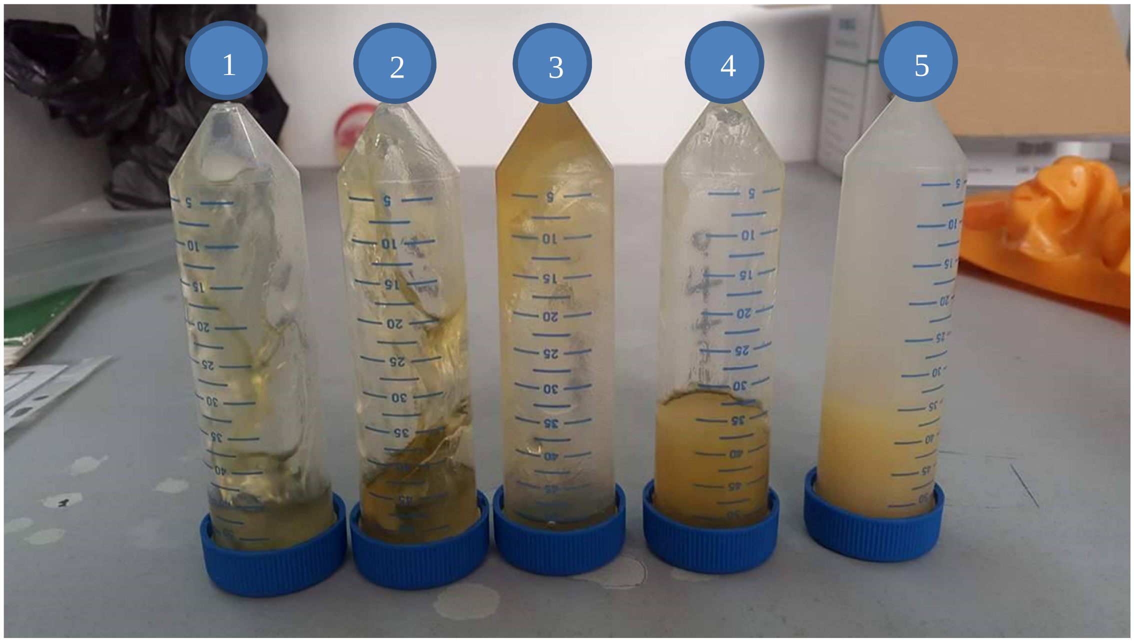

Figure 4.5: Liquid soap produced samples.

4.5 Concluding Remarks

Both hard and liquid soap were successfully produced from WCO (corn and sunflower oils) using cold process which approves the technical feasibility of the project. Many experiments were done in order to reach usable formulas with permissible output characteristics including pH and foamability. The final formulas provided soap with pH of 9.5 and a high foam level.

Chapter Five

Preliminary Economic Feasibility Study for Recycling WCO to Produce Soaps and Detergents

5.1 Introduction

A feasibility study is an investigation (i.e. gathering and analyzing information) into the potential outcome (viability) of a project. This helps the investors, sponsors, shareholders and lenders to know if the project is feasible or possible. If a feasibility study is to be useful, the techniques of data collection, evaluation and structure of the report must be objective, valid and reliable.

A feasibility study is an evaluation and analysis of the potential of the proposed project which is based on extensive investigation and research to give full comfort to decision makers.

Feasibility studies aim to objectively and rationally uncover the strength and weakness of an existing business or proposed venture, opportunities and threats as presented by the environment.

This report is evaluates the features of entering into soap production from WCO as a business enterprise. Soap is one of the most commonly used chemical products in everyday endeavors. It has been produced in different forms: liquid, powder and bar; different colors, different sizes, different textures, and different qualities. Some soaps are mild and gentle on the skin but tough on germs (medicated soaps), some are tough on stains and harsh to the skin (particularly detergents) while some are gentle on the skin (toilet soap, liquid detergent etc.).

Homes, industries, offices, hospitals and hotels all use soap on a daily basis. Soap is very essential in Medicine and the Pharmaceuticals where purity and cleanliness is very important. This has made the soap industry a lucrative industry with maximum profitability and minimal risk management.

For the project of recycling WCO we relied on the amounts of available used frying oil and the technical feasibility to produce soaps and detergents from these oils.

5.2 Purpose of the Economic Feasibility Study

1. To determine the viability of the project and the project attractiveness.
2. To serve as a plan document indicating the series of choices or strategies for realizing the objectives of the project.
3. To serves as a guide during the implementation of the project.
4. To demonstrates to investors the existence of market for the product/service, the liquidity of the project and potential revenue source for the project.
5. To serves as a control guide to the investor with regards to product specifications and performance.

5.3 The Product

The final product of the project is liquid detergent and bar soap (produced mainly by cold process). The liquid soap is canned in various transparent containers of 1 liter and 2 liters, while the bar soap is cut into various shapes and sizes to satisfy customer's needs. These two products are for both domestic and industrial uses.

5.4 Raw Materials

The raw materials required for soap making are listed below

- WCO, mainly frying corn and sunflower oils
- Sodium hydroxide (NaOH)
- potassium hydroxide (KOH)
- Water
- Surfactants (tween 20)
- Fragrances
- Colors (dyes)
- Preservatives

5.5 Sources of Raw Materials

The main raw material is WCO. It will be brought from industrial deep fryers in potato processing plants, snack food factories, households and fast food restaurants. Other raw materials for this project will be purchased from chemical suppliers.

5.6 Project Location

For the establishment of the project, there is no need for a special infrastructure, so a shop for rent with enough space would be enough to satisfy the project needs.

The project location was selected to be in Al-Jarafat street, 3 km to the south from the middle of Yatta city, where the renting price is 1000$/yr. for each door (two doors with a space of 120 m^2). It is sited in this area because it will be the first soap industry in this part of the city. This location for the business is a very good one since it has access to the other parts of the city. There is also abundant supply of both skilled and unskilled manpower for the operation of the project. Getting sales personnel is also very easy because of the high level of unemployment in the area.

5.7 Machineries and Process Design

1. Primary filtration unit: Used for removal of food remaining and other suspensions in the used oil. See figure 5.1.
2. Mixer Machine: Soap mixer machine is used for mixing all the raw materials and additives. See figure 5.2.
3. Filling Machine: Used to fill cans with liquid soap. See figure 5.3.
4. Fully Automatic Toilet Soap Plant: This unit is capable to produce bar soap starting from mixing to packing. See figure 5.4.
5. Measurement Instruments: These include pH meter, thermometer and balances. Measuring cylinders to measure the quantities required are also needed.

Table 5.1: Specifications of machines used in the proposed factory.

	Machine Model	Capacity	Price (NIS)	Dimensions L×W×H (m)
Primary filtration unit	COP-10	10 L/min	40,000	1.5×1.0×1.2
Bar soap planet	TSP	200 kgs/hr	300,000	7×2×2.5
Mixer Machine	JBJ-1000L	5000 L	6000	1× 1.2 ×2.1
Filling Machine	ZHK	5-20 bottles/min	6000	1.2×1×1.5

Figure 5.1: Primary filtration unit.

Figure 5.2: Mixer machine.

Figure5.3: Filling machine.

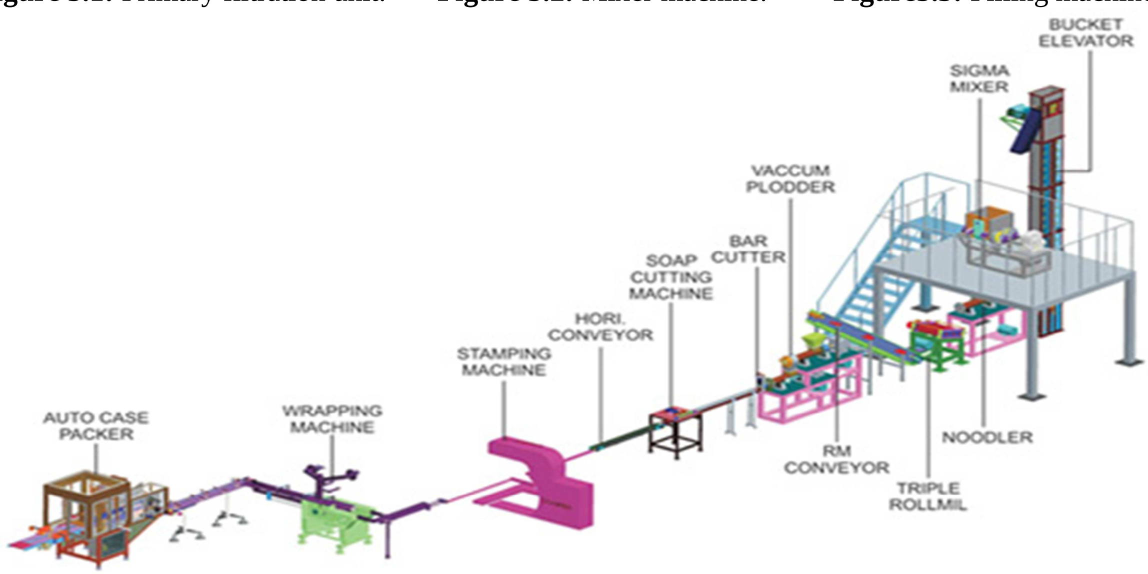

Figure 5.4: Bar soap planet.

Figure 5.5 shows machinaries, storage rooms and management office distribution and locations in the workshop.

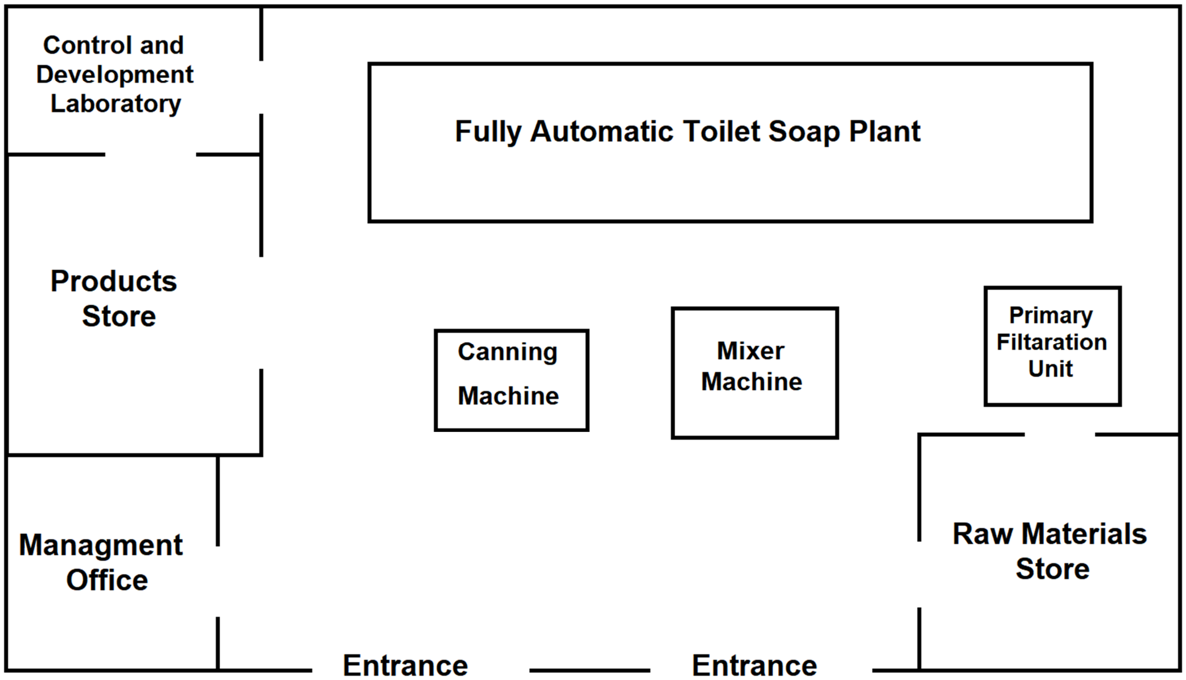

Figure 5.5: Machineries, storage rooms and management office distribution and locations in the workshop.

5.8 Quality Control and Development

This product may likely be exported, so, efforts shall be made to meet the internationally accepted standards with regards to scent, effect on skin, impurities, and thickness. To achieve this, testing kits shall be purchased and a mini-quality control and development laboratory shall be established. This entails employing a quality control officer that will be in charge of the mini laboratory. His mission is to develop and test produced soap.

Raw materials, the manufacturing process and the finished product shall undergo series of test to ensure the safety of the customers. The most important test is the test to ensure the product is not carcinogenic and eco-friendly raw materials are used in the manufacturing and packaging process.

5.9 Marketing of Product

1. The products (liquid detergent & bar soap) shall be sold directly to buyers and shops at the project site and other sites.
2. The distributor system shall also be employed.
3. Continuous effort shall be made to secure international market for the product.
4. The sales force shall be headed by an experienced marketing manager assisted by a team of enthusiastic salesmen.

5.10 Advertising and Promotion

The products shall be continuously advertised in electronic media such as radio and television both at the local and the national levels shall be extensively used to publicize the product. The company shall also engage in shows promotions to advertise the product. Another important way to advertise the products is to use the social media such as Facebook and Instagram which is considered as a cheaper and more effective way to advertise the products.

5.11 Pricing System

Because of the price influence of raw material, market demand and the volume of importation, the factory prices for the products and similar products are listed in Table 5.2.

Table 5.2: Prices for the products compared to similar products.

	Produced soap price (NIS)	Similar soap price (NIS)
Half liters of liquid soap	2.5	4
1 liter of liquid soap	5	7
2 liters of liquid soap	9	13
big bar soap (120 g)	2	90 g of bar soap is sold at 3 NIS while Nabulsi soap is sold at 2.5 – 4 NIS depending on size.
small bar soap (80 g)	1	

5.12 Production Turnover

The project shall run in a single shift (8.00am-6.00pm) system with a minimum production of 700 liters daily for liquid soap. By working for 24days in a month excluding Fridays, a minimum of 16,800 liters of liquid soap shall be produced in a month.

For the bar soap, a minimum of 500 bars of 120 g and 80 g will be produced daily and by working for 24days, 24,000 pieces will be produced monthly.

As demand of the product increases, the company shall improve on its turnover and two shift system shall be employed.

5.13 Limiting Factors

Here, it is important to highlight some of the practically experienced and envisaged factors that may occasionally have a relative impact on the project. Some of these factors are listed below.

1. Competition from other soap industries already in existence. However, the project shall handle this situation by producing at the lowest possible price and constantly being abreast with marketing information so as to respond to market fluctuations through appropriate adjustment of prices. This problem of competition shall also be resolved by constantly rebranding the product, constantly improving on the quality and through adequate advertisement.

2. Variations in the raw materials supplied. This could be due to ban on importation of the raw materials as a result of failing quality tests or as a result of transportation problems making the raw materials not to get to the manufacturers on time. This project shall solve this problem of variations in the availability of raw materials by bulk buying and proper storage of the raw materials.

3. Price variation of the finished product. There is always price variation for finished goods which may be as a result of government policies or a new company entering into production. One cannot sell a product below its production cost. Therefore, this project shall anticipate and forecast any price variation and then make adjustments before the forecast materialize.

4. Taxation. As the income is increasing, government taxation increases. This company will ensure it hires good tax consultants to deal with the issues of heavy taxation.

5.14 Risk Analysis

From the limiting factors analyzed, it is clear without reasonable doubt that the risk factors are at a minimal level. Thus, this project has about 90% chances of success if embarked upon.

5.15 Cost Estimate

Table 5.3: Fixed costs of the project.

	Items	Cost (NIS)
1.	Machines + Importation	500,000
2.	Vehicles	70,000
3.	Electrification	1,000
4.	Safety Equipment	10,000
5.	Office Equipment & Furniture	8,000
6.	Quality Control and development Laboratory	50,000
7.	Machines Installation	5,000
8.	Measuring Equipment	10,000
	Total	654,000

5.16 Labor Cost

Table 5.4: Labor required for the project and their cost.

	Number Required	Description	Monthly Salary Per Person (NIS)	Total Salary / Month (NIS)	Total Salary Per Annum (NIS)
1.	1	General Manager	3,000	3,000	36,000
2.	1	Sales Manager	2,500	2,500	30,000
3.	1	Quality Control Manager	2,500	2,500	30,000
4.	1	Accountant	2,000	2,000	24,000
5.	2	Driver	1,500	3,000	36,000
6.	4	General Labor	2,000	8,000	96,000
7.	1	Cleaner	1,000	1,000	12,000
		Total		22,000	264,000

Labor cost shall increase at the rate of 5% annually.

5.17 Projected Monthly Overhead Costs

Table 5.5: Project monthly overhead costs.

	Item	Cost per month (NIS)
1.	Shop for rent	500
2.	Transportation	1,500
3.	Maintenance & Repairs	1,000
4.	Advertisements	1,000
5.	Electricity	1,500
6.	Miscellaneous	1,000
	Total	6,500

5.18 Projected Monthly Production Cost (liquid soap)

Table 5.6: Projected Monthly Production Cost for liquid soap.

	Description	Amount/Month (NIS)
1.	Raw Materials for liquid detergent	50,400
2.	Packaging Cost	800
3.	Salaries	11,000
4.	Overhead Cost	3,250
	Total	65,450

5.19 Projected Monthly Production Cost (bar soap)

Table 5.7: Projected Monthly Production Cost for bar soap.

	Description	Amount/Month (NIS)
1.	Raw Materials for bar soap	12,000
2.	Packaging Cost	400
3.	Salaries	11,000
4.	Overhead Cost	3,250
	TOTAL	26,650

5.20 Projected Yearly Turnover and Profit Margin

At the production capacity of 700 liters per day and 16800 liters per 24 working days in a month, it will yield 201600 liters per annum.

And if the cost of producing 1 liter of liquid soap is 2.3 NIS and the selling price is 6 NIS then the annual profit can be calculated as follow:

Table 5.8: Yearly costs and profits of liquid soap line production.

		Raw Materials	Finished Product (80% of Raw Materials)
1.	Quantity	241,920 liters	201,600 liters
2.	Cost	556,410 NIS	1,008,000 NIS

Gross Profit = 1,008,000 NIS – 556,410 NIS = 451,590 NIS /yr.

Overhead Cost is 48,600 NIS (Annual cost without raw materials and salaries)

NET PROFIT = 451,590 – 48,600 = 402,990 NIS

Thus, the line of liquid soap can make an annual profit of **402,990 NIS**

At the production of 500 bars of soap per day, 12,000 bars will be produced per month and 144,000 bars per annum.

And if the cost of producing 1 bar 0.5 NIS and the selling price is 1.5 NIS then the annual profit can be calculated as follow:

Table 5.9: Yearly costs and profits of bar soap line production.

		Raw Materials	Finished Product (80% of Raw Materials)
1.	Quantity	172,800 bars	144,000 bars
2.	Cost	86,400 NIS	216,000 NIS

Gross Profit = 216,000 NIS – 86,400 NIS = 129,600 NIS /yr.

Overhead Cost is 43,800 NIS

NET PROFIT = 129,600 – 43,800 = 85,800 NIS

Thus, the line of bar soap can make an annual profit of **85,800 NIS**

Thus, annual profit of the two lines is 488,790 without the salaries, and by adding salaries to the calculations we got:

488790 – (22,000 × 12) = **224790 NIS/yr.**

5.21 Payback Period and Cash Flow

Table 5.10: Yearly cash flow for the project.

	Cash Flow (NIS)	Net Cash Flow (NIS)
Year 0	-654,000.00	-654,000
Year 1	224,790.00	-429,210
Year 2	224,790.00	-204,420
Year 3	224,790.00	20,370
Year 4	224,790.00	245,160

Payback Period: **2.909 years**

Return for the Cash Flow: **21.26% per year**

5.22 Conclusion

From the above analysis and subsequent computation, it is very clear without reasonable doubt that soap production from WCO for both domestic and industrial uses is a very feasible and viable project. What makes it really profitable is that the main raw material (WCO) is available with almost non-mentionable cost.

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Appendices

Appendix A

جامعة بوليتكنك فلسطين

كلية الهندسة

هندسة تكنولوجيا البيئة

استبيانة :مسح ميداني لكميات ونوعيات الزيوت المستخدمة في المطاعم

حضرات السادة المحترمين

تحية طيبة وبعد:

يقوم طلاب هندسة تكنولوجيا البيئة بعمل مشروع تخرج حول الزيوت النباتية المستخدمة ، ويقوم الطلاب بجمع المعلومات اللازمة حول السوق ، فنرجو التعاون في تعبئة هذه الاستبانة لأغراض بحثية علمية، مع العلم أنه سيتم الحفاظ على سرية المعلومات المزودة من قبلك، شاكرين لكم تعاونكم.

الباحثان الطالبان:أحمد خضور،محمد نواجعة.

1- ما هي أنواع الزيوت التي تستخدمونها ؟

-عباد الشمس - زيت الذرة -فول الصويا - أخرى -اذكرها : ....

2- ما هي كمية الزيوت التي تتخلصون منها يومياً ؟

....

3- هل تستخدمون الزيوت بعد انتهاء العمل منها ؟ وان وجد أين تستخدمونها ؟

....

4- أين يتم التخلص من الزيوت المستخدمة ؟

....

....

5- هل هناك جهات تتعامل مع الزيوت المستخدمة -ان وجدت -؟

....

6- اذا وجد من يشتري الزيوت المستخدمة ، كم السعر لكل لتر او قلن ؟

....