WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

BIODIESEL PRODUCTION FROM AVOCADO PEELS

A final year project submitted to the wolkite university college of engineering and technology department of chemical engineering in partial fulfillment of the requirement for the degree of bachelor of science in chemical engineering (process engineering stream).

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This is to certify that the project by Yasin Hussen, Seifedin Rdewan, Hamida Mohammode, Sewida Sadik and Jelalu Wane, entitled "Production of Biodiesel from avocado peels" and submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Chemical engineering (Process engineering stream). Complies with the regulation of the University and meets the accepted standards with respect to originality and quality.

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Abstract

The depletion and environmental problems associated with fossil fuels as main energy source motivates to look for alternative energy sources that is renewable and environmentally friendly. Biodiesel is an alternative energy source that is produced from biomass. It is renewable, sustainable, and non-toxic type of energy fuel. The main objective of this project was biodiesel production from avocado peels. Avocado peel oil was first extracted to produce biodiesel. For this, particle size of 0.25 mm-0.5 mm, solvent type hexane and time 3 hrs. were used for Soxhlet extraction and 35.5% of oil yield was obtained. A transesterification production method was selected and used to produce biodiesel from avocado peel oil using methanol and NaOH as a catalyst. To produce biodiesel, 66.15 g of sample avocado peel oil, 19.78 g of methanol and 5 g of NaOH were used in transesterification process. A maximum of 56.81 g of pure biodiesel was obtained. The physiochemical properties (density, pH, API, specific gravity, acid value and FFA) of the produced biodiesel were determined. It was found that all the physicochemical properties are within the standards. From the produced biodiesel it was concluded that the produced biodiesel is an important alternative fuel and it possesses properties like renewability, non-toxicity, biodegradability and environmentally friendly. It is recommended that further studies should be done on the physicochemical properties and factories that affect the yield of biodiesel. Biodiesel produced from avocado peel oil is economically feasible. The economic feasibility of this project was tested by using feasibility test. The study showed that, a total capital need to install the plant is $1,039,903.77/year and its pay back and return on investment are 2.31 year and 32% respectively.

Key words: Trans esterification, biodiesel, energy, avocado peels.

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List of acronyms and abbreviations

BD	Biodiesel
GL	Glycerin
CAT	Catalyst
IMP	Impurities
METH	Methanol
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
B100	Pure Biodiesel
B5	5 vol.% Biodiesel and 95 vol.% petroleum
B20	20 Vol.% Biodiesel And 80 Vol. % Petroleum- Based Fuel Blend
Cp	Specific heat capacity
CSTR	Continuous Stirred Tank Reactors
CO_2	Carbon dioxide
EN14214	European Standards for Biodiesel
EPA	Environmental Protection Agency
FA	Fatty Acid
FAME	Fatty Acid Methyl Esters
FCI	Fixed Capital Investment
FFA	Free Fatty Acid
GHG	Greenhouse Gas
H	Enthalpy
HC	Hydrocarbon
Hf	Heat of formation
Hr	Heat of reaction
Hfrr	High frequency reciprocating rig
KOH	Potassium Hydroxide
NaOH	Sodium Hydroxide
NO_X,SO_X	Nitrogen Oxide, Sulfur Oxide
NPW	Net Present Worth

CHAPTER ONE

1. Introduction

1.1. Background

Biodiesel is the most promising alternative diesel fuel and the challenging of energy problem and sustainability in our today's world increases the number of population and sustainability have been problems due to the industrial revolution. Since it has received considerable attention due to it's a renewability, reliable, secure, biodegradability, clean, environmental eco-friendly, nontoxicity, energy efficient, less emission of gaseous and sustainable energy resource substitution of fuel which can fulfill energy security needs without sacrificing engine's operational performance thus it provides a feasible solution to the twin crises of fossil fuel depletion and environmental degradation (Alimova, 2016).

It meets the currently increasing huge demands of world energy which is dependent on petroleum based fuel resources. However, energy is often known as the primary success for a country's development. It is often used as an indicator to measure the level of economic growth in a country. The occurrence of oil depletion, global warming and the greenhouse effect has become an alarming condition where it is needed to search for an alternative energy source (Carmen Leonor, 2005).

Biodiesel is a renewable and biodegradable fuel to ensure the sustainability of energy resources, and produced from a wide range of naturally occurring fats and oils by a transesterification reaction in which the triglycerides are broken down and fatty acid methyl esters (FAMEs) are formed. The fatty acid distribution of the original oil is retained in the biodiesel, thus the physical and chemical properties of the biodiesel have some dependence on the feedstock used (Marchetti et al, 2007).

Biodiesel is a good alternative fuel for internal combustion engines, is defined as a mixture of mono alkyl esters of long chain fatty acids (FAME) derived from a renewable feedstock, such as vegetable oil or animal fat, which is one of the most promising energy sources for our country (Demirbas, 2002).

Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol through transesterification reaction.

The reaction requires a catalyst, usually a strong base, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters or known as biodiesel. It is a carbon free fuel because there is no overall increase in CO2 in the atmosphere due to recycling by the growing plants used to feed the biodiesel industry. Emissions of SO2, SO3, CO, unburnt hydrocarbons and particulate matter are lower than that of petroleum diesel (R.Sattanathan, 2013).

The most common process used to produce biodiesel is through transesterification, a reaction between triglycerides and an alcohol with a low molecular weight (ethanol or methanol) in the presence of a basic catalyst (NaOH or KOH), to obtain esters and glycerol. Biodiesel is a renewable fuel which is produced from vegetable oil or animal fat through a chemical process called transesterification and can be used as either direct substitute, extender or as an additive to fossil diesel fuel in compression ignition engines (John, 2003).

The most promising feature of biodiesel is that it can be utilized in existing design of diesel engine with no or very little modifications. It has a proven performance for air pollution reduction. Biodiesel is typically produced through the reaction of vegetable oils or animal fat with methanol or ethanol in the presence of catalyst to yield glycerol as major by- product and biodiesel chemically called methyl or ethyl ester. However, the price of biodiesel is presently more as compared to petro diesel, since higher cost of biodiesel is primarily due to the raw material cost (Ma, F, L.D., Hanna,& M.A., 1999).

There are different types of feed stocks that are used for the production of biodiesel. These includes linseed oil, palm seed oil,waste cooked vegetable oil, sunflower seed oil, cotton seed oil, jatropha seed oil, castor beans oil and animal fats. Avocado peel oils are used for the production of biodiesel through the process called transesterification reaction which is a process by which alcohol reacts with vegetable oil in the presence of catalyst (John Duncan, 2003).

Avocado peel is a waste where so many people are throwing away after using the fruit flesh. It is one of the most popular fruit in Ethiopia as a result there is a significant rise in avocado fruit consumption and consequently an increase in the avocado peel waste generation. Therefore, alternative routes are needed for this waste management.

This waste cannot be used still for any consumption. The presence of nitrogen allows it to be directly used as fertilizer or as soil improver (or compost) (John Duncan, 2003).

On the other hand, waste avocado peels have oil content of 8-40 % which can be used for biodiesel production. Avocado peels are used to evaluate the possibility of using and transforming waste to something valuable product, namely biodiesel there by contributing towards alternative energy supply as well as recycles what would be discarded and resolves energy scarcity. In Ethiopia, there are many small scales (juice house) and large scale juice processing industries, one of the byproduct of this industry is avocado peels (S. D. Romano and P. A. Sorichetti, 2011).

1.2. Statement of the Problem

Due to an increase in population growth, finding an alternative fuel source for producing valuable products is becoming crucial thing at presents. In our today's world the issues of energy shortage resulting from the depletion of world petroleum reserves, increase of petroleum prices and environmental concerns has initiated the government to look for alternative renewable energy sources that are technically feasible, economically competitive and environmentally acceptable.

A more convenient way is to use by- products (wastes) as potential sources due to not only reduce the cost of production but also reduced health effect, since lack of proper management of fruit waste and not properly disposed this waste creates environmental problems in our country. A considerable amount of waste ends up in open dumps or drainage system, affecting both surface water and ground water.

Avocado peels waste largely obtained from hotels, restaurants and juice processing houses as a by-product in our country. Since this wastes can cause environmental problems unless they change or convert into some useful products or disposed properly. Our country spends about birr10 billion annually to import petroleum products for domestic consumption (Alimova, 2016). A convenient way to lower the cost of biodiesel is to use the by-product like cheaper feedstock (waste like, avocado peel oil) as a potential source of energy, rather than treat them as waste. This can be used to improve the economics of biodiesel which will lower the price of petroleum diesel.

1.3. Objective

1.3.1. General objective

The general objective of this project was to produce and characterize biodiesel from avocado peels oil.

1.3.2. Specific objectives;

- To extract the oil from the avocado peels by using Soxhlet extraction method.
- To characterize the physicochemical properties of extracted oil.
- To characterize the physicochemical properties of produced biodiesel.

1.4. Significance of the study

The significance of production of biodiesel from avocado peel are;

- The produced biodiesel will be used as energy for diesel engines.
- The production of biodiesel from avocado peel can also be helpful to create job opportunity for local community.
- The production of biodiesel from avocado peel will contribute for minimizing environmental pollution, since avocado peels are one the waste of juice processing industries. And also generate income for juice processing industries.
- The produced biodiesel will be less pollutant as compared to petrol diesel.

1.5 Limitation of the study

- In this project the factors that affect oil yield (particle size, temperature, solvent and time) was not investigated because of the following reason:
    - Materials/equipments like sieve was available to investigate the of particle size.
    - The heater used for extraction was un adjustable, so difficult to investigate the effect of temperature.
    - Due to lack of soxhlet equipments and the existed soxhlet equipment capacity is not greater than 25 g per extraction, one group not wait for more than 3hr. in extraction room.
    - Because of this the factors were not investigated, but for one trial extraction particle size, solvent, temperature and time was taken based on literatures which give maximum oil yield.

- The project does not address all the characterization of physiochemical properties because of lack of measuring equipments and chemicals.

1.6 Scope of the study

The work presented in this project is the production of biodiesel from avocado peels oil based on the availability of raw material. Utilization of crude avocado peels oil for production of biodiesel will prevent further wastage of already existing resources and use of environmentally friend fuel will create cleaner environment. The main scope of this thesis was mentioned as the following:

- ✓ Avocado peel collection
- ✓ Oil extraction and study of physiochemical characterization of extracted oil.
- ✓ Study of methods employed in production of biodiesel, i.e. trans-esterification
- ✓ Characterization of the produced biodiesel.
- ✓ Determination of loss and products using energy and material balance based on laboratory results.
- ✓ Equipment sizing and Economic analysis of biodiesel plant
- ✓ Studying the environmental impact and giving recommendation

CHAPTER TWO

2. LITERATURE REVIEW

2.1 OVERVIEWS OF BIODIESEL

Biodiesel is a renewable fuel, non-toxic and biodegradable. It is a good alternative for conventional fossil diesel fuel since it has similar properties as shown in table 2.1. However, it requires the use of additives to be suitable for motor fuel in order to overcome oxidation processes limitations (Khurshid, 2014).

Table 2.1: Comparison between biodiesel and petro diesel properties (Khurshid, 2014).

Types	Density at 20°C	Viscosity at 20°C (mm2/s)	Cetane Number	LHV (MJ/Kg)	Fuel eqv.
BD	0.88	7.5	56	37.1	0.91
DIESEL	0.83	5.0	50	43.1	1

The main feed stocks for the biodiesel production process through transesterification process (reversible reaction) are vegetable oils, waste cooking oil and animal fats. The reaction uses to be carried out in batch reactor provided with controlled heating and mixing process system. Biodiesel has been produced in EU since 1992. The annual production was up to 6,100,000 tones with about 120 production plants in the EU. From this, Austria, Germany, Italy, France and Sweden are the main producers of biodiesel in EU. The use of 1 kg biodiesel leads to a reduction of about 3kg of CO2 emissions. Since, the use of biodiesel leads to a significant reduction in CO2 emission from 65% to 90% less compared with the use of conventional diesel (Khurshid, 2014).

Biodiesel is an alternative fuel, which can be produced from renewable sources such as vegetable oils. It is biodegradable and nontoxic has low emission profiles and environmentally beneficial. The strongest motivation for increasing of production and consumption of biodiesel is environmental issues. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression-ignition (CI-diesel) engines with little or no modifications (Akhtar, 2011).

2.2 History of Biodiesel

Dr. Rudolf Diesel, who invented the first Diesel Engine in 1895, used only biofuel in his engine. His visionary statement was “The use of vegetable oils for engine fuel may seem insignificant today, but such oils may become in course of time, as important as petroleum and coal tar products of the present time”. The above prediction is becoming true today as more and more 'biodiesel is being used all over the world (Gerhard, Jon Van and Jurgen Krahl, 2005).

Dr. Rudolf Diesel invented the diesel engine to run on a host of fuels including coal dust suspended in water, heavy mineral oil, and, vegetable oils. Dr. Diesels showed his first engine experiments at the world exhibition in Paris in 1900; his engine was running on 100% peanut oil. In 1911 he stated "the diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries, which use it". In 1912, Diesel said, "the use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time". Since Dr. Diesel's untimely death in 1913, his engine has been modified to run on the polluting petroleum fuel, now known as "diesel". Nevertheless, his ideas on agriculture and his invention provided the foundation for a society fueled with clean, renewable, locally grown fuel. (Gerhard, Jon Van and Jurgen Krahl, 2005).

2.3 Biodiesel as a source of renewable energy

Biodiesel is a renewable, biodegradable, non-toxic, sulfur-free, and environmentally clean alternative diesel fuel. Biodiesel is composed by fatty acid methyl esters, produced from renewable resources, such as vegetable oils, animal fats, and waste restaurant greases. One of the attractive characteristics of biodiesel is that its use does not require any significant modifications to the diesel engine, so the engine does not have to be dedicated for biodiesel. Biodiesel has lower emissions than petroleum diesel and it does not contribute to a rise of the net concentration of carbon dioxide in the atmosphere and leads to minimize the intensity of greenhouse effects (Alimova, 2016).

Biodiesel is the type of biofuel and it can be produced by transesterification process from vegetable oil or animal fat. Biofuels appear to be more environment friendly in comparison to fossil fuels considering the emission of greenhouse gasses when consumed.

Examples of those gasses are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Those gasses pose risks as they tend to warm the earth‟s surface‟ (Randelli, 2007). The energy content of biofuels differs from conventional fuels. Total energy output per liter of biofuel is determined by the feedstock used, region where the feedstock is grown and production techniques applied (Duti et al, 2016).

Biodiesel production is a very modern and technological area for us as an alternative fuel for diesel engines because of the increase in the petroleum price, its renewability and the environmental advantages. Currently, the cost of biodiesel is high as compared to conventional diesel oil because most of the biodiesel is produced from pure vegetable oil (R.Sattanathan, 2015).

Proper utilization of agricultural waste like fruit peels to produce biodiesel is a promising approach to ensure environmental protection and energy security in this era of energy crisis. Due to the depletion of petroleum reserves and the environmental impact of using fossil fuel, it is necessary to look for an alternative source of fuel. Biodiesel, derived from vegetable oil or animal fats, can be a substitute of petroleum based diesel and considered as renewable energy source. It is estimated that biodiesel could replace approximately 10% of diesel fuel consumption within Europe and 5% of Southeast Asia's total fuel demand. Since compared to commercial diesel, biodiesel is environment friendly because of its sulphur free benefit and non-toxicity, lower greenhouse gas emission and higher flash point (Duti et al, 2016).

Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil. It is a nontoxic, biodegradable, and renewable fuel that can be used in diesel engines with little or no modification. The use of biodiesel for transportation applications are a relatively new phenomenon but is gaining acceptance and growing rapidly (R.Sattanathan, 2013).

2.4 Properties of biodiesel

Biodiesel is a clear amber-yellow liquid with a viscosity similar to that of petro diesel. Biodiesel is non-flammable and, in contrast to petro diesel, is non-explosive, is biodegradable and nontoxic, and it significantly reduces toxic and other emissions when burned as a fuel. The most important parameters affecting the ester yield during the transesterification reaction are the molar ratio of alcohol to oil and reaction temperature.

The viscosity values of oil methyl esters decrease sharply after transesterification. Biodiesels are characterized by their viscosity, density, cloud and pour points, flash point, pH, sulfur content, free fatty acid, acid value, and higher heating value (HHV) (Ma F, Hanna MA. 1999).

Table 2.2 Technical properties of biodiesel (Vazquez, 2014)

Common name	Biodiesel (BD)
Common chemical name	Fatty acid methyl ester
Chemical formula range	C_{14}–C_{24} methyl esters or $C_{15\text{-}25}H_{28\text{-}48}O_2$
Kinematic viscosity range (mm^2/s, at 40°C)	3.3–5.2
Density range (kg/m^3, at 15°C)	860–894
Boiling point range (°C)	> 202
Flash point range (°C)	147–177
Vapor pressure (mm Hg, at 25°C)	< 5
Solubility in water	Insoluble in water
Physical appearance	Light to dark yellow, clear liquid
Odor	Light musty/soapy odor
Biodegradability	More biodegradable than petroleum diesel
Reactivity	Stable.

Table 2.3: Availability of modern transportation fuel (Vazquez, 2014)

Fuel type	**Availability**	
	Current	**Future**
Gasoline	Excellent	Moderate-poor
Biodiesel	Moderate	Excellent
Compressed natural gas (CNG)	Excellent	Moderate
Hydrogen fuel cell	Poor	Excellent

2.5 Typical Oil Crops Useful for Biodiesel Production

Jatropha

Jatropha it is shrub that adapts well to arid environments Jatropha curcas is the most known variety; it requires little water or additional care; therefore, it is adequate for warm regions with little fertility. Productivity may be reduced by irregular rainfall or strong winds during the flowering season. Yield depends on climate, soil, rainfall and treatment during sowing and harvesting. Jatropha plants become productive after 3 or 4 years, and their lifespan is about 50 years. Oil yield depends on the method of extraction; it is 28–32% using presses and up to 52% by solvent extraction (S. D. Romano and P. A. Sorichetti, 2011)

Soybean

Soybean it is a legume originating in East Asia. Depending on environmental conditions and genetic varieties, the plants show wide variations in height. Leading soybean producing countries are the United States, Brazil, Argentina, China, and India. Biodiesel production from soybean yields other sub-products in addition to glycerin, soybean meal and pellets (used as food for 8 livestock) and flour (which have a high content of lecithin, a protein). Grain yield varies between 2,000 and 4,000 kg/hectare. Since seeds are very rich in protein, oil content is around 18% (S. D. Romano and P. A. Sorichetti, 2011).

Cottonseed

Cottonseed non-foodstuffs, cotton are the most widely traded commodity. In cotton mills, fiber and seeds are separated from raw cotton. Cotton fiber is processed to produce fabric and thread, for use in the textile industry. In addition, cotton oil and flour are obtained from the seed; the latter is rich in protein and is used in livestock feed and after further processing, for human consumption. The cottonseed has 18% up to 26% of oil (S. D. Romano and P. A. Sorichetti, 2011).

Castor bean

Castor is an industrial oilseed which contains more than 45% oil, which is rich (80– 90%) in an unusual hydroxyl fatty acid, ricinoleic crop grown worldwide. Its oil with more than 80% ricinoleic acid makes it a chief raw material for numerous industrial applications and biofuel production. The comparative advantage of Castor is that its growing period is much shorter than above listed crops (R.Sattanathan, 2015). A study was reported in Indian context that if 10% of total production of castor seed oil is transesterified into biodiesel, then about 79,782 tons of CO2 emission can be saved on annual basis. The CO2 released during combustion of biodiesel can be recycled through next crop production, therefore, no additional burden on environment (R.Sattanathan, 2013).

2.6 Avocado and Avocado peels

Avocado peel (persea Americana) is a waste where so many people are throwing away after using the fruit flesh. It is one of the most popular fruit in Ethiopia as a result there is a significant increase in avocado fruit consumption and consequently an increase in the avocado peel waste generation. Therefore, alternative routes are needed for this waste management. This waste can be used for various applications. Avocado contain from 5 to 40% oil, the percentage varying with the variety, growing area and seasonal conditions. Only ripe olives have higher oil content (Faris, 2016).

Avocados are one of the few fruit that contain significant quantities of oil. Oil content is a key part of the sensory quality. Oil quality is very similar to that of olive oil. However, avocado peel is one of the waste materials removed from avocado fruit. In some causes it is used for animals consumption and having all properties of avocado. The avocado fruit comprises a dark green peel, green oily pulp and a large seed which represents 10-22% of the total weight depending on the species. The peel (skin) is mainly composed of moisture, while the remaining 10% is lipids, proteins, ashes, fibre and others (Zekarias Shumeta, 2010).

Table 2.4 Physicochemical parameters of the different fractions of the avocado (Vazquez, 2014)

Parameter	**Pulp**	**Skin**	**Seeds**
Moisture (%)	70.83±3.53	69.13±2.58	54.45±2.33
Ash (%)	1.77±0.16	1.50±0.08	1.29±0.03
Proteins (%)	1.82±0.07	1.91±0.08	2.19±0.16
Fat (%)	43.5±4.62	2.20±1.65	14.7±0.32
Total soluble solids	43.5±4.62	3.01±2.03	3.54±1.97
Acidity	1.07±0.02	2.05±0.24	2.67±0.17

The results indicate in the above table has avocado skin has the second water content (69.13%) next to pulp (70.83%), and followed the seed (54.45%).

2.7 Methods for extraction of oil

In generally, there are three different methods for extraction of oil: mechanical extraction, solvent extraction, and Soxhlet extraction method (Henry, 1983).

2.7.1 Mechanical extraction method

Oils can be removed via mechanical extraction, termed "crushing" or "pressing." This method is typically used to produce the more traditional oils (e.g., olive, coconut etc.), and it is preferred by most "health-food" customers in the United States and in Europe. There are several different types of mechanical extraction. Expeller-pressing extraction is common, though the screw press and powered mortar and pestle are also used. Oil seed presses are commonly used in developing countries, among people for whom other extraction methods would be prohibitively expensive (Kiakalaiehn P et al, 2013).

The mechanical extraction method is effective for peels or seeds contain 30-70% oil. This method has several advantages compared to the other methods, such as simple equipment and low investment, low operating cost, and the oil does not undergo solvent separation process. However, the oil produced with this method usually has a low price, since it's turbid and contains a significant amount of water and metals contents. Due to low oil content of feed stocks it is not advisable to extract the oil using mechanical extraction (John, 2003).

2.7.2 Solvent extraction method

Solvent extraction is the transfer of solutes from a solid, usually in particulate form, to contiguous liquid, the extract (Henry, 1983). If the solute is uniformly dispersed in the solid, the material near the surface will be dissolved first, leaving a porous structure in the solid residue. The solvent will then have to penetrate this outer layer before it can reach further solute and the process will become progressively more difficult and the extraction rate will fall. If the solute forms a very high proportion of the solid, the porous structure may break down almost immediately to give a fine deposit of insoluble residue, and access of solvent to the solute will not be impeded (Richardson et al, 2002). Solvent extraction with peels containing only about (12 - 16) per cent of oil, solvent extraction is often used because mechanical methods are not very efficient (Duti, 2009)

The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material. In the case of mechanical pressing the residual oil left in the oil cake may be anywhere from 6% to 14%. The solvent extraction method can be applied directly to any low oil content raw materials. Because of the high percentage of recovered oil, solvent extraction has become the most popular method of extraction of oils and fats (Henry, 1983).

The advantages of solvent extraction over other methods of oil expression include, higher oil yield (about 95% of the oil content could be obtained), larger processing capacity, solvent extraction also gave oil that many considered to be of superior bleaching quality, lower refining losses, reduced susceptibility to rancidity and better retention of fat - soluble vitamin (Henry, 1983).

2.7.3 Soxhlet Extraction method

A Soxhlet extractor is a piece of laboratory designed equipment for processing certain kinds of solids invented in 1879 by Franz von Soxhlet. Soxhlet extraction is a process used for liquidsolid extractions, especially for compounds with limited solubility in a solvent (Meyer and Terry, 2008). According to the Soxhlet procedure, oil from solid material are extracted by repeated washing (percolation) with an organic solvent usually n-hexane under reflux in a special glassware. Because an avocado peel has low solubility in the solvent (n-hexane), the Soxhlet was the most suitable extraction technique. Specifically, the sample is dried and milled into small particles and placed in a porous thimble.

If the desired compound has a significant solubility in a solvent then a simple filtration can be used to separate the compound from the insoluble substance (Henry, 1983).

Avocado peel powder is placed inside a thimble made from thick filter paper, which is loaded into the main chamber of the Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing the extraction solvent. The Soxhlet is then equipped with a condenser. The thimble is placed in an extraction chamber, which is suspended above a flask containing the solvent, and a condenser is placed on top of the extraction chamber. After extraction the solvent is removed, typically by means of a rotary evaporator, yielding the extracted oil. The non–soluble portion of the extracted solid remains in the thimble, usually discard (Chemat et al., 2008).

Table 2.5 Advantage and disadvantage of Soxhlet extractor

Advantage	**Disadvantage**
Long experience of use	Long extraction time (hours)
A displacement of transfer equilibrium occurs as the solid is continuously exposed to fresh solvent.	Considerable solvent consumption.
High extraction temperature enables exhaustive recovery of interest.	Non selective extraction
Simple to operate	Risk of thermal decompositions as the extraction is conducted at the boiling point of the solvent.
Economical	Only temperature, extracted time and solvent type can be Varied.

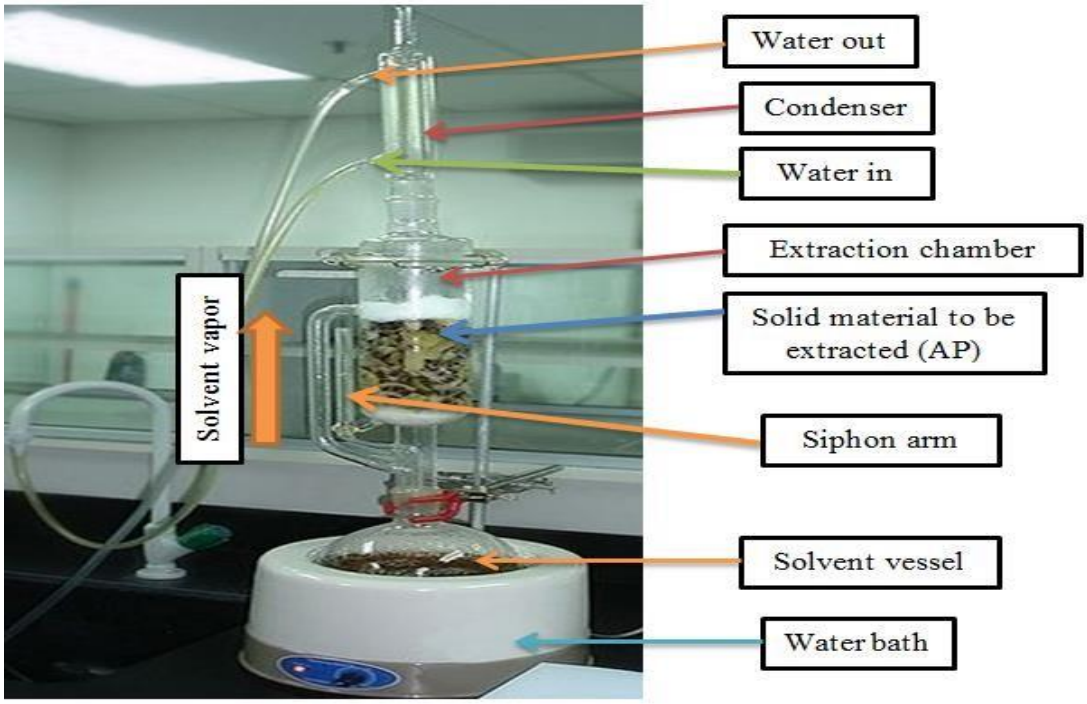


Figure 2.1 Soxhlet extractor set up

2.8 Current Technologies in Biodiesel Production

2.8.1 Pyrolysis (cracking) method of Biodiesel production

The pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. Or thermal cracking or pyrolysis is the process that causes the break of the molecules by heating at high temperatures that is, by heating of the substance in the absence of air or oxygen in temperature superior to 450°C, forming a mixture of chemical compounds with properties very similar to those of petro diesel. In some situation that process is supported by a catalyst for the break of the chemical connections, in order to generate smaller molecules (Sonntag, 1979b). Typical catalysts to be used in pyrolysis are the silicon oxide SiO2 and aluminum oxide Al2O3(Kiakalaiehn, 2013).

The equipment for Pyrolysis is expensive. However, the products are chemically similar to diesel oil. The removal of the oxygen of the process reduces the benefits of an oxygenated fuel, reducing its environmental benefits and usually producing a fuel closer to gasoline than diesel. Pyrolysis has great applicability in places that need smaller production volume and with smaller availability of qualified work (Khurshid ,2014).

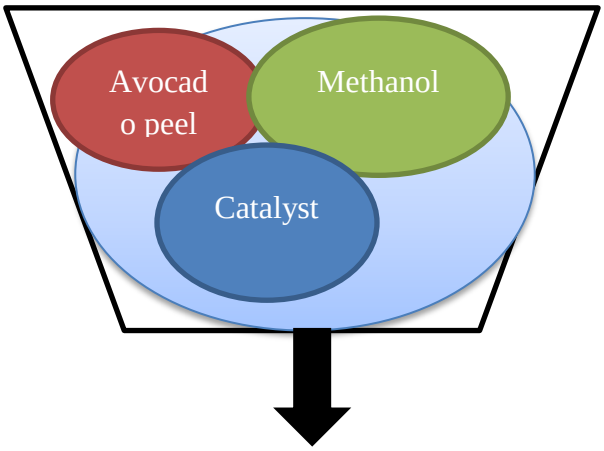
The liquid fractions of the thermally decomposed vegetable oils are likely to approach diesel fuels. The pyrolyzate has a lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values. The cetane number of the pyrolyzate is lower (Gerhard, Jon and Jurgen ,2005).

2.8.2 Micro-Emulsification Method of Biodiesel Production

The formation of micro emulsion is one of the potential solutions for solving the problem of vegetable oil viscosity. To solve the problem of the viscosity of vegetable oils, micro emulsion with solvents such as methanol, ethanol and 1-butanol have been used (Duti, (2009). A micro emulsion is defined as thermodynamically stable, isotropic liquid mixture of oil, water and surfactant (compounds that lower the surface tension of a liquid, the interfacial tension between two liquids) (Pryde, 1984b). Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersion. The droplet diameters in micro-emulsions range from 100 to 1000 Å. All micro-emulsions with butanol, hexanol and octanol met the maximum viscosity requirement for diesel fuel (Tafere (2018).

2.8.3 Transesterification Method of Biodiesel Production

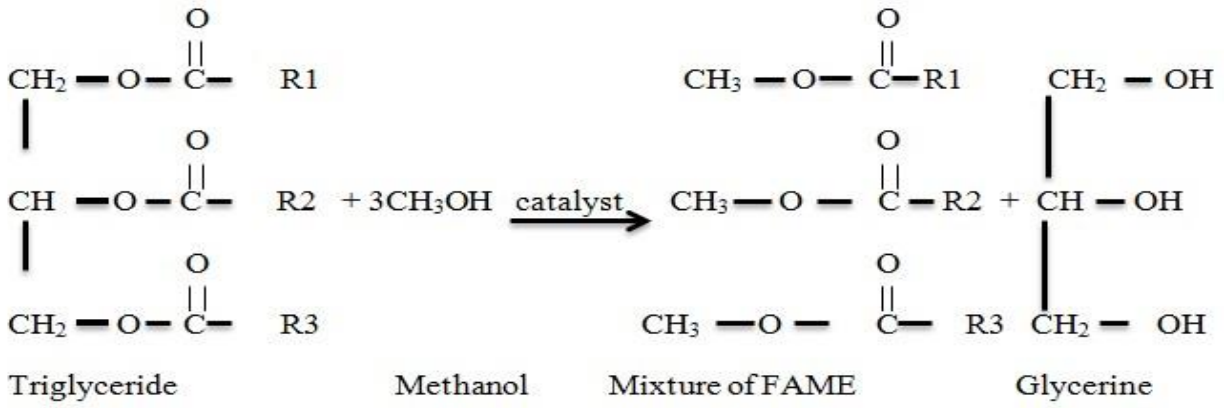
The most common way and the accepted processes to biodiesel production are by transesterification process by which to catalyze chemical reaction involving vegetable oil and an alcohol in the presence of a catalyst, to produce fatty acid alkyl esters and glycerin. A byproduct of transesterification reaction is glycerin, also known as glycerol. The most common alcohol, which is used in biodiesel production is methanol, another name for biodiesel is fatty acid methyl esters (FAME) (Alimova, 2016).



Biodiesel + glycerin

Figure 2.2 Catalytic transesterification

The mixture (NaOH + methanol) is then added to the pre-heated warm oil (normally to about (50-65°C), also with stirring for (45-90min), to undergo the transesterification reaction. The reaction mixture is normally maintained above the boiling point of the alcohol, but in some systems for safety reasons it is recommended to maintain the temperature range from room temperature to 55°C. To prevent evaporation of the alcohol the reaction should be carried out in a closed container, but it is important to avoid a sealed system (because of risk of explosion) (Alimova, 2016). According to stoichiometry, three moles of methanol reacts with one mole triglyceride to produce three moles of fatty acid methyl ester (FAME) and one mole of glycerine as shown in the following reaction.



Transesterification reaction significant reduces the viscosity of vegetable oils without affecting the heating value of the original fuel.

Therefore, fuel combustion and emission characteristics will display better results than pure vegetable oils are used in engines. Alcohols that can be used in the transesterification reaction are methanol, ethanol, propanol, butanol, and amyl alcohol. From these methanol is most commonly alcohol used for the transesterification reaction (Demirbas, 2009).

Moreover, the catalyst NaOH quickly reacts with triglycerides and is easily dissolved in it. In this case, the reaction is referred to as methanolysis. In generally the stoichiometry of methanolysis reaction requires 3 mole of methanol and 1 mole of triglyceride to give 3 mole of FAME and 1 mole of glycerol (Kiakalaiehn, 2013). This reaction, in turn, consists of three consecutive reversible reactions with intermediate formation of triglycerides and monoglycerides. After the reaction completed, the glycerol is separated by settling or density difference.

Transesterification reactions are basically of three types of catalysts used (i.e. alkali, acid and enzyme based), alkali based catalysts are most widely used in industrial processes because it is more cost effective and less corrosive to the industrial equipment (Alimova, 2016). The third one is expensive and relatively slow than the first two (Marchetti et al, 2007).

2.8.4 Blending Method of Biodiesel Production

In this method, vegetable oils are directly mixed with the diesel (Bortolomew, 1981)

The advantages of vegetable oils as diesel fuel are:

- Liquid nature-portability
- Heat content (80% of diesel fuel) ready availability
- Renewability

The disadvantages are:

- Higher viscosity
- Lower volatility
- The reactivity of unsaturated hydrocarbon chains

2.9 Selection criteria of Biodiesel production method;

Trans esterification biodiesel production is selected due to the following reason:

- Transesterification significantly reduces the viscosity of vegetable oils without affecting the heating value of the original fuel.
- Biodiesel preparing by Trans esterification process does not need to modify diesel engine before using the biodiesel.
- The physical properties of biodiesel produced by this simple process are very close to the petroleum diesel fuel.
- Low temperature and pressure.
- High yields and short reaction times.
- Direct conversion process.
- Simple in operation and environmentally friendly.

2.10 Catalyst used for Transesterification

2.10.1 Transesterification using basic catalyst

In the alkali or basic process sodium hydroxide (NaOH) or potassium hydroxide (KOH) is used as a catalyst along with methanol. Initially, during the process, alcoxy is formed by reaction of the catalyst with alcohol and the alcoxy is then reacted with any vegetable oil to form biodiesel and glycerol. This process is the most efficient and least corrosive of all the processes and the reaction rate is reasonably high even at a low temperature of 60 °C (Randelli, 1986).

For an alkali-catalyzed transesterification, the glycerides and alcohol must substantially anhydrous (Wright et al,1944), because water makes the reaction partially change to saponification, which produces soap. The soap lowers the yield of esters and renders the separation of ester and glycerol and the water washing difficult. Low free fatty acid content in triglycerides is required for alkali-catalyzed trans esterification can be used (Ma.F& Hanna, 1999).

2.10.2 Trans esterification using Acidic Catalyst

The most commonly used acids are sulfuric acid and sulfonic acid. Although yield is high, the acids, being corrosive, may cause damage to the equipment and the reaction rate was also observed to be low and needs very high temperature and pressure. If more water and free fatty acids are in the triglycerides, acid catalyzed transesterification can be used (Chemat, H, (2008).

2.10.3 Trans-esterification Using Biocatalyst

Enzymes such as lipase can be used to catalyze trans-esterification process by immobilizing them in a suitable support. The advantage of immobilization is that the enzyme can be reused without separation. Also, the operating temperature of the process is low (50 °C) compared to other techniques. Disadvantages include inhibition effects which were observed when methanol was used and the fact that enzymes are expensive (Khurshid,2014). Because of the high energy cost of the conventional chemical process and addition purification step of glycerol, application of lipase in the biodiesel industry has become attractive (Marchetti, 2007). Because of the toxicity and flammability of organic solvents, and product recovery without further organic solvent evaporation, lipase-catalyzed trans esterification in a solvent-free medium is important in industrial applications (John, 2003).

2.10.4 Trans-esterification using heterogeneous catalyst

Heterogeneous catalysts such as amorphous zirconia, titanium, aluminum, and potassium doped zirconias have also become popular for catalyzing the trans-esterification of vegetable oils. The conversion to methyl ester reaches 87% with the potassium-loaded alumina catalyst, when a mixture with a molar ratio of methanol to oil of 15:1 is refluxed for a reaction time of 7 hour. It is cost effective and highly efficient. But problems arise in the downstream operations including separation of catalyst and unreacted methanol from biodiesel. The removal of catalyst involves many complications and biodiesel requires repeated washing for attaining the necessary purity (Alimova et al, 2016).

2.11 Catalyst Selection Criteria for Biodiesel Production

Alkaline catalyst is selected for the trans-esterification process due to the following reason:

- It is cheapest.
- It is effective.
- The speed of the reaction using this catalyst is very fast.

Alcohol

The most commonly used primary alcohol used in biodiesel production is methanol, although other alcohols, such as ethanol, isopropanol, and butyl, can be used (Kiakalaiehn et al,2013). A key quality factor for the primary alcohol is the water content. Water interferes with trans esterification reactions and can result in poor yields and high levels of soap, free fatty, and triglycerides in the final fuel (Carmen et al, 2005).

2.12 Factors Affecting Trans-esterification process

2.12.1 The Effects of Moisture and Free Fatty Acids

For alkali-catalyzed transesterification, the glycerides and alcohol must be substantially anhdrous because water causes a partial reaction change to saponification, which produces the soap. The soap consumes the catalyst and reduces the catalytic efficiency, as well as causing an increase in viscosity, the formation of gels, and difficulty in achieving separation glycerol. The free fatty acid content of the oil should be as low as possible, below 0.5%, also stressed the importance of oils being dry and free of free fatty acids (Gerhard, Jon and Jurgen 2005).

2.12.2 The Effect of Molar Ratio

One of the most important variables affecting the yield of ester is the molar ratio of alcohol to triglyceride. The stoichiometry ratio for transesterification requires three moles of alcohol and one mole glycerides to yield three moles of fatty acid ester and one mole of glycerol. Excess amount of alcohol increases conversion of fats into esters within a short time. So the yield of biodiesel increases with increase in the concentration of alcohol up to certain concentration. The molar ratio is associated with the type of catalyst used. An alkali-catalyzed reaction required only a 6:1 ratio to achieve the same ester yield for a given reaction time. Conversion is complicated if oil contains higher amounts of FFA (>1% w/w) that will be form soap with alkaline catalyst. Such reaction does not respond to alkali catalyst. Acid catalyst will be effective to catalyze the reaction (Kiakalaiehn, 2013).

Practical range of molar ratio was from 3.3 to 5.25:1 methanol to vegetable oil. The ratio of 6:1 was used, with a yield of 90%-94%, depending upon the quality of the oils. Higher molar ratios result in greater ester conversion in shorter time. In the methanolysis of Avocado peels oil, a 6:1 molar ratio liberated significantly more glycerin than did a 3:1 molar ratio.

The molar ratio of 6:1 of methanol to oil gave the best conversion. When a large amount of free fatty acids was present in the oil, a molar ratio high as 15:1 was needed under acid catalysis. (Kiakalaiehn, 2013).

2.12.3 The Effect of Catalyst

Catalysts are classified as alkali, acid or enzyme. Alkali-catalyzed trans-esterification is much faster than acid-catalyst. However, if a glyceride has a higher free fatty acid content and more water, acid-catalyzed trans-esterification is suitable. The acids could be sulfuric acid, phosphoric acid, hydrochloric acid or organic sulfonic acid (Akhtar,2011). Alkalis include sodium hydroxide, sodium methoxide, potassium hydroxide, potassium methoxide, sodium amide, sodium hydride, and potassium amide and potassium hydride. Sodium hydroxide is also cheaper and is used widely in large-scale processing (Carmen et al, 2005).

2.12.4 Effect of Temperature

Reaction temperature is another important factor that will affect the yield of biodiesel. Higher reaction temperature will be increases the reaction rate and results in short reaction time due to the reduction in viscosity of oils. Increasing the reaction temperature beyond the optimal level leads to decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides. Usually the transesterification reaction temperature should be below the boiling point of alcohol in order to prevent the alcohol evaporation. The range of optimal reaction temperature may vary be from 50 °C to 60 °C depends upon the oils or fats uses.(Bereket and Tilahu, et at ,2017).

2.13 Benefits of biodiesel

Biodiesel is a renewable source or an ecological fuel which has the following characteristics has many major advantages, and some minor disadvantages:

2.13.1 Advantages of biodiesel

Important properties of the biodiesel are:

- Biodiesel is renewable. As biodiesel is produced from renewable sources, biodiesel fuel is a renewable energy source.
- It can be used in the diesel engine without little or any modifications.
- It improves combustion process. The biodiesel contains at least 11% oxygen. Biodiesel burns better (more completely with few fuel unburned emissions) than petroleum diesel.

- Less smoke is produced. The use of biodiesel can reduce the emissions of unburned hydrocarbons.
- It does not contain sulfur. No sulfur emissions are emitted during the combustion.
- Biodiesel reduces the health risks associated with petroleum diesel. The use of biodiesel decreases emission and it is non-toxic.
- Greenhouse gas benefit. Moreover, the use of biodiesel can reduced the CO2 emissions up to 50% in comparison to the use of petroleum diesel.
- Biodiesel is biodegradable. The absence of a chemical and synthetic compound makes it innocuous with our environment.

2.13.2 Disadvantages

There are few disadvantages of using biodiesel as a replacement for diesel fuel that must be taken into consideration:

- Slightly higher fuel consumption due to the lower calorific value of biodiesel.
- Production costs still can be higher than the cost of diesel itself. It all basically depends on the oil source which has been used.
- The biodiesel needs more additives, mainly in cold countries, due to its high cloud point.
- The biodiesel produces more NOx emissions than petro diesel. It can cause acid rain.
- Currently more expensive.
- More nitrogen oxide emissions.
- B100 generally not suitable for use in low temperatures.
- Concerns about B100's impact on engine durability.

2.14 Environmental Impacts of Biodiesels

Biodiesel is the only alternative fuel. It is regarded as a clean fuel since it does not contain carcinogenic substances and its sulphur content level is also lower than petro diesel (Akhtar, 2011). It has many environmental benefits, such as it is biodegradable, non-toxic, is less pollutant to both water and soil and has low emission profile (including potential carcinogens). More over since the primary feedstock for biodiesel is a biologically-based material that can be grown season after season, it is renewable (Alimova. A et al, 2016).

In contrast to diesel engine, biodiesel creates significant reduction in emission of unburned hydrocarbons, carbon monoxide and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel.

CHAPTER THREE

MATERIALS AND METHODS

The experimental work was done in the laboratory of wolkite university college of engineering and technology department of chemical engineering.

3.1 Materials

The following equipment and chemicals were used to conduct the project.

Table 3.1 Major equipment used

Equipment used	**Remark**
Oven	Drying
Plastic	Sample collection
Mortar and pestle	Size reduction
Sieve	Sieving/screening
Knife	Small size reduction
Graduated cylinders of different volumes	Volume measurement
Filter paper	Separation
Heater	To heating
Condenser	Condensation
Soxhlet extractor	Oil extraction
Glove, eye glass and gown	Safety
Aluminum foils	Closing/covering flask
pH mete	pH measurement
Distillation column	Separation
Stirrer	Shaking
weighing balance	Weighing
Thermometer	Temperature measuring

Table 3-2 Chemicals used

Chemicals used	Remarks
N-hexane	Extraction
Distilled water	Washing
Sodium hydroxide (NaOH) (97%)	Catalyst
Methanol	Transesterification
Phenolphthalein	Determination of acid
Toluene	

3.2 Experimental Methods

3.2.1 Raw material preparation

The waste avocado peels were collected from Gubire town hotels, cafeteria and juice processing house. The sample preparation process includes: - manual size reduction (Knife, cutting), drying and grinding. 1.5 kg of waste avocado peel was used for the sample preparation.

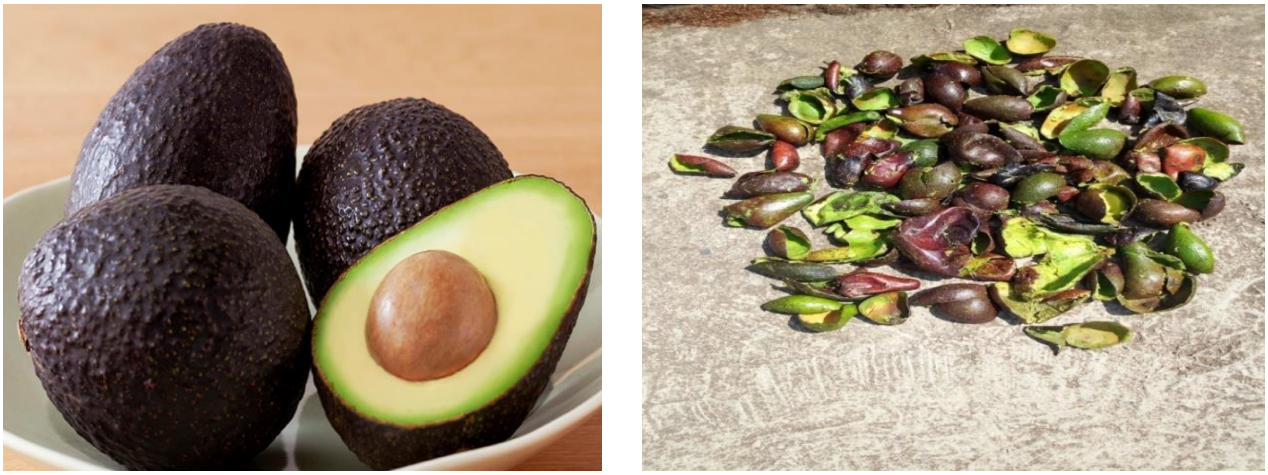


Fig 3.1: Avocado and avocado peel.

3.2.3 Drying process

To determine the most appropriate moisture content of avocado peels, avocado peels were manually crushed with a knife and the peel was dried until all of its moisture content was removed. The peel was dried by an oven for 1 hr. at 120 °C.

Figure 3.2: a) cutting of avocado peels b) drying of peels

3.2.4 Determination of moisture content of the Avocado peel

1.5 kg sample of the avocado peel was weighed and dried in an oven and the weight was measured after 1hr. After a constant weight was obtained, the mas of dried avocado peel was measured which was 0.426 kg. The percent moisture content of the peel was calculated by substituting these values into equation:

% Moisture content= $\frac{(W1-W2)}{W1}$

Where, W_1 = Original weight of the sample before drying.

W_2 = Weight of the sample after drying.

3.2.5 Milling process (Size reduction and sieve analysis)

After the moisture had been removed by placing in an oven at 120 °C for 1 hours, the dried avocado peel was milled by Mortar and pestle. Then, the sample was sieved using vibrating shaker for 15 minutes with amplitude of 5 mm. The sieve size was arranged in descending order of mesh size 4 mm, 3 mm, 1.5 mm, 1 mm, 0.7 mm, 0.5 mm and 0.25 mm to obtain a particular size of 0.5 – 0.25 mm. This particular size range was selected because literature reveled that to have a higher yield of oil, the particle size should be less than 5 mm and higher than 0.2 mm (Henry,1983).

3.3 Oil Extraction process

3.3.1. Soxhlet extraction method

A Soxhlet extraction method was used for extraction of the oil because of that literatures shows that soxhlet extraction is easy and simple to operate, used for small content of oil and gives maximum yield (Henry, 1983). A ratio of crushed avocado peels (powder) to solvent of 1:4 (m/v) was used. 100 g of avocado peel powder with the average size of 0.5 – 0.25 mm sieve was placed into the thimble and placed in the Soxhlet chamber. The solvent used for oil extraction was n-hexane. The extraction was carried out using 400 ml with n-hexane at 65 °C (below the boiling temperature) of hexane with purity of 99.0 % for 3 hr. were placed in a round bottom in100 ml flask and assembled for Soxhlet extractor. Since the capacity of thimble and round bottom flask is 25 g and 100 ml respectively, the extraction was carried out four times at 25 g and, 100 ml for three hours at 65 °C.

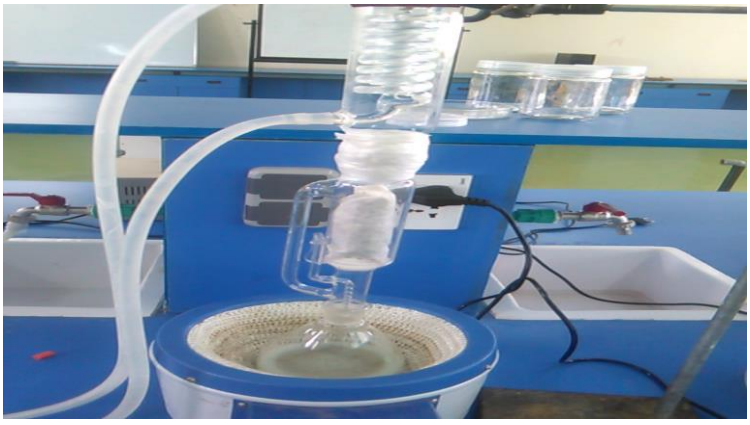


Figure **3.3**: Soxhlet extraction

3.3.2 Separation Process

After the extraction of oil had been completed separation process was continued to separate crude oil from the solvent. Distillation process was used to separate hexane from crude oil at the temperature of 69 °C.

3.3.3 Degumming process

In degumming process, distilled water was heated to 100 °C and left to boil for several minutes. Then crude avocado peels oil was poured into a beaker and equal volume of hot distilled water was added and stirred vigorously to remove the gums. The mixture was allowed to settle for 5 minutes, and the oil -water mixture separated into layers with the oil layer on top. The oil was decanted and the process repeated again.

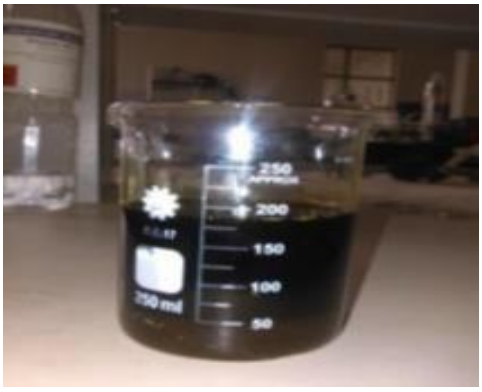


Figure 3.4 degumming process.

3.3.4 Determination of the percentage of oil yield

100 g (W_1) of the sample was placed in a thimble and about 400 ml of n-hexane was poured into the round bottom flask. The apparatus was heated at 65 °C and allowed for 3hrs for extraction process. After the extraction, the solid avocado powdered was dried in the oven at 105 °C and weighed until the constant weight (W_2) is attained and the percentage of oil extracted was determined as:

$$\% \text{ crude oil yield} = \frac{W1-W2}{W1} * 100$$

Where, W_1 =weight of sample before extraction

W_2 = weight of sample after extraction

3.4 Physicochemical characterization of the extracted oil

The oil extracted by Soxhlet extraction was used for analyzing the physicochemical properties of the oil. Physical properties such as density, pH value and chemical properties like acid value and free fatty acid values were determined for oil physicochemical properties using optimum operating parameters.

3.4.1 Specific gravity

The density of the oil was determined by using density beaker. A clean and dry bottle of 100 ml Capacity was weighed (W_0) and then the beaker was filled with the oil and reweighed to give (W_1). The oil was substituted with water after washing and drying the bottle and weighed to give (W_2). The expression for specific gravity (Sp.gr) is:

$$\text{Specific gravity} = \frac{\mathbf{W1-WO}}{\mathbf{W2-WO}}$$

Where, W_1 = Moil + Mbeaker

$W_o = M_{beaker}$

$W_2 = M_{water} + M_{beaker}$

3.4.2. Determination of density

The density of oil was determined from specific gravity of oil.

Density = specific gravity * density of water,

Density of water = Density of equal volume water =1 g/ml

3.4.3 Determination of acid value

25 ml of Toluene and 25 ml of ethanol was mixed in a 250 ml beaker. The resulting mixture was added to 4 g of biodiesel in a 250 ml conical flask and few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1M NaOH to the end point with consistent shaking for which a dark pink color was observed and the volume of 0.1M NaOH (V) was noted.

The total acidity (acid number) in mg NaOH/g oil was calculated using equation:

Acid Value = $\frac{V*C*w}{M}$

Where,

V is volume of NaOH used by the sample during titration = 11ml

C is concentration of NaOH = 0.1M

M is weight of oil taken for test = 5 g

W=Molecular weight of NaOH

3.4.4 Free fatty acid

Since the acidity is frequently expressed as free fatty acid from acid value. The % FFA value was calculated from the acid value using the relation:

$$AV = \boldsymbol{FFA}*2$$

Therefore, % FFA = $\frac{\mathbf{AV}}{\mathbf{2}}$

3.4.5. Determination of pH

The determination of pH value of avocado peel oil was determined by using pH electrode. The pH electrode was directly inserted into the oil and its pH value was displayed on the reading screen and it was recorded.

3.5. The Transesterification Method of Biodiesel Production

25 ml of methanol quantity was poured in a 200 beaker and 5 g of NaOH was used and mixed with methanol to 50 °C (in heater) and stirred by manually until the catalyst is completely dissolved in methanol.

After that, avocado peel oil was heated at 60 °C. Then, methanol and sodium hydroxide solution was poured in the warm avocado peel oil in a 500 ml three neck flask and stirred vigorously for 45 minutes using manual stirrer. Then, the mixture was allowed to settle for 24 hours in a separating funnel.

After settling, the upper layer which was the biodiesel and it was poured into a separate beaker and the lower layer (i.e. glycerol, and other residual) was collected from the bottom of the funnel. Finally, the volume of crude biodiesel was measured. Then, the crude biodiesel was further purified washing it. Warm distilled water was used to wash the biodiesel to remove any impurities like, excess methanol, glycerol and soap that remain in the biodiesel. This had been repeated until a clear biodiesel in the separating funnel was obtained.

Then, the washed sample was dried by placing it on a hot plate (oven) to evaporate the excess water in the biodiesel. Finally, the quantity of pure biodiesel was measured and collected in the sample holder.

3.6. Physicochemical Properties of Biodiesel

3.6.1. Determination of Specific Gravity

The density of the biodiesel was determined by using density beaker. A clean and dry bottle of 100 ml capacity was weighed (W_0) and then, the beaker was filled with the biodiesel and reweighed to give (W_1). The biodiesel was substituted with water after washing and drying the bottle and weighed to give (W_2). The expression for specific gravity (Sp.gr) is:

$$\text{Specific gravity} = \frac{(\boldsymbol{W1 - WO})}{(\boldsymbol{W2 - WO})}$$

Where, W1= Mbiodiesel + Mbeaker

$W_o = M_{beaker}$

$W_2 = M_{water} + M_{beaker}$

3.6.2. Determination of density

The density of biodiesel was determined from specific gravity of (biodiesel).

Density=specific gravity * density of water

3.6.3. Determination of API Gravity of Biodiesel

API Gravity of biodiesel was determined by using the formula that relates API with the specific gravity of biodiesel.

The formula that relates API to SG is:

$$\text{API} = \frac{(141.5)}{SG} - 131.5$$

3.6.4. Determination of pH Value

The determination of pH value of biodiesel was determined by using pH electrode. The pH electrode was directly inserted into the purified biodiesel and its pH value was displayed on the reading screen and it was recorded.

3.6.5 Determination of Acid Value

A 25 ml of toluene and 25 ml of methanol was mixed in beaker. The resulting mixture was added to 3 g of biodiesel in a 250 ml conical flask and few drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1 M NaOH to the end point with consistent shaking for which, a dark pink color was observed and the volume of 0.1 M NaOH (V) was noted.

The Acid value was calculated as:

$$\text{Acid Value} = \frac{(\boldsymbol{V} * \boldsymbol{C} * \boldsymbol{W})}{\boldsymbol{M}}$$

Where,

V is volume of NaOH used by the sample during titration = 0.1 ml

C is concentration of NaOH = 0.1M

M is weight of biodiesel taken for test = 3 g

W=Molecular weight of NaOH

3.6.6 Determination of free fatty acid value

The FFA value was calculated from the acid value using the relation. Therefore, the free acid value was calculated using the following formula.

$$\text{Free fatty acid value} = \frac{(Acid\ value)}{2}$$

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 RESULTS

Table 4.1 result of moisture content.

No	Measured property	Avocado peel
1	% Moisture content	71.6

The result obtained is in agreement to those of the literature since (Dagne, Djene and Ebisa,2016) and (Tafere, 2018) who reported a moisture content of 71.9% and 71% respectively.

Table.4.2: results for Soxhlet extraction

Trial	Temperature *(0c)*	Time (hr)	weight of sample before extraction(g)	weight of sample after extraction(g)	Oil yield (%)
1	60	3	100	64.5	35.5

The percentage yield of oil result obtained from this study was almost similar to the reported values of literatures by (Tafere, 2018) who reported oil yield of 35.6%.

A percentage extraction yield of 37.8% was reported by (Bereket and Tilah et at, 2017) by using hexane as solvent with extraction time of 4hr. Duti John, (2009) reported a yield of 40.6% using hexane as solvent and with extraction time of 5 hours. Additionally, Demirbas A, and Kara H, et at (2006) reported a percentage extraction yield of 43.5% with hexane as solvent and extraction time of 6 hours. The percentage result obtained in this project some different from the literatures reported. This is because of time used for extraction is the major factor for the increasing of yield.

Table 4.3: shows the result of transesterification reaction.

Oil (g)	Catalyst (g)	Methanol(g)	Reaction time (minute)	Yield of pure biodiesel (g)
66.15	5	19.78	45	56.81

The result of purified biodiesel obtained from the transesterification reaction process was 56.81 g, which is almost similar to the reported value of literatures by (Dagn, Dejene, and Ebisa) who reported the pure biodiesel 56.83 g.

A purified biodiesel yield of 57.6 g was reported by Demirbas A, et at (2008) by transesterification reaction using sodium hydroxide as a catalyst and methanol as an alcohol. A yield of 58.5 g pure biodiesel was reported by Carmen et at, (2005) by transesterification process reaction using sodium hydroxide as a catalyst and methanol as an alcohol. Again a yield of 59.3 g of was reported by Alimova et al, (2016) by transesterification reaction using NaOH as a catalyst and methanol as an alcohol. The actual yield of biodiesel obtained in this project was different from the literatures. This is because of the yield of biodiesel can affected by the factors that affect production of biodiesel such as molar ratio, catalyst temperature etc (Bortolomeen et al, 1981). Varying the factors can change the yield of BD

Table 4.4: results of APO and BD characterization with standards

Property	Avocado peel oil	Biodiesel Yields	EN 14214	ASTM D-6751
Density at 15 ^{0}C, kg/m^3	900	880 g	860-900	
PH	5.8	8.3	5- 6.7	7-9
API		31.14		30-45
Specific gravity	0.9	0.88	0.86-0.9	
Acid value , mg NaOH/g	8.8	0.133		<0.5
Free fatty acids	4.4	0.066		< 0.24

The results obtained from the characterization of avocado peel oil and biodiesel satisfies the standard putted by the EN and ASTM.

CHAPTER FIVE

MATERIAL AND ENERGY BALANCE

5.1. Material Balance

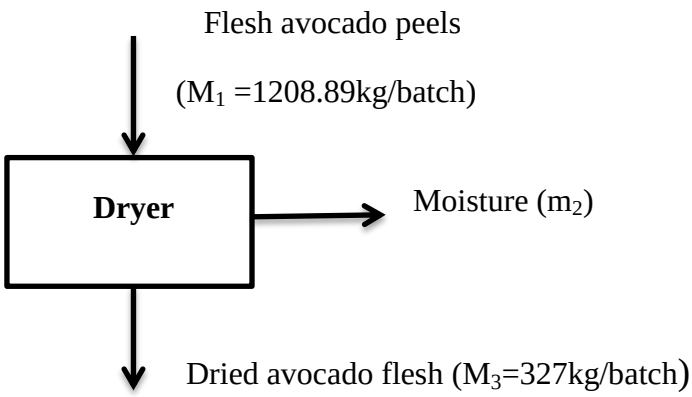
5.1.1 Material Balance for Oil Production

The mass of raw material collected for the production of BD in the laboratory scale was 1.5 kg of wet avocado peel. The amount of avocado peel needed per year for the mass production of BD in the industrial scale was obtained by scaling up the amount of mass used in the laboratory by a scale factor of 1,595,733. Therefore, the amount of avocado peel need for the industrial scale = 2393600 kg/year.

Basis:

- 330 working day/year
- The process is batch process
- 6 batch/day; 4 hour for one batch
- It is Steady state condition
- Amount of avocado peels needed per year =2,393.6 ton/year
- Amount of avocado peels needed per batch= $\frac{\mathbf{2393600kg/year}}{\left(\mathbf{330}\frac{\mathbf{day}}{\mathbf{year}}\right)*\mathbf{6}\frac{\mathbf{batch}}{\mathbf{day}}}$ =1208.89 kg/batch
- Amount of solvent used per batch depend on standards. 450 L is needed for 40 kg of samples. Therefore, 13.6 m3 (8,962.4 kg) is needed per one batch.
- Amount of solvent needed per day = 13.6 m^3/batch*6 batch/day=81.6 m^3/day
- Amount of solvent needed per year=81.6m^3/day*330day/year=26,928m^3/year
- Density of n-hexane=659kg/m^3
- Density of avocado oil=920kg/m^3

Material balance on dryer



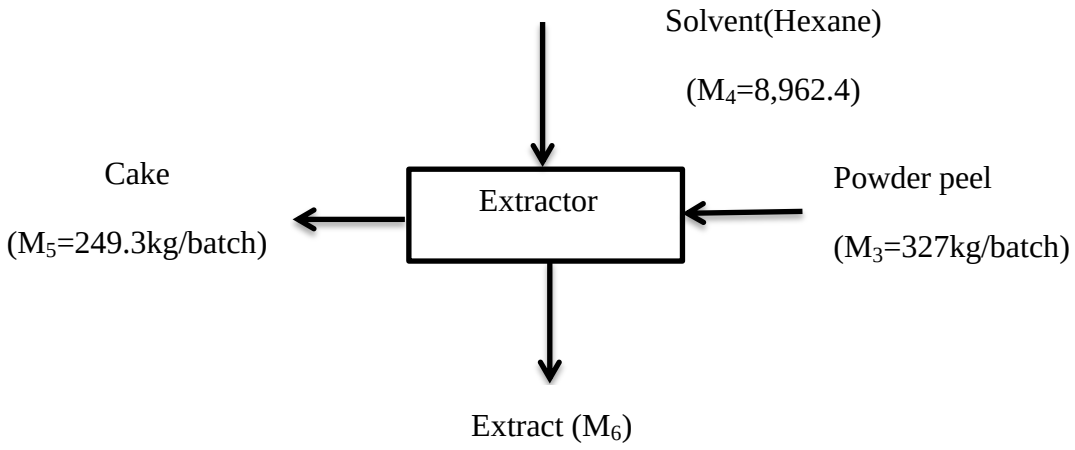
Mass in + generation = mass out +consumption +accumulation

Mass in = mass out

$M_1=M_2+M_3$: 1208.89kg/batch=M_2+327kg/batch

M_2=881.88kg/batch

Material balance on extractor apparatus



Mass in + generation = mass out +consumption +accumulation

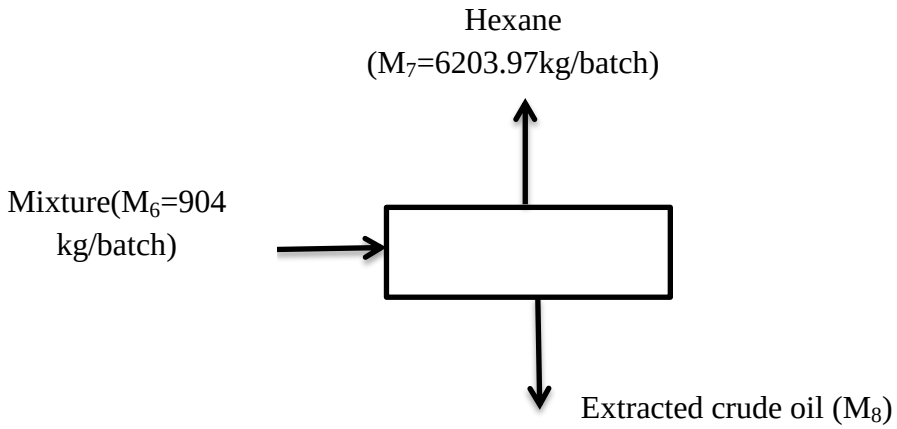
Mass in = mass out

$M_4+M_3=M_5+M_6$

8,962.4 kg/batch + 327 kg/batch=249.3 kg/batch + m6

M_6=9040 kg/batch

Material balance on evaporator



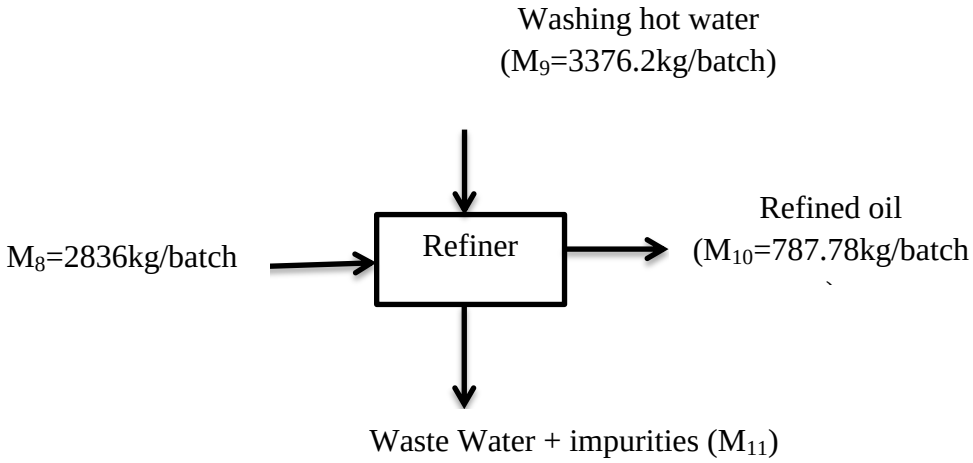
Mass in + generation = mass out +consumption +accumulation

Mass in = mass out, $M_6=M_7+M_8$

9040 kg/batch= 6,203.97 kg/batch + m8

M_8=2836 kg/batch

Material balance on refiner



Mass in + generation = mass out +consumption +accumulation

Mass in = mass out; $M_8 + M_9 = M_{10} + M_{11}$

2836 kg/batch +3376.2 kg/batch= 787.78 kg/batch + m11

M_{11} =5424.42 kg/batch (phospholipid +water) but, the amount of water used is known (3376.2 kg/batch)

Therefore, the amount of waste in crude oil=5424.42 kg/batch – 3376.2 kg/batch

=2,048.2 kg/batch

5.1.2 Material Balance for Biodiesel Production

Basis:

- 330 working day/year
- 3 batch/day; 8 hour for one batch
- Amount of avocado peels oil needed per year = 1,559.8ton/year
- Amount of avocado peels oil needed per batch= $\frac{\mathbf{1{,}559{,}800kg/year}}{(\frac{\mathbf{330\ day}}{\mathbf{year}}*\mathbf{3batc/\ hday})}$ = 1,575.56kg/batch
- From the literature avocado peels crude oil contains 0.1% impurities
- Molecular weight of biodiesel=288.3 g/mol
- Molecular mass of avocado oil=282.47g/mol
- Density of biodiesel=879 kg/m3
- Amount of catalyst used per batch=1% of oil used per batch=0.01*1,575.56 kg/batch =15.75kg/batch.

Trans-esterification reactor is based on 6:1 alcohol to oil molar ratio and 1%wt NaOH with respect to oil;

Triglyceride + 6 methano $\xrightarrow{\text{catalyst}}$ 3 Biodiesel + glycerol + 3 methanol

From the above reaction, for 1mole of oil, 6mole of methanol is needed for the completed reaction. Mole of avocado peels oil $=\frac{1575.56kg/batch}{o.28247kg/mol}$ =5,577.8 mol/batch

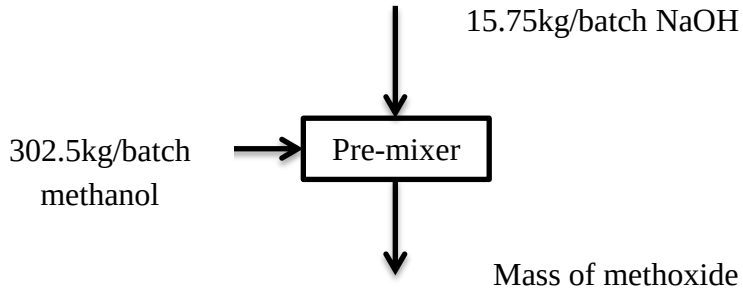
Mole of methanol needed for the reaction=mole of oil*6 depends on the ratio relationship (1:6) oil to methanol =1,575.56 mol/batch*6=9,453.36 mol/batch

Mass of methanol needed for the reaction=mole of methanol*molecular weight of methanol

=9,453.36mol/batch*32 gm/mol

=302,507.52gm/batch=302.5 kg/batch

Material balance at pre-mixer



By overall material balance

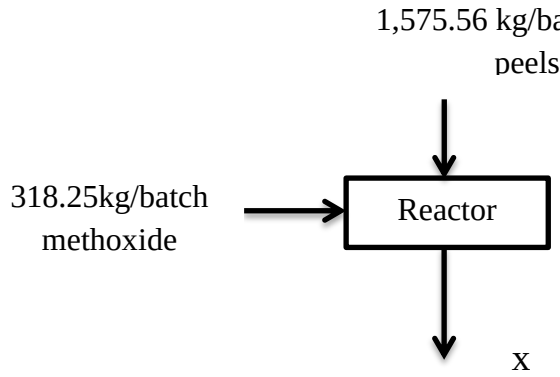
302.5kg/batch + 15.75kg/batch=mass of methoxide

Mass of methoxide = 318.25kg/batch

Material balance on the reactor

1 triglyceride + 6methanol $\xrightarrow{\text{NaOH}}$ 3Biodiesel + 1 glycerol +3methanol

The above reaction is used for considering 100% conversion yield, its ideal.



Amount of crude biodiesel in mole = $\frac{\textbf{amount of oil in mol} * \textbf{mol ofbiodiesel}}{\textbf{mol of oil}}$

Amount of biodiesel crude in mole=$\frac{\frac{\textbf{5577.8 mol}}{\textbf{batch}} * \textbf{3mol ofbiodiesel})}{\textbf{1mol of oil}}$=16.733.4 mole of biodiesel

Amount of crude biodiesel in mass=mole of biodiesel * molecular mass of biodiesel

=16,733.4mole*288.3gm/mole*1 kg/1000gm

=4824.24kg

Amount of glycerol in mole=$\frac{\textbf{amount of triglyceride in mol} * \textbf{mol of glycerol}}{\textbf{mol of triglyceride}}$

Amount of glycerol in mole=5,577.8mole/batch*1mole of glycerol=5,577.8mole/batch.

Amount of glycerol in mass = mole of glycerol*molecular weight of glycerol

=5577.8 mole/batch*92 gm/mol*1 kg/1000 gm

=513.1 6kg/batch

Amount of impurities =0.001*1,575.56 kg/batch=1.6 kg/batch

Material Balance on Decanter

Take 95% glycerol, 40% methanol, 10% catalyst and 80% impurities leaves with crude glycerol stream. Amount of glycerol separated from biodiesel=0.95*513.16 kg/batch

=487.5 kg/batch

From this amount of glycerol goes with biodiesel stream

=513.16 kg/batch - 487.5 kg/batch

=25.66 kg/batch

The amount of catalyst removed with glycerol stream = 0.1*15.75 kg/batch

=1.575 kg/batch

The amount of catalyst goes with biodiesel=15.75kg/batch - 1.575kg/batch

=14.175 kg/batch

Amount of impurities goes with glycerol=0.8*15.7556 kg/batch=12.6 kg/batch

Therefore, the amount of impurities goes with biodiesel=15.556 kg/batch-12.6 kg/batch

=2.95 kg/batch

Amount of methanol excess = half of methanol used

=1/2*302.5=151.25 kg/batch

Amount methanol of removed with glycerol stream=0.4*151.25 kg/batch

=60.5kg/batch

The amount of methanol remain in biodiesel=151.25 kg/batch-60.5 kg/batch=90.75 kg/batch

The total mass goes to the glycerol stream=mass of glycerol + mass of catalyst + mass of impurities +mass of methanol = 487.5 kg/batch + 1.575 kg/batch + 12.6 kg/batch +60.5 kg/batch

=562.175 kg/batch

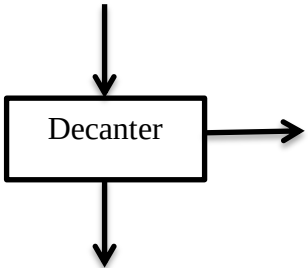
Total feed to decanter=total crude biodiesel stream + total crude glycerol stream

Total crude biodiesel stream =total feed to the decanter- total crude glycerol stream

=4824.24 kg/batch-562.175 kg/batch

=4262 kg/batch

Total feed=4824.24 kg/batch)



Crude biodiesel=4262 kg/batch

BD=4127.9 kg/batch

Glycerol= 25.66 kg/batch

Catalyst=14.75 kg/batch

Impurities=2.95 kg/batch

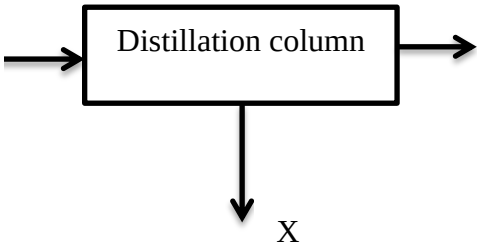
Crude glycerol=562.175 kg/batch

Pure glycerol=487.5 kg/batch

Catalyst=1.575 kg/batch

Impurities =12.6 kg/batch

Crude biodiesel=4262 kg/batch



Methanol =90.75 kg/batch

BD=96.85%

GL=0.6%

CAT=0.35%

IMP=0.069%

X

Over All Material Balance: 4262 kg/batch=X+90.75 kg/batch

X=4171.25 kg/batch

Component material balance for biodiesel

0.9685*4262 kg/batch=4171.25 kg/batch*y

Y=0.98=98%

Similarly for glycerol, catalyst and impurities; x, w, z respectively

X=0.0061, w=0.0035, z=0.01

Material balance on washing tank

From the literature the proportion of crude biodiesel to water is 1:1 ratio.

5% of feed water goes with biodiesel and by gently washing, all impurity is removed with wash water. 100% purification yield, all salt, wash water and glycerol are removed.

The amount of water removed=95% of hot water added.

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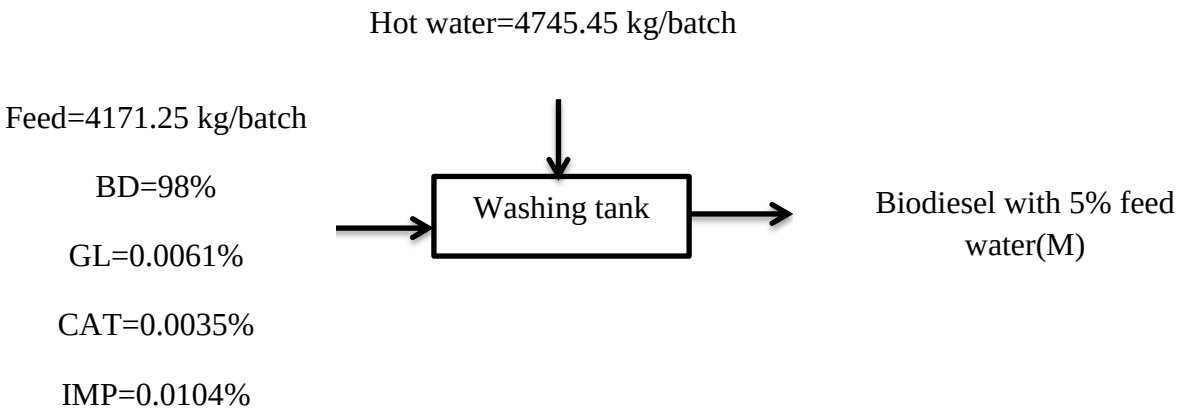


Amount of Water Removed=95%*4745.45 kg/batch

=4508.17 kg/batch

Amount of water goes with biodiesel=4745.45kg/batch-4508.45 kg/batch

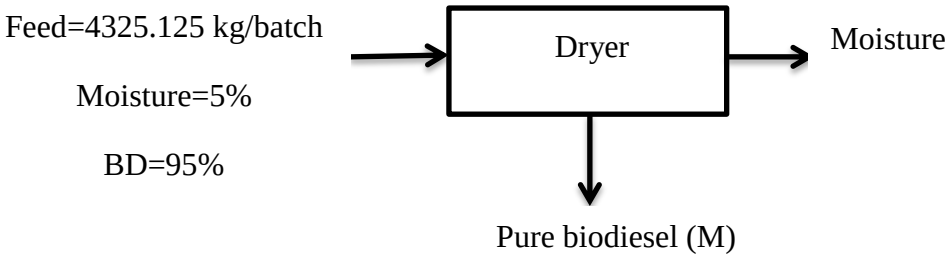
=237.3 kg/batch

Component Material balance on biodiesel

M=0.98*4171.25 kg/batch+237.3 kg/batch

=4325.125 kg/batch

Material balance on dryer



The efficiency of the dryer is 99.5%

Amount of water removed =5%*4325.125 kg/batch*0.995 =215.2 kg/batch

Amount of water remain in biodiesel=237.3 kg/batch-215.2 kg/batch =22.1 kg/batch

Biodiesel produced (M)=0.95*4325.125 kg/batch +22.1 kg/batch =4,130.97 kg/batch

5.2.1 Energy balance Energy
Energy Balance on Major Unit Operation

Energy balance on Extractor

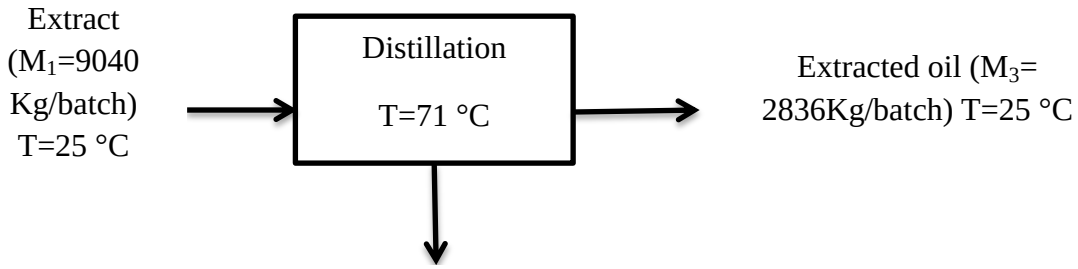
From conservation of energy,

Energy in+ energy generation = energy out + energy consumption + energy accumulation

Energy in = energy out

Q= mcP=(327 kg/batch+8962.4 kg/batch)* $\frac{(\mathbf{1.55kJ/kg°C+2.26KJ/Kg°C})}{\mathbf{2}}$ (70°C-25°C) = 55.3kw

Energy balance separator



Energy in+ energy generation = energy out + energy consumption + energy accumulation

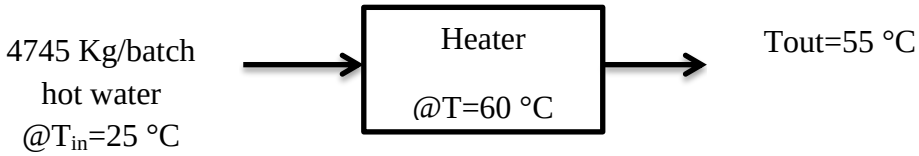
Energy in = Energy out

Q= mcP (6203.97 kg/batch+2836 kg/batch) *(1.55 KJ/Kg°C+2.26KJ/Kg°C)/2(71 °C-25 °C)

=438.9 kw

Energy balance on water heater

Hot water @ 55 °C is supplied to washer to remove waste from biodiesel. Since the hot water needed to wash is 1:1 ratio with crude biodiesel.so the amount of hot water is needed to washer is nearly equal to the amount of crude biodiesel feed too biodiesel.



C_p water=4.18 KJ/kg°C

Q=MW*Cp*=4745.45 Kg/batch*4.18 KJ/kg°C*(55-25) °C = 595.1 MJ/batch.

CHAPTER SIX

SIZING OF MAJOR EQUIPMENTS

Assumptions

- All tanks are 10% safety factor.
- Sizing of equipment is depending on the material balance calculated on the above section.

Sizing on storage of avocado peels

$$V_{substance} = \frac{\text{mass flow of substance/batch}}{\text{density of sustance}} = \frac{\text{mass flow of substance/batch}}{\text{density of avocado peels}}$$

$$= \frac{1208.89\ kg/batch}{633.33\ kg/m3} = 1.9\ m^3/batch$$

With 10% safety factor, $1.9\ m^3/batch + 1.9\ m^3/batch * 0.1 = 2.1\ m^3/batch$

Take 6 days storage time for avocado peels and 4 days for another storage tank

$V_{avocado\ peels\ for\ one\ day} = 2.1\ m^3/batch * 6\ batch/day = 12.6\ m^3/day$

$V_{avocado\ peels\ for\ 6days} = 12.6\ m^3/day * 6\ day = 75.6\ m^3$

Sizing on grinder

$$V_{substance} = \frac{\text{mass flow of substance/batch}}{\text{density of sustance}} = \frac{\text{mass flow of avocado peels powder/batch}}{\text{density of avocado peel}}$$

$$= \frac{327\ kg/batch}{633.33\ kg/m3} = 0.516\ m^3/batch$$

With 10% safety factor, $0.516\ m^3/batch + 0.516\ m^3/batch * 0.1 = 0.567\ m^3/batch$

Sizing of extractor apparatus

$$V_{substance} = \frac{\text{mass flow of avocado peels powder/batch}}{\text{density of avocado peel}} + \left(\frac{\text{mass hexane/batch}}{\text{density of hexane}}\right)$$

$$= \frac{327\ kg/batch}{633.33\ kg/m3} + \frac{8962.4\ kg/batch}{659\ kg/m3} = 14.12\ m^3/batch$$

With 10% safety factor, $14.12\ m^3/batch + 0.1 * 14.12\ m^3/batch = 15.53\ m^3/batch$

Sizing on distillation column

$$V_{substance} = \frac{\textbf{mass of substance/batch}}{\textbf{average denisty of substace}} = \frac{\textbf{mass of mixtuer/batch}}{\textbf{density}\frac{\textbf{of(hexane+crude vocado)}}{\textbf{2}}}$$

$$= \frac{\textbf{9040 kg/batch}}{\frac{\textbf{(840+659)kg}}{\textbf{2 m3}}} = 12\ m^3/\text{batch}$$

With 10% safety factor, 12 m^3/batch+0.1*12 m^3/batch=13.2 m^3/batch

Sizing on biodiesel storage tank

$$V_{substance} = \frac{mass\ of\ sustance/batch}{density\ of\ sustance} = \frac{mass\ of\ biodiesel/batch}{density\ of\ biodiesel}$$

$$= \frac{\textbf{4130.97 kg/batch}}{\textbf{880 kg/m3}}$$

With 10% safety factor, 4.7 m^3/batch+0.1*4.7 m^3/batch=5.17 m^3/batch

For one day it becomes=5.17 m^3/batch*3 batch/day=15.51 m^3/day

Vbd for 6 days=15.51 m^3/day*6 day= 90 m^3

CHAPTER SEVEN

PRELIMINARY ENGINEERING ECONOMIC ANALYSIS

7.1 Purchasing equipment cost

- The purchasing costs of equipment is estimated using the website

http://www.mhhe.com/engcs/chemical/peters/data/

Table 7.1: Purchasing equipment cost

NO	Equipment name	Volume(m3)	No.of equipment	Materials of constriction	Cost($)
1	Storage tanks	75.6	1	Galvanized steels	2082.4
2	Dryer	2.1	1	Stainless steel	2271
3	Grinder	0.567	1	Stainless steels	138348
4	Extractor	15.53	1	Stainless	2123
5	Distillation column	13.2	1	Galvanized	27543.2
6	Refiner	7.4	1	Stainless steel	4321.2
7	Oil storage tanks	33.66		Galvanized	14321.2
8	Methanol storage tanks	6.07	1	Light steel	11233.12
9	NaOH storage tanks	0.098	1	Light steel	850
10	Pre-mixing tanks	6.68	1	Stainless steel	26720
11	Reactor	3.17	1	Al, Cu, Si	23215
12	Decanter	6.1	1	Glass	18241.5
13	Distillation of BD column	5.42	1	Galvanized Stainless steel	8953.48
14	Washing tanks	9.4	1	Ceramics	54833.33

15	Evaporator(dyrer)	5.366	1	Stainless steel coil	32194.4
16	BD storage tanks	90	1	Galvanized steel	4933.33
17	Methanol recovery storage tanks	2.1	1	Light steels	2180.67
18	Total cost (T.P.E.C)				**374,365.36**

Total purchased equipment cost (T.P.E.C) = **$ 374,365.36**

7.2 Fixed capital investment

- Fixed capital investment values for direct and indirect cost
- Assume that total purchased equipment cost = 40% F.C.I

TPEC = 40%FCI

$$\textbf{FC I}=\frac{\textbf{TPC}}{\textbf{0.4}}=\frac{\textbf{374,365.36}}{\textbf{0.4}} = \$935,913.4$$

7.2.1 Direct cost (DC)

Table 7.2: Direct cost, the range is on the basis of FCI.

Components	**Range**	**Assumed %**	**Cost $**
Total purchased-equipment	15-40	40% of FCI	374,365.36
Instrumentation and controls	2-8	5	46,795.67
Pipe (installed)	3-20	10	93,591.34
Electrical (installing)	2-10	5	46,795.67
Building (including service)	3-10	8	74,873
Yard improvement	2-5	3	28,077.4
Service facility	8-20	10	93,591.34
Total direct cost			**$758,089.8**

7.2.2 Indirect cost

Table 7.3: Total indirect cost

Cost expense for	**Range**	**Assumed% of FCI**	**Cost($)**
Engineering and supervision	4-21	5	46,795.67
Construction expenses	4 – 16	8	74,873
Contractors fee	2 -14	3	28,077.4
Contingency	25 – 50	28	262,055.75
Total indirect cost			**$411,801.8**

The total capital investment = fixed capital investment + working capital investment

In most chemical plants working capital investment takes (10-20) % of total capital investment.

In this plant, it is assumed that 10% of total capital investment.

Therefore, **Total capital investment** = **fixed capital investment** + **working capital investment**

$$TCI = FCI + 0.1TCI$$

$$TCI = FCI/ (1-0.1)$$

$$TCI = \frac{935,913}{(1-0.1)} = \$\ 1,039,903.77/year$$

Working Capital

Working capital investment = total capital investment – fixed capital investment

= $1,039,903.77/year - $935,913.4year

= **$103,990.38/year**

7.3 Estimation of total product cost

I. **Manufacturing cost** = **direct production cost** + **fixed charges** + **plant overhead cost**

A. Direct product costs (60% total product cost)

Let X be total product cost

1. **Raw materials**: (10-50% of total product cost)

Consider the cost of raw materials = 16% of total product cost

Raw material cost=0.16X

2. **Operating labor cost (OL):** (10-20% of total product cost)

Consider the cost of operating labor = 13% of total product cost

Operating labor cost = 0.13X

3. **Direct Supervisory and clerical labor (DS and CL):(**10-25% of OL)

Consider the cost for Direct Supervisory and clerical labor = 12% of OL

Direct Supervisory and clerical labor Cost = 0.13 *0.12X=0.0156X

4. **Utilities**: (10-20% of total product cost)

Consider the cost of utilities = 14% of total product cost

Utilities cost= 0.14X

5. **Maintenance and repairs (M and R):** (2- 10% of fixed capital investment)

Consider the maintenance and repair cost= 3% of fixed capital investment

i.e maintenance and repair cost= 0.03 x $935,913.4= $28,077.4

6. **Operating supplies**: (10-20% of M&R or 0.5-1% of FCI)

Consider the cost of operating supplies =11% of M $ R

Operating supplies cost = 0.11 * $28,077.4=$3088.5

7. **Laboratory charges**: (10-20% of OL)

Consider the Laboratory charges = 13% of OL

Laboratory charges = 0.13 * 0.13X= 0.0169X

8. **Patent and Royalties**: (0-6% total product cost)

Consider Patent and Royalties = 4% of total product cost

Patent and Royalties =0.04X

Direct cost= 0.16X + 0.13X + 0.0156X + 0.14X + $28,077.4+$3088.5 +0.0169+0.04X

=0.5129X + $31,165.9

B. Fixed charges (10-20% total product)

i. **Local Taxes**: (1-4% of FCI)

Consider the local taxes = 2% of FCI

i.e Local taxes = 0.02 x $935,913.4/year=$18,718.3/year

ii**. Insurances**: (0.4- 1%) of FCI)

Consider the insurance= (0.6% of FCI)

i.e Insurance= 0.006*$935913.4/year=$5615.5/year

Thus, total fixed charges = $ 119,422.6/year

C. Plant overhead costs: (50-70% of operating labor, supervision, and maintenance or 5-15% of total product cost); includes for the following: general plant up keep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, recreation, salvage, laboratories and storage facilities.

Consider the plant overhead cost = 10% of total product cost

Plant overhead cost= 0.1*X

Thus, **manufacturing cost** = **Direct product cost** + **Fixed charges** + **plant overhead cost**

Manufacture cost = 0.5129X + $119,422.6 +$31165.9 + 0.1X

=0.6129X + $150,588.5/year

I. General Expenses= Administrative costs + distribution and selling costs + research and development costs

A. **Administrative**: (2-6% of total product cost)

Consider the administrative costs = 5% of total product cost

Administrative costs= 0.05X

B. Distribution and selling costs: (2-20% of total product cost); includes costs for sales offices, salesmen, shipping, and advertising.

Consider the distribution and selling costs = 14% of total product cost

Distribution and selling costs = 0.14X

C. Research and Development costs: (about 5% of total product cost)

Consider Research and Development costs = 5% of total product cost

Research and Development costs= 0.05X

D. Financing (interest): (0-10% of total capital investment)

Consider interest = 7% of total capital investment

i.e interest = 0.07*$1,039,903.77/year=$72,793.3/year

Thus, **General Expenses** = $72,793.3 + 0.05X + 0.14X + 0.05X

=$72,793.3 + 0.24X

II. Total product cost = Manufacture cost + General Expenses

X=0.6129X + 150,588.5 + $72,793.3 + 0.24X

X= 0.8529X+ $223,381.8/year

X=$1,511,772.944/year

Total product cost(X) = $1,511,772.944/year

Total biodiesel production per year = 1830.97 kg/batch * 3 day/batch * 330 day/year

=1,812,660.3kg/year= 2,062,184.6 L/year

Unit selling price= $\frac{\textbf{Total product cost/year}}{\textbf{annual production}} = \frac{\$\mathbf{1,511772944/year}}{\mathbf{206,218,462\ L/yar}} = \mathbf{\$0.733/L}$

Selling price of biodiesel per liter = $0.733/L

Total Income= selling price per litr x Quantity of product manufactured (liter/year)

Total income = 2,062,184.6 liter/year * $ 0.733/liter

=$1,511,581/year

Tax rate 35%

Annual earning= (total income (si) – all product cost except depreciation (Coj)) * (1- tax rate)

= ($1,511,581/year - $602,962.78/year)* 0.65

=$379,564.87/year

Take VS = 0, and the service life (n) = 13 years

Depreciation (dj) $\frac{\textbf{FCI−Salvage}}{\textbf{N}} = \frac{\$\mathbf{9355913.4−0}}{\mathbf{13}} = \mathbf{\$71,993.34/year}$

Net profit = Annual earning – 0.65 * depreciation (dj)

=$379,564.87/year – 0.65*$71,993.34/year

=$332,769.2/year

Percent rate of return

The yearly profit divided by the total initial Investment necessary represents Return on Investment. Taking the risk factor Mar = 12%, to be the plant feasible RoI>Mar (must).

Net income=$332,769.2/year

Total capital investment (TCI)= $1,039,903.38/year

ROI=$\frac{\text{Net profit}}{\text{TCI}} * 100 = \frac{\$332,769.2/\text{year}}{\$1,039,903.38/\text{year}} * 100$ =32%> 12% it is acceptable

Payback period

The minimum length of time theoretically necessary to recover the original fixed capital investment in the form of cash flow is called payback period.

Assume 13 years Project service life and we use straight line method to calculate depreciation.

Dep=$\frac{\boldsymbol{FCI - Salvage\ value}}{\boldsymbol{service\ life}} = \frac{\mathbf{935913.4}}{\mathbf{13}} = \mathbf{71993.33}$

Payback period=$\left(\frac{\mathbf{FCI}}{\mathbf{Dep+Net\ profit}}\right) = \frac{\mathbf{935913.4}}{\mathbf{71993.33+332769.2}} = \mathbf{2.31\ years}$

2.31 year < 5 year, it is acceptable

CHAPTER EIGHT

SITE SELECTION AND ENVIRONMENTAL ASSESSMENT

8.1 Site Selection

There are several aspects to be considered regarding the sitting and operation of biodiesel plant. First, a suitable site must be chosen and second the plant layout must be planned after the site characteristics are assessed. Finally, an environmental impact analysis needs to be performed to ascertain the expected effect of the plant and the chemicals on the surrounding areas.

There are a number of considerations concerning the choice of site location for a Biodiesel plant within Ethiopia. Some of these are general considerations whereas the others related directly to the process and its requirements. Those considerations relevant to this study include:

- Raw material availability
- Close proximity to the anticipated market
- Utility costs and availability
- An availability of fundamental infrastructure (including port facilities road and other access)
- A suitable local labor force
- Amount of area required for the plant
- Environmental aspect on the residents

Depending on these factors we select Addis Ababa a site location for our project area which fulfills the above requirements.

8.2 Environmental impact of Assessment

Diesel fuel consumption significantly contributes to the emission of GHG,NOX, SOX,CO,VOCS and nitrated PAH compounds. The use of biodiesel could reduce CO2 and other harmful substances. Average biodiesel emissions compared to diesel is very low. The potential GHG reductions from switching to biodiesel from petroleum based diesel depend largely on the type of feedstock used to produce the fuel. Biodiesel production is less energy intensive than that of petroleum diesel. Burning fossil fuels releases more 6 million tons of CO2 per year, twice as much as the biosphere can absorb. The excess CO2 in the atmosphere would increase global temperature.

CHAPTER NINE

CONCLUSION AND RECOMMENDATION

9.1. Conclusion

In this project oil was extracted from avocado peel using soxhlet extractor. Under this investigation particle size range; 0.25-0.5 mm, solvent type; hexane and extraction time 3 hrs were considered. From the experiment it was found that oil yield of 35.5% was obtained. This results were similar to some reported literatures.

In conclusion, a pure biodiesel of 56.81 g was produced from the extracted avocado peel oil of 66.15 g by a transesterification process using sodium hydroxide as a catalyst and methanol alcohol. The result was similar to some reported literatures. In generally, the following properties were concluded for the biodiesel produced from APO: -

- The produced biodiesel is an important alternative fuel and it possesses properties like renewability, non-toxicity, biodegradability, and environmentally friend.
- The fuel property of biodiesel production is strongly affected by parameters such as effects of molar ratio of oil to alcohol; reaction temperature; reaction time and amount of catalyst concentration.
- Transesterification is the most commonly employed method for FAME production. The purpose of this method is to reduce the viscosity of oil using base catalyst in the presence of methanol. The yield is strongly dependent on the product of the transesterification step.

9.2 Recommendation

In this project, the physicochemical properties like saponification, iodine value, flash point, cetane number etc of biodiesel was not investigated so, we recommend that further characterization studies should be done on these physicochemical properties. And also, the factors that affect the yield of biodiesel was not studied so, we recommend that further studies should be done on it to determine the effect it on the yield of biodiesel.

In generally we recommend that;

- Alternative production methods of biodiesel such as micro emulsion or pyrolysis have to be used in order to investigate the variation that could be arise on the quality and quantity of the biodiesel yield as a result of using different extraction methods
- To achieve maximum yield of biodiesel using the Avocado peels oil feedstock, the optimum conditions should be studied and compared with those produced from neat oil and to improve the technique that enhance the product purification process, consequently achieves higher biodiesel yield and further reduces the production costs of biodiesel.
- Well organized laboratory should be used to determine the quality parameter of biodiesel produced from Avocado peels oil,

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Appendices

Appendex-1:

Biodiesel Standards Table-A: Biodiesel standards EN14214

Property	Test method	Limits	Units	
Density @15	ENISO 3675,12185	860-900	Kg/m^3	
Viscosity@40	ENISO 3104,ISO3105	3.5-5.0	mm^2/s	
Flash point	ENISO 2719,3979	101 min		
Sulfur content	ENISO 20846.20884	10.0 max	mg/kg	
Iodine value	EN 14111	120 max	1g	iodine/100g
			Sample	
Methanol content	EN 14110	0.20 max	%(m/m)	
Monoglyceride	EN 1405	0.80 max	%(m/m)	
Content				
Oxidative stability	EN 14112,15751	6.0 min	H	
@110				
Carbon residue(10 %	ENISO 10370	0.30 max	%(m/m)	
dist,res.)				
Cetane number	ENISO5165	51 min		
Water content	ENISO 12937	500 max	mg/kg	
Total contamination	EN12662	24 max	mg/kg	
Acid value	EN14104	0.5 max	Mg KOH/g	
Free glycerin	EN14105,14106	0.02 max	%(m/m)	
Total glycerin	EN14105,14106	0.02 max	%(m/m)	
Die glycerides	EN14105	0.02 max	%(m/m)	

Ester content	EN14103	96.5 min	%(m/m)

Appendix-2

Table-A: compares certain key parameters for B100 biodiesel fuel versus conventional

petroleum-based diesel fuel.			
Fuel property	Diesel	Biodiesel	Units
Fuel standard	ASTM D975	ASTM D6751	
Lower Heating Value	192,050	118,170	Btu/gal
Kinematic Viscosity @40	1.3 – 4.1	1.9 – 6.0	mm^2/s
Specific gravity @60	0.85	0.88	Kg/l
Density	7.079	7.328	lb/gal
Water and sediment	0.05 max	0.05 max	% volume
Carbon	87	77	wt%
Hydrogen	13	12	wt%
Oxygen	0	11	
Sulfur	0.0015	0.0 to 0.0024	wt%
Boiling point	180 to 340	315 to 350	^oC
Flash point	60 to 80	130 to 170	^oC
Cloud point	-15 to 5	-3 to 12	^oC
Pour point	-35 to -15	-15 to 10	^oC

Table B: Physico-Chemical Properties of Biodiesel from Different oil raw material

Feed stock	Kinematic Viscosity (at 40^0C	Density (kg/m^3)	Saponification value	Iodine value	Acid val-ue (mg KOH/g)	Cetane Number	Heating value (MJ/kg)
Soybean	4.08	885	201	138.7	0.15	52	40
Sunflower	4.9	880	200	142.7	0.24	49	45.3
Palm	4.42	860-900	207	60.07	0.08	62	34
Peanut	4.42	883	200	67.45		54	40.1
Corn	3.39	880-890	202	120.3		58-59	45
Cotton	4.07	875	204	104.7	0.16	54	45
Pumpkin	4.41	884	202	115	0.48		38
jatropha	4.78	864	202	108.4	0.496	61-63	40-42
used cook-ing oil	4				0.15		