WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

FINAL PROJECT ON :

PRODUCTION OF BIODIESEL FROM COTTON SEED OIL

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A THESIS TO BE SUBMITTED TO THE WOLKITE UNIVERSITY COLLEGE OF ENGINEERING AND TECHNOLOGY DEPARTMENT OF CHEMICAL ENGINEERING IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR THE DEGRE OF BACHELOR OF SCIENCE IN CHEMICAL ENGINEERING(STREAM PROCESS)

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AUGUST, 22, 2021

WOLKITE, ETHIOPIA

DECLARATION

This project done by Dinaol Feyisa, Efa Tekilu, Lemi Tilahun, Takile Ejeta, and Yaikob Ejeta and we are fifth year chemical engineering student. We undersigned and declare that this final project is our original work and compiled according to the department of chemical engineering.

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ACKNOWLEDGEMENT

First of all we would like to thank the Almighty GOD! For giving us his astonishing provision, strength and patience for the suceessful accomplishment of this study and our families tireless for 17 years! Starting from the initial, those who were participated and encouraged to compete the valuable results have to be thankfully and give credit to all individuals, who have provided project forward.i.e. assistance and department all Engineering Technologies as well as Biotechnology. Whether be it gentle guidance or access to material or services that helped us in our thesis (work) either within working or anywhere without missing the time. Moreover, we would like to express ande heart full appreciation and thank to Advisor Mr Zeynu for her sustainable and appreciable guidance, tireless advising, for sharing her knowledge, skill, experience and improvement up to the successful completion of this thesis as well as Mr.Yohnes Who guided how the equipments were functioning and adjusted the labratory equipments in the labratory appropriately and well being with his full of knowledge at all the time .

ABSTRACT

Biodiesel, known as fatty acid methyl ester (FAME), was produced from crude cottonseed oil (triglycerides) by transesterification with methanol in the presence of sodium hydroxide.Biodiesel has become more attractive recently because of its environmental benefits and the fact that is made from renewable resorces.the cost of biodiesel however, it's the main handle to commercialization of the product. Theused cooking oils are used as raw material, adaption of continuous transesterification process and recovery of high quality glycerol fom biodiesel by product (glycerol) are primary options to be considered to lower the cost of biodiesel. There are four primary ways to make biodiesel, direct use and blending, microemulsions, thermal cracing (pyrolysis) and transesterification.The most commonly used method is Transesterification of vegetable oil and animal facts. The Transesterification reaction is affected by molar ratio of glycerides to alcohol, catalysts, reaction temperature, reaction time, free fatty acids and water content of oils or facts. In the present work, the Transesterification process for production of cotton seed oil methyl ester has been investigated.

Keywords

Biodiesel: Cotton seed oil: Transestrification; Blending; Micro emulsion; Thermal cracking

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LIST OF ACRONYMS

ASTM	American Society for Testing and Material
CL	Clerical Labor
CO	Carbon Monoxide
CO2	Carbon Dioxide
CSO	Cotten Seed Oil
DPC	Direct Product Cost
DS	Direct Supervisony
FAME	Fatty Acid Methyl Ester
FCI	Fixed Capital Investment
FFA	Free Fatty Acid
GHG	Green House Gases
KOH	Potassium Hydroxide
NaOH	Sodium Hydroxide
NO2	Nitrogen Dioxide
NPW	Net Present Worth
P	Profit
PBP	Pay Back Period
R	Annual Cash Flow
ROI	Rate Of Investment
RSM	Response Surface Methodology
SVO	Straight Vegetable Oil
TCI	Total Capital Investment
WCO	Waste Cooking Oil

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CHAPTER ONE

INTRODUCTION

1.1. Background

Recent technological, social, and environmental changes are forcing the search for new alternatives for both edible and non-edible oil-derived fuels. Presently, the first-generation biofuels, such as biodiesel and bioethanol, dominate the biofuel sector. These biofuels can be used in low-percentage blends with conventional fuels and can be distributed through the existing infrastructure. Today, these fuels are not competitive with fossil fuels and can be seen as an intermediate step to reduce greenhouse gas (GHG) emissions and to diversify transport energy sources. The advantages of using vegetable oils as engine fuels lie in their renewable nature and wide availability from a variety of sources. This is particularly attractive to countries lacking sources of liquid fossil fuels. They can also be produced on a small scale for on-farm operation to run tractors, pumps, and small engines for power generation. There is the potential for a lower contribution, on combustion, to the atmospheric concentration of the "greenhouse gas" carbon dioxide, than from the fifixed carbon in fossil fuels. Disadvantages of the use of vegetable oil include a relatively high viscosity, incompatibility with petroleum lubricating oils, and the problem that pyrolysis products foul injector nozzles.

Biodiesel, the most promising alternative diesel fuel, has received considerable attention in recent years due to its following merits: biodegradable, renewable, non-toxic, less emission of gaseous and particulate pollutants with higher cetane number than normal diesel. In addition, it meets the currently increasing demands of world energy that,in a large degree, is dependent on petroleum based fuel resources, which will be depleted in the foreseeable future if the present pattern of energy consumption continues. Biodiesel is derived from vegetable oils or animal fats through transesterification [1]. Transesterification is also called alcoholysis, which uses alcohols in the presence of catalyst (e.g., base, acid or enzyme depending on the free fatty acid content of the raw material) that chemically breaks the molecules of triglycerides into alkyl esters as biodiesel fuels and glycerol as a by-product. The commonly used alcohols for the transesterification include methanol, ethanol, propanol, butanol, and amyl alcohol. Methanol and ethanol are adopted most frequently, particularly the former due to its low cost. Commonly used feedstocks (vegetable oil) for transesterification include soybean oil, rapeseed oil, etc. In recent years, there exist active researches on biodiesel production from cottonseed oil [2-7], of

which the conversion between 72% and 94% was obtained by enzyme catalyzed transesterification when the refined cottonseed oil reacted with short-chain primary and secondary alcohols. The application of solid acid catalysts on cottonseed oil transesterification was investigated by He et al. The results showed that the yield of methyl ester was above 90% after 8 hours of reaction [8]. In contrast, transesterifying cottonseed oil by microwave irradiation could produce a biodiesel yield in the range of 89.5-92.7% [9]. No matter what kind of catalysts or approaches were applied, all those studies aimed to produce high yield of biodiesel by optimized reaction conditions based on optimized parameters in terms of alcohol/oil molar ratio, catalyst concentration, reaction temperature, and time. However, nearly in all studied cases, there existed complex interactions among the variables that remarkably affected the biodiesel yield. Moreover, it seems unrealistic to optimize the process by the traditional 1-factorat-a-time approach, which is time-consuming and nearly impossible to achieve the true optimal condition. Alternatively, response surface methodology (RSM), an experimental strategy described first by Box and Wilson for seeking an optimal condition for a multivariable system, is an efficient technique for processing optimization [10]. In this study, RSM was applied to optimize the transesterification of crude cottonseed oil with methanol in the presence of sodium hydroxide to produce biodiesel with the highest yield.

1.2. Statement of the problem

The issue of energy security resulting from the gradual depletion of world petroleum reserves, rising of petroleum price and environmental concerns has energize the search for alternative renewable biofuels. In addition, now a days the country's population growth increases fastly following to this the fuel consumption also increased significantly. For this reason, it needs searching alternative renewable bio fuels that are economically competitive, environmentally acceptable and capable of fulfilling an increasing energy demand. To produce environmentally friendly and economically acceptable biodiesel using heterogeneous catalyst prepared from cotton seed is better. Biodiesel production process using homogeneous catalysts such as sodium and potassium hydroxides causes apparatus corrosion, not reusable and requires further process for catalyst separation this leads to extra cost expense, but using a heterogeneous catalysts such as CaO is low cost, easily separated, reusable and provides higher conversion efficiency than a homogeneous catalyst. Thus all simplifies the production and purification processes. Although, most of the researchers has worked with methanol alcohol as a reactant during transesterification reaction it causes significant human health effect and environmental problems when

compared to ethanol alcohol. Based on this it is better to use ethanol alcohol instead of methanol since it is locally available, cheap in price and bio based. Therefore, this study seeks to create green environment with reduced cost by overcoming the above limitations. Moreover, to produce environmentally friendly and economically acceptable biodiesel Cotton seed is preferable. As it is a waste of textile industry its price is less expensive. This makes it a potential alternative feedstock for biodiesel production. So such vegetable based biodiesel can be promote environmental conservation, decrease greenhouse gas emission and solve problems related with energy security.

1.3. Objectives

1.3.1. General Objective

The general objective of this project was to produce biodiesel from cottonseed oil.

1.3.2. Specific Objectives

- ✓ To determine the physical and chemical properties of the cotton seed.
- ✓ To extract oil from cotten seed incroporated purification.
- ✓ To optimize the parameter to produce the biodiesel

1.4. Significance of the project

Currently in Ethiopia the demand for modern energy sources such as petroleum fuels is increasing with increase in population and economic growth. The country imports its entire petroleum fuel requirement by spending over 46 % of the foreign earning annually. To overcome the above problem the government of Ethiopia gives attention to environmental-friendly renewable energies such as biodiesel since importing of petroleum adds a lot of cost to the country besides to higher environmental pollution through emitting of CO2 and NOX gases. So this study is significant on solving problems related to environmental concern, energy security and economy. Biodiesels developed from vegetable oil reduces environmental pollution, greenhouse emission and has higher combustion efficiency because it is non-toxic, renewable, and biodegradable. The production of biodiesel from locally available resource is reliable, renewable and domestically distributed, this reduces dependency on imported petroleum and energy crisis. The other significance of this research is to improve the economic development of the country and helps on finding different alternative biofuels so as to increase the farmer's income by creating job opportunity around the rural areas and this motivates agricultural and sustainable development.

CHAPTER TWO

LITERATURE REVIEW

2.1. History of Biodiesel

Biodiesel is the general name for fatty acid alkyl esters and the most common alternative fuel for traditional diesel engines. Biodiesel has significantly lower emissions than petroleum based diesel. It does not contribute to a net rise in the level of carbon dioxide in the atmosphere and leads to minimize the intensity of greenhouse effect. In addition, biodiesel is better than diesel fuel in terms of sulphur content, flash point, aromatic content and biodegradability [11]. In Ethiopia the One main issue is that around 65% of the export earnings are to pay for the import of petroleum products. Amongst the identified alternative renewable energy sources, biofuels in particular energy crops received attention as a promising and sustainable energy sources, of which, biodiesel has arisen as a potential candidate for a petro diesel substitute that minimize the escalating budgetary pressure for diesel oil [12]. In the world several seeds such as soybeans, canola, sunflower, Jatropha, coconut, cotton seed, palm, corn and castoroil was used for the production of biodiesel, mainly by the transesterification reaction with short chain alcohols (methanol or ethanol) and employing alkaline catalysts. Out of those Cottonseed oil is the oldest vegetable oil used industrially produced and widely consumed in Brazil. Consumption decreased with the increase in soybean production, but still occupies a place of great economic importance [13].

2.2 Biodiesel Development Status in Ethiopia

The initiative for biofuels development in Ethiopia originally came from the private sector, though it did not take too long to get the government to buy-in. Mitigation of climate change is often presented by governments as a key policy goal for biomass fuel developments, but in the case of Ethiopia, the government is explicit about its reasons for promotion of biofuels. The reasons, among others, are energy security through the use of biofuels and to improve the balance of trade by import substitution and new export market development. Following population growth and economic development, the need for more modern fuels has increased significantly over the years. In general the demand for petroleum in the country indicates that there is a gradual increase from a year of 2000 to 2008. A Biofuels Development and Utilization Strategy has been formulated by the Ministry of Mines and Energy in August 2007. The objective of the strategy is to facilitate sufficient production of biofuels

from indigenous resources so as to substitute imported petroleum and export excess products. The biofuels strategy document identified some energy crops such as sugarcane, Jatropha, castor and palm trees as potential feedstock for biofuels production [14].

2.3 Feed stocks for Biodiesel Production

The primary feed stocks used in the production of biodiesel are vegetable oils, animal fats, and recycled greases. The feed stock used for the production of biodiesel is best if, it is not be competitive with food, land used for the oil plantation and oil production, with forest and other agricultural products [15].

Animal fats

Animal fats used to produce biodiesel include tallow, choice white grease or lard, fish fat (in Japan) and chicken fat. Compared to plant crops, these fats frequently offer an economic advantage because they are often priced favorably for conversion into biodiesel. Animal fat methyl ester has some advantages such as high Cetane number, non-corrosive, clean and renewable properties. Animal fats tend to be low in FFAs and water, but there is a limited amount of these oils available, meaning these would never be able to meet the fuel needs of the world.

Used edible oils

Because of the poor quality of soap produced from WCO, a large amounts of WCO are illegally dumped into rivers and landfills, causing environmental pollution. Hence the management of such oils and fats pose a significant challenge because of their disposal problems and possible contamination of the water and land resources. The production of biodiesel from WCO to partially substitute petroleum diesel is one of the measures for solving the twin problems of environment pollution and energy shortage. In order to reduce the cost of biodiesel production, WCO would be a good choice as raw material since it is cheaper than virgin vegetable oils and other feed stocks. But the problem related with this is its high free fatty acid content and high viscosity.

Vegetable oils sources

Biodiesel has been predominantly (more than 95 %) produced from edible vegetable oils all over the world, which are easily available on large scale from the agricultural industry. Currently, biodiesel is mainly prepared from rapeseed in Canada, soybean in US, sunflower in Europe and palm in Southeast Asia. The largest biodiesel producers were the European Union, the United States, Brazil, Indonesia, with a combined use of edible oil for biodiesel production of about 8.6 million tons (7.8 million hectares were used) in 2007. There are a large number of oil plants that produce non-edible oils, such

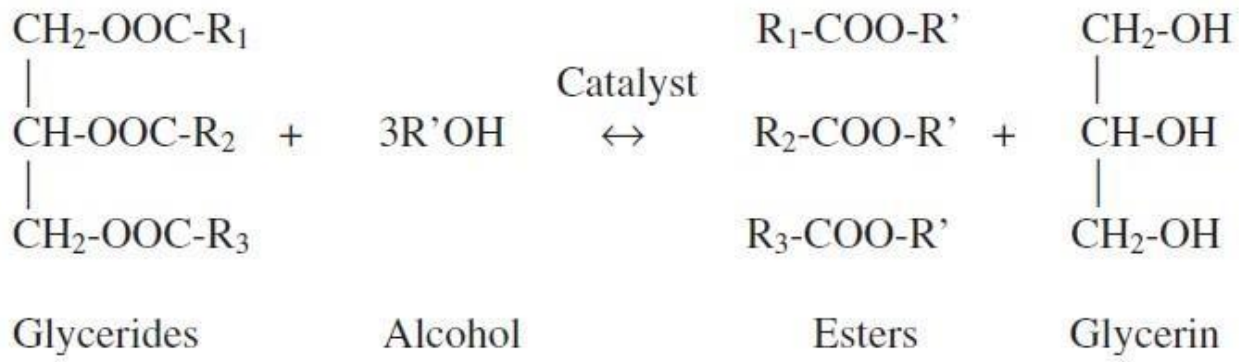
as Jatropha, karanja, tobacco, mahua, neem, rubber, sea mango, castor, and cotton. Of these feed stocks, Jatropha, moringa and castor oils are the most often used in biodiesel production. Cottonseed comes after Soybean, Corn and Canola (rapeseed) in the list of genetically modified crops.

Cottonseed

Cottonseed contains averagely 18-25% of oil and 20-25 % high quality protein (Rathore, 2007) but presently cottonseed is not used in food preparations. It is used in animal feed in regulated manner due to the presence of gossypol [13]. Cottonseed oil contains different fatty acids, such as saturated fatty acids (1.2% of myristic acid, 18–25% of palmitic acid, 1–25% of stearic acid, 1– 2% of palmitoleic acid), monounsaturated fatty acids (17–38% of oleic acid) and diunsaturated linoleic acid (45–55% of linoleic acid) [13].

2.4 Chemistry of biodiesel production

Biodiesel is produced by means of transesterification. Transesterification is the reaction of a fat or triglyceride with an alcohol in the presence of acid or base catalyst to form esters commonly methyl or ethyl esters and a byproduct, glycerol. It is, in principle, the action of one alcohol displacing another from an ester, referred to as alcoholysis [16].



General Formula forTrans esterification reaction in the presence of a catalyst

2.5 Biodiesel production process systems

2.5.1 Batch Process

During batch process the refined vegetable oil is charged to trans esterification reactor in the presence of an excess amount of alcohol, and catalyst. An excess of alcohol is necessary chiefly to ensure full solubility of triglyceride and keep the viscosity of the reaction mixture low and also for shifting the chemical equilibrium. The transesterification reaction may be considered finished when maximum

conversion is achieved. Separation of ester and glycerol is takes place by decantation. Then the ethanol is recovered by rotary evaporator and this is used for next batch. At the end the ester is washed with hot water and dried [17].

2.5.2 Catalytic continuous process

Catalytic continuous process technology of biodiesel production is a conceptual scheme of a continuous process working at low pressure that is capable of processing a feedstock with a larger amount of free fatty acids, such as unrefined non edible vegetable oils, tallow fat and used cooking oil. For this reason in the first reactor the esterification of free fatty acids with ethanol is carried out. Then the transesterification reaction follows in the second reactor. A homogeneous catalyst is currently used, either as alkaline hydroxide or alkaline ethoxide. Ensuring high yield in monoester and minimum amounts of mono or di-triglycerides a minimum of two reactors in series with glycerol intermediate separation ought to be employed. The reaction mixture is then submitted to phase separation in crude ester and glycerol phase and separation can take place by decanting or centrifugation [18].

2.6 Biodiesel production process methods

Vegetable oils and animal fats are comprised of a complex mixture of triglycerides and other minor components, such as free fatty acids, gums, waxes, etc. Triglycerides are esters of glycerol with three chains of aliphatic or olefinic FFAs of variable length (12–24 carbons). Among all the proposed methods to convert oils to biodiesel, transesterification of the triglycerides seems to be the best choice, as the physical characteristics of fatty acid esters (biodiesel) are very close to those of diesel fuel [19].

2.6.1 Hydrolysis and Esterification

The manufacturing procedure is first the hydrolysis of triglycerides and isolating the fatty acids followed by esterification employing the robust technology of a solid heterogeneous catalyst. Significant advantages would be the possibility of extracting high value fatty acids from the lipid material, as well as obtaining high purity glycerol [20].

2.6.2 Trans Esterification Reactions

Trans esterification is the reaction of a fat or oil triglyceride with an alcohol to form esters and glycerol. A catalyst is usually used to improve the reaction rate and yield. There are different types of trans esterification, such as Homogeneous acid-catalyzed trans esterification, Homogeneous alkali (base)

catalyzed trans esterification, Heterogeneous acid and base-catalyzed trans esterification, Supercritical and subcritical alcohol trans esterification [21].

Types of transesterification reaction

Supercritical transesterification

This new supercritical methanol process requires a shorter reaction time and a simpler purification procedure because of the absence of dissolved catalyst. Of course this method does necessitate high temperature and pressure (and therefore energy costs) and also requires an expensive workup because of dissolution of the glycerol by-product in methanol under these reaction conditions.

Homogeneous catalyst transesterification

The transesterification reaction can be catalyzed by Brønsted acids, preferably sulfonic and sulfuric acids, but the reactions rates are low and require relatively high temperatures to get high product yields. The most common homogeneous acid catalysts employed are H2SO4 and HCl. Currently it is synthesized using homogeneous alkaline catalysts because the transesterification reaction by an acid catalyst is much slower than the base-catalyzed reaction. The most common basic catalysts are KOH, NaOH, NaOCH3 (sodium methoxide), and NaOCH2CH3 (sodium ethoxide). Even though homogeneous catalyzed biodiesel production processes are relatively fast and show high conversions with minimal side reactions, they are still not very cost competitive with petro diesel. The other disadvantages include that:

The catalyst cannot be re covered and must be neutralized at the end of the reaction.

There is limited use of continuous processing methodologies, and the processes are very sensitive to the presence of water and FFA; consequently they need a high quality feedstock to avoid undesired side reactions (hydrolysis and saponification).

Heterogeneous catalysts transesterification

The synthesis of biodiesel using solid base catalysts instead of homogeneous catalysts could have a potential to reduce a production cost by enabling reuse of the catalyst and opportunities to operate in a fixed bed continuous process. Now, the heterogeneous catalytic process has a potential to overcome the disadvantages of homogeneous catalytic process, in particular from the sustainability standpoint of view, some advantages of heterogeneous catalyst are listed below:

It can be recovered easily and re-usable, It minimizes purification cost and reduces energy and water consumption and Can be obtained from a variety of waste sources such as bones, ashes, rocks and shells. Recently, the application of natural calcium sources from waste materials has been considered as a new

trend for biodiesel production [22]. The steps performed during biodiesel productions are alcohol and catalyst mixing, chemical reaction, separation alcohol removal and biodiesel washing and drying [21].

a. Mixing of alcohol and catalyst

At this stage the common alkali catalysts (potassium hydroxide and sodium hydroxide) are mixed with common alcohols (methanol and ethanol) to facilitate the reaction. Alkali hydroxide is dissolved in the alcohol to produce methoxide or ethoxide solution.

b. Chemical reaction

The mixture is then poured into a rector which is contained preheated oil. The reaction system is takes place in a closed reactor to prevent the loss of alcohol. The reaction mixture is kept just near the boiling point of the alcohol to speed up the reaction. Excess alcohol is normally used to ensure total conversion of the oil to its esters.

c. Separation

After the reaction is completed, there exists glycerol and biodiesel formation. Both have a significant amount of th excess alcohol that was used in the reaction which is in need of being recovered. The reacted mixture issometimes neutralized at this step if the basic media that is caused by alkali hydroxide is occurred. Decantation is applied to separate the biodiesel from glycerol, since glycerol is denser.

d. Alcohol removal

After the glycerol and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation commonly. But currently extractive distillation can instead be used to fasten the process and to be more economical. After the alcohol is being recovered it is used as main raw material.

e. Biodiesel washing

After the Biodiesel is separated from the glycerol, it is purified by washing with hot water to remove residual catalyst, alcohol or soaps to make more pure. The washed biodiesel needs drying in order to remove trace impurities. In some processes washing step is not necessary depending on the quality of biodiesel produced

Factors Affecting Biodiesel Production

The process of transesterification brings about drastic change in viscosity of the vegetable oil. The high viscosity component, glycerol, is removed and hence the product has low viscosity like the fossil fuels. The biodiesel produced is totally miscible with mineral diesel in any proportion. Flash point of the biodiesel is lowered after transesterification and the cetane number is improved. The yield of biodiesel

in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil.[23] and[24]

Temperature

Reaction temperature is the important factor that will affect the yield of biodiesel. For example, higher reaction temperature increases the reaction rate and shortened the reaction time due to the reduction in viscosity of oils. However, the increase in reaction temperature beyond the optimal level leads to decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides [25] and causes methanol to vaporize resulting in decreased yield [26]. 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 from 50°c to 60°c depends upon the oils or fats used [25]. Therefore, the reaction temperature near the boiling point of the alcohol is recommended for faster conversion by various literatures. At room temperature, there is up to 78% conversion after 60 minutes, and this indicated that the methyl esterification of the FFAs could be carried out appreciably at room temperature but might require a longer reaction time. In butyl esterification, however, temperature had stronger influence. Temperature increases the energy of the reacting molecules and also improves the miscibility of the alcoholic polar media into a non-polar oily phase, resulting in much faster reactions.

Reaction time

The increase in fatty acid esters conversion observed when there is an increase in reaction time. The reaction is slow at the beginning due to mixing and dispersion of alcohol and oil. After that the reaction proceeds very fast. However the maximum ester conversion was achieved within 90 min. Further increase in reaction time does not increase the yield product i.e. biodiesel/mono alkyl ester. Besides, longer reaction time leads to the reduction of end product (biodiesel) due to the reversible reaction of transesterification resulting in loss of esters as well as soap formation [25] and [27].

Methanol to Oil Molar ratio

One of the most important parameters affecting the yield of biodiesel is the molar ratio of alcohol to triglyceride. Stoichiometrically 3 moles of alcohol and 1 mole of triglyceride are required for transesterification to yield 3 moles of fatty acid methyl/ethyl esters and 1 mole of glycerol is used. In order to shift the reaction to the right, it is necessary to either use excess alcohol or remove one of the products from the reaction mixture. The second option is usually preferred for the reaction to proceed to

completion. The reaction rate is found to be highest when 100% excess methanol is used [28] and [26]. Methanol, ethanol, propanol, butanol and amyl alcohol can be used in the transesterification reaction, amongst these alcohols methanol is applied more frequently as its cost is low and it is physically and chemically advantageous (polar and shortest chain alcohol) over the other alcohols. In contrast, ethanol is also preferred alcohol for using in the transesterification process compared to methanol since it is derived from agricultural products and is renewable and biologically less offensive in the environment. The effect of volumetric ratio of methanol and ethanol to oil was studied. Results exhibit that highest biodiesel yield is nearly 99.5% at 1:6 oil/methanol. In comparison, biodiesel yield using methanol continuously increases with the raise of methanol molar ratio [29].

Type and Amount of Catalyst

Biodiesel formation is also affected by the concentration of catalyst. Most commonly used catalyst for biodiesel production is sodium hydroxide (NaOH) or Potassium hydroxide (KOH) [25]. The type andamount of catalyst required in the transesterification process usually depend on the quality of the feedstock and method applied for the transesterification process.

For a purified feedstock, any type of catalyst could be for the transesterification process. However, for feedstock with high moisture and free fatty acids contents, homogenous transesterification process is unsuitable due to high possibility of saponification process instead of transesterification process to occur. The yield of fatty acid alkyl esters generally increases with increasing amount of catalyst. This is due to availability of more active sites by additions of larger amount of catalyst in the transesterification process. However, on economic perspective, larger amount of catalyst may not be profitable due to cost ofthe catalyst itself. Therefore, similar to the ratio of oil to alcohol, optimization process is necessary to determine the optimum amount of catalyst required in the transesterification process [29 and 27].

Mixing Intensity

Oils and alcohols are not totally miscible, thus reaction can only occur in the interfacial region between the liquids and transesterification reaction is a moderately slow process. So, Mixing is very important in the transesterification process, adequate mixing between these two types of feedstock is necessary to promote contact between these two feed stocks, therefore enhance the transesterification reactions to occur [27] and [29]. Most literatures indicate that during the transesterification reaction, the reactants initially form a twophase liquid system. The mixing effect has been found to play a significant role in the slow rate of the reaction. As phase separation ceases, mixing becomes insignificant. The effect of mixing on the kinetics of the transesterification process forms the basis for process scale-up and design

is required to overcome the negative effect of viscosity to the mass transfer between oil, alcohol and catalyst [27] and [29].

Free fatty acid and water content

The FFA and moisture contents have significant effects on the transesterification of glycerides with alcohol using catalyst. The high FFA content (>1% w/w) will happen soap formation and the separation of products will be exceedingly difficult, and as a result, it has low yield of biodiesel product [31]. In addition formation of gels and foams hinders the separation of glycerol from biodiesel [25]. For instance, Water content in waste cooking oil will accelerate the hydrolysis reaction and simultaneously reduce the amount of ester formation [32].

To overcome this problem, supercritical methanol method was proposed. It may be noted that water has less influence in supercritical methanol method [25].Therefore, water content should not always exceed 0.5% to obtain 90% yield of biodiesel [31] and. One drawback of biodiesel is that there is an inverse relationship between biodiesel's oxidative stability and its cold flow properties. Saturated compounds are less prone to oxidation than unsaturated compounds but they raise the cloud point of the fuel. The reaction of FFAs with alcohol produces ester, but also water that inhibits the of the transesterification glycerides. This is due to the effect of the water produced when the FFAs react with the alcohol to form esters. The coincidence of the lines indicates that water formation is the primary mechanism limiting the completion of the acid catalyzed esterification reaction with FFAs.

Physicochemical properties of biodiesel

Specific Gravity

The oil had a specific gravity of 0.92 while that of the biodiesel was ranged from 0.856 to 0.9. Specific gravity is a dimensionless property that has profound effects on performance of the engine. Since the power developed will depends on the specific mass flow of the fuel into the engine. High specific gravity would translate to high kinematic viscosity of the fuel.

PH: The PH value of CSO is ranged from 5-6.07 and PH of biodiesel before washing is around 9 and after washing it is close to 7.

Refractive index: The refractive index of biodiesel is 1.4428

Cold Flow properties

The cloud point, pour point and cold soak filtration are cold flow properties of fuels and are crucial quality criteria, because when fuels are frozen, fuel flow to the engine would be restricted and the engine will stop running. The maximum cloud and pour points for biodiesel are 6, and -1,°C respectively and are all above zero, which limits their applications in cold regions. The cold soak filtration was 85°C for biodiesel and well below the ASTM maximum value of 360°C.

Flash Point

Flash point is a measure of how easily the fuel burns and thus a strong safety factor. Cottonseed oil (CSO) has a flash point of 316°C., the value for Biodiesel is 130°C which although is below the minimum for biodiesel, is higher than that for diesel fuel. Flash point always fall after transesterification [33].

Fire and smoke Point

The oil has a fire point of 322°C and biodiesel 228°C, the smoke point for the oil is 216°C which are very high and gives reduced fire risk hence its common use for frying in restaurant and fast food shops.

Kinematic Viscosity

The kinematic viscosity of the oil is 50.7mm2/s and reduced to 4.10mm2/s after transesterification. The high kinematic viscosity of the oil precludes it from being used neat in the engine but that of the biodiesel is within the ASTM limits for biodiesel.

Heating Values

The lower heating value for CSO is 41.25 MJ/kg and 39.54 MJ/kg for the biodiesel. These values are slightly less than that of diesel fuel which is consistent with the trend for biodiesel. The lower heating value of vegetable oils has been reported to be dependent on the composition of the fatty acids [34].

Water and residue, and moisture content

CSO contains 7.21% water and residue by weight, which fell drastically after transesterification because of the drying after treatment. The maximum moisture content of biodiesel is 0.05. Water has been shown to inhibit the transesterification process.[35]

Iodine Values

The iodine values for the CSO and bio diesel are 94.7 and 70.2 mg respectively and well below the ASTM maximum limit for biodiesel. Iodine value is an indication of the drying quality of oil.

Peroxide Value

This is an indicator of oil auto ignition and high value is an indication of high degree of rancidity and fuel oxidation. The peroxide values are 9.25 and 8.0 meq/kg for the oil and biodiesel respectively

Oxidation Stability

The oxidative stability of CSO at 110°C was 6 hr and 10 hours for biodiesel respectively. The oxidiative stability of biodiesel should be limited because products of oxidation can form gums that can block the fuel system .

Acid Value

Acid value is the quantity of base required to titrate a sample to a specified end point. The acid values of the oil was 11.50 And biodiesel 0.04 mg KOH/gm. Excessive free fatty acid in the fuel can be corrosive and may be a symptom of water in the fuel or oxidative degradation.

Free Fatty Acid

The free fatty acid values are 0.31% and 0.63 % for the oil and biodiesel respectively. The FFA value is very low hence no pretreatment was required. Excessive free fatty acid can promote soap formation that can retard biodiesel yield.

Saponification Values

The Saponification value of 189 for the oil is within the range for most vegetable oils. Hence, it is widely used for the production of soap and shampoo. The value for the biodiesel of 202 is about the average value for biodiesel. Moderate amount of soap in biodiesel can help reduce friction between moving parts and improve cleanliness in the fuel pump. However, too much soap in biodiesel can cause the engine operation to be rough leading to incomplete combustion and as a consequence, increased exhaust emissions and reduced engine power output.

Free Glycerol

The free glycerol for the oil and biodiesel are 0.062 and 0.041% respectively. Mono- and di- glycerides are unstable intermediate compounds components which, are undesirable in biodiesel and is manifested as gums and sediments.

Sulphur

The sulphur content of oil was 2.23% and 1.314% for the biodiesel. The value for biodiesel is lower than the maximum specified by EN. Sulphur can affect catalytic converter effectiveness but contribute to the reduction of friction when present in diesel fuel.

Phosphorus Content

Phosphorus originates from the phospholipids in the oil and can adversely affect the effectiveness of exhaust emission catalytic systems after some time. The value for the oil was 4.37% and 8.06 % for biodiesel which are less than the maximum specified by EN standard.

Color, Smell and taste

Cotton seed kernel is black and the oil extracted was like black used engine oil, the biodiesel was light yellow while the glycerol was brown. The oil had a pungent smell but the biodiesel was less pungent. However, after refining it usually has a bland taste and is flavorless, hence preferred oil for frying potatoes chips as it gives a full-flavored chip unmasked by oily residue.

The Advantages of Biodiesel

Biodiesel production is a very modern and technological area for researchers due to the relevance that it is winning everyday because of the increase in the petroleum price and the environmental advantages.

Although biodiesel cannot entirely replace petroleum-based diesel fuel, there are at least five reasons that justify its development, such as provides a market for excess production of vegetable oils and animal fats, decreases the country's dependence on imported petroleum although will not eliminate. Biodiesel is renewable and does not contribute to global warming due to its closed carbon cycle. A life cycle analysis of biodiesel showed that overall CO2 emissions were reduced by 78% compared with petroleum-based diesel fuel. The exhaust emissions of carbon monoxide, unburned hydrocarbons, and particulate emissions from biodiesel are lower than with regular diesel fuel. Unfortunately, most emissions tests have shown a slight increase in oxides of nitrogen (NO2). When added to regular diesel fuel in an amount equal to 1–2%, it can convert fuel with poor lubricating properties, such as modern ultra-low-sulfur diesel fuel, into an acceptable fuel.

The Comparison between Biodiesel and Diesel Fuel

There are a number of ways in which a comparison between conventional fuels and biodiesel can be made. For overall ozone forming potential of biodiesel is less than diesel fuel. The ozone forming potential of the speculated hydrocarbon emissions was nearly 50 percent less than that measured for diesel fuel. Sulfur emissions are essentially eliminated with pure biodiesel. The exhaust emissions of sulfur oxides and sulfates from biodiesel were essentially eliminated compared to sulfur oxides and sulfates from diesel. Criteria pollutants are reduced with biodiesel use. The use of biodiesel instead of diesel engine resulted in substantial reductions of unburned hydrocarbons, carbon monoxide, and particulate matter.

Emissions of nitrogen oxides however were slightly increased. The exhaust emissions of carbon monoxide from biodiesel were 50 percent lower than carbon monoxide emissions from diesel. Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from biodiesel were 30 percent lower than overall particulate matter emissions from diesel. The exhaust emissions of total hydrocarbons were 93 percent lower for biodiesel than diesel fuel. NO2 emissions from pure (100%) biodiesel increased in this test by 13 percent. However, biodiesel's lack of sulfur allows the use of NO2 control technologies that cannot be used with conventional diesel. So, biodiesel NO2 emissions can be effectively managed and efficiently eliminated as a concern of the fuel's use.

Biodiesel degrades about four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85 to 88 percent in water. The flash point of a fuel is defined as the temperature at which it will ignite when exposed to a spark or flame. Biodiesel's flash point is over 300 deg. Fahrenheit, well above petroleum based diesel fuel's flash point of around 125 deg. Fahrenheit. Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases. Therefore, biodiesel and blends of biodiesel with petroleum diesel are safer to store, handle, and use than conventional diesel fuel .

Type	Diesel	Biodiesel(cottonseed)
Calorific value (kJ/kg)	43350	40580
Viscosity (sq.mm/s)	4.3	11
Octane number	47	45-52
CO (ppm)	2225	2500
NO2 (mg/cu.Nm)	2100	1500

Table 1 Fuel and Emission properties of Diesel and Biodiesel

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1. Site Description

The sample for biodiesel production were collected from West wollega and the other equipment such like soxhlet apparatuse, digital balance, heating mantel, measuring cylinder, flask, stirring rod, beakers and PH meter can be gained in a chemical engineering labiratory and also the chemicals suach as hexane, methanol, sodium hydroxide obtained in chemical engineering labiratory but distilled water can obtain from food processing engineering labiratory.

3.2. Chemicals and Equipments/instruments used in laboratory

List of Chemicals

N-Hexane: Used to extract oil from a cotton seed.

Methanol: **U**sed to be as a reactant

Sodium hydroxide: To neutralize the crude oil

Distilled Water: Used to washed the product

List of Equipments/instruments used in laboratory

Sieves :To separate oversized and under sized of cotton seed.

Heating mantle : Used to boil hexane and cotton seed

Disk miller: It is used to grind the sample**.**

Digital balance : **T**o weigh the samples

Measuring cylinder: To measure sample of water, oil and solvent

Beakers: To hold samples of water and essential oil during characterization.

Soxhlet apparatuses: To extract essential oil from cotton seed

Flask: To mix sample with solvent

Stirring rod: It is used for mixing liquids and solids

PH meter: To measure the PH value of essential oil

Digital oven: It is used for drying and heating processes.

3.3. Methodology

Plant Sample Collection

Cotton seeds were collected from local agricultural institutions and cotton production industries.

Preparation of seeds sample

Healthy cottonseeds were selected, cleaned and de-shelled. Seeds were pulverized prior to analysis and extraction of oil. The cottonseeds collected were sorted and the unwanted parts discarded as waste. Seeds that need to be dried in for 72 Hrs at atmospheric temperature prior to which the wet weight of seeds will have been taken and recorded and after drying the dry weight was taken and recorded. The seeds were then crushed in a mortar and pestle to increase the surface area for oil extractio

Figure 1 Raw cotton seed

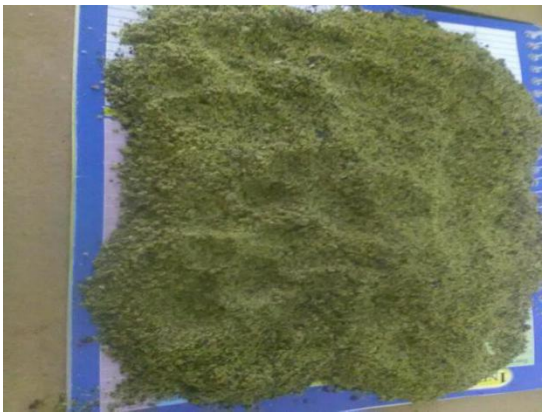


Figure 2 Grinder of cotton seed

Oil extraction

Cottonseed was procured from the local market. It was delinted, decorticated, dehulled and then dried in the atmospheric temperature for 3 days to reduce the moisture content and ground using miller. The ground seeds would have their weights taken and recorded as the mass of dry sample. The oil was

extracted by soxhlet extractor using normal hexane as solvent and operated at 60°C. Since hexane is highly toxic and harmful to the environment, the hexane in the oil was removed using a rotary evaporator (distillation). After finding the crude oil degumming comes next. In this process the hydratable and non- hydratable phosphatides along with various resinous and mucilaginous materials were separated from the neat oil. The oil was treated with 13% volume of NaOH at 80°C. The hydratable portions absorbed and became heavy and the heat helps to coagulate these smaller portions. The soap formation created and separation was achieved through difference in specific gravity, oil being lighter floated on top and soap, gums being heavier settled down. After and before added the NaOH, the oil was washed three times using water at 90°C. The weights of seeds used and that of the oil extracted were measured.

Procedure of oil extraction

1) An empty and clean thimble was weighed and its weight recorded.

2) 100g of the dried sample was weighed and put into the empty thimble.

3) 425ml of n-Hexane was measured and poured into a round-bottomed flask. The soxhlet apparatus was mounted on this flask and fixed under a condenser, which was already clamped to a retort stand. In addition, the condenser was already connected to two pipes, one pipe connected to a water supply (tap) and the other removes water from the condenser. The electro thermal heating mantle was switched on and temperature set at 60°C with the time this was done being noted.

4) The set-up was reassembled as earlier described and the heating mantle switched on with a set temperature of 60°C. The pure solvent began to evaporate and condense back into the soxhlet apparatus. A solvent in the soxhlet apparatus was poured back in to the flask

5) After 3:30 hours, the heating mantle was switched off. The soxhlet apparatus was disconnected from the condenser and the thimble removed and the round bottomed flask allowed cooling when no appreciable quantity of solvent could be gotten any more from the flask. Cold oil was then poured in to a glass container and the round bottomed flask rinsed with small quantity of solvent.

6) The oil that extracted using soxhlet contains hexane and the mixture was separated by distillation at a temperature of 60°C.

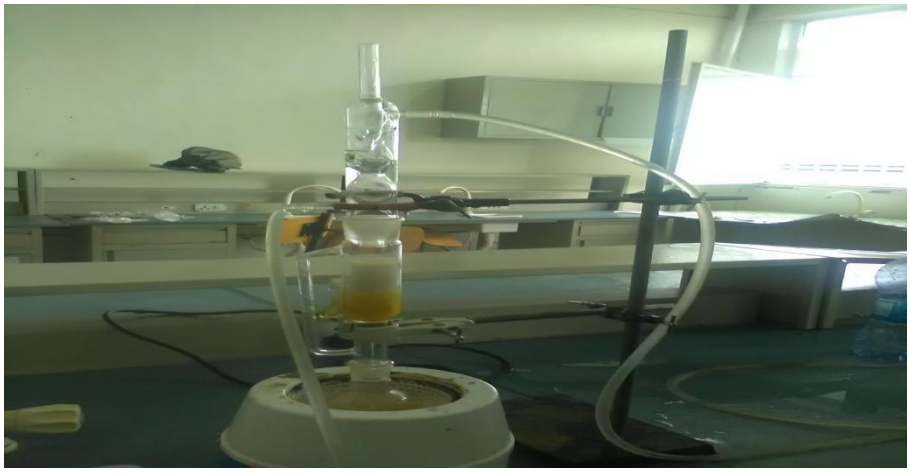


Figure 3 .soxlet apparatus

1. Refining processes.

Degumming

ing was the first step in the refining process. It removes phospholipids and mucilaginous gums the presence of substantial amounts of phospholipids can lead to darkcolored oils, and they can also serve as precursors of off-flavors. Hence, the removal of nearly all the phospholipids is very important for the finished oil quality. In this work, distilled water was heated to 100°C and left to boil for several minutes. The crude cottonseed oil was poured in to a beaker and equal volume of hot distilled water added and stirred vigorously to remove the gums. The mixture was allowed to settle for 5 minutes the oil -water mixture separated into layers with the oil layer on top.

Then the oil was decanted.

Figure 4 degumming process

Methodology to produce cottonseed oil

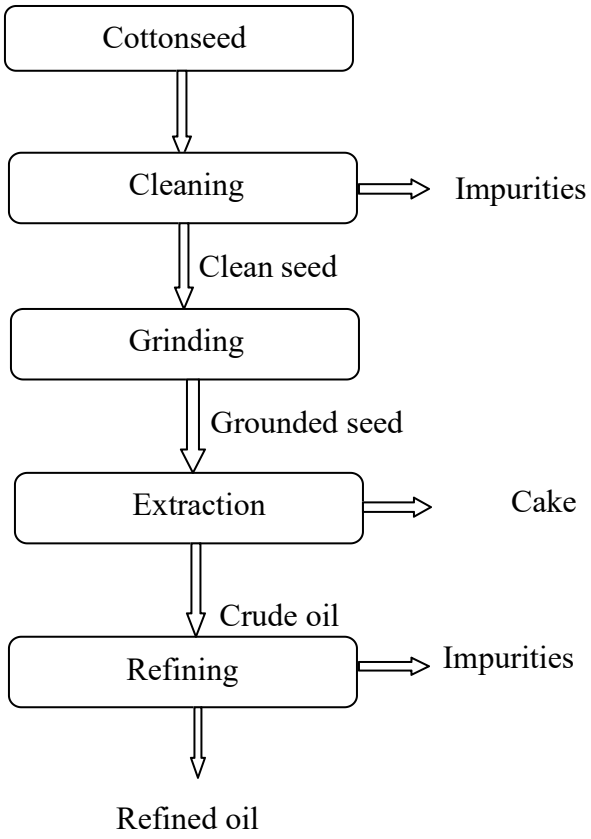


Figure 5 Block diagram of oil extraction from cottonseed.

The degummed cottonseed oil was poured in to an empty clean beaker and put into an oven set at 80°Cfor 30minutes. 0.5 ml of 40% NaOH was then added to it after removal from the oven. The oil was then stirred and left for 20 minutes. The soap formed settled at the bottom of the beaker. The oil was decanted and washed with distilled water to remove residual soap from the oil.

Transesterification Process

The transesterification reaction is very popular one and use of vegetable oils is the best way for carrying out the reaction for the production of biodiesel. In the laboratory, the transesterification of cottonseed oil was carried out in flask of capacity 500 ml. Cottonseed oil was taken in flask, heated the oil at 110˚C temperature. So that moisture content in it was removed, then it was cooled. In a beaker sodium hydroxide solution catalyst and methanol was added, shaking was done so that NaOH pellet gets mixed with the methanol and sodium meth oxide is formed. Round bottom flask was kept on magnetic stirrer with needle inside it. The cottonseed oil was poured into the flask.

Heating and stirring of oil was started at same time, heated up to 40˚C & sodium meth oxide added into the round bottom flask by opening , stirring and heating & continuous mixing was continued for hours.

The mixture allowed settling for 24 hours at which two separate layers were obtained. Optimum conditions of the transesterification reaction results into two phases that are separated in few minutes. The top layer will be methyl ester of cottonseed oil and the bottom one of glycerol. Using a conical separating funnel the glycerol is separated at the bottom. In a good completion reaction glycerol begins to separate immediately when stirring and heating is stopped with two layer ester and glycerol being separated by means of separating funnel. In the ester, the traces of glycerol, unreacted methanol. Soap present in these traces could be removed by adding hot distilled water. The separation of ester requires 2-3 hrs. The methanol, soap and glycerol were separated as byproduct. The recovery of ester obtained is nothing but the biodiesel. Wash the product by adding 10 cm3 of distilled water to the top layer, with gentle mixing.

Procedure of biodiesel production

1) Mixing of the 24ml Methanol and the 0.6g catalyst in a flask..

2) The mix Methanol and NaOH was heated to 50°C and stirred by stiring rod until the catalyst was completely dissolved in the methanol.

3) 100 ml cottonseed oil was heated at 40°C.

4) The solution Methanol-catalyst and the oil were mixed in a flask. The flask was introduced at 55°C and stirred by stirring rod. The reaction was performed during 60 minutes.

5) The final solution then settled for about 24 hours until two separate layer were formed. The top layer was the biodiesel and the bottom darker layer was the by-product, glycerol.

6) Removal the glycerol from the biodiesel, and measure the glycerol.

7) The product was washed by distilled water to the top layer, with gentle mixing.

8) Measurement of the amount of produced biodiesel.

9) Finally entered to the dryer (spray dryer) in order to remove the moisture.

Methodology to produce biodiesel

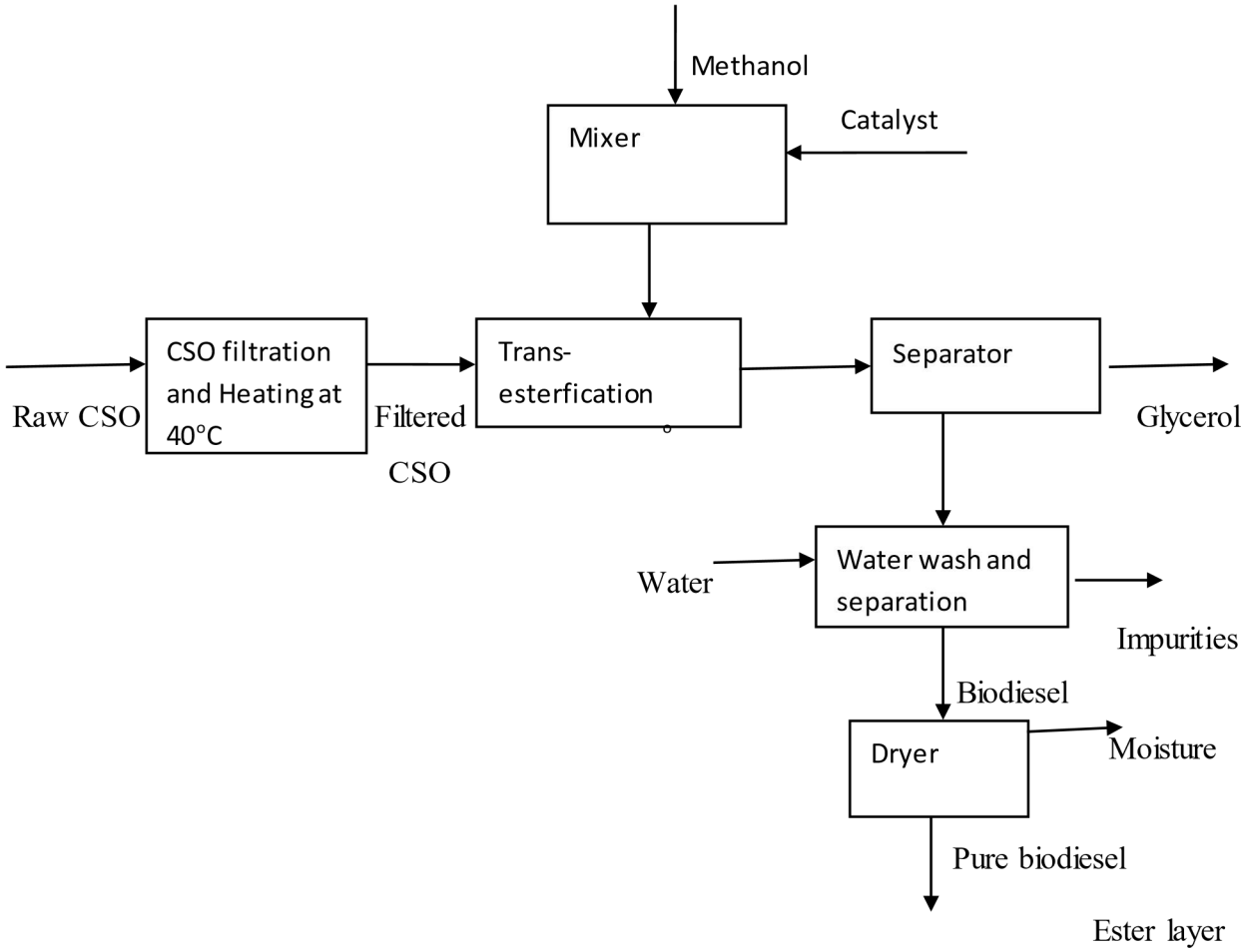


Figure 6 Block diagram of biodiesel production

CHAPTER FOUR

RESULT AND DISCUSSION

Raw material preparation

The moisture content test of the dry cottonseed was calculated and the results were summarized in the table below.

Moisture content (W) = [(W1 – W2) / W1]

Where, W1 = original weight of the sample before drying

W2 = weight of the sample after drying

Run	Weight before drying(kg)	Time	Temp(0C)	Weight after drying(kg)	Moisture content (%)
	W1			W2	[(W1－W2)/(W1)]
1	1.058	3 days	25	1	0.05

Table 2 Block diagram of biodiesel production

Oil extraction

1kg of cottonseed was used for oil extraction. After extraction, about 0.1liter of oil or 0.0925 kg of oil was obtained. Then the density (ρ) of oil was calculated and the result was:

Density (ρ) =mass of the oil / volume of the oil

ρ = m/v=0.0925/0.1= 0.925kg/L

Oil yield (%) =(mass of extracted oil / mass of cottonseed used)*100%

= (0.0925kg / 1kg)*100% =9.25%

Specific gravity

Oil sample was brought to 25oC and density of the sample was calculated for specific gravity calculation.

SG = ρ oil/ ρ water where, ρ oil= Density of oil used = 0.925kg/L

ρ water =Density of water = 1kg/L

$$SG = \frac{0.925kg/L}{1kg/L} = 0.925$$

From literature review SG of the standard cottonseed oil is 0.92. When the SG of the extracted oil compare with the standard it was nearly the same.

PH measuring

PH of extracted oil was measured using digital PH meter and its value was 5.8. The value was under the standard PH value range from the literature review.

Biodiesel characterization

Moisture content

The moisture content of biodiesel was calculated and the result are summarized in the table 4.2

Moisture content (W) = [(W1 – W2) / W1]*100%

Where, W1 = original weight of the sample before drying

W2 = weight of the sample after drying

Run	Weight before drying (kg)	Time (hr)	Temperature (o C)	Weight after drying (kg)	Moisture content
	W1			W2	[(W1-W2)/W1]*100
1	0.0488	1	115	0.0394	0.19

Table 3 moisture content of biodiesel

Density of Biodiesel

After production of biodiesel, about 0.045Lit or 0.03937kg was obtained. From the result density of biodiesel was calculated as follow

Density of biodiesel (ρ) = $\frac{\text{mass of biodiesel}}{\text{volume of biodiesel}}$ ρ =0.03937kg/0.045Lit=0.8748g/cm3

Specific gravity of biodiesel

Specific gravity was determined as:

A clean and dry bottle of 100ml capacity was weighed (W0) and then filled with the biodiesel sample, stopper inserted and reweighed to give (W1). The sample was substituted with water after washing and drying the bottle and weighed to give (W2). The specific gravity (SG) was determined by (W1-W0) / (W2-W0).

From the experiment, W0=45.97g, W1=81.083g , W2=86.10g

SG= (81.08-45.97)/ (86.10-45.97) =0.875

PH measurement

The PH of biodiesel was measured using digital PH meter and its value was 7.4. The value of specific gravity and PH were under the range of standard values in the literature. The standard values are 0.856-0.91 and 7-8 respectively.

Refractive index

The refractive index of biodiesel was measured using refractometer and the obtained value was 1.457 and the value was similar to standard value of biodiesel.

Biodiesel yield (%) = (total mass of biodiesel produced/total mass of oil used)*100

Biodiesel yield (%) = (0.03937kg/0.0925kg)*100=42.56%

Biodiesel was optimized by optimizing the parameters (temperature, time and catalyst concentration) using different trials. Here two parameters kept constant and third one changed and variation in biodiesel yield was studied. But the time of reaction was taken as a constant that was 60 minute from the literature.

Trial	Concentration of catalyst (NaOH) in gm	Biodiesel obtained in gm
1	0.8	No product
2	0.6	39.37
3	0.4	No product

Table 4 Effect of concentration catalyst on the yield

The result from the table indicates that when the amount of catalyst concentration was very high then the oil was changed to solid form (soap) because there was no optimum reaction and the same was true for small amount of catalyst concentration it did not change to biodiesel and it becomes suspension form. The optimum value was obtained when the concentration was 0.6.

Trial	Temperature in o C	Biodiesel obtained in gm
1	70	No product
2	55	39.37
3	45	No product

Table 5 Effect of temperatur in the reaction

In this table there was no biodiesel production at high temperature and low temperature because the boiling pointof methanol was 65°C and it wasvaporized at high temperature and also at low temperature the reaction was very slow. The optimum temperature value was obtained 55°C at a given time.

Properties	Biodieselproduced from lab	Standard biodiesel	Fossil diesel
Density	0.8748gm/cm3	0.875gm/cm3	0.876gm/cm3
Specific gravity	0.875	0.856-0.9	0.850
PH	7.4	7-8	3-5.6
Refractive index	1.457	1.445	1.45-1.475
Moisture content	0.618	0.05	0.02

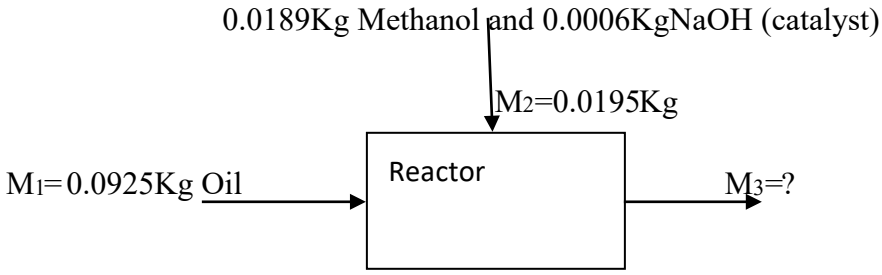
Table 6 Comparison between biodiesel and diesel

CHAPTER FIVE

MATERIAL AND ENERGY BALANCE

5.1 Material Balance

5.1.1 Material balance on Reactor

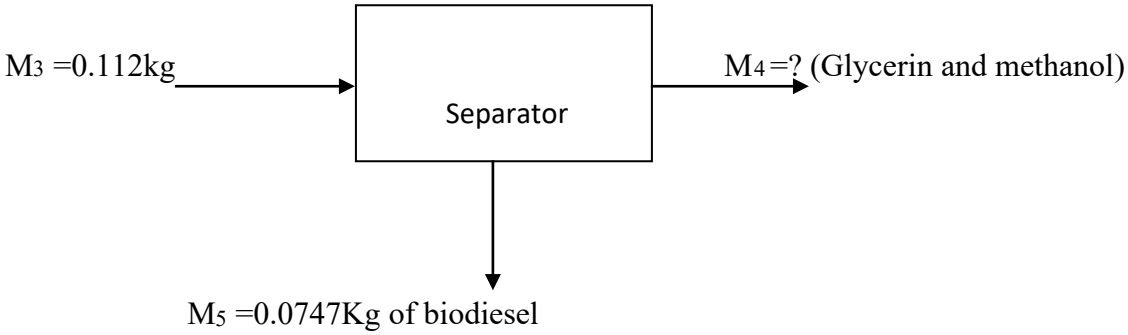


Mass of input = mass of output

M1 + M2 = M3

0.0925 + 0.0195 = M3 then M3=0.112Kg

5.1.2 Material balance on Separator

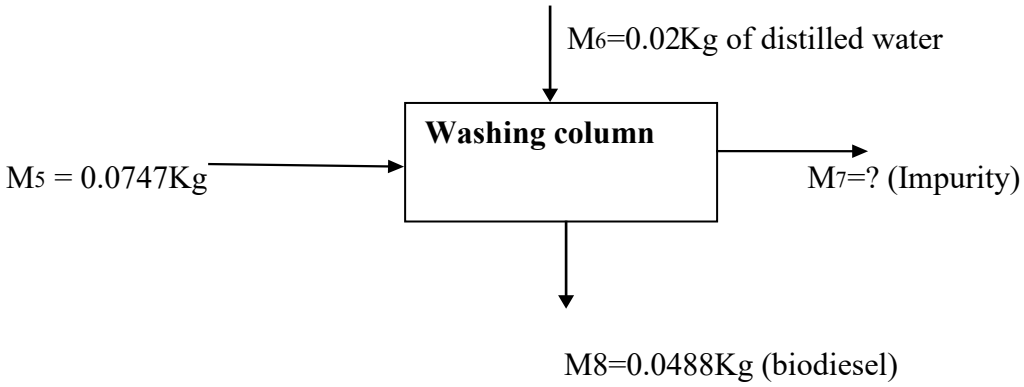


Mass of input = Mass of output

M3 = M4 + M5

0.112Kg =M4 + 0.0747Kg, M4 =0.0373Kg of glycerin

5.1.3 Material balance on wash column



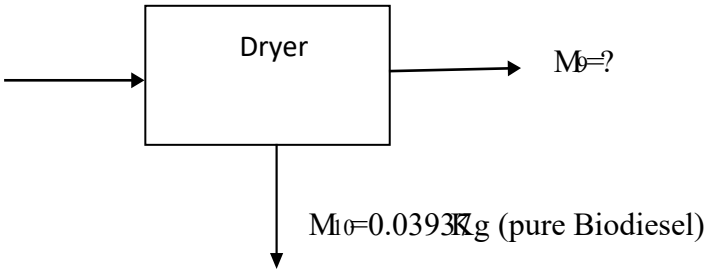
Input mass = output mass

M5 + M6 =M7 + M8

(0.0747+0.02)Kg= (M7 + 0.0488) Kg

M7=0.04948Kg

Material balance on dryer



M8=M9 + M10

M9= M8 –M10

M9=0.0488 – 0.03937

M9=0.00943Kg of moisture

5.2 Energy balance

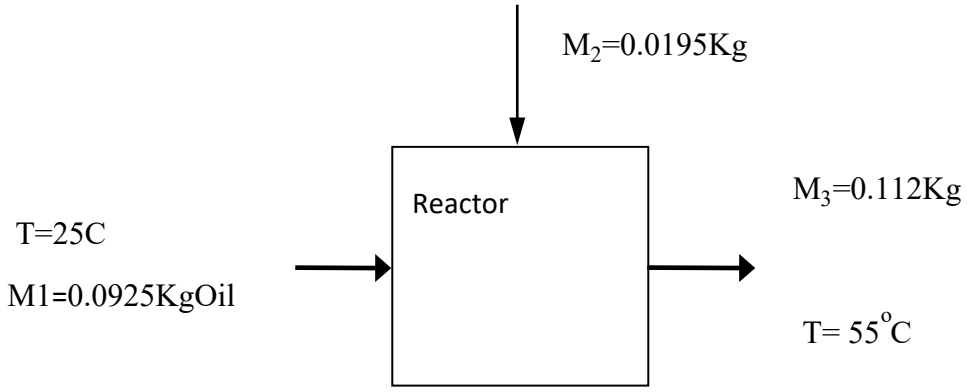
From process flow diagram, energy balance was calculated on Reactor and dryer

Equipment	Temperature	
	Input temperature (°C)	Output temperature (°C)
Reactor	25	55
Dryer	25	120

Table 7 input and output temperature

5.2.1 Energy balance on the reactor

0.0189Kg Methanol and 0.0006KgNaOH (catalyst)



Note that; Cp of oil= 2200KJ/Kg o C

Cp= specific heat capacity

Cp of methanol=2.533KJ/Kg o C

ΔT= change in temperature

Cp of NaOH= 3.471KJ/Kg o C

m= mass of mixture

m=m3= 0.112Kg

Q1+Q2-Qreaction = Q3

Q1= m1CpΔT = 0.0925* 2200*(40-25) = 3052.5KJ

Q2 = m2CpΔT= 0.0195*[(2.53+3.47)/2]*(50-25) =1.46KJ

Q3= m3CpΔT=0.112*[(2200+2.53+3.47) / 3)]*(55-45) =82.35KJ

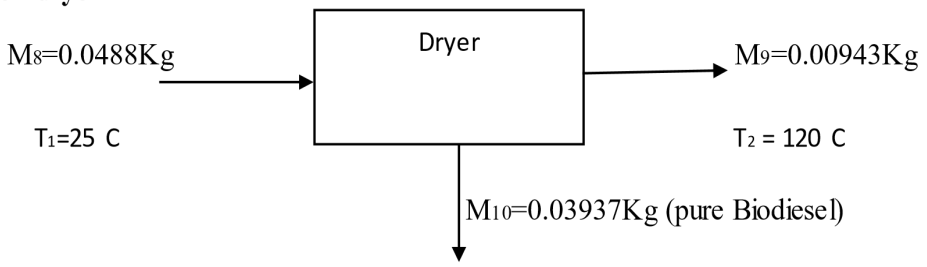
Therefore, Q reaction= Q1 + Q2 - Q3

Q reaction =(3052.5KJ+1.46KJ)-82.35KJ

Q reaction =2971.6KJ

5.2.2 Energy balance on dryer

Energy balance on dryer



Note that: Cp for biodiesel= 2.0731KJ/kg .K

Cp for water=4.2 KJ/Kg .K

hfg = 1726.4KJ/Kg, from thermodynamic table at a temperature of 120oC(saturated water table)

Q supplied + QM8 = QM9+QM10+ Q Latent

Q Latent = M9 * hfg=0.00943Kg*1726.4KJ/Kg =16.27KJ

QM8= M8CpbiodΔT=0.0488*[(2.0731+4.2)/2]*(25) =3.82KJ

QM9= M9CpwΔT=0.00943*4.2*(120 -25) =3.76KJ

QM10= M10CpbiodΔT = 0.03937*2.0731*(120 -25) = 7.75KJ

Therefore, Q supplied = (QM9 + QM10+ Q latent) - QM8

Q supplied = (16.27+7.75+3.76) KJ -3.82KJ

Q supplied = 23.96KJ

Industrial scale up

From lab results the processes was scale up into industrial scale as following;

Basis: one operation day/24hr

Production: 1*106 lit/year of biodiesel with plant operation of 300 calendar days per year

Biodiesel (L/hr) $= \frac{\text{Total capacity}}{24*300} = \frac{10000000\ \text{lit}}{\frac{24\text{hr}}{\text{day}}*300\text{day}} = 138.88$ lit/hr

m =ρ*V , ρ=density of biodiesel=0.875kg/lit m

= 0.875kg/lit*1388.89lit/hr = 121.53kg/hr

Material balance

Material balance on Reactor

Laboratory level of oil = 0.0925kg of cottonseed oil: 0.03937kg of biodiesel

0.0925Y = 0.03937; Y = 0.42562 Where Y is a conversion factor

Industry level oil = M kg of cottonseed oil: 121.53kg /hr of biodiesel

M*Y = 1215.27kg/hr $\Longrightarrow$ M = 121.53kg/0.42562 = 285.53kg/hr

Laboratory level of methanol=0.0925Kg oil: 0.0189kg methanol

Industry level of methanol=285.53Kg oil: mass of methanol (Mm)

Mm= (285.53Kg oil*0.0189Kg methanol)/0.0925Kg oil

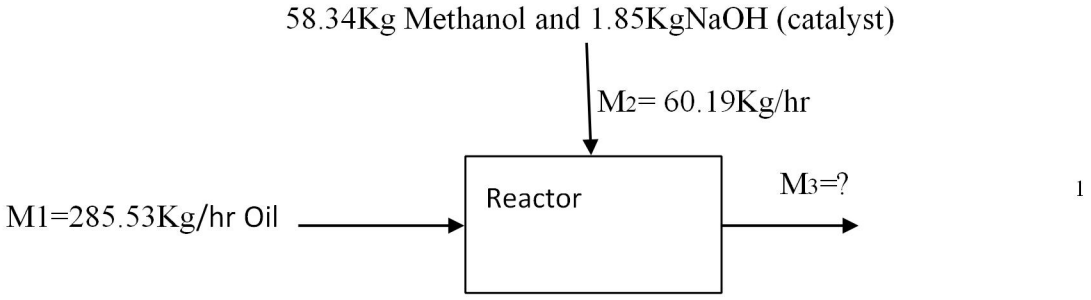
Mm= 58.34Kg methanol

Laboratory level of catalyst (NaOH) = 0.0925Kg oil: 0.0006Kg catalyst (NaOH)

Industry level of NaOH =285.53Kg/hr oil: mass of catalyst (MNaOH)

MNaOH = (285.53Kg oil*0.0006Kg NaOH)/0.0925Kg oil

MNaOH =1.85Kg/hr NaOH

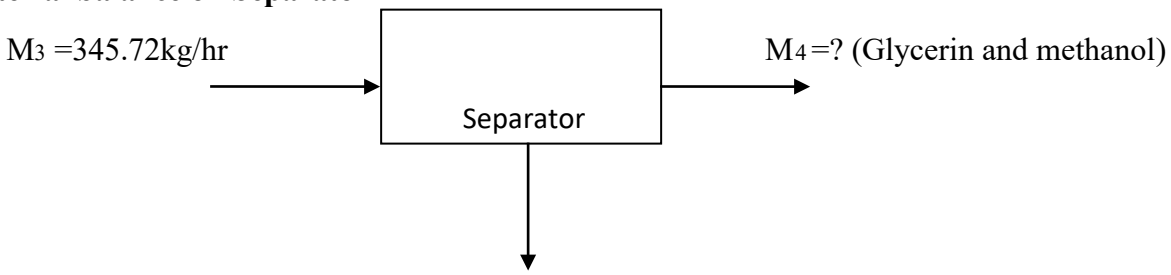


Mass of input = mass of output

M1 + M2 = M3

285.53+ 60.19 = M3 then M3=345.72Kg/hr

Material balance on Separator



From the literature the conversion of oil to biodiesel was 95% and 97% of methanol was converted.

Mass of input = Mass of output

M3 = M4 + M5

345.72Kg =M4 + 328.44Kg

M4= (3457.22-328.44)Kg/hr

M4=17.276Kg/hr

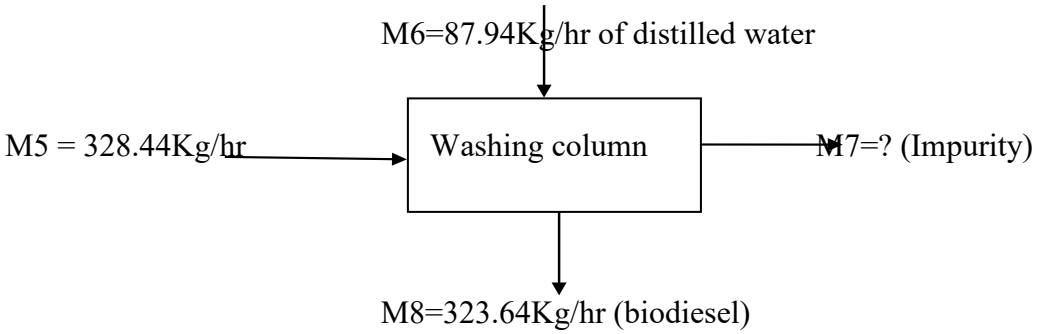
Material balance on wash column

Laboratory level of distilled water=0.0747Kg biodiesel: 0.02Kg of distilled water

Industry level of distilled water=3284.46Kg/hr of biodiesel: MDw

MDw= (3284.46*0.02)/0.0747

MDw=879.37kg /hr



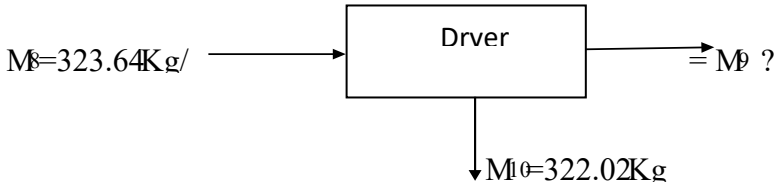
Input mass = output mass

M5 + M6 =M7 + M8

(328.44+87.94)Kg/hr= M7 + 323.64Kg/hr

M7=92.74Kg/hr

Material balance on dryer



Input mass = output mass

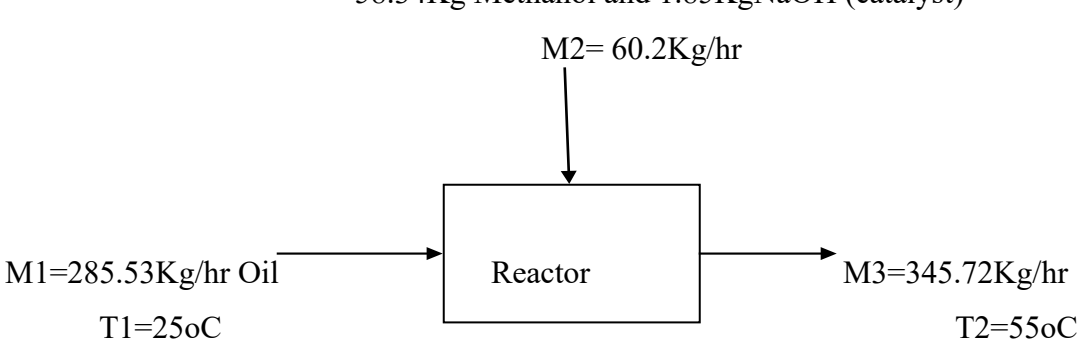
M8=M9 + M10

M9= M8 –M10

M9=323.64-322.02, M9=1.62Kg/hr of moisture

Energy balance

Energy balance on reactor



Q1+Q2-Qreaction = Q3

Q1= m1CpΔT = 285.53* 2200*(40-25) = 9422.49KJ

Q2 = m2CpΔT= 60.19*[(2.53+3.47)/2]*(50-25) =4.51KJ

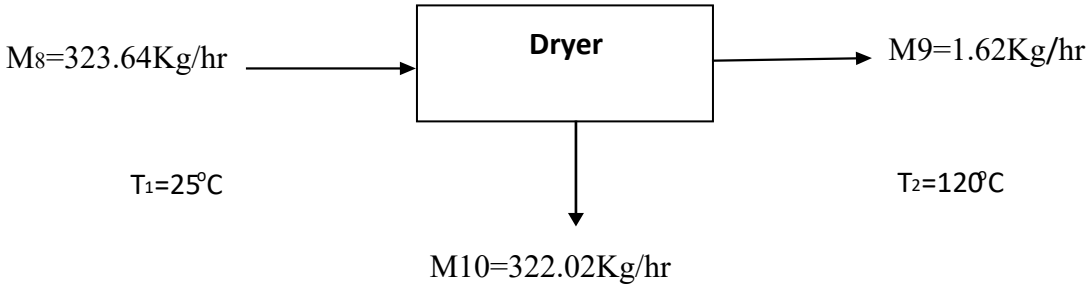
Q3= m3CpΔT=3457.22*[(2200+2.53+3.47) / 3)]*(55-45) =2542.21KJ

Therefore, Q reaction= Q1 + Q2 - Q3

Q reaction =9422.49KJ+4.51KJ-2542.21KJ

Q reaction =6884.79KJ

Energy balance on dryer



Note that: Cp for biodiesel=2.0731KJ/kg .K Cp for water=4.2 KJ/Kg .K

hfg = 1726.4KJ/Kg, from thermodynamic table at a temperature of 120°C(saturated water table)

Q supplied + QM8 = QM9+QM10+ Q Latent

Q Latent = M9 * hfg=1.62Kg*1726.4KJ/Kg =2796.7KJ

QM8= M8CpbiodΔT=323.64*[(2.0731+4.2)/2]*(25) =25377.59KJ

QM9= M9CpwΔT=1.62*4.2*(120 -25) =677.10KJ

QM10= M10CpbiodΔT = 322.02*2.0731*(120 -25) = 63419.67KJ

Therefore, Q supplied = (QM9 + QM10+ Q latent) - QM8

Q supplied = (677.10+63419.67+2796.7) KJ -25377.59KJ Q supplied = 41648.88KJ

CHAPTER SIX

EQUIPMENT SIZING

6.1 Sizing of Main Equipment

Volume of reactor

Volume of the reactor $(Vr) = \frac{\text{mass of oil}}{\text{density of oil}} + \frac{\text{mass of methanol}}{\text{density of methanol}} + \frac{\text{massof NaOH}}{\text{Density of NaOH}}$

$$Vr = \frac{285.53kg}{0.925kg/L} + \frac{58.34kg}{0.791kg/L} + \frac{1.85kg}{2.13kg/L}$$

Vr =3.83m3

Volume of mixer

Volume of mixer (Vm) $= \frac{\text{mass of methanol}}{\text{density of methanol}} + \frac{\text{massof NaOH}}{\text{Density of NaOH}} = \frac{58.34kg}{0.791kg/L} + \frac{1.85kg}{2.13kg/L} = 0.746m^3$

Volume of separator

$$Vs = \frac{\text{mass of biodiesel}}{\text{density of biodiesel}} + \frac{\text{mass of grycerin}}{\text{density of grycerin}}$$

$$Vs = \frac{328.4kg}{0.875kg/L} + \frac{17.276kg}{1.261kg/L}$$

Vs=4m3

Volume of washing column

$$Vwc = \frac{\text{mass of biodiesel}}{\text{density of biodiesel}} + \frac{\text{mass of water}}{\text{density of water}}$$

$$Vwc = \frac{328.4kg}{0.875kg/L} + \frac{87.94kg}{1kg/L}$$

Vwc=4.6m3

Volume of dryer

$$Vd = \frac{\text{mass of biodiesel}}{\text{density of biodiesel}} + \frac{\text{mass of moisture}}{\text{density of moisture}}$$

$$Vd = \frac{322.0kg}{0.875kg/L} + \frac{1.69kg}{1kg/L}$$

Vd =3.77m3

Volume of storage tanks

$$Vst = \frac{\text{mass of biodiesel}}{\text{density of biodiesel}}$$

$$Vst = \frac{322.02kg}{0.875kg/L}$$

Vst=3.75m3

Thickness of reactor

For cylindrical shape

Wall thickness (t) $=\frac{Pi*Di}{2SE-1.2Pi}$ where, S=maximum allowance stress of stainless steel is 110316kpa

E=welded joint efficiency=0.85

Pi= internal pressure

Di=internal diameter

$V=\frac{\pi D^2 H}{4}$, since the ratio of H/D is 1.5, then H=1.5D

V=(πD2 ∗ 1.5D)/4

3.83m3= πD3 /4 D=1.48m

Pi=static pressure + working pressure

Static pressure=ρ*g*H= 3.85kg/m3*9.8m/s2*2.22m

=83.67pa

The reactor vessel is operate at a 1400kpa

Pi=1400kpa + 0.083kpa=1400.083kpa

Wall thickness $=\frac{1400.083kpa*1.48}{2*110316kpa*0.85-1.2*1400kpa}$=11.15mm

t=11.15 +2=13.15mm

Head of reactor closure

Hemispherical heads, $t=\frac{Pi*Di}{4SE-0.4Pi} = \frac{1400kpa*1.48m}{4*110316kpa*0.85-0.4*1400kpa}$=5.5mm

t=5.5mm +2(allowance) =7.5mm

Thickness of storage tank

Wall thickness (t) $=\frac{Pi*Di}{2SE-1.2Pi}$ 3.75m3=(πD2 ∗ 1.5D)/4, D=1.47m

$t=\frac{800kpa*1.47m}{2*110316kpa*0.85-1.2*800kpa}$=6.3mm

t=6.3mm +2(allowance) =8.3mm

CHAPTER SEVEN

COST ESTIMATION

A capital investment is required for any industrial process and determination of the necessary investment cost. The total investment cost consists of fixed capital cost and working capital cost.

Fixed capital cost includes: Pipe installing cost, Service facilities cost, Building cost, Engineering and supervision cost, Construction expansion cost, Contingency cost and Purchased equipment cost.

Working capital cost includes: Raw material cost, Finished product in stack cost, Account receivable cost and Tax payable cost

Total annual cost sale=product per year*unit of cost of product

Total capital cost=fixed capital cost + working capital cost

Total fixed capital cost=direct cost+ indirect cost

Purchased equipment cost=15-40%of fixed capital cost

Gross profit =product sale cost-total capital cost

Net profit gross =growth profit (1-income tax)

By using www.matches.com website the present equipments cost were listed in the table below.

No	Type of equipment	Required number	Capacity (m3)	Present equipment cost($)	Material of construction
1	Reactor	1	3.83	75600	Stainless steel
2	Mixer	1	0.746	17200	Stainless steel
3	Separator	1	4.49	54500	Stainless steel
4	Wash column	2	4.6	17789	Stainless steel
5	Dryer	1	3.77	184900	Carbon steel
6	Storage tank	3	3.75	13500	Stainless steel
7	Settling tank	1	4.6	4500	Stainless steel
8	Pump	7	0.084hp	11639	Cast iron
Total cost				379628	

Table 8 Purchased equipment cost

7.1 Fixed capital investment estimation

Fixed capital investment for direct and indirect cost

Components	Range	Assumed %	Cost($)
Purchased equipment cost	15-40%	38	379628
Purchased equipment insulation and paint	25-55%	37	144258.64
Instrumentation and control	6-30%	22	83518.16
Piping and installing	10-80%	53	201202.84
Electrical installation	10-40%	36	136666.08
Building, process and auxiliary	10-70%	63	239165.64
Service facilities and yard improvement	40-100%	78	296109.84
Land and service facilities	4-8%	7	22777.68
Total direct cost			1503326.88

Table 9 Total direct cost

Component	Range (%)	Assumed (%)	Cost ($)
Engineering and supervision	5-30	24	91110.72
Construction expense and constructor fee	6-30	26	98703.28
Contingency	8-20	12	45555.37
Total indirect cost			235369.37

Table 10 Total indirect cost

Total fixed capital investment (FCI) = direct cost + indirect cost

FCI =$1738696.25

Total capital investment =fixed investment + working capital investment

In most plants working capital investment takes (10-20) % of total capital investment. In this plant it is assumed to be 15% of total capital investment.

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

TCI = FCI + 0.15TCI

TCI =FCI/ (1-0.15)

TCI = $1738696.25/ (1-0.15) =$2045525.00

7.2 Total production cost Estimation

Total production cost = Manufacturing cost + General expense

I. Manufacturing cost = direct production cost + fixed charge + plant over head cost

Fixed charge: (10-20% total production cost)

Depreciation = 10% of FCI for machinery

Depreciation =0.1*$1864349.72 =$186434.972

Local taxes: (1-4% of FCI) and consider the local taxes of 1% of FCI.

=0.01*$1864349.72=$18643.49

Insurances: (0.4-1% of FCI) and consider the assurance =0.6% of fixed capital cost

i.e. 0.006*$1864349.72= $11186.098

Thus, fixed charge =depreciation + local taxes + insurance

=$186434.972 +$18643.49 + $11186.098

=$216264.56

Direct production cost:(about 60% of total production cost)

Let, the total product cost be 'X'

i) Raw materials: (10-50% of total production cost) and consider the cost of raw materials =35% of total production cost

Raw material cost =$0.35*X

ii) Operating labor (OL):(10-20%of total production cost) and consider the cost of OL=15% of total production cost. OL=$0.15*X

iii) Direct supervisory and clerical labor(DS &CL): (10-25% of OL) and consider the cost for DS &CL =20% of OL

DS &CL =0.2*0.15*X=$0.03*X

Utilities:(10-20% of total production cost) and consider the cost of utilities= 15% of total production cost

Utilities cost =$0.15*X

Iv) Maintenance and repair(M & R): (2-10% of FCI) and consider the M & R cost =6%FCI

M &R =0.06*1864349.72=$111860.98

vi) Operating supplies:(10-20% of M&R or 0.51% of FCI) and consider 15% of M&R

operating supplies=

$0.15*1118660.98=$16779.15

vii) Laboratory charges: (10-20% of OL) and consider to be 15%

Laboratory charges=$0.15*X

viii) Patent and Royalties: (0-6% of total production cost) and consider to be 3% of total production cost Patent and royalties=$0.03*X

Thus, direct production cost (DPC) =$(0.35X + 0.15X +0.03X +0.15X +128640.13 +0.15X + 0.03X)

DPC =$0.86X +$128640.13 C.

7.3 plant overhead cost

Plant overhead cost =(50-70% of operating cost, supervision, and maintenance or 5-15% of total product cost); it includes:- general plant up keep and overhead, payroll overhead, packaging, medical service, safety and protection, restaurants, recreation, salvage, laboratory, and storage facilities. Consider the plant overhead cost 20% of total product cost

Plant overhead cost= $0.2%*X

Manufacture cost= Direct production cost + Fixed charges + plant overhead cost

Manufacture cost= $0.86*X + $128640.13 + $216264.56 +$0.2*X

=$0.96*X +$344904.69

General expense = Administrative costs + Distribution and selling costs + Research and development costs

A) **Administrative costs**: (2-6% of total production cost) and consider 5% of total production cost

Administrative costs =0.05*X

B) **Distribution and selling costs**: (2-20% of total production cost) in this includes costs for sales offices, salesmen, shipping, advertising. And consider it to be 15% Distribution and selling costs=0.15*X

C) Research and development costs:(about 2-5% of total production cost) and consider the research and development costs=4% of total production cost Research and development costs= 0.04*X

General expenses= Administrative costs + Distribution and selling costs + Research and development costs

General expenses= $0.04*X + $0.1*X + $0.03*X= $0.24*X

Total product cost(X) = manufacture cost + general expenses

Total product cost(X) =$1.06*X +$344904.69 +$0.24*X

Total product cost, X= $344904.69/0.3=$1149682.3

7.4 Gross earning/income

Income =unit selling price* Quality of product manufactured

From the material balance the total annual product is 2318544Lit/year

=$0.8/lit* 2318544 Lit /year=$1854835.2

Gross income = total income – total product cost

=$1854835.2- $1149682.3

=$705152.9

Gross income including depreciation = Gross income-depreciation

Depreciation= (FCI-salvage value, Vs)/life period

The service life of the plant is 15 year and fixed capital investment (FCI) of this plant is $1,864,349.72 taking the salvage value of zero.

Depreciation= $1864349.72/15=$124289.98

Gross income including depreciation=$705152.9 -$124289.98=$580862.92

Let the Tax rate be 15%

Net profit=Gross income including depreciation (1-Tax rate)

=$580862.92 (1-0.15) =$493733.48

Profitability standard

Minimum acceptable rate of return (Mar) is 12%

Rate of return on investment (ROI)

Rate of return= (Net profit/Total capital investment)*100

Rate of return= ($493733.48/$2193352.61)*100=22.5%

Since ROI>Mar, 22.5%>12% the project is feasible

Payback period

Pbp= depreciable FCI/ (average net profit/year + average depreciation/year)

Pbp= (FCI-Vs)/(avg net profit/year + avg depreciation/year)

Pbp= $(1864349.72-0)/ ($493733.48+ $124289.98)

Pbp= $1864349.72/$618023.46= 3.02years

Net present worth (NPW)

$$NPW=\sum_{1}^{15}(1+\mathrm{i})^{-k}(\mathrm{NPj}+\mathrm{dj}+\mathrm{recj})-\mathrm{TCI}$$

Recovery =salvage value + working capital=$329,002.89

Annual cash flow (R) =Npjavg + djavg

R = $ (493733.48+124289.98) =$618023.46

$$\mathrm{p}=\frac{R(1+i)^{n}-1}{i(1+i)^{n}}+\mathrm{rec}((1+\mathrm{i})^{-\mathrm{n}})$$

,wherei=Mar=12%

$$\mathrm{p}=\frac{\$618023.46(1+0.12)^{15}-1}{0.12(1+0.12)^{15}}+329002.89((1+0.12)^{-15})$$

p= $5210303.09

Therefore, NPW=P-TCI=$5210303.09-$2193352.61

NPW=$3016950.48

Since the value is positive the investment is acceptable and feasible.

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATION

8.1.Conclusion

Fossils fuels are non renewable forms of energy resources and they are depleting day by day, so the production of bio fuels such as biodiesel is increasing rapidly, because they are renewable, eco-friendly and non toxic energy resources. In our project cottonseed oil was selected as a potential non edible vegetable oil for the production of biodiesel. The study was carried out for the production of cottonseed biodiesel by base transesterification process on which the major focus was on the increment of methyl ester content by changing the basic process parameters. From the study it was found that excessive catalyst concentration results in the formation of soap and decrease the yield of biodiesel. In addition to the catalyst concentration the process was highly affected when the reaction temperature was higher than the boiling point of methanol because there was incomplete reaction due to vaporization of methanol. And also we conclude that the moisture content was highly affected the yield and if the moisture content was above the standard (0.05) it does not burnt easily. Moreover, the purity of the cotton seed oil was also the major factor which affects the yield of biodiesel. As a result we concluded that the use of more pure oil and optimum process parameters like temperature, catalyst concentration and time of reaction with a value of 55oc, 0.6 gm and 1 hour respectively were preferable for the better yield of biodiesel. Therefore, from our study this project is feasible because it requires low capital investment, less complex manufacturing process and low energy consumption.

8.2.Recommendation

In Ethiopia fossil diesel consumption was higher than that of bio fuel. Here we recommended that the consumption of fossil diesel must be decreased by producing biodiesel from cottonseed oil because of the non toxic, less costly and environmentally friendly behavior of biodiesel. In addition to that, in order to get a better yield in both quantity and quality of biodiesel:-

There must be careful selection of catalyst and the reactor

Appropriate characterization studies like viscosity, flashpoint measurement must be carried out on biodiesel.

Sufficient laboratory equipments should be provided for the production of biodiesel.

Since the oil produced from cottonseed was not used for food consumption. So we recommend that all the extracted oil must be used for biodiesel production, which introduces more profit. Finally we recommended that the Ethiopian government should encourage the production of biodiesel from non edible oil resources particularly from cottonseed using transesterification process because this process was less complex, require less investment cost and it utilizes less energy for production.

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APPENDIX

Table1. Selected properties of diesel and biodiesel fuels

Fuel properties	Diesel	Biodiesel
Fuel standard	ASTM D975	ASTM D6751
Lower heating value, BTU/gal	~129050	~118170
Kinematic viscosity, @40oC	1.3-4.1	4.0-6.0
Specific gravity, kg/L @60oF	0.85	0.88
Density, lb/gal@15oC	7.079	7.328
Water and sediment, vol%	0.05Max	0.05Max
Carbon, wt%	87	77
Hydrogen, wt%	13	12
Oxygen, by dif, wt%	0	11
Sulfur,wt%	0.05Max	0.0 to 0.0024
Boiling point, o C	180 to340	315 to 350
Flash point, o C	60 to 80	100 to 170
Pour point, oC	-15 to 50	-3 to 12
Cloud point, oC	-35 to 15	-15 to 10
Cetane number	40 -55	48-65

Table2. The test instruments and used methods

Parameters	ASTM test No	Instruments
Kinematic viscosity (mm2/s)	ASTM D88	Herzog HVM472
Heating value (kJ/kg)	ASTM D240	IKA C2000 Basic Calorimeter
Density (at 15 0C) (kg/m3)	ASTM D1298	Anton Paar DMA5000
Specific gravity	ASTM D1299	Anton Paar DMA5000
Flash point (ºC)	ASTM D93	Herzog HFP360(closed-cup)
Cold filter plugging point (ºC)	ASTM D6371	FPP 5Gs - CFPP/ ISL
Cloud point (ºC)	ASTM D2500	Dortmund 1/Coesfeld D-4600