Biodiesel Production from the Selected Non edible Seed Oil Using catalyst

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Biodiesel fuels
Biomass energy
Catalytic craking.

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In the Name of Allāh, the Most Gracious, the Most Merciful

Final Approval

It is certified that we have read the project report submitted by Ambarin. It is our judgment that this project is of sufficient standard to warrant its acceptance by the International Islamic University, Islamabad for the MS Degree in Environmental Science.

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List of abbreviation

$C_{20}H_{14}O_4$	Phenolphthalein
C_5H_{14}	n-hexane
CH_2OH	Methanol
CH_3	Methyl
$CHCl_3$	Chloroform
C-O	Carbonyl group
FAME	Fatty Acid Methyl Ester
FFA	Free fatty Acid
FTIR	Fourier Transform Infrared
GC-MS	Gas-Chromatography mass spectroscopy
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
KOH	Potassium Hydroxide
Na_2SO_4	Sodium Sulphate
NaOH	Sodium Hydroxide
OH	Alcohol group
POB	Palm Oil Biodiesel
R	Alkyl
TP	Table Palm
TPOB	Table Palm Oil Biodiesel

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ABSTRACT

Abstract

The present research work is confined to the production and characterization of biodiesel from novel non edible seed oil of Table Palm (). The oil content of Table Palm seeds is found to be 48%. Two different catalysts (KOH and NaOH) were used in the transesterification process. Thebiodiesel synthesized by transesterification reaction by using homogenous catalyst. Highest yield of biodiesel was obtained using KOH i.e. 0.04 g. Furthermore the optimization conditions for highest yield of Table Palm oil biodiesel was applied which was 60°c temperature, 1:3 oil to methanol ratio and 45 min stirring time.

All the synthesized sample was analytically characterize by FTIR and GC-MS techniques. The results of both techniques confirmed the conversion of oil to biodiesel or FAME (fatty ACID Methyl ester). In short all the results were found according to the standards by comparing the values with high speed diesel. Furthermore it is recommended that Table Palm is the potential source of biodiesel and need further research to be used globally.

INTRODUCTION

1. Introduction

1.1 Background

Energy is everywhere and drives everything. It is the utmost necessary ingredient for a high technology society and is used in the production of raw materials in agriculture, hospitals, transportation, lighting, heating, cooking and so on (Botkin and Edward, 2007). Due to such high dependencies the global demand for more and more energy is growing which causes the depletion of finite energy sources.With the exception of hydroelectric and nuclear energy, the greater part(about 80 %) of the world's energy needs is supplied through petrochemical sources, coal and natural gas. All of these sources are limited and are prone to be consumed by the end of the next century at present usage rates (Leung,*et al.*, 2010).

No doubt, the ordinary energy resources are indispensable to the economic and technological advancement however,they have many drawbacks e.g. they cause constrains in the environment and are unsafe to human health. The notable upswing in the level of greenhouse gases and air pollution in the earth atmosphere over the last decade has been warrant only due to the intensified use of fossil fuel (Luo,*et al.*, 2011).The subsequent addiction of petro fuel will create a further rise in the environmental pollution as well as in energy cost.

The Alternate renewable sources are very important to fill in the giant demand of limited depleting resource of fossil fuel due to the imbalance demand and supply of oil in the international market (Tariq,*et al.*, 2012). Thus it is imperative to find out innovative technologies for renewable resources that the universe has blessed us with by exploring the opportunities not only to address the scarcity of fuel but also to tackle with environmental challenges. Thus the exhaustion of the world petroleum provisions and increased environmental concerns hasmotivated recent interest in alternative non petroleum sources for petroleum based fuels.

It is the requisite for one and all to have access to cheap and affordable energy sources. Therefore because of a great dependence on fossil fuels, the depletion of finite resources, high oil import dependencies, as well as the negative impact of fossil fuels on the environment are the most important barriers that motivatethe states to hunt for new options.

There are differenttypes of alternative energy sourceslikesolar, wind, tidal and hydro energy. Biofuels are one of the most important alternative sources of energy. It can form the basis of sustainable development in terms of socioeconomic and environmental alarms as compare to fossil fuel.

There are different types of biofuels; the most familiar ones are bioethanol and biodiesel: bioethanol is produced from seed with a high sugar contentsby fermentation process whereas biodiesel is produced from vegetable oil and animal fat by transesterification process.

1.2 Biodiesel as a Renewable Source

Biodiesel is a fuel derived from renewable biological sources to be used in a diesel engine and emits less pollutants and greenhouse gases as compared to petro fuel. Hence the use of this fuel is a shift toward "sustainable energy. In recent years it has gained increasing attention worldwide as a direct replacement for diesel fuel in vehicle engines. It is produced by the reaction of energy crop oil and alcohol, can be used with same or even better performance in existing diesel engine, as it possess a significantly higher cetane number which indicates the ignition quality of a fuel (Titipong, 2011).

1.3 Techniques used for biodiesel production

There are several techniques to use vegetable oil as a fuel such as dilution, micro emulsion, pyrolysis and transesterification. In dilution process vegetable oil is mixed directly or diluted with diesel fuel to improve the viscosity. This method is able to overcome the problems regarding high viscosity of vegetable oil in compression ignition engines. Another approach to reduce the viscosity of the vegetable oils is by micro emulsion in which butanol, hexanol, and octanol are usually used as a solvent. Pyrolysis has also been used to reduce the viscosity of oil by employing elevated temperature with the addition of the catalyst without air or oxygen (Farobie,2015).

1.4 Transesterification

Transesterification has been well known to be the best techniques due to physical and chemical similarity with conventional diesel fuel and forming little or no deposits once used in diesel engines. In this transesterification process, three consecutive reversible reaction steps occur. Triglyceride (TG) is firstly converted to diglyceride (DG) and followed by the conversion of diglyceride to monoglyceride (MG). The next step involves the conversion of monoglyceride to glycerol. Each reaction step produces a fatty acid alkyl ester. Consequently, a total of three fatty acid alkyl esters are obtained in the transesterification process. It is very simple and cost effective. Transesterification process is composed of first conversion of triglycerides into diglyceride and at the second step diglyceride is converted into mono glycerides and finally into glycerol that is separated at the bottem and the biodiesel floats on the top. The overall reaction is given in figure 1.1 (Farobie, 2015).

Trigyceride + ROH $\xrightarrow{\text{Catalyst}}$ Digyceride + aFAME

Digyceride + ROH $\xrightarrow{\text{Catalyst}}$ Monogyceride + FAME

Monoglyceride + ROH $\xrightarrow{\text{Catalyst}}$ Glyceride + FAME

• FAME (Fatty acid Methyl Ester

• ROH (Methyl Alcohol)

Figure 1.1 Steps of Transesterification reaction.

Biodiesel is an ideal way out for global energy demands and also to overcome environmental problems. It reduces net carbon dioxide emission by 78% on a life cycle basis when compared with conventional diesel fuel (Tyson, 2001). It appears to be a promising future energy source (1). It is an environmental friendly diesel fuel prepared from renewable resources i.e. manufactured from vegetable oils and animal fats and is most popular as an alternative energy sources because it is nontoxic and biodegradable and have no contribution to global warming. (Akhihiero, *et al.*, 2010).Nevertheless, biodiesel also has some disadvantages, namely slightly higher nitrous oxide (NO_x) emissions and freezing point than diesel fuel.

1.5 Role of Catalysts in biodiesel production

Currently, three types of catalyst are being used for biodiesel production homogenous, heterogeneous and enzymatic. Different factors interact in choosing the catalyst, for instance: catalyst thermal stability, deactivation and conversion rate. Various types of catalysts have been exploited such as alkaline earth metal oxides, alkali oxides, metal oxides, cation exchange resins, metal phosphates and acid supported on different materials which show promising results in biodiesel production (Khurshid, 2014).

If the catalyst remains in the same (liquid) phase to that of the reactants during the transesterification, it is homogenous catalytic transesterification. On the other hand, if the catalyst remains in different phase (i-e Solid, immiscible liquid or gaseous) to that of the reactants the process is called heterogeneous catalytic transesterification. (Helwani, *etal.*, 2009). The heterogeneous catalytic transesterification is included under green technology due to the following attributes.1: The catalyst can be recycled (reused), 2. There is no or very less amount of waste water produced in during the process and 3. Separation of glycerol is very much easier (Sarma,*et al.*,2008). During homogenous catalytic transesterification the glycerol produced is of low quality and require lengthy process and distillation for purification. The main motivation behind the use of homogenous catalyst is its low cost and easy availability and acccss (Granados, *et al.*, 2007; Karmee and Chadha, 2006).

1.6 Edible and non-edible Feedstock of Biodiesel

Biodiesel is a diesel replacement fuel that is formed from diffcrent feedstock including vegetable oils, recycled cooking greases or oils, or animal fats, Algae, Cyano bacteria, and seeds of some terrestrial plants like Sun flower, Olive oil, Jatropha, Pongamia, Castor, Palm, Tobacco, Jojoba, Karanja, Neem, Rice bran oil, used cooking oil and Animal fats. The most promising feature of biodiesel is that it can be utilized in existing design of diesel engine with no or very little modifications and has a proven performance for air pollution reduction (Bahadar, 2014)

The use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food materials. As the demand for vegetable oils for food has increased due to the tremendous increase in population in recent years, so it is impossible to justify the use of these oils for fuel use purposes such as biodiesel production. Moreover, these oils could be more expensive to use as a fuel. Hence, the contribution of non-edible plant seed oils will be significant source for biodiesel production.

According to miscellaneous researches cost is the leading concern in biodiesel production and trading (mainly due to oil prices), so the use of non-edible oils has been considered for several years with good results. The one more giant advantage of using non edible plants oil is that no foodstuffs will be spent to produce fuel. Due to these reasons several countries have led to develop large scale biodiesel production plants, using non-edible oils such as castor oil, Tung, cotton,jojoba, table palm and jatropha. Animal fats are also an interesting alternative, especially in countries with plenty of livestock resources, although it is necessary to carry out pilot treatment since they are solid.Furthermore, highly acidic grease from cattle, pork, poultry, and fish can also be used. However the usage of vegetable oil directly for engine fuels has a problem due to high viscosity of this oil. Therefore, it is needed to reduce the viscosity of vegetable oil (Farobie 2015).

1.7 Palm plant description

The palm oil shows an indispensible part for biofuel production in South Asia. Different parts of the palm fruits can be used for the production of oil for various purposes likeproduction for human consumption and industrial applications. The oil produced from the mesocarp of the fruit is characterized by high amounts of palmitic acid, fatty acid and oleic acid. Palm oil also contains tocopherols in concentrations which grant the oil its typical red color (Demirbas, 2003).

Two kinds of oil are obtained from the fruit: palm oil proper which is obtaining from the pulp, and palm kernel oil from the nut of the fruit. Indonesia and Malaysia are the leading producers of palm oil. According to several research studies during the past years international demand for palm oil has increased steadily. It is important to remark that pure palm oil is semisolid at room temperature (20–22C), and in many applications is mixed with other vegetable oils, sometimes partially hydrogenated.

In the recent study non edible seed oil of table palm plant (***Livistona rotundifolia***) is used. It is a tropical plant of 20 – 25 m height with a life cycle of about 25 years, native to South – East Asia i.e. Malaysia, Indonesia and Philippine but now cultivated in all around the world as an ornamental plant. Naturally it is found in low and high altitude forest. Full production is reached 8 years after planting (Santamaría, *et al.*, 2004).

The palm oil employed for biodiesel production is very propitious. Palm oil can be categorized into two parts i.e. solid palm stearin and liquid palm olein. So palm oil liquid and palm stearin parts have tantalized attention of the world to use itas raw materials for biodiesel production. The major advantages of palm oil are its low price and yieldas compared to other vegetables oils (S. D. Romano and P. A. Sorichetti (2011).

Furthermore the oil palm is a low value, reasonable raw material crop.Hence, production of biodiesel from palm oil generates economic sense in spite of its high saturated fatty acids contents. Moreover high contents of free fatty acids in the feedstock cause problems in traditional alkalicatalyzed biodiesel production and thus necessitate acidification or acid-catalyzed preesterification steps (Murphy, 2003).

1.8: Scope of Study

Preparation and development of useful heterogeneous catalyst is significant because it open up different alternative for biodiesel production. This research will give environment friendly approach in biodiesel and green technology. It will produce more diesel on a board level and on cheap rates.

1.9: Objectives of the Present study

The specific objectives of the study are:

1. To find out the Oil content in the seeds of table Palm plant.
2. To determine the FFA content of the table palm plant seed oil by using basetitration method.
3. Selection of catalysts for the production of eco-friendly biodiesel.
4. To characterization of synthesized Biodiesel (FAMES) using FTIR and GC-MS.

LITERATURE REVIEW

2.0 Literature review

Biodiesel is an important substitute to the broadly used petro-diesel fuel. It can be generated from the domestic natural resources such as palm oil, soybeans, rapeseeds, coconuts and even used cooking oil. According toKiakalaieh*et al*(2013),Bio diesel is environmental friendly fuel as it has a more favorable emission profile, such as low emissions of GHGs like carbon monoxide, particulate matter and unburned hydrocarbons and the threat of climate change. Carbon dioxide (CO_2) produced by combustion of biodiesel can be recycled by Photosynthesis, thereby minimizing the effect of the greenhouse gas on the environment(Alia, 2012).

2.1 History of biodiesel

The history of biodiesel is not new; it isas old as diesel engine, as the inventor of the diesel engine Rudolf Diesel designed his diesel engine to operate on peanut oil. Hence this engine became an example of Diesel's vision, as this engine was powered by vegetable oil, still not biodiesel that time (Abdullah, 2012).

After R. Diesel death the industry of petroleum was rapidly developing and made a cheap "diesel fuel" operating a modified "diesel-engine". Thus from that time, the clean vegetable oil was forgotten as a renewable source of power and the petroleum has been used all around the world as a source of energy. Later on in the 20 century theincrease in environmental issues, going up of petro diesel prices and shortage of petroleum start to appear on the recorddue to thetotal dependence of the whole world on fossil fuel. As a result the world start search for alternative energy once again,that have low environmental impacts, and also cover up the energy scarcity space (Reza, 2009).

In 1990s the France started the local production of biodiesel fuel obtained by the transesterification of rapeseed (Gashaw and Lakachew, 2014). According to Farobie 2015, the application of biodiesel to our diesel engines for daily activities is advantageous for its environmental friendliness over petro-diesel. However, the usage of vegetable oil directly for engine fuels has a problem due to high viscosity of this oil. Therefore, it is needed to reduce the viscosity of vegetable oil. Today this deficiency of biodiesel is compensating through the transesterification process.

The first world biodiesel Train was launched in 2007 and was run successfully from Landudo to London (Mandi, 2009). In 2007 about 1.8 million alternative fuel vehicles were sold in US, which show the progress of Biodiesel. But still the Alternative fuels need the economic and political growth for its development (John,*et al.*, 2015). According to Dr. Reza Mandi, Now more and more researches are need to be done to find out most suitable plants and crops to improve oil yield (Mandi, 2009).

2.1.2Bio diesel production in Global perspective

Globally, the production of biofuels has increased ominously since 2000 (IEA, 2010). Most of these biofuels are bio-ethanol and biodiesel. Bioethanol is produced from seed with a high sugar contents by fermentation process whereas biodiesel is produced from oil coming from vegetable and animal fat by transesterification process. According to (Berni, 2014) the Brazil has the most widespread supply, usage and export of bioethanol all over the world.

First Biodiesel creativities were reported in 1981 in South-Africa and then in 1982 in Austria, Germany and New Zealand (Kombitz, 1999). Already in 1985 a small pilot plant in Austria tested the production of RME (Rapeseed oil Methyl Ester) with a new technology (ambient pressure and temperature) and in 1990 the first farmers' cooperative started commercial production of Biodiesel. In the same year the accomplishment of an enormous fleet tests led to engine warranties by most of the tractor producers as e.g. John Deere, Ford, Massey-Ferguson, Mercedes, Same, as a big innovation towards a successful market introduction of Biodiesel. Another main phase was the first fuel standard for Biodiesel in 1991 by the Austrian Standardization Institute declaring a high quality of the fuel. Complete tests about the product properties such as engine performance, emission reductions, biodegradability and toxicity were monitored. While process economics improved as well continuously Biodiesel plants were started mainly in the European Union but also in East Europe, Malaysia and in the US (Kdrbltz, 1999).

The global production of biodiesel has increased almost sevenfold since 2005. The top 5 biodiesel producing countries included USA, Brazil, Germany, Indonesia, European countries and Argentina. Europe is the largest consumer of biodiesel (54% of world demand); North

America, Latin America, and Asia account for about 17%, 14% and 12% respectively (Marchant, 2016).

According to llic,*etal.*,(2012),universallymore than 350 oil-bearing crops recognized as probable foundation for biodiesel production. In recent time's non edible feedstock are recognized as second generation feedstock for the manufacturing of biodiesel. This is typically credited to their ability to overawe the difficulties of fuel disaster against food merely exist in several areas of world particularly inhospitable surroundings that are not appropriate for food harvests, naturally welcoming and cost effective diminish deforestation rate and profitable analogous to edible oils (Atabani *et al* .,2013). In the current year, rational study has been completed on the diverse edible and non-edible vegetable oils as energy in compression ignition engines (Patil and Deng, 2009). Promotion of the rate of edible oil causing a biodiesel manufactured thriftily unachievable as paralleled to petroleum derived diesel. in order to over whelm this matter, numerous scholars have begun pointed for inexpensive non edible oil to be used as a feed stock for biodiesel limited alternative sources have been recognized such as jatropha crucas, pongamia pinnata, calophyllum inophyllum etc (Abbaszadaadeh *etal.*, 2012; Kansedo *et al.*, 2009).

2.1.3 Biodiesel in Pakistan

Pakistan is an agricultural depended country. Due to improved agricultural growth rate, it is predicted that approximately 70% of Pakistani nationals do agro based jobs. The existing barren land of Pakistan is about 28 million hectare (Butt,*et al.*, 2013). Pakistan is in front of a severe scarcity of edible oil and considerable quantity of foreign give and take is being consumed on the import of edible oil. Pakistan ingests about 8 million tons of furnace oil per year and 8 million tons of diesels annually (Sheikh, 2010). The Pak Government has permitted to attain at least 5% by volume share of bio fuel in the overall petroleum diesel ingesting by 2015 and progressively up to 10% by 2015(Ali,*et al.*, 2013).

It is a fact that Pakistan is an energy deficient country but not natural resource deficient. In Pakistan, different variety of flora and biodiesel yielding plant species are present.Numerous oil seeds crops are grown as a source of edible vegetable oils as well as many oil bearing wild plants are found in different regions of the country. Furthermore, Pakistan has a rich biodiversity of natural resources with special reference to oil yielding plants (Ahmad,*et al.*, 2007).According to (Chakrabari,*et al.*, 2012) Pakistan can produce 56 million tons of biodiesel annually if it uses all its uncultivated land for biodiesel production.Many researchers have done researches with productive result in the field of biodiesel. Ahmad *et al.*, (2012) published the practical handbook of biodiesel and studied different parameters of biodiesel. Eruca sativa (Rice) is very latent source used for biodiesel production. Pongamia pinnata is oil yielding plant and it can be grown easily on non-agricultural land (Ahmad *et al.*, 2012).

In Pakistan the Government strongly has interest to introduce the unified petroleum from the potential to meet the high demands of the country (Tunio *et al.*, 2016).So for the convenience of energy crises different Institute like NED University of Engineering and technology Karachi, Quaid e Azam University Islamabad, University of Agriculture Faisalabad and Institute of Punjab University conducted Researches in order to fulfill the raising demands of fuel and Energy (M.H. Chakrabarti *et al.*, 2012). According to Ahmad *et al.*, (2009), our country possess high potential for biofuel because we have greater potential for almost all type renewable resources like Eruca sativa with potential of 35% oil (Ahmad *et al.*, 2009). Ricinis communis with 32 % oil yield (Azam *etal.*, 2005), Brassica compestris with 32 % oil yield (Ahmad *et al.*,2009), so it's the need of a day to developand keep continue the researches and trails on alternative energy sources hunting to save the homeland Pakistan from energy crisis.

2.1.4Biodiesel Production process (Transesterification)

The biodiesel production process is also known as transesterification. Oil, Alcohol and catalysts are the main constituent of this process. The Gerhard Knothe elucidate about the commonly used aklcohol in his book as; Methanol is least expensive alcohol therefore it is mostly used in the preparation of methyl ester though there is some exceptional cases also i.e. In Brazil, ethanol is less expensive as compare to methanol, so it is used in ethyl esters Both chemical and biological catalysts are used for the nominal and useful result of the reaction. The chemical catalysts include Alkali and Alkaline whereas the biological catalysts include enzymes like lipase and esterase etc. The most commonly used alkali catalysts are potassium hydroxide and Sodium hydroxide (Pinto *et al.*, 2005; Gerpen *et al.*, 2004).

Three consecutive reversible reactions occur in the process of Transesterification. The first one is the transformation of triglycerides to diglycerides, followed by the change of diglycerides to monoglycerides, and finally monoglycerides into glycerol, generating one ester molecule from each glyceride at each step. The reactions are reversible and proceeds well in the presence of catalysts.

Vegetable Oil + Alcohol ⟶ Biodiesel + Glycerin

2.1.5 Chemistry of the Whole Reaction

The overall mechanism of the reaction is;

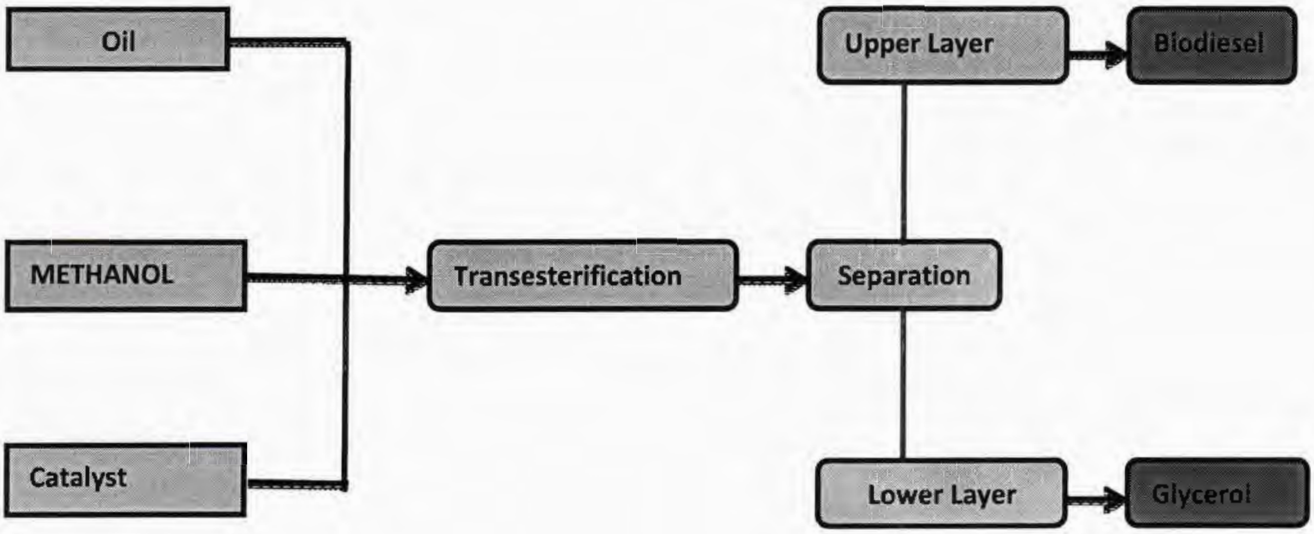
$CH_2 - O - COR_1$ $\qquad\qquad\qquad\qquad$ $CH_3 - O - COR_1$ $\qquad$ $CH_2 - OH$

$CH - O - COR_2$ + $3CH_3OH$ ⟶ $CH_3 - O - COR_2$ + $C - OH$

$CH_2 - O - COR_3$ $\qquad\qquad\qquad\qquad$ $CH_3 - O - COR_3$ $\qquad$ $CH_2 - OH$

TRIGLYCERIDE (OIL)	ALCOHOL (METHANOL)	BIODIESEL	GLYCEROL

2.1.6 Overall biodiesel production process



2.6 Properties of Biodiesel

Several chemical and physical parameters are used to determine the properties, compatibility and composition of biodiesel. The major properties include viscosity, cloud point, cetane number, flash point, ignition, glycerin production and reacted and unreacted alcohol. Different methods are used to determine these properties like ASTM method (American society for testing materials and EN methods (Europeon Union Standard). In both of these methods different protocols are used for the determination of different parameters for example ASTM D613/ EN ISO 5165 for cetane number and ASTM D93/ EN ISO/CD 3679 for flash point etc.

According to Bajpai and Tyagi (2006) and pinto *et al.*,(2005) the viscosity and surface tension of biodiesel are high as compare to petro diesel and this is probably due to glycerin production and other compound. So due to such issues both are not suitable to be used directly in diesel engine. Vegetable oil has high flashpoint, viscosity, odorant, water, phospholipids and other impurities. So it cannot be used as fuel directly without treatment. To solve all these matter it is necessary to do minor chemical changes in the oil like transesterification, pyrolysis, and esterification (Han, 2014). According to Farobie (2015), the viscosity problem can be resolved by mixing vegetable oil with diesel fuel.

2.1.7Sources of biodiesel

Biodiesel is formed from renewable sources of triglyceride. There are different feed stocks used for the production of biodiesel. These are;

1. First generation feedstock or edible vegetable oil
2. Second generation feedstock or non-edible vegetable oil
3. Third generation feedstock or Microalgae

Table 2.1 Comparison between different feed stocks generation

Sr. no	First generation	Second generation	Third generation
1	Generally contain edible plant oil, grains, seed and sugar	Generally contain non edible plant oil, cereal straws etc.	Generally contain micro algae oil
2	Grown locally and have high production	Mostly include wild plant and can be cultivated on waste land	Can be grown anywhere (i.e.salt water, sewage water) and have high growth and productivity
3	Not sustainable biomass feed stock	Sustainable biomass feedstock	Sustainable biomass feedstock
4	Produce in significant commercial quantities	Insufficient commercial production	Not available on commercial scale
5	Require more land and produce food insecurity	Require less land and don't compete with required food	Technically hard to control and need sufficient sunlight
6	Commonly used in Europe	Commonly used in United State	New technique and in developmental process
7	Example: Sunflower oil, Soybean oil, Peanut oil,	Example: Jatropha oil, Neem oil, Pongamia oil, Caster oil,	Example:Microalgae, Diatom algae,

	coconut oil, Olive oil etc.	Bitter Almond,	

(Source: Tariq *et al.*, 2012)

2.1.8 Edible feedstock

Over the last few decades, there has been an increasing amount of research and interest in the different edible feedstock that can be used to make biodiesel and the effects of the different feedstock on the quality of the biodiesel. Currently, biodiesel is produced from different crops such as, Jojoba oil, palm oil,canola (Issariyakul*et al.,* 2008), rice bran, sunflower, coconut, rapeseed, soybean (Zhang*et al* ., 2006) and sunflower oil (Abdullah *et al.,* 2011). The major difference between various edible oils is the type of fatty acids attached in the triglyceride molecule. Fatty acid composition affects the yield percentage, reaction temperature, FFA content and molar ratio of the biodiesel oil

Table 2.2 Different types of Edible oil

Sr. No	Edible source	Study Title	Reference
1	Soybean Oil	Combustion Analysis of Esters of Soybean Oil in a Diesel Engine	Zhang*et al* ., 2006
2	Sun flower oil	The Optimization of Bio-diesel Production from Sunflower Oil using RSM and its Effect on Engine Performance and Emissions	Abdullah*et al.*, 2011
3	Linseed Oil	Synthesis of Ethyl Ester (Biodiesel) From Linseed Oil, Using Transesterification Double Step Process (TDSP)	Tahvildari And Mohammadi,(2014)
4	Coconut oil	Fast, easy ethanolysis of coconut oil for biodiesel production assisted by ultrasonication',Ultrasonics Sonochemistry	Kumar*et al.*,2010
5	Peanut oil	Biodiesel production via peanut oil extraction using diesel-based reverse-	Nguyen*et al*, (2010)

		micellar microemulsions	
6	Peanut oil	Methyl ester of peanut (Arachis hypogea) seed oil as a potential feedstock for biodiesel production	Kaya, *et al.*, 2009
7	Pumpkin seed oil	Pumpkin (Cucurbita pepo L.) seed oil as an alternative feedstock for the production of biodiesel in Greece	Schinas, *et al.*, 2009
8	Maize oil	Microwave assisted transesterification of maize (Zea mays L.) oil as a biodiesel fuel	Ozturk, *et al.*, 2010
9	Soybean Oil	Transesterification of soybean oil to biodiesel using SrO as a solid base catalyst	Liu, *et al* ., 2007
10	Canola oil	Biodiesel production from mixtures of canola oil and used cooking oil	Issariyakul, *et al.*, 2008
11	Canola oil	Investigation of biodiesel production from canola oil using Mg-Al hydrotalcite catalysts	İlgen, *et al.*, 2007
12	Vegetable oil	Transesterification of neat and used frying oil: optimization for biodiesel production	Leung, *et al.*, 2006
13	Fish Oil	Biodiesel Production from Fish Oil	Khanum, *et al.*, 2013
14	Wild apricot	Base catalyzed transesterification of wild apricot	Faizan Ullah, *et al.*, 2009
15	Cashew Nut oil	Extraction and Characterization of Cashew Nut (Anacardium Occidentale) Oil and Cashew Shell Liquid Oil	Idah *et al.*, 2014
16	Groundnut oil	An Experimental Study of Biodiesel Synthesis from Groundnut Oil. Part I:	Yusuf and Sirajo,(2009)

		Synthesisof Biodiesel from Groundnut Oil under Varying Operating Condition	

2.1.9Non edible feedstock

Non-edible oil plants are well adapted to arid, semi-arid conditions and require low fertility and moisture demand to grow. Moreover they are commonly propagated through seed or cuttings. Since these plants do not compete with food, seed cake after oil expelling and may be used as fertilizer for soil enrichment (Azam et al.,2005). Researchers have identified several non-edible crops that can be used for biodiesel production. Some of the literature about non-edible seeds used for biodiesel production is as follow;

Sr No.	**Non-edible source**	**Study Title**	**Reference**
1	Milo seed	Biodiesel from Milo (Thespesia populnea L.) seed oil	Rashid *et al.*, 2011
2	Castor oil	Transesterification studies on Castor oil as a first step towards its use in bio diesel production	Ahmad *et al.*, 2008
3	Mustard oil	Biodiesel Production from Mustard Oil, Coal Ash using as a catalyst	Khan *et al.*, 2011
4	Neem oil	Synthesis of biodiesel from Neem oil using sulphated zirconia via transesterification	Muthu*et al.*, 2010
5	Jatropha oil	Production of Biodiesel through transesterification of Jatropha oil using KNO_3/ALO_3catalysts	Amish*et al.*, 2009
6	Distaff Thistle oil	Heterogeneous catalysts for biodiesel synthesis by transesterification	**Satish*et al.*, 2014**
7	Pongamia pinnata	Preparation of biodiesel from Crude oil of Pongamia pinnata	Karmee*et al.*, 2006
8	wild Safflower oil	Variable Effecting the optimization of non-edible wild Safflower oil biodiesel using Alkali catalyzed transesterification	Haleema*et al.*, 2013
9	Okra	Okra (Hibiscus esculentus) seed oil for biodiesel production	Anwar*et al.*, 2010

Different grades of oil quality are obtained from the pericarp and kernel with the pericarp oil used mainly for cooking and the kernel oil used in processed foods (Osanyinbgemi, 1995).

For each hectare of oil palm which is harvested year round the annual production averages 10 tonnes of fruit, which yield 3,000 kg of pericarp oil and 750 kg of seed kernels which in turn yield 250 kg of high quality palm kernel oil.

2.3.2 Plantation

The oil palm trees grow the best within 5° north and south of the equator, where rainfall is evenly spread throughout the year, sufficient sunshine and temperatures of 25-33°C (Gunstone, 2011). When the palms are around three years old they begin to produce fruits and have its peak between 9 and 12 years old (Coelli *et al.*, 2004). The palms can become up to 200 years (Gunstone, 2011), but their life cycle is 25 years after which the commercial trees have to be replanted **(Lin, 2011)**.

2.4 Properties of Palm oil

Palm kernel oil has a very heavy brunt smell that more or less persist although the shelf life of the oil. It is dark-brownish oil that is insoluble in water but rapidly dissolved in non-polar solvents.

2.5 Uses of Palm Oil

It is used as drug being given to a child suffering from convulsion; it is used as a hair ointment in the treatment of dandruff.

It is also used as a moisturizer mostly for new born children to prevent cold and lowering bodily temperature in a sick child and also for the prevention of scaly skin.

2.6 Previous research done on Palm oil Biodiesel

Palm oil is the most suitable oil among all vegetable oils as a source of biodiesel production. This oil attracts the scientist due to its high crop production and low price qualities for biodiesel production (Tan *et al.*, 2009). The Mekhilef, *et al*, worked on the production of biodiesel from palm oil. He clarified that the Palm oil is the most prospective biodiesel feedstock as compared to other oilseeds. He further explained as; from a palm bunch, approximately 25–28% of Crude palm oil can be obtained(Mekhilef, *et al.*, 2011).

The oil yield from the crops is always the key factor to decide the suitability of a feedstock for biodiesel production. Oil crops with higher oil yield are better in the biodiesel industry because it can reduce the production cost. Generally the cost of raw materials accounts about 70–80% of the total production cost of biodiesel. It is clear that higher oil yield always corresponds with lower cost (Gui, *et al.*, 2008) and Palm oil produces up to ten times more oil per hectare (Tincliffe and Webber, 2012).Two types of oil can be produced from oil palm fruit, i.e., crude palm oil (CPO) which is produced from the mesocarp and palm kernel oil which is produced from the kernel or endosperm (kernel) (Abdullah andWahid, 2010; Mba *et al.*, 2015).

Palm kernel (PK) has been found to be an alternative source of energy (Knothe et al, 2005). These oils cannot be used directly in internal combustion engine due to two main reasons: low volatility and high viscosity (Knothe *et al*, 2005; Atabani *et al.*, 2012). Nagi *et al.*, 2008), observed that, palm biodiesel gives lower performance on diesel engines for torque and thermal efficiency, compared to petroleum diesel.It was observed that palm biodiesel blends produced lower CO emissions than petroleum diesel for the entire engine load rangc,The reduction of CO2 emissions is logical because of the oxygenated nature of palm oil and the lower amount of carbon in the palm biodiesel (Krunal*et al.*,2013).

Palm oil is well-known vegetable oil feedstock to produce biodiesel through the transesterification process.The different parameters which could impact the overall efficiency and yield of the transesterification process include,

1) Temperature of the mixture,

2) Moisture quantity in the mixture,

3) Mass transport (intensity of mixing),

4) Molar ratio of alcohol to oil

5) Type of catalyst (Korus, 1993;Mamilla *et al.*, 2012).

According to the successful result of the research work conducted by Eman N. Ali; 88% biodiesel production of palm oil can be obtained at the optimum condition likemethoxide: oil ratio of 6:1, reaction for 60 minutes at temperature of 60 °C .She further explained that the physical characteristics obtained from the final optimum biodiesel yield were within ASTM D 6751 and European Standards EN 14214 (Ali, 2013).

MATERIAL AND METHODS

Material and method

3.1 Chemical used

The chemical used weremethanol (CH_2OH), Chloroform ($CHCl_3$) n-hexane (C_5H_{14}), Phenolphthalein ($C_{20}H_{14}O_4$), Sodium hydroxide (NaOH) and Potassium hydroxide (KOH). Methanol (CH_2OH) and n-hexane (C_5H_{14}) was used as an extraction solvent. All the chemicals were of high analytical grade and were purchased from Merk (Germany), Sigma- Aldrich (USA) and scharlu (Spain) and were of analytical grade.

3.2 Equipment used

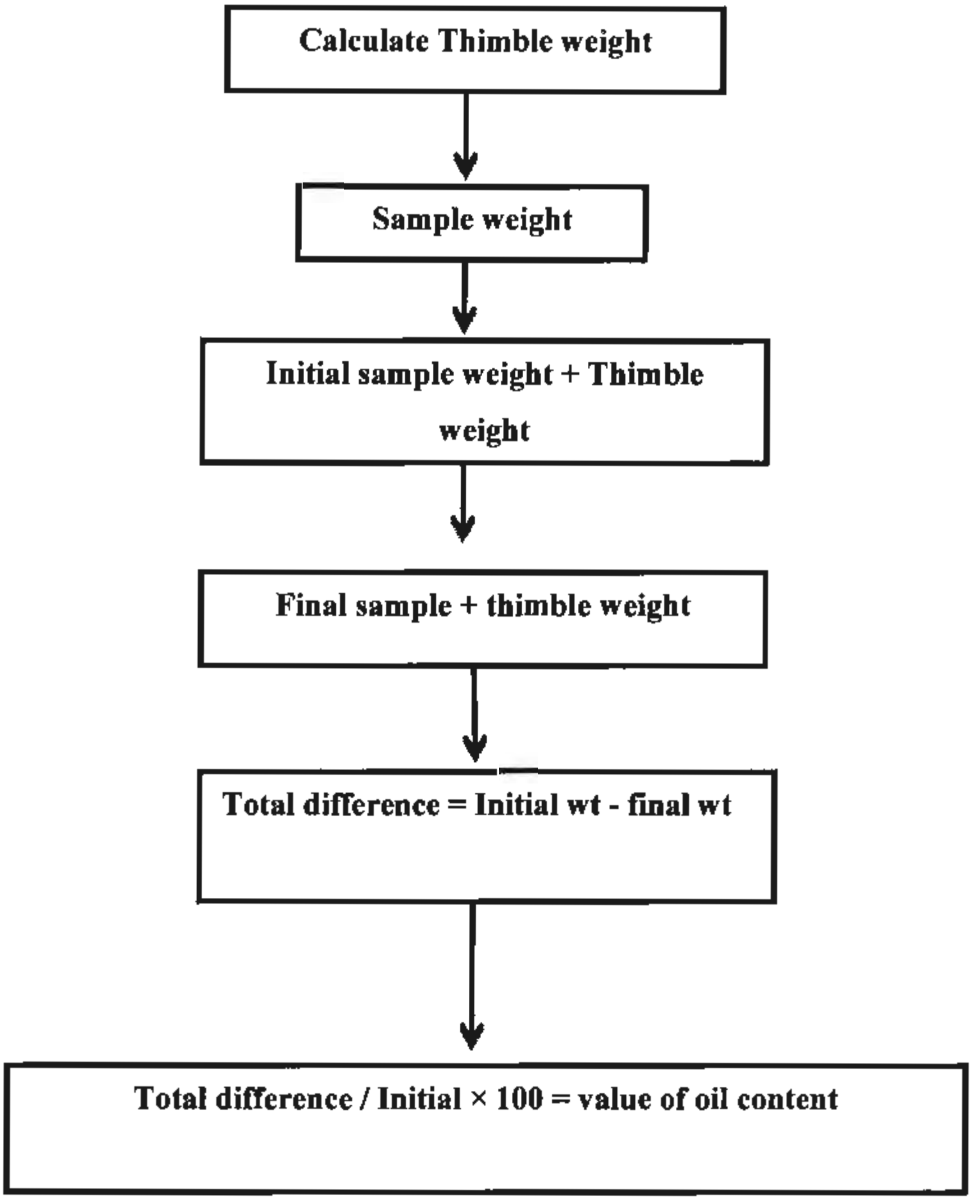
The Equipment used in experiment were beakers,thermometer,pippete, filter paper, Aluminum foil, cutter, Digital balance (GF- 3000), Oven (Memmert), mortar pestle, magnetic stirrers, Soxhlet Apparatus(Behr lobor – Technik EZ 100), multiple heating magnetic stirrer (Am4. VelpScientifica).

3.3 Collection of seeds

About 10-12 kg of matured Table Palm seeds was collected from IIUI campus and the nearby localities. The seeds were then dried in the sunlight to reduce the moisture content for about 2 weeks.

Fig 3.1: Pam plant, seed and oil

3.5.1 Calculation of oil content



3.6 Methodology

3.6.1 Oil Filtration and purification

Before going to start biodiesel production process, it is necessary to filter the oil for 2 – 3 times to remove the impurities which may create hurdles in the reaction time and results.The purification of crude oil was carried out by simple method of filteration in which Whatman paper no 42 was used for the removal of impurities.The purified oil was then stored in a properly covered glass container in dry place and room temperature.

3.6.2 Determination of Free Fatty Acid Content

Titration method is used for the determination of FFA content by using the following steps.About 0.14g KOH was dissolved in 100 ml of distilled water for keeping in burette. Then Phenopthaline indicator was made for which about 0.5 g of phenopthaline was dissolved in 50% ethanol. Then blank titration was done for which 10 ml isopropanol was taken in a beaker and 1-2 drops of phenopthaline was added. The solution of burette was allowed to fall drop by drop in the beaker until the color of the solution became change. Then noted the reading of the burette and repeated it 3 times for accuracy. After blank titration the sample (Table Palm oil) titration was done in which 1 ml oil and 9 ml isopropanol was taken in a beaker and added 1 – 2 drop phenopthaline indicator. Then the solution of the burette was added drop by drop in the beaker until the color becomes changed. Then noted the reading and repeat it for 3 times for accuracy.

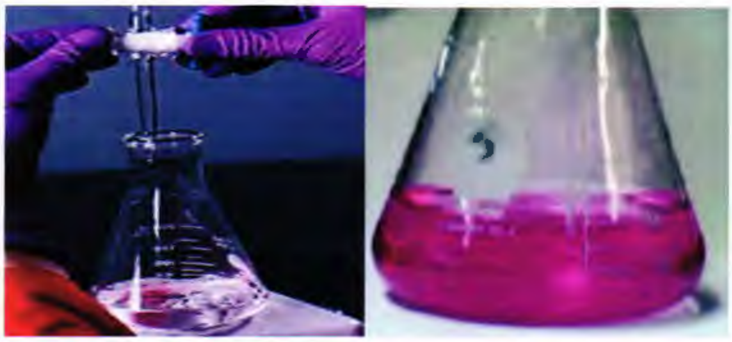


Figure 3.3: Process of Titration

The following Formula is used for FFA content calculation

FFA = (Mean of sample titration) –(Mean of standard titration) / (Amount of oil) × (Amount of KOH)

3.7 Preparation of Biodiesel

The Biodiesel was produced through transesterification process of Table Palm oil by using the following steps.

1. Mixing and stirring of Alcohol and catalyst
2. Heating of oil up to 120 ^{0}C
3. Mixing of palm oil (at 60) and catalyst at 60 ^{0}C
4. Stirring of palm oil and catalyst solution for 45 min
5. Leaving the solution for 24 hour
6. Separation of layers i.e. glycerol and diesel
7. Washing of biodiesel in case of any impurity

3.6.1 FAMES Washing Process

The methyl ester was purified by washing with distilled water in order to remove impurities. This process was repeated 3 – 4 time. The removal of water content was ensured by adding anhydrous Sodium Sulphate (Na_2SO_4). In the next step biodiesel was filtered with the help of filter paper to remove the remaining impurities.

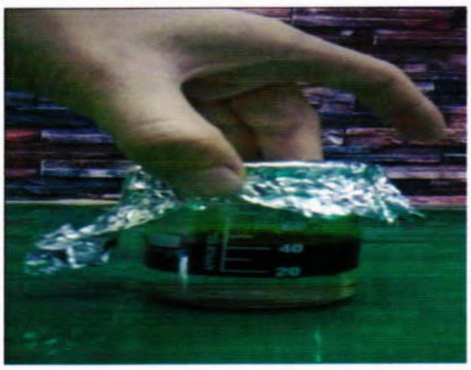


Fig 3.4: Washing process of biodiesel

3.7 Optimization Reactions

The chemical reaction takes place when the oil is mixed with methoxide at specific temperature. For maximum amount of biodiesel production optimization reaction were formed.The following 5 parameter were selected for optimization.

1. Methanol to oil ratio
2. Reaction temperature
3. Stirring time
4. Amount of Catalyst changed
5. Effect of catalyst type

3.7.1 Methanol to oil Ratio

In this parameter 1:1, 1:3, 1:5 and 1:7 of methanol to oil ratio were done to check the favorable one.

Oil amount	Methanol amount
10 ml	10 ml
10ml	30 ml
10 ml	50 ml
10 ml	70 ml

Table 3.1: Oil to Methanol ratio

3.7.2 Reaction temperature

The reaction temperature was changed to 40 ^{0}C, 50 ^{0}C, 60^{0}C, 70 ^{0}C and 100 ^{0}C to find out the suitable one.

Oil amount	Methanol amount	Temperature
10 ml	30 ml	45 ^{0}C
10 ml	30 ml	50 ^{0}C
10 ml	30 ml	60 ^{0}C
10 ml	30 ml	60 ^{0}C

Table 3.2: Variation of temperature

3.7.3 Stirring time duration

The stirring time duration was changed like 30 min, 45min, 60 min and 1 hour.

Oil amount	Methanol amount	Stirring time
10 ml	30 ml	30 min
10 ml	30 ml	45 min
10 ml	30 ml	60 min
10 ml	30 ml	1 hour

Table 3.3: Variation in stirring time

3.7.4 Amount of catalyst used

The amount of catalyst changed was 0.02 g, 0.04 g, 0.06 g and 0.08 g.

Oil amount	Metbanol amount	Amount of catalyst
10 ml	30 ml	0.02 gram
10 ml	30 ml	0.04 gram
10 ml	30 ml	0.06 gram
10 ml	30 ml	0.08 gram

Table 3.4: Variation in catalyst amount

3.7.5 Effect of catalyst changed

The catalyst used for the transesterification reaction may be classified into basic and acidic. The basic catalyst includes NaOH and KOH catalyst and the acidic catalyst include Sulphuric acidand Hydrochloric acid. The basic catalyst is used when the FFA content value is less than 3 and acidic is used when it is above 3. In this reaction setup basic catalyst i.e. KOH and NaOH was used because the Value of FFA content was 0.28. And by trying both NaOH and KOH catalyst no change was found in the reaction composition and biodiesel production so KOH was used for further reactions.

3.8 Characterization of biodiesel

The characterization of oil was done through GCMS, FTIR and ASTM.

3.8.1 FTIR

The synthesized biodiesel were characterized by using Fourier Transfer Infrared Spectroscopy model BRUKER – TENSOR 27 in the range of 4000 cm – 6000 cm^{-1}.

3.8.2 GCMS

The chemical composition of Table Palm Oil biodiesel was analyzed by gas chromatograph Mass spectroscopy. The uses of mass spectrometer eliminate any ambiguity about the nature of eluting materials. The solution of sample was prepared by dissolving 1 ml of synthesized biodiesel in 4 ml chloroform. After that 1 ml ofthis prepared sample was injectedin GCMS model QP 2010 ultra (Shimadzu, Japan).

3.8.3 Physical properties of biodiesel

The fuel characteristics of synthesized biodiesel include; flash point, color, density, pours point, kinematic viscosity, cloud point, total acid number and sulfur % weight were determined according to ASTM standards.

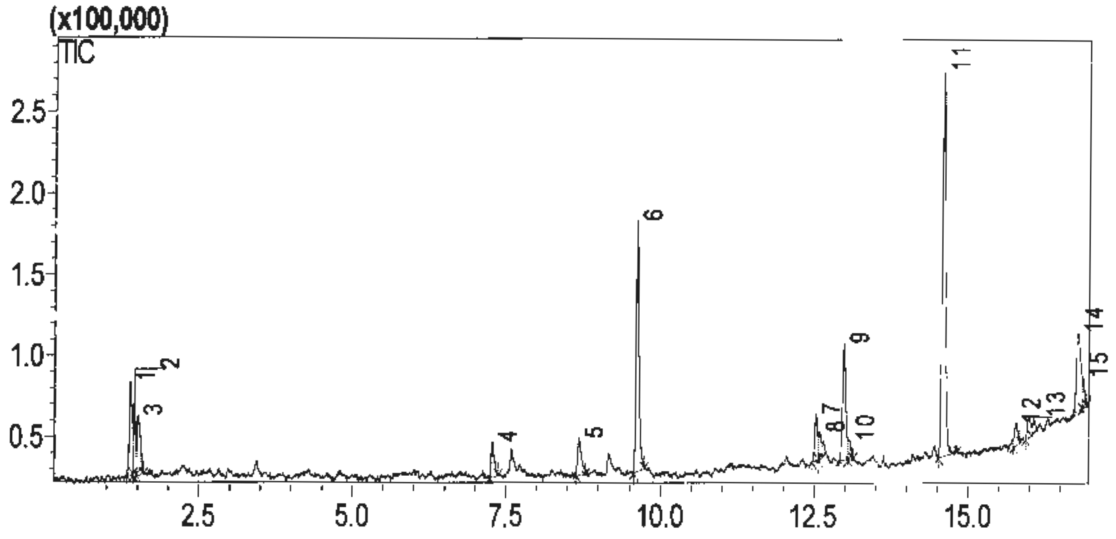


Fig 4.7: GCMS spectrum of Table Palm oil diesel

In the present study methyl esters was observed on different peak number. The major fatty acid components were identified by GC/MS, and their identity was further confirmed by comparing the GC data to that of known standards. Furthermore by using retention time different FAMEswere identified which was also confirmed by MS (mass spectroscopy) analysis (Shah *et al.,* 2014).Six different peaks of FAMES and 4 peaks of different solvents were analyzed and observed in the palm biodiesel.Helium was used as a carrier gas and the temperature of reaction was set at 300oc for about 40 minutes (Shah *et al.,* 2014).

Following chemical compounds were identified when POB produced by transesterification process was analyzed by GC-MS. Ethanol at peak 1, propyl alcohol at peak 2, Trichloro methane at peak 3, isobutanol at peak 4, isopropyl alcohol at peak 5and hexadecanoic acid at peak 5, 9-12, octadecanoic acid at peak 6, elaidic acid at peak 10.

Table 4.5: Chemical compounds of biodiesel identified by GCMS

Peak	Identified compound	Chemical formula	Retention Time
1	Ethyl alcohol	C_2H_6O	1.0
2	Propyl alcohol	C_2H_8O	1.0
3	Trichloromethane	$CHCL_3$	1.0
4	Isobutyl alcohol	C_4H_{100}	1. 75
6	3,7-Nonadien-2-one,8-methyl	$C_{10}H_{16}O$	9.5

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RESULTS AND DISCUSSION

Results and discussion

4.1Oil content in seeds of Table Palm

The oil content of Table Palm seeds were evaluated through soxhlet extraction method using n-hexane as solvent (Binhu et al., 2012). The oil percentage obtained from the seed powder was 48%.

4.2FFA determination

FFA for table palm was determined in order to find the free fatty acids percentage in the oil. The Table Palm oil contained 0.28 of the free fatty acid contents. This was the reason that the oil was then subjected to one step transesterification process. The free fatty acids were analyzed by using sample and blank titration method. The FFA has to be minimal i.e. less than 2%, otherwise soap formation occurs rather than ester (Shikha and Rita, 2012). According to ISST, 2006, the amount of the FFA acceptable for a base catalysts reaction is 2.5 % and oil having higher FFA than 2% need pretreatment step before transesterification process.

4.3Biodiesel Production

4.3.1 Effect of Temperature on biodiesel

Four experiments were designed for the optimization of reaction temperature to obtain high yield of biodiesel. To achieve maximum yield of biodiesel different reaction temperature was kept under consideration i.e.45, 50, 60 and 1 hour and 15 minute and meanwhile the other factors were kept constant. The maximum amount of hiodiesel yield (90%) was obtained at 55°C to 60°C. According to (Hayyan *et al.*, 2010; Supardan and Sutriana, 2009; Vibhanshu *et al.*, 2014) the similar amount (89%) of biodiesel produced at 60°C.

Table4.1:Effect of Temperature variation on biodiesel yield

SNo	Temperature	Production	Glycerin
1	45^0C	46%	15%
2	50^0C	68%	12%
3	55^0C	89%	5%
4	60^0C	90%	5%

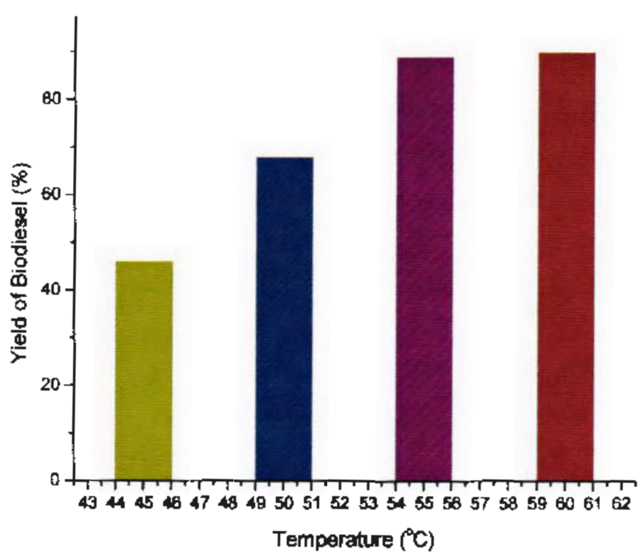


Fig 4.1: Effect of Temperature variation on biodiesel yield

4.3.2 Effect of Stirring Time on Biodiesel

Total of four experiments were designed for the optimization of reaction temperature. The reaction time was changed 4 times (30 min, 45 min, 60 min and 1 hour and 15 min) in order to obtain maximum biodiesel production. The maximum yield was obtained at 45°C. The literature support the result that 45°C is optimal time for biodiesel production (Wang*et al.*, 2011).

Table 4.2: Effect of Stirring Time on biodiesel yield

In order to find out the optimum concentration of catalyst for maximum yield production the catalyst amount were changed several times while all other parameter like reaction temperature, time and methanol to oil ratio were kept constant. The experiments were designed for different concentration i.e. 0.02g, 0.04g, 0.06g and 0.08g. In this study the maximum amount (80 to 85%) of biodiesel was obtained at 0.06g to 0.08g with KOH and NaOH.

Table 4.3: Effect of Catalyst Concentration on biodiesel yield

S.No	Catalyst Concentration	Biodiesel	Glycerin
1	0.02 g	90 %	5 %
2	0.04 g	88 %	11 %
3	0.06 g	80 %	11 %
4	0.08 g	78 %	12 %

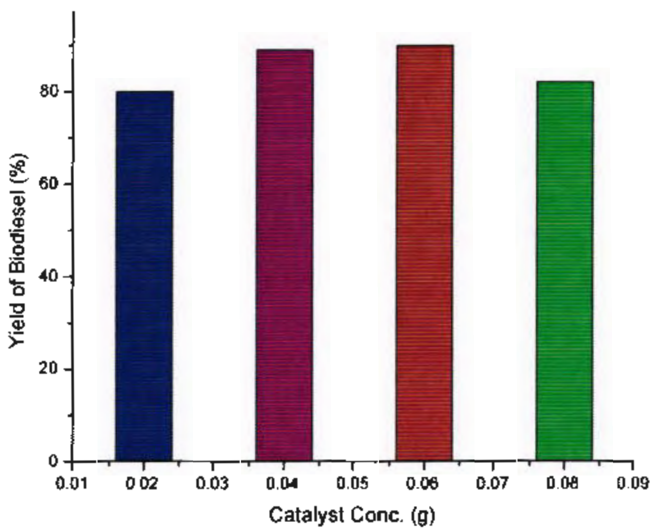


Fig 4.3: Effect of Catalyst concentration on biodiesel yield

4.3.4 Effect of Methanol to Oil Ratio

To maximize the yield of methyl ester it is necessary to derive the transesterification reaction to move to the product that is methyl esters and glycerol. It is needed to increase the concentration of alcohol so that the reaction becomes more favorable to produce greater amount of FAME. Different experiments were designed by varying the molar ratio of oil to methanol ratio (1:1, 1:2, 1:3, 1:5 and 1:7) by keeping all other parameter constant. In this study the maximum yield of 85% to 87 % were obtained at 1:3 with KOH. The results showed that there is no effect of further addition of methanol.

Table 4.4: Effect of Methanol to Oil Ratio on biodiesel yield

S. No	Oil to Methanol Ratio	Yield of Biodiesel	Glycerine
1	1:1	71 %	15 %
2	1:3	90 %	5 %
3	1:5	85 %	10 %
4	1:7	82 %	15 %

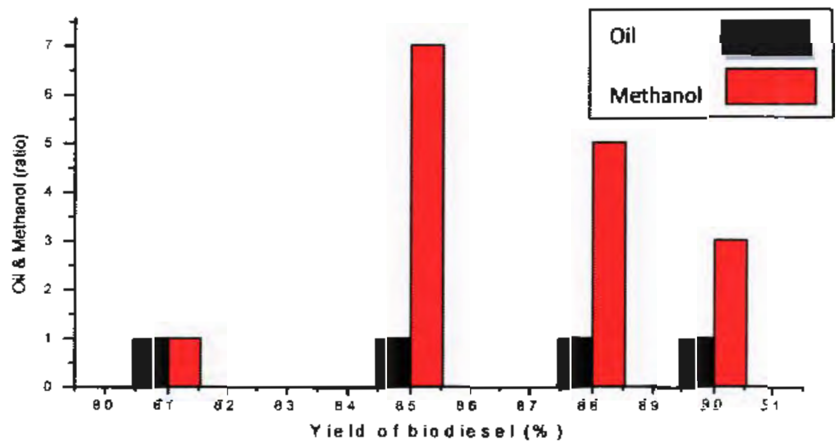


Fig 4.4: Effect of Oil to Methanol ratio on biodiesel yield

The results showed that there is no effect of further addition of methanol. The Wang*et al.*, 2011, proved from his research work that there is a minor effect of molar ratio. He further elucidatesthat, as the molar ratio increased; only a slight increase in the conversion efficiencies occurred.

4.4 Fourier Transform Infrared (FTIR)

The biodiesel prepared from Table Palm oil was analyzed using Fourier Transform Infrared region. The FT-IR spectra are used to identify the functional groups and the bands corresponding to various stretching and bending vibrations in the samples of oil and biodiesel.The position of carbonyl group in FT-IR is sensitive to substituent effects and to the structure of the molecule (Guillen *et al.*, 1997). The difference resemble to their bending and stretching frequencies of functional groups in FT-IR spectra of table palm seed oil and diesel indicates that during transesterification, there is change in their functionality. The replacements have great influence on the position of carbonyl group in FT-IRspectrum. Ester identification in molecule of biodiesel can be done by occurrence of two absorption peaks in the range of 1300-1000cm^{-1}for C-O group stretching and 1750-1730cm^{-1} for carbonyl group in the ester.

The bands in the range of 2980-2950cm^{-1} denote CH_3 stretching vibration, whereas the bands in the range of 3050-3000cm^{-1} denote CH_2 stretching. The bands due to CH_3 bending appear in the range 1475- 1350cm^{-1} while CH_2 bending is attributed by 1350-1150cm^{-1} and bending of CH group is established by the presence of band at 722cm^{-1}(Soares*et al.*, 2008; Guillen *et al.*, 1997).

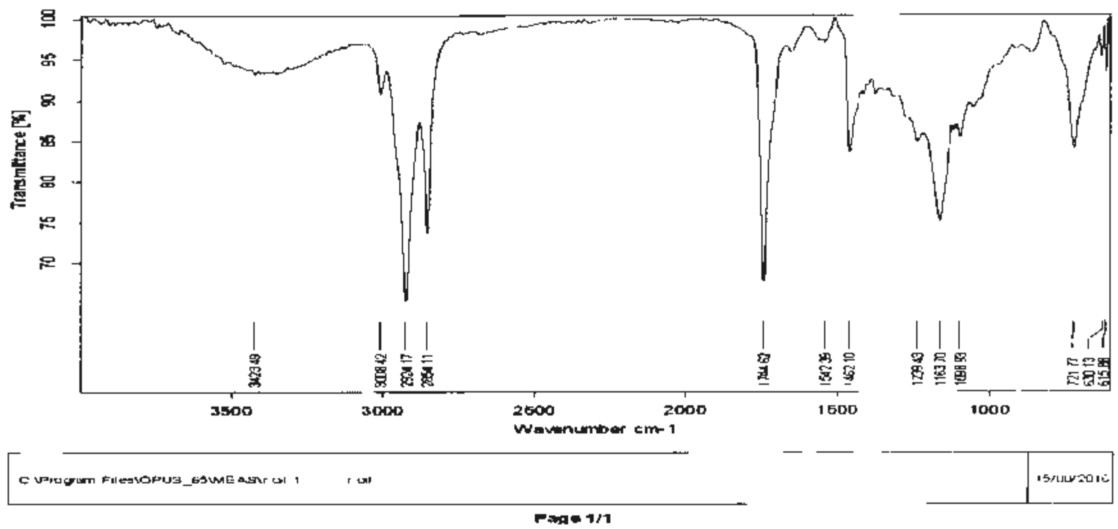


Fig: 4.5: FT-IR spectrum of table oil biodiesel using KOH

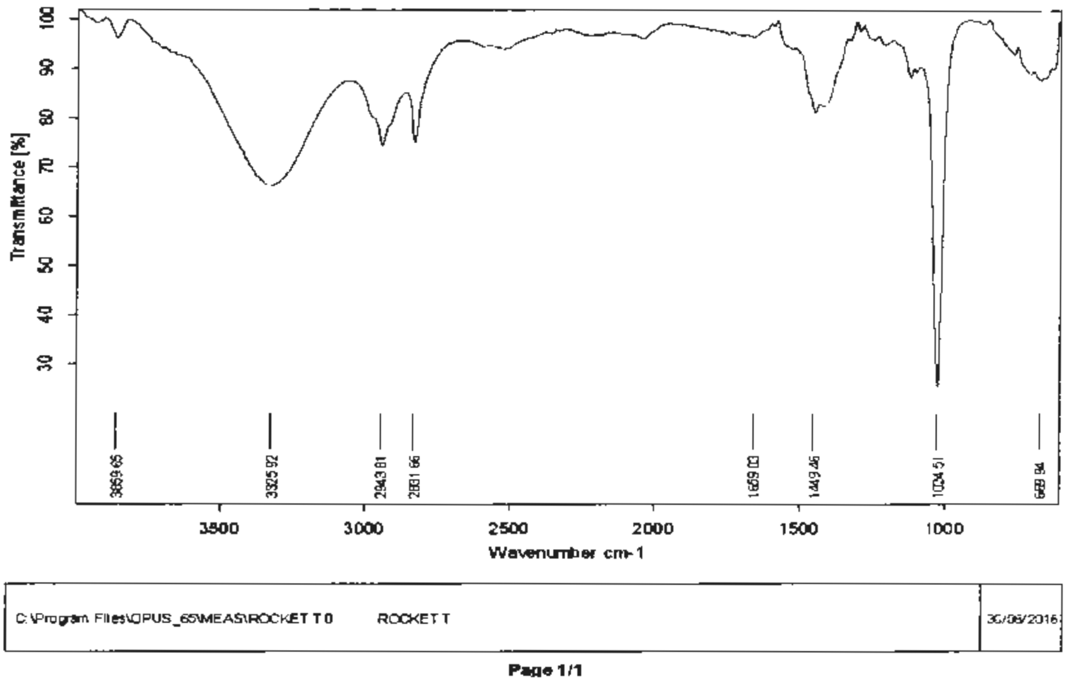
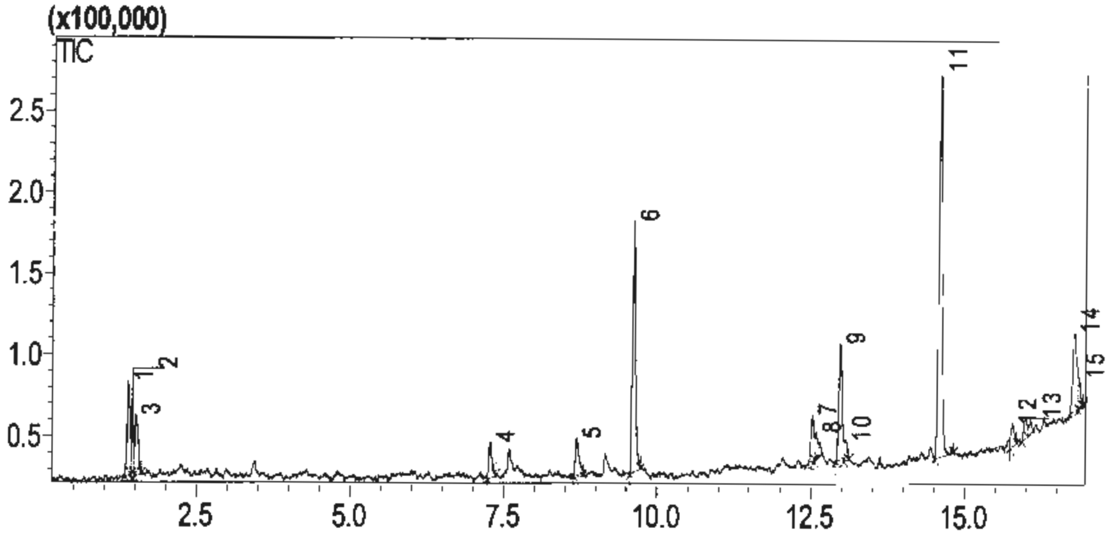


Fig4.6: FT-IR spectrum of Table Palm oil

Fig 4.5 represents the FT-IR Spectrumof diesel and fig 4.6 represent FT-IR Spectrum of oil. The Aklyne group was observed at 300.28cm^{-1} and Alkane group stretch (C-H) at 2904 cm^{-1} Esters and saturated aliphatics (C = O) were found at 1752 cm^{-1}. The presence of esters in the sample is the sign of conversion of oil to diesel. The 1462 peak indicate the presence of alkane group while 1163 cm-^{1} represents the presence of Alkyl halide radical. The aliphatic amines (C-N) were observed at 1088 cm^{-1} whereas the bend of alkyl halide group were present at 638 cm^{-1}.

4.4 Gas-Chromatography mass spectroscopy (GCMS)

Gas-Chromatography mass spectroscopy is used to analyze the chemical composition of biodiesel i.e. fatty acids, methyl ester. According to Monteiroa*et al*., 2008, GC has been the most used technique due to its high accuracy for the quantification of minor componentsIt play an important role in modern quality control analysis of biodiesel hence, it'scommonlyused in the study of biodiesel analysis. These relevant studies have contributed immensely to the rapid growth of biodiesel production and analysis, with modern techniques providing better results (Muhammad *et al*, 2013).



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Peak	**Identified compound**	**Chemical formula**	**Retention Time**
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4	Isobutyl alcohol	C_4H_{100}	1. 75
6	3,7-Nonadien-2-one,8-methyl	$C_{10}H_{16}O$	9.5

9,10			13
11,12,13	Nitrous acid	$C_{15}H_{11}NO_2$	15
14,15	Benzene, 1,2,4-trimethyl	C_9H_{12}	16

CONCLUSION AND RECOMMENDATION

Conclusion and Recommendations

5.1 Conclusion

Table Palm oil biodiesel was investigated through experimentalperformance and assessment. Various experimental variables were employed. The current studyproved the oil yield of table palm tree. Valuable biodiesel is produced from non-edible TP plant.The value of FFA was confirmed to be 2.8 by the result of free fatty acid analysis. This amount of FFA initiated the experiment to single step transesterification reaction. The maximum yield of biodiesel obtained (90%) at oil to methanol molar ratio (1:3), 45 min of stirring, 0.06 g of KOH and 60°C. The FT-IR results revealed about functional groups in TP diesel. Carbonyl group was described by a strong peak at 1746 cm^{-1}, hydroxyl group by two strong peaks at 3857.97cm^{-1}, 330079cm^{-1}, two medium amine peaks at 112.86cm^{-1}, 1024.62cm^{-1}. The result confirmed that Table Palm tree is a potential feedstock for biodiesel synthesis and can be grown on barren land of Pakistan on commercial scale.

5.2 Recommendations

The following are some recommendations for further studies:

- The selected oil showed better results in comparison with other oils, so there is dire need of research on different resources in order to enhance the production of biodiesel.
- As the effect of selected catalyst KOH has been found to be highly efficient so other catalysts can also be checked by fellow researchers.
- In recent days, Nano technology has been proved to be most promising technique for the solution of almost every problem so the use of Nano catalysts for the biodiesel production is highly recommended.
- The purification of glycerol into Glycerin is suggested too in order to increase its market value of biodiesel.

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