Enzymatic Hydrolysis of Mustard oil towards Bio-jet fuel Production.

Dissertation submitted in partial fulfillment of the requirement for the degree of

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BIOTECHNOLOGY

By

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HP-173234, INDIA, May 2022

DECLARATION

I hereby declare that the work reported in the M. Tech. thesis entitled **"**Enzymatic hydrolysis of Mustard oil towards Bio-jet fuel production**"** submitted at Jaypee University of Information Technology, Waknaghat, India, is an authentic record of my work carried out under the supervision of Dr. Garlapati Vijay Kumar, Dept. of Biotechnology and Bioinformatics, JUIT, Waknaghat, HP-173234, India. I have not submitted this work elsewhere for any other degree or diploma.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the M. Tech. thesis entitled "Enzymatic hydrolysis of Mustard oil towards Bio-jet fuel production", submitted by Sara Bhinta (202553) at Jaypee University of Information Technology, Waknaghat, India, is a bonafide record of her original work carried out under my supervision. This work has not been submitted elsewhere for any other degree or diploma.

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ABSTRACT

Bio aviation fuel, generally termed Jet fuel or aviation fuel is the fuel that powers aircraft. Air transportation has increased tremendously in the past some years. The aviation sector and many other transport sectors across the world still rely on conventional methods to power their engines. Fossil fuel has and is still the major source of energy. The carbon gases emitted from these fuels are not only affecting humans but are also affecting the environment. The aviation sector alone contributes to about 2-3% of the total carbon dioxide emission. Not only are the convention fuels affecting the environment but they are the costliest means to power the engines. Hence the production of bio-jet fuel across the world has started. The need for a renewable and sustainable alternative to conventional jet fuel has become the top priority of the sectors across the globe. The use of Mustard oil as jet fuel and not long been discussed. It is recently that mustard oil has been highlighted. It is nearly estimated that mustard oil as a sustainable fuel will reduce about 68% of the total carbon dioxide emission in the aviation sector alone. But there are cons to doing the same that will be highlighted in the paper. Hydrolysis of oil has been practiced for ages now to produce free fatty acids. The composition of a free fatty acid determines the rancidity value of the oil. The free fatty acids are removed from the oil before being manufactured for the market. In this paper, we will perform hydrolysis by using lipase as an enzyme. After which decarboxylation will be performed this will result in the removal of carbon from the hydrolyzed oil. The last step will be the fractional distillation of the oil to obtain jet fuel.

Keywords: Mustard oil, Immobilized Lipase; hydrolysis, free fatty acids

CHAPTER 1
Introduction & Review of Literature

1.1 Introduction

The air transportation sector runs a vital role in the economy of the globe. The aviation sector is one of the biggest sectors in the world transporting about two million passengers every day across the globe [1]. Because of the expanded sector facilities, the sector also serves around fifty-seven million jobs worldwide. Contrary to that the aviation sector is estimated to produce about 2-3 % of the total carbon emission and the number is still increasing. The need for bio-jet fuel does not only apply to the aviation sector but is now the need for the whole system. The environment is being affected by the carbon that has been emitted by airplanes daily. Due to the overgrowing population, transportation has also increased. There are hundreds of flights that are flying every day carrying millions of passengers from one place to another. Every flight requires hundreds of liters of fuel in just an hour for it to power. The amount of carbon released is even more. This carbon is causing various harmful effects to the environment which in turn is causing human harm. Not only the fuel but the defeat of the flights is another issue. Many technical improvements need to be some to ensure the same. All this will require even more cost and energy. Hence the need for sustainable alternatives to save both the cost and the environment is required.

The conventional ways to power aircraft by using fossil fuel is still being practiced. The use of fossil fuels not only impacts the environment but also affects the economy. Fuel is the biggest operating cost for the aviation sector. Hence the use of any further aviation fuel should be eliminated and the use of more renewable, sustainable and cost-effective fuel should come into practice. Throughout the globe, the practice of producing SAF has already begun. Speaking of India, the prices of oil are likely to increase in the year 2022 due to the lesser production of the oil, but the pricing will gradually decrease as the production of oil in India will increases in the coming time. The main issue in the production of SAF does not lie in the airlines but lies in the quantity of the fuel being produced. Approximately 100 million liters of SAF were produced in the year 2021 globally which is a very small amount to meet the required needs.

Fortunately, various airlines are committed to bringing about a change in the airline sector. They are determined to bring the percentage down by 50 % by the year 2050 [2]. Never the less many aspects are produced for the achievement of the goals described by the IATA. The first one is the improvement on the technological front. There are already technological mystifications being made in the parts of the engines like in the engines that are being manufactured are now lightweight have a stronger built to avoid any technical faults. The second one is improvements in the operational sector. The third is the market costs and capital and the last is the ATJ (alternative jet fuel) itself [3]. This might take the longest time but if this all started on time, the future of the aviation sector will both be economically and environmentally sustainable. The only issue at the current is lower production of SAF at higher costs. Many pathways are currently being used in the production of SAF across the world. These pathways vary according to the aircraft being used. For military aircraft, the production process varies differently from that of domestic aircraft. Four pathways are used in the production namely; oil to jet fuel, alcohol to jet fuel, gas to jet fuel and sugar to jet fuels. A detailed analysis of these will be done further in the paper along with some more detailed analysis of what bio-jet fuel is and how the storage and transportation of feedstock can affect the future analysis. Not only do these pathways depend on the type of aircraft we use, but it strongly also depends upon the type and classifications of feedstock's we use. For example, corn, starch, ethanol, and vegetable oil, all have different process pathways. Like all the soil feedstocks are converted to oil through gasification. We will study them in detail in the rest of the paper.

1.2 Bio Jet Fuel

The extraction of aviation fuel like any other fuel starts with crude oil. Crude oil as we know is the mixture of numbers of hydrocarbons and various impurities. The crude oil after its extraction from the earth's core is heated at 400 C to separate the components according to their boiling points. The components with lower boiling points vaporize. One of the components called Kerosene is what constitutes aviation fuel today. The hydro-carbon length of jet fuel is that between diesel and gasoline which is from 8 to 16 [4]. Kerosene is preferred for jet fuel over diesel or gasoline due to its volatile nature, flash point, and freezing point, and kerosene is denser than the rest mentioned fuels. Aviation fuel has harsh requirements and specifications for it to meet with the sustainable jet fuels. One of the many being its freezing and flashpoint. The main reason by aviation sector uses kerosene is safety. Kerosene is estimated to and has a higher flash point than the other categories of oils like diesel who is 150°C and also higher than petrol [6]. By the previous statement, we conclude that kerosene takes a higher temperature to ignite than the rest of the oils. This is not the sole reason for kerosene to be used for jet fuel, but also that kerosene can stay liquid even when the temperature at higher altitudes falls to minus. This is very important in the case of aircraft as airplanes fly at a very high altitude and any freezing in the oil can lead to disastrous results. Jet fuel in part of the world is of two types. Jet A and jet A-1. There are mainly three types of engines that are used in vehicles. Gas turbine engines are used in aircraft to power them with fuel. The jet of type A is mainly produced and put into use in the

United States and jet A mainly powers commercial aircraft as it has a freezing point of –40°C which is suitable for commercial flights. On the other hand, the type of jet A-1 is not produced in the US but instead is produced across the world. The jet A-1 has a freezing point of about -47°C and is mainly used in military aircraft and military aircrafts required a lesser freezing point. But to meet all the specifications the oil freezing point alone cannot contribute; hence some additives are used with the oil to meet the necessary specifications. Additives like icing agents to prevent the water in oil from freezing, anti-microbial agents to prevent any growth of the microbes in the oil, anti-corrosive agents to prevent any corrosion in the engine, and gum inhibitors to prevent any kind of gum are used in the oil. The additives content of jet fuel varies considerably depending on whether the fuel is for civil or military use. Fuel system icing inhibitor (FSII) is of most importance for jet fuel. It reduces the freezing point of any unwanted water present in the fuel. Various specifications must be met for the production of sustainable jet fuel in comparison to conventional jet fuel. Some of them are that the fuel should have high calligraphic value, should flow easily under all conditions, should have combustion under all conditions, be non-corrosive, have no damage to the engine from combustion, have low fire hazard, and should be a good lubricant. Many companies have their targets set to meet the required list for the production of renewable jet fuel through various techniques. Four main techniques are used for the production of SAF.

- The first one is from oil to jet fuel. Oils like waste cooking oil and vegetable oil are considered to convert them into jet fuels.
- The second one is for mostly soil feedstock, gas to jet fuel.
- The third one is from alcohol to jet-fuel
- And the last one is from sugar to jet fuel [5]

Now, according to the IATA specifications, only the oil to jet fuel by HEFA is approved to use while the rest are still under pending approvals. These pathways ensure the production of bio-jet fuel but the main factor that determines the success rate of any product is its cost and environmental effectiveness. Without the fuel being sustainable for both the economy and the environment, the fuel has no significant value. Many challenges are faced while the production of the fuel, one of the many being feedstock's. The other difficulties are its transport and storage. These few mentioned factors can determine the success rate of the production. Cutting the cost of feedstock, transport, and storage can make the fuel sustainable to the economy and the environment itself. As mentioned before for us to choose the correct and the most cost-effective pathways to be used, the arability and choice of the feedstock play a major role. Feedstock's like cooking oil, plant oils, and fats from the animals, are the major used oils for the oil to jet fuel production from processes like catalytic hydrogenation, HRJ etc. The sugar-producing plants like all the lignocelluloses plants are under the production pathways from sugar to jet.

1.3 Mustard Oil

Mustard oil goes by its scientific name *Brasslike Junkie* is a crop that is grown and consumed across the world. In India mustard covers about 40% of the total vegetable crops. Mustard oil is consumed in various parts of the world differently. In India, it is used as cooking oil. Mustard oil has a pungent smell to it which makes it non-edible in some parts of the world [7]. Not only is this but mustard oil known for its high value of uric acid which is bad for health. Due to this, it is even banned in some countries. Mustard oil has a great composition of chemicals that makes it one of those oils that are to be the future of sustainable jet fuel. It is estimated that shortly mustard oil will lower the carbon emission caused by the aviation sector by 68%. Studies and experiments on mustard oil have already started and there is a hopeful future for the aviation sector. India has one of the largest plantations for mustard which give us the advantage to lower the cost and take a step close to producing sustainable jet fuel. The properties of mustard oil are discussed and calculated in TABLE 1. Through the table we have made a difference between the known values of mustard oil compared to what was performed in the lab through titration itself. Mustard oil for the production of bio-jet fuel is first hydrolyzed and then decarboxylated. There are various methods by which we can produce the same.

Table1. Properties of mustard oil.

Values	**Saponification value mgKOH/g**	**Peroxide value megO_2/kg**	**Acid value %**	**Free fatty acid value %**
Known values	170-178	0.83	6.1	3.05
Experimental values	179.4	2.4	6.05	3.03

1.4 Production Pathways

Many process pathways are developed for the conversion of oils, sugars, algae fats, etc. to jet fuel. Some of these pathways are also commercially available and some of them are not. HEFA is the most sustainable and cost-effective pathway. There are four main pathways available. We will discuss them briefly in this section one by one.

HEFA -is one of the commercially available pathways that are being used by many companies across the world for the production of jet fuel. Not only is this pathway sustainable, but is also cost-effective and less harmful to the environment. The main advantage of this technology is the availability of the feedstock. The feedstock used for these pathways mainly comprises oils and fats. Oils from vegetables, plants algae and animals are the feedstock for this pathway. This pathway uses feedstock from both the first generation and the second generation. This pathway can be made more cost-effective depending upon the choice of feedstock used. There are mainly four steps in this pathway. The first one is the extraction of oil and fats from the feedstock. This step can be made even more cost-effective by using extraction methods that are easily available and cost-effective like centrifugation, and fractional distillation [8]. This step after the extraction is followed by hydrogenation. Hydrogenation of the breaking of unsaturated bonds into saturated bonds. Hydrogenation breaks the bonds in the oil and produces free fatty acids. The hydrogenation step is then followed by the third step of cracking. In this process, the molecules with heavier hydrocarbons are broken down into lighter ones so that we can obtain the desired oil. Then comes the final step of distillation. This step is the basic step in all the pathways in which the desired oil is separated from the feedstock by distillation.

The advantage of HEFA lies in its sustainability. The process and the pathway followed in HEFA are completely exothermic making it effective cost vice and environment vice as the energy that is produced in the first step is then used in the rest of the steps also. Another important aspect to keep in mind is oxidation. Excess oxygen in the oil can cause contamination of the oil and will not be good to use, which will lead to a waste of money and resources. Fortunately, the HEFA pathway removes any oxygen present in the oil and does not cause oxidation. But this pathway has its limitations. The feedstock availability for HEFA is not up to the mark currently. This leads to lower production of SAF.

FT: the Fischer-tropsch pathway is another highly used pathway. This pathway is said to be more sustainable than HEFA. Due to a variety of options in its availability of feedstock that does not come in the way of the food chain, this pathway is used in many companies already. The feedstock used in the pathways is natural gas and a variety of coal. Coal is already being used to produce jet fuel by converting it into liquid forms. The oil produced from this pathway is lower in Sulphur and aromatic content making it more attractive a pathway. The first step in this pathway is the gasification step. There are many ways by which the gasification process is carried out. In his step, the feedstock is made to undergo a reaction with an oxidant like carbon dioxide or steam. But mainly carbon is used as an oxidant over stem as it improves the selection of the downstream process.

These oxidants are made to react with the feedstock so that partial oxidation takes place and syngas are produced. The gasification step is then followed then synthesis. Before this step begins, all the impurities are removed from the syngas which also includes the removal of carbon dioxide [9]. In this process, alkenes are produced and water is removed. This step can occur at both high and lower temperatures. After this process, the syngas is moved to the separation unit where they can undergo steps like hydrogenation, isomerization etc. to produce lesser Sulphur and aromatic content. The main advantage of this step lies in the maturity of the pay ways itself. The aromatic content in this pathway is in the required range and the oil is mostly Sulphur free. The required range of the aromatic content makes it a viable pathway to be used in the future as a lower aromatic range is not required whereas a higher range produces more GHC emission. The disadvantage of this pathway is its feedstock's. This pathway still used conventional feedstock like coal and natural gases that are hazardous to the environment and are more costly than the other feedstock's available.

ATJ: The ATJ pathway uses feedstock's that is sugar-rich like lignocelluloses feedstock. This pathway is also used widely across the world but has still not gained importance due to its drawbacks. But there has been researching going on how to make this pathway even more sustainable to use. Like any other step, ATJ has main basic three steps. The first step involves the dehydration of alcohol. The second step after dehydration is oligomerization and the last step follows is hydration. The common advantage of ATJ concerning FT is that the aromatic content is also in the required range with that of conventional fuels. Just like in another step the last batch is separated by distillation. Another very important advantage of this pathway is that this pathway also used municipal waste as a feedstock. This technique in the future will provide us with amazing results. Butanol is a feedstock that has many advantages. Like butanol has a very lower requirement in terms of temperature and pressure which makes it very cost-effective than ethanol. Not only this but butanol has a lower value of corrosion and has a higher calligraphic value than ethanol which meets all the main requirements of the conventional fuel and makes it a very cost-effective feedstock for the production of jet fuel. Moreover, there is already existing infrastructure for ethanol production which can cut down the cost of butanol production. These infrastructures only require minimal up-gradation [10]. The process of ATJ requires even more understanding and study as this process meets both the air and the land requirements and due to its low yield, it will be very difficult to serve any of the above-mentioned means of transportation.

1.5 Comparison between Jet-fuel and Biodiesel

Just like any other oil produced, both jet fuel and diesel start their production with crude oil. Crude oil is extracted from the earth's surface. It is produced on the surface of the earth by the decomposition of dead animals and plants. These dead remain are what produce crude oil. Crude oil is black and is of thick consistency. After its extraction, the crude is put into a unit which is called a distillate. When the crude oil is boiled at very high temperatures, it evaporates. As the vapors move higher and higher, they vapors cool down and turn into liquid [11]. This is where we get diesel, kerosene (jet fuel), gasoline, and petrol. These are the fuel that is a source of power used across the world. Due to the difference in their boiling points, the cooled vapors settle into their respective chambers. The figure shows a represents the production of different fuels according to their difference in their boiling points.

This is where we can study the major difference between diesel fuel and jet fuel. Diesel is the heaviest oil amongst any other produced by crude oil. Heavier the oil, more the number of hydrocarbons in that oil. Hence the hydrocarbon length of diesel fuel is between 12-20 carbon atoms. Speaking of kerosene, it is also heavy oil having a carbon number length ranging from 8 to 16. Jet fuel being lighter than diesel is one of the starting reasons for it being used as jet fuel. Lighter oils ensure safety. The second major difference lies in their freezing points. Diesel has a freezing point of about 32 °C. And the freezing point of jet fuel is -40° C to - 47°C. This means that diesel can freeze faster and more frequently than jet fuel. When flying at such high altitudes, it is to be made sure that the fuel does not freeze, unlike what diesel does in colder weather. The third difference lies in their flashpoints [12]. Flashpoint is the lowest temperature at which a substance starts to ignite. Therefore, the flashpoint of diesel is from the range of 55°C to 65°C whereas the flashpoint of jet fuel is 38° C. This means that jet fuel will take a higher time to an engine than diesel fuel. Hence this can provide safety to the ones travelling by air.

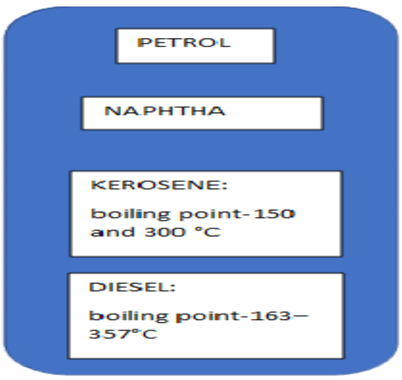


Figure1. Different oils extraction from crude oil at different boiling points.

CHAPTER 2
Materials and Methods

2.1 Materials

Low-cost samples were taken for the conduction of the experiment. Mustard oil of the brand P mark was used that is easily available locally in the markets. Lipase (SEBake L 80) in powdered form was easily available in the institute which was purchased from advanced enzyme technology. For the immobilization of the lipase, the entrapment technique was used. Phosphate buffer was prepared for the production of sodium alginate beads. Other materials like sodium alginate, calcium chloride, methanolic sodium hydroxide, and hexane were collected for the experiment.

2.2 Methods

2.2.1 Preparation of bio-catalyst

For the preparation of a biocatalyst, first Lipase enzyme was immobilized by a sample entrapment technique. Firstly, phosphate buffer was prepared and the pH of the same was set to 7.0. For the preparation of phosphate buffer NaCl (0.8g), KCl (0.02g), Na_2HPO_4 (0.142g), KH_2PO_4 (0.025g) were dissolved in 1000ml of distilled water. To this phosphate buffer, 2g of Sodium Alginate was added. The mixture was then heated at 40°C till both the substances mixed completely. The mixture was then let to cool down at normal room temperature. To this mixture, 2g of lipase was added and the mixture was mixed completely. In a separate flask, a solution of calcium chloride was prepared by adding 11.7g of CaCl to 100ml of distilled water. For the preparation of SAL beads, a syringe was taken by which the sodium alginate solution was dropped into calcium chloride solution one by one. The beads were then stored at -4°C for at least 12 hours for them to solidify completely. After 12 hours the beads were washed with distilled water three times.

2.2.2 Pre-treatment of Mustard oil by Enzymatic Hydrolysis

In the pre-treatment of Mustard oil firstly 2g of SAL beads were taken in a 250 ml flask. To this 50ml of mustard oil was added with the subsequent addition of 50ml of distilled water [13]. The mixture was then moved to a shaker incubator for enzymatic hydrolysis of the oil having temperature of 40°C, rpm 200 for 6 hours. After 6 hours the sample was moved for the analysis of free fatty acid and acid value determination.

2.2.3 Determination of FFA % in hydrolyzed oil

For the determination of FFA content first, the acid value of the hydrolyzed oil was determined by which we got the FFA composition. The following formula was used for the determination of acid value and FFA content in the oil

$$\text{Acid value} = 56.1 \times V \times N / W$$

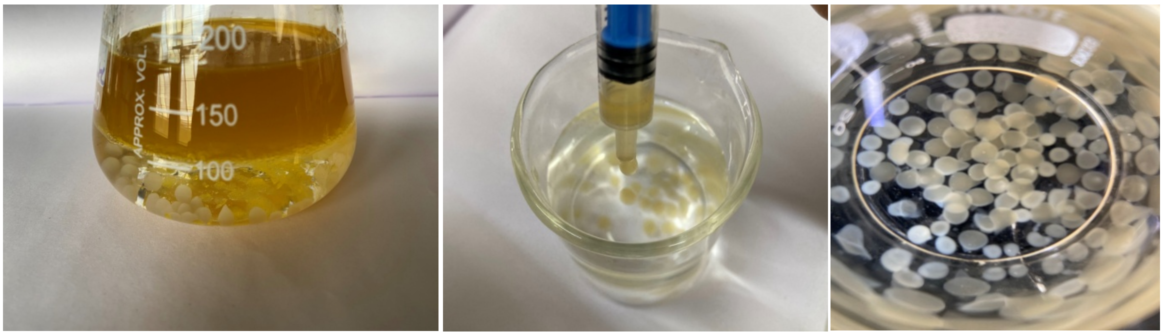
$$\text{FFA} = \text{acid value}/2$$

Where: V is the titer value

N is the normality of KOH

W is the sample weight

For the determination of the acid value, titration was carried out. Firstly 0.1N KOH was prepared for the titration. Then 2g of oil sample was weighed in a flask, to which 50ml of ethanol was added. The solution was mixed completely by shaking the flask. To the same flask, two to three drops of phenolphthalein indicator were added. Titration was then started. The initial reading was noted. Drop wise KOH was left to pour into the flask with vigorous shaking of the flask. The titration was stopped when the solution turned pink. The final reading was then noted. The acid value was then calculated by the above-mentioned formula. Here are picture attached.



(a) **(b)** **(c)**

Figure 2. (a) Pre-treatment of mustard oil by enzymatic hydrolysis. (b) Dropping of sodium alginate beads in calcium chloride solution (c) SAL beads

CHAPTER 3
Results and Discussion

3.1 Effect of temperature and different agitation time on hydrolyzed oil.

Optimization for both temperature and time was carried out by placing the sample at different temperatures and different agitation times. After the following hydrolyzed oil was analyzed to determine the percentage of FFA. This was done by performing a titration. Table 2 and 3 shows the acid value along with the percentage of FFA at different time and temperature. When any vegetable oil undergoes hydrolysis in presence of an enzyme along with water, esters bonds are broken in the oil and the fatty acids are removed from the glycerol producing free fatty acids. The enzyme lipase has been used as a catalyst that breaks down the ester bonds in the oil. The process of hydrolysis always takes place in two scenarios, one is partial hydrolysis and the second is complete hydrolysis. In the case of partial hydrolysis, the ester bonds are broken into only one of two FFA whereas, incomplete hydrolysis, the ester bonds are broken into three FFA. A higher value of free fatty acids should be removed from the oil as it causes rancidity in the oil making it bad for health. Not only has this but after the process of hydrolysis, the acid value of the oil also increased making the oil bad. As observed in figure 3, after 6 hours of agitation, the acid value of the oil has increased drastically.

Not only is this but it also observed that with an increase in the temperature the acid value of oil is found to decrease. At 40°C the acid value and the FFA percentage are the lowest compared to other temperatures. And in the case of time, the lowest acid value and the lowest FFA percentage were observed at 6 hours at 40° C temperature. Hence for the experiment 40° C at 6 hours was chosen as the standard time and temperature to obtain the lowest FFA.

Table 2: Optimization of temperature in hydrolyzed oil.

Temp (°C)	**FFA (%)**	Acid Value (%)
20	1.68	3.36
25	2.6	5.32
30	2.9	5.89
35	4.3	8.69
40	1.4	2.80

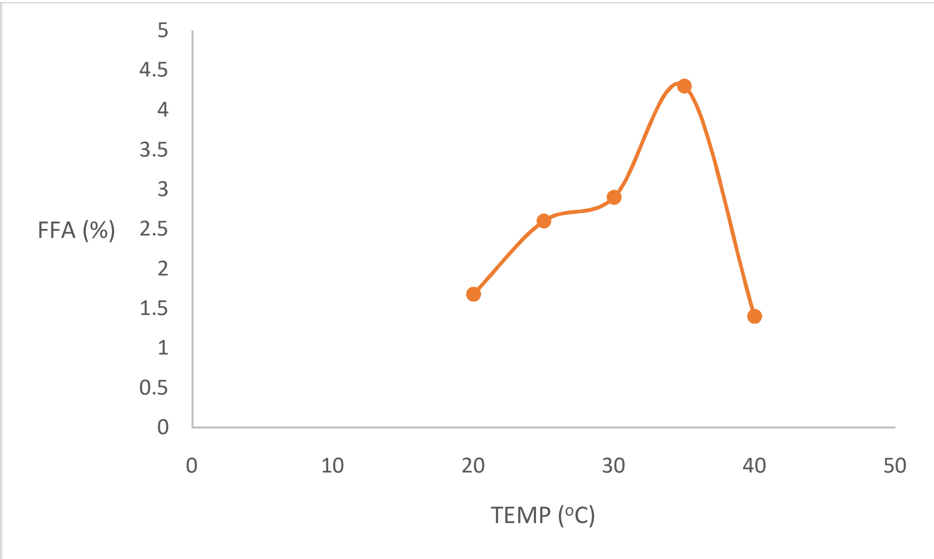


Figure 3. Effect of Temperature on fomation of free fatty acids (FFA, %)

Table 3 : Optimization of time in hydrolyzed oil to produce FFA

Time (h)	**FFA (%)**	**Acid Value (%)**
2	5.89	11.78
4	4.6	9.25
6	4.3	8.69
8	10.7	21.59
10	14.3	28.61

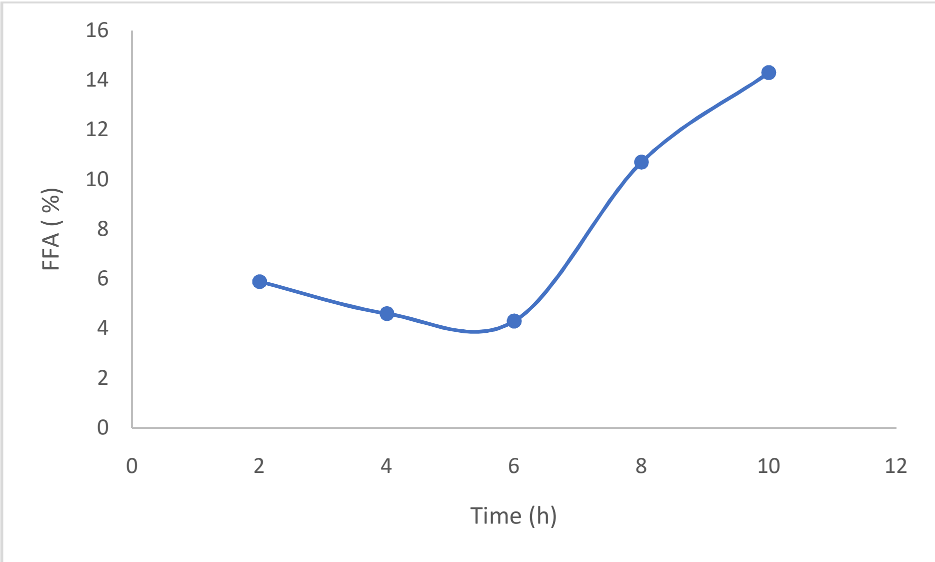


Figure 4. Effect of Time on fomation of free fatty acids (FFA, %)

CHAPTER 4

Conclusions and Future Directions

4.1 Conclusions

The need for jet-fuel is definite and the near future will be even more sustainable by the production of the same. There are many processes and methods that are in practice today for the production of the same. The goal of decreasing the carbon emission by 50% by the year 2050 will face many issues and challenges. But these challenges will need to be overcome for a better sustainable future. In this paper, all the possibilities to reduce the carbon footprint were discussed. With the increasing demand for bio-jet fuel, major steps should be no taken to reduce the cost to maintain the sustainability of the oil. Crops like oil palm and jatropha should be given more importance to produce cost-effective jet fuels. A range of feedstocks is available for the production of bio-jet fuel. Some of these can provide short to medium-term solutions for the development of sustainable jet fuel. Moreover, there are many ongoing studies in search of long-term feedstock that will be must more cost-effective and friendly to the environment. Along with this, many production pathways are present out of which HEFFA is one of the most cost-effective and sustainable ways of production SAF, but with new technologies, this too can improve even more and give us better results. More strategies are required for the better storage and transportation of thisfeedstock's and oils.

4.2 Future Directions

The IATA and ICAO, for future sustainability, should work on better planning and implementation of storage and transportation areas. They should develop cross-link roads across the borders and within the nations to minimize pollutants and costs. The development of new technologies to scale up the existing technologies can also help minimize the concerned factors. The aviation sectors across the nations should have fine support from their government that should provide them with incentives and subsidies [14]. Over or shortly these subsidies offset the cost of the fuel. Low cost, high yielding, sustainable crops should be planted more keeping in mind they do not hinder the natural habitat or alter the natural course. The jet fuel is comparatively higher than that of any other jet fuel. If in the future no heed is paid to the sustainability of the aviation sector, both the cost and the harmful effects to the environment. For this first awareness is the first and the most important thing to be kept in mind. Planning is what comes side by side. It is most important that people across the world are educated on sustainability. Not only the sustainability in the aviation sector but also the other sectors like clothing. They should be educated about the fact that sustainability will take time and will not involve instant results. It will take time if everyone contributes their part. Sustainability will also include some costs but the cost will be reduced in the future if implemented now [15]. There will be a brighter future not only in the aviation sector but also in the other sectors.

Also, the decarboxylation was not performed due to unavailability of the equipment's in the institute. The process shall be performed in the near future at the arability of the equipment's.

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