Current Trends and New Perspectives in Biodiesel Production: A Focused Review on Interesterification Reaction

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ABSTRACT

The consumption of energy has risen to 12 billion tons/year due to the ever-increasing population and urbanization which has directly led to more energy demand. Hence, there is an obvious need for an alternative source of fuel energy. One of the best alternatives is the use of renewable fuel energy. Biodiesel is an example of a renewable fuel energy which is produced from biomass by different technologies such as direct blending of oil, emulsification, pyrolysis, and transesterification. However, the drawback of these methods has propelled research experts to persistently search for better technologies. Over the years, transesterification reaction methods have been globally identified for in biodiesel production. Nonetheless, its by-product named glycerol has limited its utilization in biodiesel production. Therefore, it has been reported that the integration of glycerol into biodiesel composition may be a better option. In this review, the latest biodiesel production technology discussed is the interesterification reaction. This method integrates the by-product (glycerol) by producing a glycerol free Fatty Acid Methyl Esters (FAME), triacetin which is a useful fuel additive is produced instead. After the production of biodiesel and triacetin through the interesterification reaction route, there is always no need to separate both products which makes this process interestingly more sustainable and economical. The current trends of this production technology are also expounded.

Keywords**:** Energy; FAME; Fuel; Interesterification; Triacetin

1. INTRODUCTION

Within the past three decades, several international conventions have been organized to globally address the potentialities and plans of replacing fossil fuels by other alternative energy sources and technologies such as the renewable energy (Estevez *et al.*, 2019). There has been a very fast depletion of the sources of these fossil fuels and oil reserves which have additionally been found to be one of the major contributors of the greenhouse gases (GHG) emissions that has led to loss of biodiversity, rise in sea level, climate change, amongst other environmental concerns (Manley *et al.*, 2017; Martins *et al.*, 2019). Due to the high demand for fossil fuel, there is an increase in the price of crude oil which also affects global economic activities (Gaurav *et al.*, 2017). Affordable and clean energy provision is one of the seventeen Sustainable Development Goals (SDGs) and it is economically and environmentally important in the majority of the African countries such as Nigeria (Adewuyi, 2020; Antwi-Agyei *et al.*, 2018; Davies *et al.*, 2019). For energy stability, the best alternative of fossil fuels from social, economic and environmental point of view is biofuel(Ayadi *et al.*, 2016; Mizik and Gyarmati, 2021). Also, annual world energy consumption has been projected to hit, by 2050, over 900 EJ, close to 1100 EJ in 2100 and also giving a pointer that global warming could be limited shown in Figure 1 (Moriarty and Honnery, 2019).

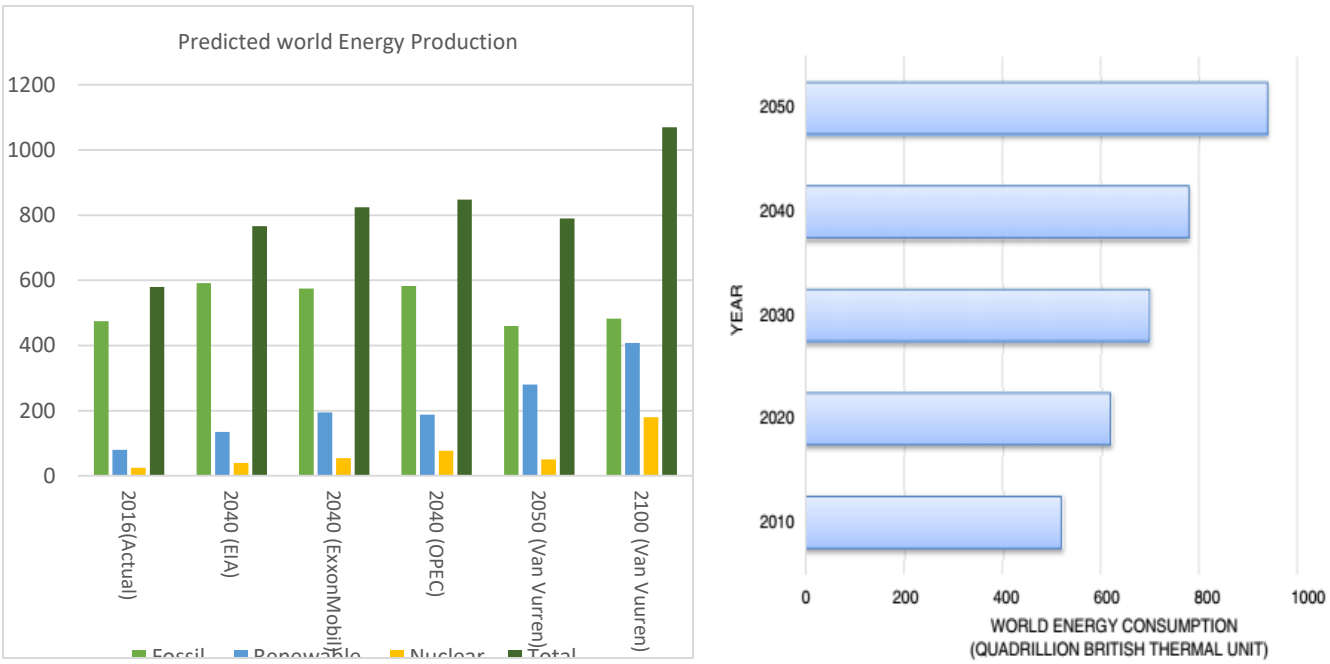


Figure 1. Predicted World Energy Production (2016 – 2100) and Consumption (2010- 2050) (Esan *et al.*, 2021; Moriarty and Honnery, 2019).

*EIA- Energy Information Administration; *OPEC- Organization of the Petroleum Exporting Countries.

In principle, the energy enriched chemicals that are produced through biological processes or that are basically obtained from biomass of living organisms such as plants, bacteria etc. are termed "biofuels" (Rodionova *et al.*, 2017). Universally, great attention has been given to biofuel as an alternative fuel because of its ability to be revamped with gasoline for as much as 85% volume blend without any engine modification (Hossain *et al.*, 2019). Biofuel that are principally produced from biomass can be in solid, liquid and gaseous fuel forms (Afolalu *et al.*, 2021). They can basically be classified into three generations i.e. the first, second and third generations based on complex and chemical nature of the biomass used in the biofuel production (Sharma and Sharma, 2018). Biodiesel produced from crop plants is an example of the first-generation fuels, bioethanol and bio-hydrogen produced from agricultural by-products and energy that needs a lush land for growth is an example of the second-generation biofuel and cyano-bacteria, seaweeds, marine resources are examples of the third generation biofuels which produces large biomass within a short period of time and no lush land is needed for growth (Adewuyi, 2020; Gaurav *et al.*, 2017).

Samuel and Adekomaya (2012) stated that, biodiesel is a renewable fuel for diesel engines that meet the specification of ASTM D 6751. It is produced from oils like canola, palm kernel, waste cooking oil etc. It has been severally reported as a type of fuel that can serve as a replacement for diesel fuel in engines. It produces lesser carbon dioxide and reduced emission to the atmosphere when compared to fossil diesel. The cost of production of biodiesel basically depends on three things; the cost of feedstock, the capital cost and the by-product, which is majorly the glycerol (Roick *et al.*, 2021)). The price of feedstock is almost same as the price of refined production cost of biodiesel. This is because the capital cost to produce biodiesel is minimal but, the value of the by-product i.e., glycerol is low. Hence, this novel review revolves around the discussions on the prospects of integrating glycerol into biodiesel composition. This integration process is capable of increasing the production efficiency of biodiesel by 10% (Macario *et al.*, 2011). However, the use of catalyst to propagate the reaction is pertinent towards achieving the desired optimized product

2. BIOFUELS

For West Africa, biofuel is a fascinating source of energy because the economy can be protected or shielded against the skyrocketed crude oil prices in the world market. It is a feasible source of climate-friendly energy (Samuel and Adekomaya, 2012). Biofuels can be divided into two class i.e., the primary and secondary biofuels. The biofuels produced directly from firewood, plants, animal waste, crop residue and so on are called the primary biofuels while the biofuels produced from plants, micro-organisms, etc. are called secondary fuels which can be further subdivided into three generations; the first, second and third generation biofuels (Rodionova *et al.*, 2017). Biofuels would not only replace the global demand of fuel, but they would be able to cover an increasing part of the demand, which can drastically reduce the dependence on fossil fuel, prolonging the life of the existing oil reserves, thus making easy the transition to a predictable world without fossil fuels (Luna *et al.*, 2016)

2.1 Historical background of biodiesel

The term "biodiesel" was first used in 1988 but from history, the use of vegetable oil to replace diesel as fuel could be traced back to 1900. The genesis of what became known as biodiesel stretches back to the discovery of diesel engine by Rudolf Diesel. At the 1900 world's fair in Paris (Exposition Universelle), the first demonstration of diesel engine happened, French Otto's company built a diesel engine which was tested at the event using peanut oil (Songstad *et al.*, 2009). More biodiesel history has been reported by Balasubramanian and Steward (2019) De Oliveira and Coelho (2017) and Rouhany and Montgomery (2019).

2.2 Biodiesel production

Biodiesel comprises of fatty acids methyl esters produced from free fatty acids (FFA), diacylglycerols (DAG), triacylglycerols (TAG) and phospholipids which are commonly gotten from animal fats and vegetable oils (Chen *et al.*, 2012). Several technologies have been used in previous research works to produce biodiesel. Some of the accepted technologies are direct use and blending, micro-emulsion, pyrolysis, transesterification (Estevez *et al.*, 2019) and interesterification (Kusumaningtyas *et al.*, 2016). This section would talk about all the technologies laying more emphasis on interesterification method and using data from already existing publications both analytically and empirically.

2.2.1 Direct use and blending

V. K. Mishra and Goswami (2018) reported that considerations were made in 1980 to use vegetable oil as fuel. Research was conducted using sunflower in South Africa due to the oil embargo. In 1980, Caterpillar Brazil made use of pre-combustion engines mixed with 10 % vegetable oil to maintain maximum power without making any change to the engine. At the end, it was found that it was not practical to totally replace 100 % vegetable oil with diesel fuel but to make use of 80 % diesel fuel and 20 % vegetable oil as blend. The use of this method was not satisfactory for both direct and indirect diesel engine because of the high viscosity, free fatty acid content, acid deposition, gum formation due to polymerization and oxidation during storage. Also, there were problems of lubricating oil thickening and carbon deposits.

2.2.2 Micro-emulsion

Since there are limitations to direct use and blending method. Further research was undertaken and it birthed the micro-emulsion method. Micro-emulsion was basically known as thermodynamically stable, water and surfactant, isotropic liquid mixtures of oil. Using this method solved the problems of viscosity and atomization properties of oil. Nonetheless, if a micro-emulsified diesel is used in a diesel engine there would be problems of incomplete combustion, nozzle failure and carbon deposits (Dze and Buyinda, 2020; Rajalingam *et al.*, 2016).

2.2.3 Pyrolysis

Pyrolysis can be defined as a thermochemical process of converting biomass that is in abundance and cheap into useful materials such as chemicals, fuels, gases in an oxygen deficient environment under inert conditions (Hassan

et al., 2020). Rajalingam *et al.* (2016) stated that pyrolysis is the conversion of hydrocarbons with complex structure into its simplest structure with or without a catalyst. Some of the challenges experienced in pyrolysis are bad quality of the bio-oil produced as a result of high water and oxygen content present in the oil which is not suitable for fueling engines directly. Also, the process of removal of water and oxygen contents gives rise to a bio-oil with high quality i.e. expensive and this might find it difficult to compete with fossil fuels (Zadeh *et al.*, 2020).

2.2.4 Transesterification

Transesterification is splitting of chemicals of heavy molecules to produce simple esters. Fatty acid triglycerides are esters of fatty acids. A very suitable alcohol is reacted with this triglyceride making use of a controlled temperature in the presence of a catalyst at a specified time. When the reaction has taken place, it produces Alkyl esters and glycerin. The alkyl ester is the main product which would possess properties as that of a fuel which is used in diesel engines and the glycerin (glycerol) is the by-product (B. K. Mishra *et al.*, 2012).

There are many published articles on the transesterification of sunflower oil (Yin *et al.*, 2012), waste cooking oil (Maneerung *et al.*, 2016), neem oil (Sathya and Manivannan, 2013), castor oil (Sánchez *et al.*, 2019), waste canola oil (AlSharifi and Znad, 2020) and so on. However, it was stated by Macario *et al.* (2011) that we have so many economic and environmental processes associated with transesterification such as saponification reaction which reduces the efficiency of biodiesel production, amongst other processes. Also, the transesterification of lipids with mono-alcohol in the presence of enzymatic, acidic, alkaline catalysts would produce Fatty Acid Methyl Ester (FAME) and glycerol (Rezania *et al.*, 2019). One of the problems associated with transesterification reaction is the production of glycerol in the process which sometimes results to 10 % by weight of the total biodiesel produced, this glycerol needs to be completely removed. To remove the glycerol, several washes with water needs to be done which then makes the process tedious and expensive (Estevez *et al.*, 2019). Furthermore, the washing phase usually requires high energy cost, and high-water consumption. To solve this problem, a biodiesel production method capable of integrating glycerol in the form of a soluble derivative called inter-esterification is needed (Hurtado *et al.*, 2019).

2.2.5 Interesterification

The most recent replacement for transesterification reaction is the interesterification reaction (Simões *et al.*, 2020). Interesterification reaction as defined bis the reaction that takes place between triglyceride and methyl acetate to produce biodiesel and triacetin. Triacetin is soluble in biodiesel Nunes and Castilhos (2020) and it can also be used as additives in fuel to upgrade pour point, cloud point, cold filter plugging point generally known as cold flow properties, as substrate in confectionary manufacture, pharmaceutical products Akkarawatkhoosith *et al.* (2020) as plasticizer, and gelatinizing agent in explosives, additives in the cosmetics production (Dhawan *et al.*, 2020). The difference between the reaction that occurs in transesterification and interesterification reaction is represented in Figure 2 and also a stepwise interesterification reaction represented in Figure 3 below.

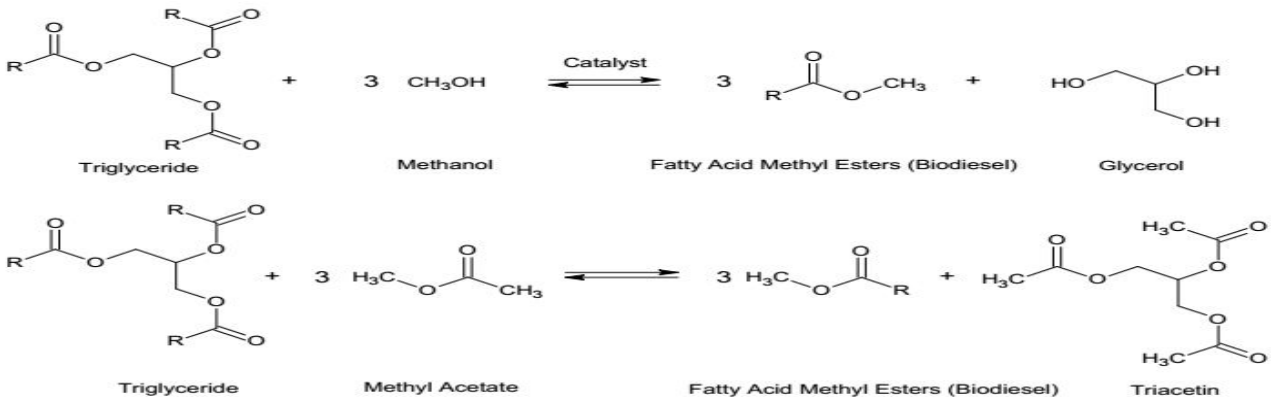


Figure 2. Reaction that occurs in Transesterification(up) and Interesterification (down) (Casas *et al.*, 2021)

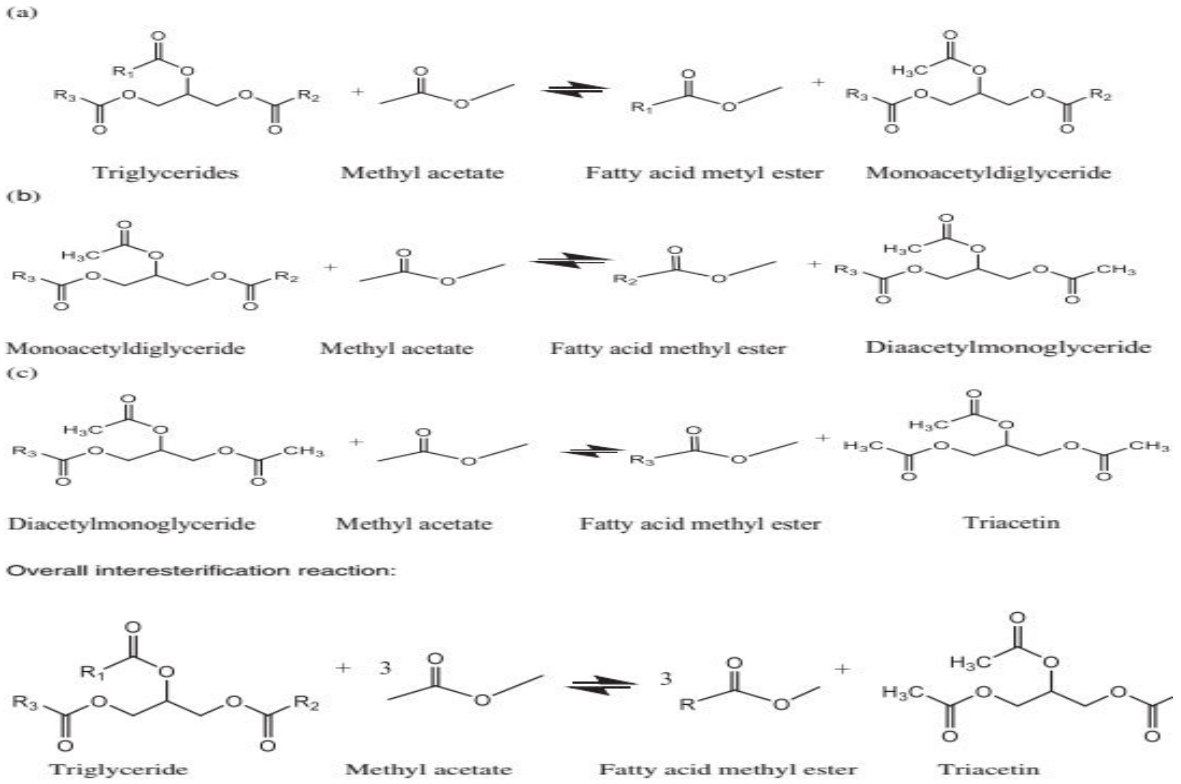


Figure 3. A Stepwise Interesterification Reaction Between Triglyceride And Methyl Acetate (Esan *et al.*, 2021).

Table 1 below shows the comparison between transesterification and interesterification in terms of reaction, products, product value, processes, cost and reaction time.

Table1. Comparison between Transesterification and Interesterification Reaction

Factor	Transesterification	Interesterification	Reference
Reaction	Triglyceride + Methanol	Triglyceride + Methyl acetate	(Maneerung *et al.*, 2016; Nunes and Castilhos, 2020)
Products	FAME + Glycerol	FAME + Triacetin	
Product Value	Glycerol is a by-product and has to be removed to achieve an impurity free biodiesel	Triacetin can be incorporated in the obtained product and the value is higher	(Ansori and Mahfud, 2021; Postaue *et al.*, 2019)
Processes	Separation and washing are required to achieve a good quality biodiesel	No separation is needed	(Ansori and Mahfud, 2021)
Cost	Higher production cost as a result of product separation from by-product (glycerol)	Reduced production expenses	(Abelniece *et al.*, 2020)

Reaction time	Longer reaction time is required	Ester can be obtained within the shortest reaction time	(Ansori and Mahfud, 2021; Postaue *et al.*, 2019)

3. BIODIESEL PRODUCTION BY DIFERENT INTERESTERIFICATION REACTIONS

The interesterification reaction that occurs between triglycerides and methyl acetate (replacing methanol used in transesterification reaction) produces triacetin instead of glycerol (Casas *et al.*, 2021). This section gives an overview of various published articles that have used the interesterification method to produce biodiesel from different feedstocks using different catalyst under different conditions. Macaw oil was reported to have been interesterified with methyl acetate using a heterogeneous catalyst and was carried out in a 500 mL batch reactor (PARR 4575, IL, USA) that was made of stainless steel and attached to a pressure indicator, rotation indicator and temperature controller. Macaw oil and methyl acetate was introduced into the reactor at a molar ratio of 1:30 (oil to methyl acetate ratio) and a 55 w/w of catalyst. After the reactor has been closed, the stirrer was set to about 600 rpm at an approximate pressure of 345 kPa applied using a nitrogen gas. At a temperature of 250 ^{o}C, the reaction time started and after 2 h the reactor was cooled and opened. The catalyst used was separated from the reaction mixture using a centrifuge (Fanem Excelsa Baby 206-R) and a 0.45 mm syringe was used to filter the liquid phase removing the remaining particles. The excess methyl acetate and acetic acid was also removed. The products obtained after proper quantification of its components was corresponding to FAME and triacetin based on the European standard EN 142103. Additionally, the catalyst's regeneration/reusability was analyzed (dos Santos Ribeiro *et al.*, 2017).

It was reported by Esan *et al.* (2021) that biodiesel was produced through the interesterification reaction crambe oil and methyl acetate. The extraction of crambe oil from crambe seed was carried out using pressurized liquid extraction technique (PLE). The PLE of crambe seeds took place in a semi continuous experiment making use of temperature of 140 ^{o}C and a pressure of 10 kPa. A commercial crambe oil was employed as well. The ester yield of the commercial crambe oil to the PLE oil was in the ratio of 53.7% and 66.59% respectively at a temperature of 375 ^{o}C and 35 mins. 5.01% triacetin content was gotten in 35 mins at a temperature of 325 ^{o}C while 3% was the maximum triacetin content gotten from crambe oil at 375 ^{o}C in 15 mins. The crambe oil extracted with PLE method was observed to have higher ester and triacetin yields and this was due to the fact that using the PLE method can extract significant percentage of antioxidant. Also, it was reported that there was no significant change in the ester yield even if the molar ratio of methyl acetate and crambe oil was increased.

The interesterification of soybeans oil and methyl acetate in the presence of calcium oxide catalyst was carried out in a batch reactor of 500 mL that is made of stainless steel (PARR, model 4575), temperature controller, rotation and pressure indicators. The reactor was initially filled with soybeans oil, methyl acetate and catalyst at an initial reaction volume of 300 mL. Closing the reactor, the rate at which it was stirred was set to 600 rpm, the heat was switched on and the reaction time started counting. The samples from the reaction was collected and the catalyst was separated from the liquid phase by centrifugation. To further discard all solid, the liquid phase was filtered using 0.45 μm syringe and the filtrate was introduced into a vacuum evaporator to remove excess methyl acetate at a temperature and time of 80 ^{o}C and 20 mins, respectively. To check and compare the calcination temperature of the catalyst the reaction was carried out with oil to methyl acetate molar ratio of 1:40 with catalyst relative to oil mass of 6% at 275 ^{o}C for 120 mins. A reaction without the use of catalyst was also performed to check the effect of catalyst on interesterification. Statistica software (StatSoftInc) was used to perform Tukey test ($p < 0.05$), to statistically analyze the conversion results. With the procedure used, the most suitable calcination temperature of calcium carbonate was determined for the reaction. From the experiments carried out, at the temperature of 250 ^{o}C and 325 ^{o}C, oil to methyl acetate molar ratio of 1:40 and 1:10, catalyst content of 6 wt% and 10 wt% for 360 mins, the kinetic behavior was checked. The optimum calcination temperature was 800 ^{o}C. The highest FAME content achieved was 62.3 wt% at 325 ^{o}C, 10 wt% of catalyst and methyl acetate to oil ratio of 40:1 (Nunes and Castilhos, 2020). Also, the interesterification reaction of soybean oil to investigate the potential of using heterogenous catalyst was reported by (Simões *et al.*, 2020).

The interesterification of cotton oil with methyl acetate assisted by an ultrasound biodiesel production was reported by (Medeiros *et al.*, 2018). The objective of the paper was to analyze the behavior of cotton oil when used as a feedstock for interesterification reaction. A 150 mL cylindrical reactor was coupled with a reflux condenser which would help prevent the loss of methyl acetate, thermostatic bath, thermocouple and an ultrasound with a probe to help aid the emulsion of solution. The use of response surface methodology (RSM) along with statistical techniques can be applied to study complex processes, being used to evaluate the importance of independent variables. Therefore, a central composite planning was used to optimize experimental conditions of the cotton oil interesterification reaction. The evaluated parameters were the molar ratio of oil/acetate with 1 second cycle. Other variables used in the study are catalyst concentration of (0.1%, 0.4%, 0.7%, 1.0%, 1.3%), ultrasonic concentration in percentage (30, 45, 60, 75, 90), vibration pulse in percentage (50, 60, 70, 80, 90) in which the values were set based on some previous studies. The interesterification of cotton seed oil showed a very promising alternative transesterification and using RSM made it possible to study several variables that has an influence on the process and the model developed was proficient enough in accomplishing optimization. Also, a comparison was done between an experiment which was performed using a mechanical agitation i.e. the conventional way of producing biodiesel and using ultrasound method. A 14% increase in triglyceride was obtained using the ultrasound method

The interesterification of rapeseed oil catalyzed by a low surface area tin (II) oxide heterogeneous catalyst was reported. The catalyst recovery was found to be a serious challenge practically and due to this the catalyst was heterogenized using several supports. But unfortunately, in cases that effectual bonding was achieved there was reduction in the catalyst performance. Since the tin (II) based insoluble heterogenous catalyst proves difficult to separate tin (II) oxide powder was sourced commercially for the interesterification reaction. It was noticed that the commercially sourced homogeneous tin (II) octanoate showed similar performance with heterogenous supported tin (II) oxide without any trace of leaching of the ion even when it possesses low surface. The research aimed to study the effect of selected operative parameters on the performances of tin (II) oxide in the interesterification of rapeseed oil. The experiments were performed in a batch reactor that has a free volume of 20 mL. The research included a magnetic stirrer that was used to provide the mixture with agitation. Also, a type k thermocouple that was used to measure temperature value, a pressure transducer used to measure the pressure value, a valve that was connected to the system which was used to purge argon into the system. A certain amount of the oil and methyl acetate were mixed together to form a homogenous solution and tin (II) oxide (catalyst) was rapidly weighed and loaded into the reactor alongside the mixture and the reactor was then sealed. Low pressure argon was used to wash the free volume of the reactor six times and the reactor was then put into a metal block and it was heated to a desired temperature while stirring started. The experimental temperature was 483 K, therefore, the majority of the experiments were carried out at this temperature. Also, the average heating rate of the reactor is 9 K/min and the operating temperature was achieved in 20 mins. Since the effect of temperature was studied on the performance of catalyst, it was deduced that at any temperature lesser than 443 K the rate of reaction is negligible and following experimental information, the exact transient time was achieved about 5 mins because of this singular reason it is unwise to consider the total heating period and when the temperature reached the desired temperature the reaction time measurement commenced. The FAME and triacetin yield at oil to methyl acetate ratio of 1:20, 1:40, 1:60 are 60% and 30%, 90% and 70%, 90% and 83% respectively. The average rate of generation was then calculated to be 0.7 mol/h.mol_{cat} ,1.0 mol/h.mol_{cat} and 1.0 mol/h.mol_{cat} for each run. It was then concluded that the highest FAME yields were obtained at a temperature between 473 and 503 k, at oil to methyl acetate molar ratio of 1:40 (Interrante *et al.*, 2018).

3.1 Feedstock for biodiesel production by interesterification

Most production of biodiesel uses edible food crops as feedstock i.e., about 95 %, but using edible oil for biodiesel production subjects the world to a greater risk which the supply of food could be affected awhile putting economy at a negative balance. If food and fuel are in competition for resources like lush land availability then the small land that is available for growing food crops would be compromised (Mardhiah *et al.*, 2017). With this fact the use of non-edible oils is greatly encouraged. We can then classify feedstock into non-edible and edible oil, algal oil, waste oils, animal fats and oils from microorganism. Feedstock compositions varies from the way it is refined and the source of the oil. The required composition of oils needed for biodiesel production are triglycerides, diglycerides, monoglycerides, and free fatty acid (FFA). The production of biodiesel from low cost non-edible vegetable oil is an

effective way to handle the issues accompanied with energy crisis and environmental concerns and the overall cost reduction of the system and also from using non-edible feedstock, it is also desirable if the non-edible feedstock is a no or low-cost waste material to have double benefits to the environment; reduce waste pollution and produce environmental friendly fuel (Amini *et al.*, 2017).

Interesterification process using non-edible oil have been reported in some published works like cotton seed oil (Hognon *et al.*, 2014), karanja oil (Kashyap *et al.*, 2019), Macaw oil (dos Santos Ribeiro *et al.*, 2017; Ribeiro *et al.*, 2018), macauba pulp oil (Ciftci *et al.*, 2017), jathropa oil (Campanelli *et al.*, 2010; Niza *et al.*, 2011). Table 2 shows the classification of different feedstocks oil into edible oils, non-edible oils, animal fats/waste oils, solar biodiesel and others.

Table 2. Classification of Various Feedstock Oil (Delvi *et al.*, 2019; Singh *et al.*, 2020).

Types	**Sources**
Edible oils	Safflower, Canola, Coconut, Sunflower, African oil palm, Corn, Rapeseed, Sesame, Rice bran oil, Soybeans, Barley, Sorghum, Groundnut, Wheat.
Non-edible oils	Salmon oil, Cotton seed, Karanja, Rubber seed tree, Jatropha curcas, Pongamia, Cynara, Cumaru, Coffee ground, Passion ssed.
Animal fats/Waste oils	Chicken fat, Fish oil, Pork lard, Beef tallow, Poultry fat, waste cooking oil
Solar biodiesel	Electro biofuels, Synthetic cell, Photobiological solar biodiesel
Others	Switch grass, Terpenes, Latexes, Bacteria, Microalgae, Fungi, Algae, Poplar.

3.2 Catalyst used for biodiesel production by interesterification

Different catalyst can be used in the production of biodiesel ranging from homogenous, heterogenous to enzyme catalysts.

3.2.1 Homogeneous catalysis

The homogenous catalyst can be further subdivided into acidic and basic catalyst (Abbaszaadeh *et al.*, 2012). The homogenous catalyst is a catalyst widely used in the commercial industry (Nnaji, 2020) , a basic homogenous catalysis such as sodium hydroxide can be used in biodiesel production and it produces a high conversion to FAME in approximately 1 h but the FAME produced from this type of catalyst has to undergo further purification to remove excess impurities with water from it. Also, the basic catalyst would dissolve in this phase, making the overall process more expensive and the residence time of the reaction is increased and also there is generation of wastewater that needs to undergo further treatment before it is discarded (Soria-Figueroa *et al.*, 2020). Also, the catalyst cannot be used again I.e. no room for reusesability (Mansir *et al.*, 2017).

3.2.2 Heterogenous catalysis

Heterogenous catalyst can be defined as catalyst that give room for active sites with its reactants constantly during a reaction. (Rizwanul Fattah *et al.*, 2020). Heterogenous catalyst is better than the homogenous catalyst because of the advantages it possesses such as mild reaction conditions, reusability, improved product yield, selectivity, simple workup. Then, we can boldly say it is a better replacement for homogenous catalyst (Maheswari *et al.*, 2020). The usage of heterogenous catalyst lowers the processing cost, there is easy separation of the catalyst, the process of biodiesel production also becomes less corrosive and toxic, less intensive and energy intake is reduced. Also, for

biodiesel production from high acid oil the catalyst can be used without need to do any further pre-treatment for FFA content reduction (Mardhiah *et al.*, 2017).

For the production of biodiesel, we can classify heterogenous catalyst as solid acid or base catalyst (Amini *et al.*, 2017). Metal oxides such as magnesium oxide, calcium oxides and so on are classified as basic heterogenous catalyst. Taking Calcium oxide (CaO) for example, it has so many advantages because of this it is a widely used catalyst. CaO can also be gotten from wastes such as egg shells, fish scales, fish bones and many more (Patil *et al.*, 2021). The shells contained calcium carbonates that would be calcined which then produce a basic calcium oxide which can be used as catalyst in biodiesel production. Also, the addition of metallic element to the surface of the produced catalyst increases the basis characteristics and can produce 9% FAME yield during biodiesel production (Borges and Díaz, 2012). So, the idea of an acid base heterogenous catalyst would yield a better result.

3.2.3 Catalyst Derived from Waste Biomass

Apart from the chemical catalyst we generally use, we also have biocatalyst or bio-based catalyst. These are catalyst produced from biomass and can be grouped under the heterogenous catalyst and they are gaining world recognition (Chua *et al.*, 2020). The heterogenous catalyst produced from waste materials such as industrial waste, agricultural waste, animal parts and their use in organic transformation is emerging as an interesting area in recent research and using this method also help solve waste disposal problem and also produces highly active catalyst (Maheswari *et al.*, 2020). Correspondingly, some published articles talks about the production of catalyst from waste fish scales (Paul *et al.*, 2017), *luffa cylindrica* (Shih et al., 2019), waste sludge (Acosta *et al.*, 2016), tobacco petiole (Zhang *et al.*, 2018) and many more. Table 3 below summarized the advantages and disadvantages of using various types of catalyst.

Table 3. Summary of the Advantages and Disadvantages of Various Catalyst

Catalyst	Advantages	Disadvantages	Reference
Homogeneous acid catalyst	No formation of soap and it has a good catalytic activity using mild conditions. It can be utilized for processes with high FFA content.	The reaction with the use of this catalyst is corrosive, requires high reaction temperature and methanol to oil ratio. The reaction is slow	(Chua *et al.*, 2020; de Lima *et al.*, 2016)
Homogeneous base catalyst	It has the tendency to produce high biodiesel yield. The reaction can be carried out using mild reaction temperature, atmospheric pressure and minimal methanol to oil ratio. It is non-corrosive and has high activity site	It is not good with feedstock that has high free fatty acid content. The neutralization reaction is cost intensive and requires more energy.	(Clohessy and Kwapinski, 2020; de Lima *et al.*, 2016)
Heterogenous acid catalyst	It can produce biodiesel under mild conditions. It has environmental benefits and produces an ASTM standard biodiesel	it possesses weak catalytic activity. It takes longer reaction time to produce the needed biodiesel.	(Mardhiah *et al.*, 2017)
Heterogenous base catalyst	The catalyst can be reused i.e. it possesses reusability properties. It reduces effluent generation.	It is expensive	(de Lima *et al.*, 2016)
Acid-base bio-based	It helps improve		(Aderibigbe *et al.*, 2021)

Catalyst	environmental stability. It gives room for the production of low-cost biodiesel.

4. FUTURE OUTLOOK

Much work has not been done on interesterification reaction for biodiesel production and has not been carried out on some oils such as catfish oil, *Dioclea Reflexa* (Agbaarin) oil, amongst others. The interesterification reaction of *Dioclea Reflexa* oil with methyl acetate using a biobased heterogenous catalyst of fish scale and *luffa cylindrica* in the production of biodiesel would be feasible research investigation using some methodologies from previous published works. It would also produce a glycerol free oil which is the solution to one of the problems productions of biodiesel by transesterification reaction created.

Biochemical/Biotechnology research group, Chemical Engineering Department, University of Ilorin, Ilorin, Nigeria is currently undertaking some research investigations in this area. Globally, there is a common interest of finding new and alternative fuel against fossil fuels due to the oil reserve reduction and over consumption of hydrocarbons which has been resulting in the accumulation of greenhouse gases in the atmosphere which invariably causes global warming and researchers all over the world are putting lots of efforts to the search towards finding a sustainable and renewable energy that could help reduce carbon emission on earth. Adopting the methodology of dos Santos Ribeiro *et al.* (2017), *Dioclea Reflexa* oil is currently been interesterified with methyl acetate using a bio-based heterogenous catalyst which is carried out in a magnetic stirrer connected to a temperature controller, agitation controller and an automatic stop watch at a reaction time of 1 h, temperature of 75 ^{o}C, catalyst loading of 5 w% (with respect to oil),Oil to Methyl acetate ratio of 1:30, pressure of 103 kPa (15 Psi) and constant agitation of 600 rpm . The bio-based heterogenous catalyst was obtained from wastefish scale and *Luffa cylindrica* (Luffa sponge) which was calcined and sulfonated respectively to obtain an acid base catalyst. At the preliminary stage of the research different catalyst combination was used to get the catalyst with the best combination. The best catalyst combination was found out to comprise of 40% calcined fish scale and 60% sulfonated *Luffa cylindrica* which produced a biodiesel and triacetin yield of 80.01%. This catalyst combination and the above stated conditions is being currently optimized to get the optimal condition which would further be used for the kinetics studies.

5. CONCLUSION

The review has substantially elucidated the use of interesterification reaction method for the production of biodiesel. Transesterification reaction has been widely used for biodiesel production compared to other methods of production. Despite that, the production of glycerol alongside biodiesel has increased its cost of production and also reduced the yield of the biodiesel production. Therefore, this review has shown that interesterification reaction methods could eradicate the production of glycerol in biodiesel production which would in turn reduce its cost of production, reaction time, amongst other pertinent variables and enhance biodiesel production. Also, with the aid of bio-based heterogeneous catalyst in interesterification reaction, it is worthy to state that the overall production cost of biodiesel could significantly decrease as the yield increases. However, there is a need that further research investigations be carried out in order to optimize the process operating conditions as well as the potential economics for commercialization purposes.

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