Review Article

BIODIESEL OIL EXTRACTION TECHNOLOGIES: STATE OF THE ART REVIEW

ABSTRACT: There is acritical need for energy diversification due to over depended on fossil fuel and its daunting challenges. These problems associated with fossil fuels have driven the search for alternative energy sources of which biodiesel is oneof the potential alternatives. Biodiesel is renewable, non-toxic, environmental-friendly and an economically feasible choice to tackle the depleting fossil fuels and its negative environmental impact. It can be produced from seeds oil plant, vegetable oils, animal fats, waste oils and algae. Here areseveral methods for the production of the biodiesel oil which includes; mechanical, chemical/solvent and enzymatic oil extraction methods etc.Report from the open literatures revealed that, all the extraction methods have its own merits and demerits but in all, oil expeller machine which is based on mechanical means of extracting oil from the common wastage seeds oil plant prove to be efficient especially for large scale extraction.Thus, for efficient oil extraction from wastage seeds oil plant,oil expeller machine is appropriate. This research seeks to discuss an improve ways of maximum oil yield with an expeller machine from the wastage seeds oil plant commonly available in our environment.

Key Words:biodiesel production process, oil extraction methods, seeds oil, screw press oil expeller

1. INTRODUCTION

Generally, energy is an essential element of industrialization and socio-economic development of any country. The petroleum reserves concentrated in certain regions of the world are fast depleting day by day and at the current usage rate, these sources will soon be exhausted. Recently, due to the shortage of fossil fuels throughout the world, crude oil price increase and contribution of these fuels in polluting the environment, biodiesel is attracting increasing attention as a potential alternative and renewable fuel for diesel engines worldwide [1].

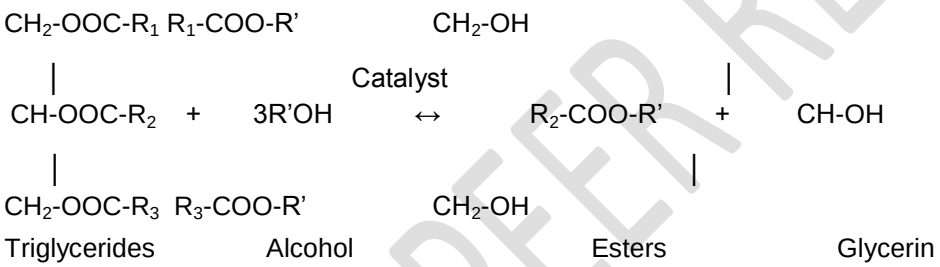
The choice of biodiesel as an alternative fuel has been receiving a lot of attention throughout the world due to its renewable, biodegradable, non-toxic as well as its environmentally friendly nature. It produces lower pollutant emissions, possesses a high flash point, better qualities of lubrication and high cetane number with very close physical and chemical characteristics to those of conventional diesel fuel. This allows its use either as pure biodiesel (B100) or mixed with petroleum-based diesel fuel at a ratio of between 5– 20%, (B5–B20) with very few technical adjustments or no modifications. Burning of biodiesel fuel does not contribute to a rise in the level of carbon dioxide in the atmosphere and does not pose a danger to the ozone layer [2].

The biodiesel produced from renewable resources could help to minimize the fossil fuel burning and CO_2 production. Biofuels and bio products produced from plant biomass mitigate global warming. This is as a result of the CO_2 released in burning being equal to the CO_2 tied up by the plant during photosynthesis and does not increase the net CO_2 in the atmosphere [3]. Therefore, an increase in biodiesel production by trans-esterification may lead to an excess of glycerol production as a by-product. The glycerol is mostly used in medical, pharmaceutical and personal care applications [4].

Over the years, several review articles have been published by many researchers onthe extraction of oil for biodiesel production [5]. However, in this research we shall discuss efficient ways of maximum oil yield with an expeller machine from the oil seeds. The review paper seeks to present; first, an overview of biodiesel focusing on theproduction methods of the biodiesel and various ways of oil extraction for biodiesel production. It goes further to compare oil extraction process of automatic screw press oil expeller and the manual oil expeller process. The problem associated with eachoil extraction processes wereidentified and their respective appropriate remedies were proffered in the course of this review.

1.1 Overview and History of the Use of Biodiesel Fuels

Biodiesel according to [6] is defined as the mono-alkyl ester of long chain fatty acids derived from renewable lipid feedstock such as vegetable oils or animal fats. It is a non-toxic, biodegradable and renewable fuel that can be produced from a range of organic feedstock including fresh or waste vegetable oils, animal fats, and oilseed plants [7]. The biodiesel formation procedure according to [8,9] is given as follows:



Transesterification reaction for biodiesel production [8,9]

The use of fuels of biological origin like vegetable oil dates far back to the days of Rudolf Diesel in 1896 who's first used peanut oil in Internal Combustion Engine. Henry Ford, one of the pioneer automobile manufacturers, designed his first car model to run on ethanol is another biologically derived fuel. These visionary inventors expected their new inventions would continue to run on fuels derived from plants, but petroleum was preferred because it was more economical and available. However, the oil crisis of the 1970s together with environmental factor renewed interest in the use of biofuels [10]. Beginning in 1980s, there was considerable discussion regarding use of vegetable oil as a fuel [11]. Bartholomew addressed the concept of using food crop for fuel, indicating that petroleum should be the "alternative" fuel rather than vegetable oil and alcohol being the alternatives and some form of renewable energy must begin to take the place of the non-renewable resources [12]. Vegetable oil can be obtained from different plant; it

can be edible oil or non-edible oil. Non-edible plant is considered in order to prevent the already rising cost of edible oil as production of biodiesel from edible seeds would make them more expensive as it is used both as food. These plants are considered due to their presence in many parts of the world, beingat low costin some countries [13]. The summary of biodiesel production from non-edible feedstock is presented in Table 1.

Table 1**.** Non-ediblefeedstock for biodiesel synthesis.

Feedstock	Catalyst	Temperature (◦C)	Time (min)	Oil to Alcohol Ratio	Yield (%)	Reference
Mahua oil	KOH	-	-	6:1	98	[14]
Mahua oil	KOH	60	30	4:1	-	[15]
Karanja oil	NaOH	50	70	-	84	[16]
Jatropha oil	KOH	55	60	9:1	90–95	[7]
Jatropha oil	H_2SO_4	60	120	9:1	80	[7]
Canola oil	KOH	50	60	9:1	90–95	[7]
Rubberseed oil	NaOH	-	-	9:1	80	[17]
Honne oil	KOH	45–65	30–150	4:1	89	[18]

2.0 Methods of Biodiesel Production Process

Significantefforts have been made by many researchers to develop the methods of biodiesel production and are still in study to increase the product yields, improve fuel properties and reduce the cost of production [19, 20, 21]. Straight vegetable oils used in engine lead to various problems like fuel filter clogging, poor atomization and incomplete combustion because of high viscosity, high density and poor non-volatility. Transformation of vegetable oils into biodiesel can be realized using four methods: Heating/pyrolysis, dilution/blending, micro-emulsion, and transesterification. Among all these techniques, the transesterification is an extensive, convenient and the most promising method for the reduction of viscosity, density and other properties of the straight vegetable oils. However, this adds extra cost of processing because of the transesterification reaction involving chemical and process heat inputs [22]

2.1 Pyrolysis

The pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. The liquid fractions of the thermally decomposed vegetable oils are likely to approach diesel fuels. The pyrolyzate has a lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values. The cetane number of the pyrolyzate is lower. The pyrolyzed vegetable oils contain acceptable amounts of sulfur, water and sediments and give acceptable copper corrosion values but unacceptable ash, carbon residual and pour point [23]. Depending on the operating conditions, the pyrolysis process can be divided into three subclasses: conventional pyrolysis (550 -900 K), fast pyrolysis (850 – 1250 K) and flash pyrolysis (1050 -1300) [24,25,26]. The constraint of high energy for pyrolysis and other limitations compel the researchers to pursue for more suitable methods for the cost-effective production of biodiesel.

2.2 Micro-emulsification

The formation of micro emulsion is one of the potential solutions for solving the problem of vegetable oil viscosity and some other atomization properties as reported in the studies of [27,28]. Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersion. The droplet diameters in micro-emulsions range from 100 to 1000nm. A Micro- emulsion can be made of vegetable oils with an ester and dispersant (co solvent), or of vegetable oils, and alcohol and a surfactant and a cetane improved with or without diesel fuels. All micro-emulsions with butanol, hexanol and octanol met the maximum viscosity requirement for diesel fuel. The 2-octanol was found to be an effective amphiphile in the micellar solubilization of methanol in triolein and soybean oil [29,30, 31, 32]. However, findings from the studies of [33, 34]. Revealed that if micro-emulsified diesel is used in diesel engine, there is usual occurrence of some problems such as incomplete combustion, carbon deposit and nozzle failure.

2.3 Dilution

The dilution of vegetable oils can be accomplished with such material as diesel fuels, solvent or ethanol. Dilution results in the reduction of viscosity and density of vegetable oils. The addition of 4% ethanol to diesel fuel increases the brake thermal efficiency, brake torque and brake power, while decreasing the brake specific fuel consumption. Since the boiling point of ethanol is less than that of diesel fuel, it could assist the development of the combustion process through an unburned blend spray [35]. From above highlight, literature reveals that some researchers accomplished the successful blending of vegetable oils with diesel. According to [36], the use of neat vegetable oil or oil blended with diesel as fuel during World

War II in Europe. Cater Piller Brazil Company in 1980 successfully maintained the total power using 10 % vegetable oil blended with diesel in the pre-combustion chamber without any modification of the engine. The blending of vegetable oil with diesel in the ratio of 20:80 was reported with successful results. It was also reported that a mixture of 5 % diesel with 95 % of used cooking oil was explored successfully in the diesel engine in 1982 [37]. Report from the study of [38]showed that the use of 50 % blended Jatropha curcas oil(JCO) operate the engine without any major operational difficulties. After several attempts by researchers, in August 1982, a discussion regarding the development of methodology and limitation on the use of vegetable oil as fuel was undertaken in the conference of Fargo, North Dakota as reviewed by [34,39]. Dilution or blending is found to be comfortable only for liquid nature-portability and heat content (approximately 80 %) of diesel fuels. Blending is not suitable for oils with higher viscosity, high unsaturated carbon chain, and low volatility. There are several associated issues with the utilization of 100 % vegetable oil in the engine such as coking and trumpet formation, carbon deposition, oil ring sticking and thickening as well as gelling of lubricating oil for compatible use of vegetable oil as fuel [37,40]. A comprehensive technology for overcoming these challenges in an efficient way of biodiesel production is the theme of emphasis for consideration as an alternative fuel for the future.

2.4 Transesterification

Transesterification is one of the most convenient methods for biodiesel production that involves the transformation of vegetable oil or any triacylglycerol with alcohol in presence of a catalyst forming alkyl esters (biodiesel) and glycerol [41].Several researchers have investigated the methods of biodiesel production and reported that the most preferable one is transesterification [42]. Biodiesel produced through this method has the fuel property within the limits of EN 14214 and ASTM D6751 standards. This method showed fuel properties with higher cetane numbers, lower emissions, and higher combustion efficiency. However, the criterion of excess methanol is the major demerit of transesterification [40].The search for suitable conditions for trans-esterification as well as efficient cost-effective and environmentally friendly catalysts is a majorconcern for industrial-scale production of biodiesel.

Transesterification method can be carried out by two ways according to literature [43].

(a) Catalytic transesterification.

(b) Supercritical methanol transesterification.

2.4.1 Catalytic transesterification

The “Catalytic Transesterification” process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of some catalyst to form esters and glycerol. A triglyceride has a glycerin molecule as its base with three long chain fatty acids attached. The characteristics of the oil/fat are determined by the nature of the fatty acids attached to the glycerin. The nature of the fatty acids can in turn affect the characteristics of the biodiesel [22,44,45,46,47].

2.4.2 Super critical transesterification

The simple transesterification processes discussed above are confronted with two problems, i.e. the processes are relatively time consuming and needs separations of the catalyst and saponified impurities from the biodiesel. The first problem is due to the phase separations of the vegetable oil/ alcohol mixture, which may be dealt with by vigorous stirring. These problems are not faced in the supercritical method of transesterification. This is perhaps due to the fact that the tendency of two-phase formation of vegetable oil/alcohol mixture is not encountered and a single phase is found due to decrease in the dielectric constant of alcohol in the supercritical state (at 340°C and 43 MPa). As a result, the reaction was found to be complete in a very short time within 2-4 minutes. Furthermore, since no catalyst is used, the purification of biodiesel is much easier, trouble free and environment friendly [48, 49, 50, 51, 52].

2.5Effect of Reaction Parameters on Transesterification

The yield of biodiesel in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil [10].

The effect of reaction parameters on transesterification are discussed as follows:

2.5.1 Effect of free fatty acid (FFA) and moisturecontent (MC)

FFAs and water always produce negative effects, since the presence of FFAs and water causes soap formation, consumes catalyst and reduces catalyst effectiveness all of which result in a low conversion. In catalyst methods, the presence of water has negative effects in the yields of methyl esters. In acid catalyzed transesterification fatty acids can be formed. These free fatty acids react with the alkaline

catalyst to produce soaps that inhibit the separation of the biodiesel, glycerin and wash water. Findings from the studies of [53, 54,55,] reported that to carry the base catalyzed reaction to completion in producing quality biodiesel, a free fatty acid value lower than 2% is needed. According to [56] water content in waste cooking oil will accelerate the hydrolysis reaction and simultaneously reduce the amount of ester formation. To overcome this problem, supercritical methanol method was proposed. It may be noted that water has less influence in supercritical methanol method [53]. Therefore, water content should not always exceed 0.5% to obtain 90% yield of biodiesel and it is more critical for an acid-catalyzed reaction than base catalyzed reaction [57].

2.5.2 The effect of molarratio and alcohol type

The percentage of biodiesel yield increases with increase in alcohol and oil molar ratio giving as optimal yield of 85% at 6.1, molar ratio above 6.1, does not necessarily result to an increase in biodiesel yield but could rather increase the cost of production and hence the pump price of biodiesel. Although the stoichiometric molar ratio of methanol to triglyceride for transesterification is 3.1, higher molar ratios are used to enhance the solubility and to increase the contact between the triglyceride and alcohol molecules. Higher molar ratios result in greater ester conversion in a short time. Another important variable affecting the yield of methyl ester is the type of alcohol to triglyceride. In general, short chain alcohol such as methanol, ethanol, propanol and butanol can be used in the transesterification reaction to obtain high methyl ester yield methanol gives the best yield as compared to butanol and ethanol because methanol has a simple chemical structure [58, 59,60].Figure 1 shows the effect of oil to alcohol ratio on biodiesel yield.

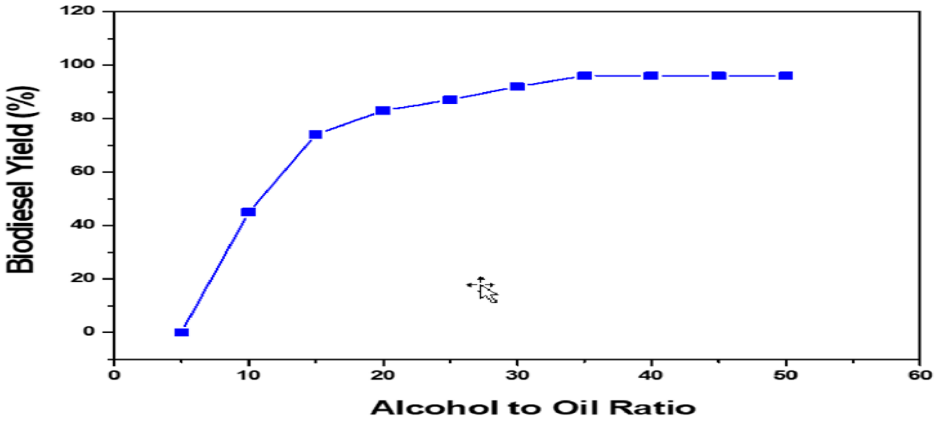


Figure 1. Oil to alcohol ratio effect on biodiesel yield, Source [53].

Figure 1 shows the effect of oil to alcohol ratio on supercritical transesterification using methanol and carbon dioxide as solvent and co-solvent, respectively. The temperature for this study was maintained at 280 ◦C. However, this rising trend in biodiesel yield can be observed up to approximately 23 min. Because a higher amount of alcohol causes contamination in the product and increases the cost of the overall process, decreasing the overall biodiesel yield as it was reported[53].

2.5.3 The effect of catalyst

Alkali catalyzed transesterification is much faster than acid catalyzed transesterification and hence it's commercial success. Transmethylation process occurs 4000 times faster in case of an alkaline catalyst than those catalyzed by the same amount of acidic catalyst because alkaline catalysts are less corrosive than acid catalysts for industrial equipment. Catalyst concentration also effects biodiesel yield. However, increasing catalyst concentration above an optimal value is not profitable because it results in increased residues on the biodiesel and thus, increasing cost of washing [61,62]. Also, it was reported in literature that excessive usage of catalyst is found to cause emulsions reflecting on higher viscosity causing the biodiesel recovery difficult [63]. Similarly,[64] in their work established that when KOH conversion was enhanced from 2 to 12%, biodiesel yield increased from 20 to 95%. Based on the research carried out by [65] in their study also observedthe highest yield of jatropha biodiesel with 1 wt.% catalyst. The concentration of the catalyst effect on biodiesel yield is shown in Figure 2. It shows the effect of amount of NaOH, KOH, and CaO used. It is observed that biodiesel yield initially increases with the increase of concentration of alkali catalysts (NaOH and KOH), then decreases after reaching a certain peak value.

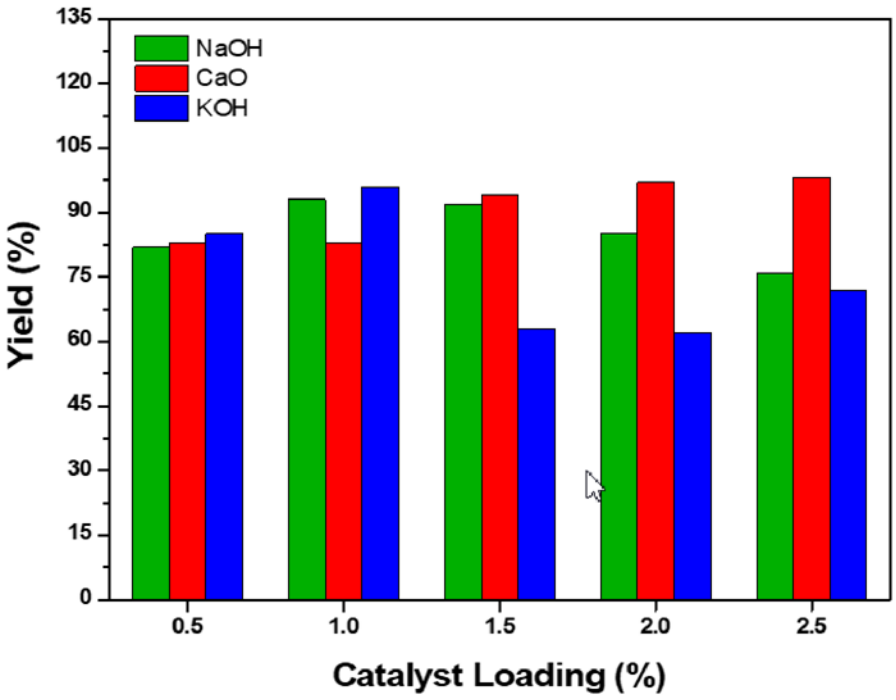


Figure 2. Influence of catalyst concentration on biodiesel yield [66,67].

2.5.4 The effect of reaction temperature and time

Transesterification can occur at different temperatures depending on the type of oil. The reaction temperature has a significant effect on rate of reaction if done at room temperature. Given enough time it can proceed to completion, whereas an increase in temperature increases the rate of reaction. Generally, the reaction is conducted at atmospheric pressure near the boiling point of methanol (60 to 70^{o}C). Further increase in temperature affects the conversion process negatively. Studies from previous work of [68, 69, 70] have shown that by giving enough time at ambient temperatures the reaction goes satisfactorily using alkaline catalyst and at low temperature, conversion is unaffected but biodiesel recovery is significantly affected.According to investigation carried by [71], it was also observed that temperature increases the rate of reaction up to an optimal level.

Figure 3 extracted from the previous research of [53] shows the influence of temperature on FAMEs composition in the presence of co-solvent (CO2). The increase in temperature increased the energy of reacting molecules. Secondly, the transesterification reaction is endothermic in nature. Therefore, transesterification is favorable at elevated temperatures. This graph also concludes that the optimum

range of transesterification reaction is 250 to 350 ◦C. Further increase in temperature will lead to the thermal decomposition of the product.

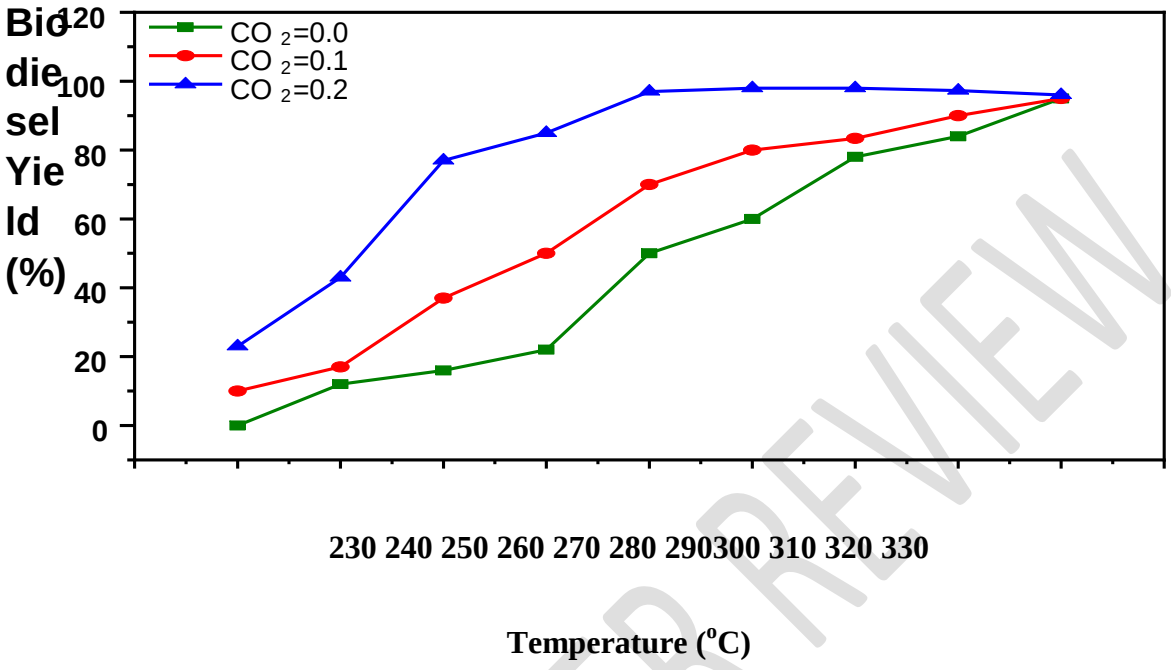


Figure 3.CO_2 and temperature effect on biodiesel yield [53].

As shown in Figure 4, there is a rising trend in the concentration of fatty acid methyl ester when the reaction is carried out for a long time period and the rate of reaction is relatively slower at the start of the reaction due to a little agitation and dispersion of solvent and oil. The reaction is occurring at the outer surface of oil and triglycerides only.

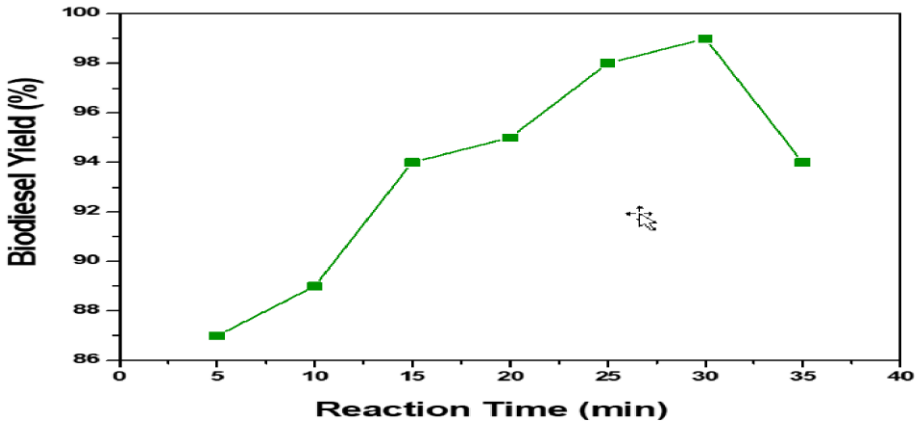


Figure 4.Influence of reaction time on biodiesel production [71, 72].

From figure 4, the graph shows that elevated reaction time results in the increase of fatty acid alkyl esters concentration in the product. However, this effect can be observed up to 30 min of reaction time. After 30 min, the yield of reaction became independent of reaction time. This as a result of equilibrium was already achieved at 30 min as reported by [73, 74]. It is recommended to perform supercritical transesterification between 6 to 12 min reaction time and conventional transesterification between 30 to 60 min.

According to literatures report, table 2shows the effect of various parameters on biodiesel synthesis.

Table 2.Effect of different parameters on biodiesel synthesis.

Feedstock	Molar Ratio	Time (min)	Catalyst Loading	Temperature (°C)	Agitation Speed (rpm)	Type of Transesterification	Yield (%)	Reference
Palm oil	6:1 (methanol)	60	1% KOH	60	600	Homogeneous base	88	[75]
	6:1	60	1% NaOH	60	600		93	
	9:1	480	8.5% KOH	65–75	-		96.2	[75] [76]
	10:1	-	0.4% KOH	70–110	-		98	[77]
Jatropha oil	10:1	480	9% KOH	60–80	-	Homogeneous base	96.8	[64]
Waste frying Oil	4.83:1 to 9.65:1	300–480	1–4%	50–65	-		87.3	[78]
Soybean oil	12:1	60	6% CaFeAl	60	270	Heterogeneous transesterification	90	[79]
Jatropha oil	3:7	180	1% H_2SO_4	65	400	Homogeneous acid and base	21.2	[80]
	3:7		1% NaOH	50	400		90.2	
Waste cooking oil	3:7	180	1% H_2SO_4	65	400	Homogeneous acid and base	21.2	[81]
	3:7	180	1% NaOH	50	400		90.6	
Canola oil	3:1 to 8:1	25–75	0.2–1.2% KOH	30–70	100–600	Homogeneous base	-	[82]
Mustard oil	-	30	KOH	40–60	450	Homogeneous base	-	[83]
Sunflower Oil	6:1	90–330	1% CaO	23–60	-	Heterogeneous	91	[84]
	6:1							
	12:1	-	0.06–0.34	23–60	400	Homogeneous base	99	[85]
	24:1							
Peanut oil	30:1	30–360	-	250–310	500	Supercritical transesterification	>90	[86]
Waste lard	6:1	20	4–6 wt.% enzyme	50	-	Ultrasound assisted transesterification	96.8	[87]
Silybum Marianum seed oil	6:1	75	4–6% sulfonated solid acid catalyst	60	600	Carbon acid esterification and homogeneous base transesterification	96.9	[88]

Canola oil	6:1	-	0.5% KOH	45	-	Homogeneous base	95	[89]
Used frying Oil	6.03:1	120	0.55% KOH	60–100	-	Homogeneous base	-	[90]
Rapeseed oil	3.5:1 to 42:1	120	-	200–500	-	Supercritical transesterification	95	[91]
Neem oil	10:1	60	10% CZO	55	-	Heterogeneous transesterification	97.1	[92]

3.0 Biodiesel Fuel Specification

The latest specification for B100 biodiesel is the ASTM D6751-078 or D6751, ASTM (American Society of Testing and Materials) is a standard group comprised of engine and fuel injection manufacturers, fuel producers and users whose standards are recognized in the United States of America by government entities including state agencies for ensuring fuel quality. Biodiesel fuels that do not meet those specifications are declared unfit for use in I.C.E (Internal Combustion Engine). In pursuant of quality also, Nigeria through the Nigerian biofuel policy and incentives has by legislation instituted standard organization of Nigeria (SON) and department of petroleum resources (DPR) which eventually adopted the ASTM standard. For now, biodiesel blend B20 has been approved for use commercially in ICEs, though this fuel is not available in open market. Table 3 shows that biodiesel has similar physico-chemical properties to conventional diesel fuel and does not necessarily require engine modification for diesel engines.

When biodiesel that merits its specification is properly blended into diesel fuel which meets its specification, and is handled according to proper fuel management techniques, the resulting fuel is a high quality. Premium diesel fuel which has been shown to perform well in virtually any unmodified diesel engine. However, the use of any fuel that does not meet its quality specifications could cause performance problem or equipment damage and this includes biodiesel [93].

3.1 ASTM and EN Biodiesel Specification

Table 3 shows comparative analysis of physico-chemical properties of some biodiesel standard used in gas turbine in Europe and America continent. The values obtained from various fuel properties varies largely due to climatic condition of the particular country.

Table 3 Specification of biodiesel standard [1]

Properties	**ASTM D6751**	**EN 14214**
Density (15 ^{o}C, g/cm^{3})	NS	0.86–0.90
Kinematic viscosity (40 ^{o}C, mm^{2}/s)	1.9 – 6.0	3.5 – 5.0
Cetane number	47 min	51 min
Flash point (^{o}C)	130 min	120 min
Sodium (ppm) Potassium (ppm)	Na & K combined 5 (max)	Na & K combined 5 (max)
Acid value (mg of KOH/g)	0.50 max	0.50 max
Iodine value (g I_2 /100 g)	NS	120 (max)
Total sulfur (ppm)	15 max	10 max
NS: not specified. Max: maximum. Min: minimum.		

4.0 Oil Extraction from Seeds

One of the essential aspects in the production of biodiesel is oil extraction, and different methods

and techniques of oil extraction are in place as reported in the studies of [94,95,96,97].These includes: mechanical, chemical/solvent,enzymatic oil extraction methods, microwave-assisted extraction, supercritical fluid extraction and accelerated solvent extraction. For the purpose of this article, discussion will be centered on the mechanical method where comparison is made between the manual oil extraction machine process and automatic oil extraction process are x-rayed. The improvement on the machine will also be discussedin bridging the gap in term of oil production process.

4.1 Feedstock preparation

Oil extraction begins with seed preparation. The preparation of seeds involves removal of outer layers of the fruit to expose the kernels or seeds, and its dry to reduce moisture content [98]. The seeds are separated from fruits, and the fruits that do not dehisce are cracked open manually. The Seeds are majorly dried in the sun or in the oven during the raining season to the appropriate moisture content. The kernels or seeds have to be prepared in such a way that they contain optimum moisture content for high

oil extraction. The separated dried seeds or kernels are sieved, cleaned and stored at room temperature in readiness for extraction of its oil content, as it reported in the literatures[99, 100, 101].

4.3 Oil Extraction Methods

The explanation of the common oil extraction methodsis described in this section. These methodsinclude: chemical/solvent, enzymatic, microwave-assisted, supercritical fluid extraction accelerated solvent extraction and mechanical

4.3.1chemical/solvent

Solvent extraction is the process in which the oil is removed from a solid by means of a liquid solvent, it is also known as leaching as reported in the studies [99,102]. Several factors affect the chemical leaching process such as the size of a particle, type of the liquid used, temperature, and mixing speed of the system. Small particle size is used to allow the interfacial area between the feedstock and the solvent. The viscosity of the solvent must be lower to promote free circulation. Temperature is also the significant parameter influencing the rate of extraction, the solubility of the oil rises with temperature increase. Rate of mixing is also one of the factors affecting the process, since it promotes the rate of diffusion, consequently enhancing the material transfer from the surface of the particle as reported in[103]. The solvent extraction method offers a number ofmerit and demerit. As pointed out by [104] the solvent extraction process is a very effective method, with high yield and consistent performance, though cost of production was relatively higher than mechanical press methods due to high cost of solvent.

4.3.2 EnzymaticExtraction

In this method, enzymes are used to extract oil from crushed seeds [105]. Aqueous enzymatic oil extraction can also be used in combination with other methods of oil extraction.Although the process is proving its potential, the application of this technology is still facing limitations such as higher cost of enzymes, higher incubation time, and the need for de-emulsification during downstream processing [106,107]. The implementation of techniques such as affinity chromatography and perfusion

chromatography make the downstream processing easier, while the immobilization of enzymes minimizes the enzyme losses and overall cost [108]. However, enzymes immobilization causes the reduction of reaction rates due to steric hindrance. Moreover,

the application of solvents such as n-hexane increases the production of wastewater and release of volatile organic matter, besides n-hexane flammability and toxicity [109]. This requires the use of a substitute extraction process such as an aqueous enzymatic oil system along with ultra-sonication pre-treatment [106, 110].The main advantages of using enzymatic oil extraction are that it is environmental-friendly and does not produce volatile organic compounds. However, the long process time is the main disadvantage associated with this technique asreported by [105].

4.3.3 Microwave-Assisted

Microwave-assisted extraction also called microwave extraction according to [111] is a new extractionmethod, which combines microwave and traditional solvent extraction. Microwave-assisted extraction has beenrecognized as a technique with several advantages over other extraction processes, such as reduction of costs, shorter time, less solvent, higher extraction rate, better products with lower cost, reduce energy consumption and CO_2 emissions [112]. These merits have been attested by many researchers who have successfully used microwave-assisted extraction in their work as it can be read from literatures [113, 114,115,116].However, as reported by [117], one disadvantage of microwave-assisted extraction is that it may not always be suitable for plants, since high microwave energy disrupts plant structure.

4.3.4 Supercritical fluid extraction

Supercritical fluid extraction method is used to avoid the use of organic solvents and to increase the speed of extraction. Supercritical fluid extraction using CO_2 has numerous advantages over the solvent extraction according to the literature [118]. It uses CO_2 as a solvent which is a nontoxic, inexpensive, nonflammable, and nonpolluting supercritical fluid solvent for the extraction of natural products, and also almost 100% oil can be extracted by this method [119].However, the main limitation of theSupercritical fluid extraction is the high cost at production scale. This is not only due to the use of high-pressure

equipment but also because of the raw material that should be freeze dried to reduce its moisture to values below 20%, as high-water concentration in fluid phase negatively affects the oil yield [120, 121].

4.3.5 Accelerated solvent extraction

Accelerated solvent extraction is also referred to as pressurized solvent extraction is another modern oil extraction method which uses organic or aqueous solvents at elevated temperatures and pressures [94]. It has been observed that high temperature accelerates the extraction rate, while elevated pressure prevents boiling at temperatures above the normal boiling point of the solvent.

Inaccelerated solvent extraction, time as well as solvent consumption is significantly reduced compared to the other solvent extraction methods [122]. And this can be witness in the extraction of different materials including wheat germ and flaxseed hulls according to literature [123].

Accelerated solvent extraction, has its own drawback, these includes; very high initial cost,high preparation required,special equipment and skill required, potential for solvent contamination and only kernel can be processed as reported in [124,125]

4.4 Mechanical screw press oil extraction

Mechanical screw press oil extraction is the most conventional method for large scale oil extraction. This process as reported in the study of [126] can be achieved using manual press or an engine driven screw press

4.4.1 Manual Oil Expeller

Manual oil expeller involves oil extraction through manual means in which human energy is expended as it compares to the automatic oil expeller process that squeezes oil out of the seeds plant with aid of oil expeller. In the manual expeller, the products (seeds, nuts and fruits) are crushed into powder form either through pounding of the feedstock with the help of mortal and pistol or by grinding machine, thereafter water is sprinkling on it. The paste is preheated in oven for the oil to flow from the cake. The preheated paste is put into sleeve bag and place on hydraulic press, for pressing to enhanced extraction of oil from the cake. This oil extraction process is found to be a very tedious means

4.4.2 Automatic Screw Press Oil Expeller

The screw press oil expeller is more efficient than all other methods of oil extraction. The seeds are fed through the hopper crushed and transported by a rotating screw in a press barrel. Continuous transport of feedstock by the screw shaft causes the pressure to increase to a level needed, which increases the friction inside the screw press and generates heat which lowers viscosity of the oil in the crushed seeds thereby increasing the oil flow rate. The oil and cake are usually collected at the oil outlet and press cake exit.As pointed out in the studies of [99, 127], mechanical extraction (automatic screw press oil expeller) have several advantages over the other extraction methods most especially in the aspect of low operation cost, and producing high quality light coloured oil with low concentration of free fatty acids (FFAs) as reported in [128]. Similarly, report from the study of [129] revealed that about 68–80% of oil can extract from seed oils through the driven screw press. However, as observed in the [130] it has a relatively inadequate oil yield compared to solvent extraction and therefore, some portion of oil left in the cake after extraction. Additionally, it has been reported in the previous study of [131] that chemical/solvent yield higher oil than mechanical method but in expense of cost and environmental issue due to the use of toxic and flammable solvents which limit this method for use. The view of improving this method of oil extraction optimally considering its aforementioned merit over other methods of oil extraction as summarized and presented in Table 4 is needful to be researched on and tackled on to aids its better application in biodiesel production industry.

Table 4. Merits and demerits of oil extraction methods [94,98, 131].

Method of Oil Extraction	Merits	Demerits
Mechanical	✓ No environmental problem regarding the use of mechanical method ✓ No potential for solvent contamination ✓ Relatively inexpensive after initial capital costs	• Relatively dirty process • Oil not completely extracted from the cake • Filtration or degumming process of oil is required • Operators require experience to achieve best results

	✓ Minor consumable costs	
chemical/solvent	✓ Repeatable and reproducible results and process ✓ High oil yields ✓ Relatively simple and quick ✓ Hexane can be recovered and reused, reducing cost significantly	• Less sought after than virgin oil • Potential for solvent contamination • Safety issues and environmental concerns regarding the use of hexane • Very costly if the hexane cannot be recovered
enzymatic	✓ No negative effect on the environment. ✓ The method is sustainable	• Requires high cost of enzyme and incubation time. • Requires de-emulsification during down-stream operations.
microwave-assisted	✓ It nullifies the release of CO_2 ✓ Only fraction of energy is required as compared to conventional heating.	• Not applicable when the solvent or desired compound is non-polar or volatile in nature.
supercritical fluid extraction	✓ The higher extraction takes place at supercritical conditions	• High temperature and pressure required in supercritical technique

	due to the enhanced solubility with solvent. ✓ The use of CO_2 as a solvent makes it cheaper process due to easier availability and non-flammability of CO_2.	increases the overall cost.
accelerated solvent extraction	✓ Time as well as solvent consumption is significantly reduced compared to the other solvent extraction methods	• Very high initial cost, high preparation required • Special equipment and skill required • Potential for solvent contamination

4.5 Summary

Based on analysis above, the following improvement are available

The production of biodiesel oil from the seeds could be done through mechanical means (automatic mean or manual) as it was highlighted above. The automatic method involves the use of the friction inside the screw press and generates heat which lowers viscosity of the oil in the crushed seeds thereby increasing the oil flow rate without preheating the paste in order to produce the oil but this process yield low oil due to some oil remaining in the cake as a result of absence of preheater, this lead to waste of oil. On the other hand, the manual involves crushing the feedstock into a powder form and water is sprinkling on it to make it a paste which in turn preheated in a separate oven for about 60 minutes to reduce the viscosity in the paste. After preheating, it's then taken to presser to squeeze the oil out of the cake. Although, the method is quite laborious but yield more oil production than automatic. Consequently, this research work seeks to bridge the gap between automatic and manual by integrate heater or heating element in the crushing chamber of the automatic machine to reduce oil viscosity in the paste which in turn produce more oil, less time consumed and make the production of the oil an easier process.

5.0 Conclusion

Due to the increasing demand of energy as a result population growth and economic expansion.Fossil fuels, which is the main source of energy continues to depleting day by day at the current usage rate, these sources will soon be exhausted. However, due to the crude oil price increase and contribution of these fuels in polluting the environment, biodiesel is attracting increasing attention as a potential alternative and renewable fuel for diesel engines worldwide. Therefore, four methods of biodiesel production are highlighted in the study which includes: Heating/pyrolysis, dilution/blending, micro-emulsion, and transesterification. Among all these techniques, the transesterification is one of the most convenient methods for biodiesel production due to reduction in the viscosity of oil or fat using acid or base catalyst in the presence of methanol or ethanol. However, the yield of biodiesel in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil. Different types of oil extraction are used to extract oils from the seeds.The oil expellers fall in this category, however, two kinds oil expeller; automatic screw press and manual are discussed above.

All the oil extractiondiscussedhas its own efficiency but this research bridge the gap between automatic and manual byrecommending integrate heater or heating element in the crushing chamber of the automatic expeller machine to reduce oil viscosity in the paste which in turn will produce more oil, less time consumed and make the production of the oil ease.

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