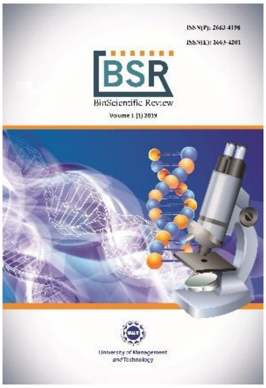

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Research Article

Optimum Time and Temperature for Biodiesel Production using Melon (*Cucumeropsismannii*), Groundnut (*Arachis hypogea*), and Soybean (*Glycine max*)

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Abstract

This study investigated the optimum condition for biodiesel production at varying temperatures and time using melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seed oils. Oil was extracted from *Cucumeropsismannii*, *A. hypogea*, and *G. max* using n-hexane (67.7-69.2^{o}C) as the solvent. Biodiesel was produced from three different seed oils at varying temperatures of 65^{o}C, 55^{o}C, and 45^{o}C at varied durations of 60mins, 50mins, and 40mins. The best percentage yield was obtained at 65^{o}C for the duration of 60 minutes. The transesterification process was not complete at 40 min; however, at 50 min the process was completed. The process also remained incomplete at 45^{o}C.The maximum percentage yield of biodiesel obtained through transesterification was 90.83% for *G. max*, 78.00% for *A. hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. Fuel properties of biodeisels, such as kinematic viscosity, pour point, carbon residue, cloud point, water content, flash point, cetane index, and sulfated ash, were examined. The flashpoint, carbon residue, kinematic viscosity, and water content of biodiesels were within the standard specified for petrol diesel; however, cloud point and pour points of this product were found to be greater than that of petrol diesel. The cetane index of biodiesels was lower than the standard specified for petrol diesel. Additionally, the samples were not found to contain sulfated ash. Therefore, *Cucumeropsismannii*, *A. hypogea*), and *G. max* are good sources of biodiesel production.

1. Introduction

Energy is the most basic requirement for human survival. According to the International Energy Outlook 2019, global energy consumption is expected to increase by 50% between the years 2018 and 2050 [1, 2].At present, consumption of global energy is heavily reliant on fossil fuels such as crude oil, natural gas, and coal, which account for over 80% of total consumption. As demand for fossil fuels grows, it is expected to reach 109.1 million barrels per day by 2045 [3]. The use of fossil fuels has expanded astronomically, and as a result, their usage has a significant environmental impact [4].

According to the analysis, based on the current daily fossil fuel usage figures, it is just a matter of time before the world's fossil resources are completely exhausted due to their depletable nature [5].The significance of this work spurs from the fact that biodiesel has been investigated as a viable alternative to fossil fuels in recent decades since it is a more sustainable way of meeting global energy demands. Recent developments in biotechnology has opened the doors to investigate diverse biodiesel sources and the work ability of the fuels generated. Energy needs are dependent on population, economy, and technological advancement, all of which are essential to the societal and economic development of a country [6, 7]. The two distinctive sources of energy are renewable and non-renewable sources. Renewable energy sources include the sun, wind, hydro, biomass, and waste; whereas, non-renewable energy sources include fossil fuels [8, 9].

The growing energy needs of our society and the ecological problems stemming from the burning of fossil fuels draws attention to our need to find alternative renewable fuels [10]. It is imperative to find acceptable alternative fuels that could be employed in engines to contest the steady depletion of the world's petroleum supplies and decelerate the impact of environmental contamination from rising carbon emissions from various man-made sources [11]. The increased awareness of greenhouse gas emissions and global warming necessitates the implementation of more stringent environmental legislation around the world [12].

Biodiesel is a clean-burning, oxygenated mono-alkyl ester fuel manufactured from natural renewable sources, such as new/used vegetable oil and animal fat [12]. Biofuels are fuels generated from biological sources, such as plants, animals, and microbes, that are biodegradable, renewable, reasonably clean, and environmentally safe [13]. Furthermore, biodiesel is a sulfur-free, superior lubricant that has significant socioeconomic benefits [14]. Biodiesel is proven to have better properties compared to petroleum. Due to these factors, the use of biodiesel has become more appealing since it can minimize the number of carcinogens emitted into the environment. In recent years, the production of biodiesel has increased. This could be due to the fact that it is considered an acceptable alternative to fossil fuels as more and more people and communities are seeing the need for a paradigm shift towards alternative and renewable energy sources. Biodiesel can be made from any fatty acid source; however, in recent studies, transesterification reactions are studied for several vegetable oils like rapeseed [15], pomace [16], sunflower [17], safflower [18], canola [19], palm [20] as well as fish oil [21]. Because edible vegetable oils like soybean oil are more expensive than diesel fuel, waste vegetable oils [22–25] and non-edible crude vegetable oils such astiger nut oil [26] and *Pongamia pinnata* [27] are intensively being investigated as possible cost-effective biodiesel sources.

It was estimated that biodiesel made from these feedstocks would be more cost-effective than biodiesel made from refined vegetable oil [28]. The process of making biodiesel from both sources is similar [29]. Vegetable oils have been shown to have substantial potential as a fuel for diesel engines in short-term engine performance testing [30,31, 28].

In one study, the effects of temperature on biodiesel in the range of 45-60ºC were investigated, and the quantity of methyl esters was evaluated using GC-MS. It was noted that the reaction's temperature has a considerable impact on the transesterification reaction, with the best biodiesel conversion of waste cooking oil occurring at 55 ºC having a methyl ester level of 81.19% [32]. Valentinoh *et al.*, [33] investigated biodiesel production using beef tallow. The greatest yield of 82.43% beef tallow methyl ester was obtained under ideal conditions by applying a 9:1 molar ratio of methanol to beef tallow at 55 ºC for 90 minutes in the presence of 3 wt% CaO catalyst. According to Abba *et al.*,[34], the greatest ester conversion of neem seed oil was attained at a reaction period of 40-50 minutes, a methanol oil ratio of 6:1, a temperature of 65°C, and a stirring speed of 350rpm.

Therefore, this article inspects and evaluates the production of biodiesel from edible vegetable seed oils such as melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seed oils with special emphasis on identifying optimum temperature and time to get the best transesterification reaction.

2.1. Sample Collection

Melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seeds were collected from a neighbourhood market in Okigwe, Imo State. Okigwe Local Government Area (Figure 1) is made up of twelve (12) communities and numerous villages. It lies between the longitudes of 7º44¹ and 7º26¹E and latitudes of 5º30¹ and 5º57¹N. Okigwe LGA encompasses 360km^2 and has a population of 132,237 [35]. It is bordered on the north by Umuahia South LGA, Abia State, on the east by Onu-imo LGA, Imo State, on the south by Umunneochi LGA, Abia State, and on the west by Isuikwuato LGA, Abia State. The climate is tropical, with annual rainfall ranging from 1800 to 2000 mm, mean temperature of 28 to 42 ºC, and relative humidity of 65%. The dry season (November-April) and the rainy season (May-October) are the two main seasons in the area [36]. The samples were appropriately identified at the Department of Plant Science and Biotechnology, Abia State University. The seeds were separated from all contaminating impurities and crushed using an electrical blender.

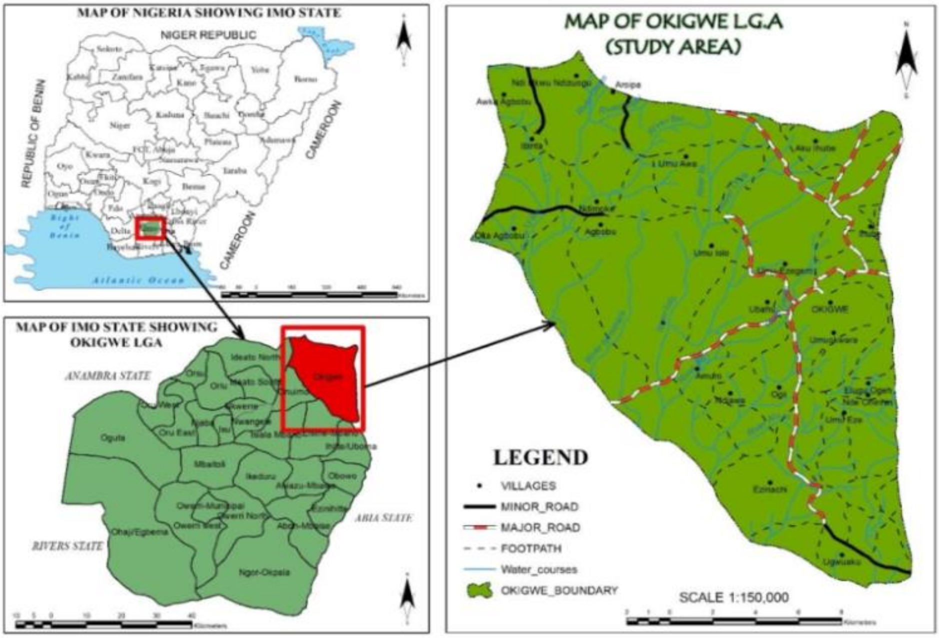

Figure 1. Map of Okigwe, Imo State

2.2. Extraction of Oil

The crushed seeds were sun-dried for three days and weighed. The crushed samples were separately put into a porous thimble and were properly covered with cotton wool. The thimble and its contents were inserted into the tube of reflux extractor connected to a round bottom flask containing 400 ml of n-hexane. The oil was extracted from the seeds using the Soxhlet extraction technique and the American Oil Chemists Society method [37]. n-hexane (67.7ºC–69.2ºC) was utilized as the extraction solvent.

2.3. Preparation of Methyl Ester (Biodiesel)

To remove any remaining water molecules, the extracted oil was filtered and heated to around 65ºC for 60 minutes. The temperature of the measured sample of oil was maintained at 65ºC to make sure that solid fats melted if present. Sodium methoxide solution was freshly prepared by the addition of a preset amount of methanol (28.39%) by weight of oil, with (100%) by weight of methanol in a container. Methyl ester (biodiesel) was produced using a modified method reported by Refaat *et al.* [4]. The transesterification process was examined at constant catalyst loading (1% of NaOH) and constant alcohol-to-oil molar ratio (6:1) at three reaction temperatures (45ºC, 55ºC, and 65ºC) and three reaction time intervals (40mins, 50mins, and 60mins).

2.4. Analysis of the Samples

The extracted samples were analyzed to identify the properties of primary fuel such as flash point, carbon residue, pour point, kinematic viscosity, total acid number (acid value), sulfated ash, moisture content, and cetane index. The flashpoint was determined by the American Standard Test Method (ASTM No. D92) [38]. Carbon residue was determined by ASTM D6271 [39]. The other parameters were determined as follows: Pour Point (ASTM D751) [40], Kinematic Viscosity (ASTM D445) [41], Sulphated ash (ASTM D874) [42], Moisture content (ASTM D6751) [43], and Cetane index (ASTM D4737) [44].

3. Results

The percentage yield of biodiesel from the oil extracted was calculated using the equation below.

Percentage yield = (Vol. of oil used/Vol. of biodiesel produced) x100 (1.0)

Figure 2 depicts the percentage yield of biodiesel. The maximum percentage yield of biodiesel obtained was 90.83% for *Glycine max*, 78.00% for *Arachis hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. These findingscompare favourably with thepercentage yield of biodiesel obtained from waste vegetable oil [4]. This means that *Glycine max* gave a higher yield than waste vegetable oil, followed by *Arachis hypogea* and *Cucumeropsismannii* seed oils, respectively.

The summary of the experiment is shown in Table 1. Sodium hydroxide was used as the catalyst at a catalyst loading of 1% wt/wt. Refaat et. al reported an elevated percentage yield for a catalyst loading of 1% when compared to a catalyst loading of 0.5%[4].It has been reported that potassium hydroxide was used as a catalyst to produce biodiesel with the finest characteristics [45-48], but several other studies achieved better results using sodium hydroxide [49-52]. Catalyst loading greater than 1% has been reported to favour backward reactions [48]. The alcohol-to-oil molar ratio is another crucial determinant in methyl ester production. In this study, a molar ratio of 6:1 was used which has been used in other studies [47, 48, 49, 53]. Other alcohol-to-oil molar ratios have also been reported such as (3:1) and (9:1) [4]; 10:1 [45, 50].

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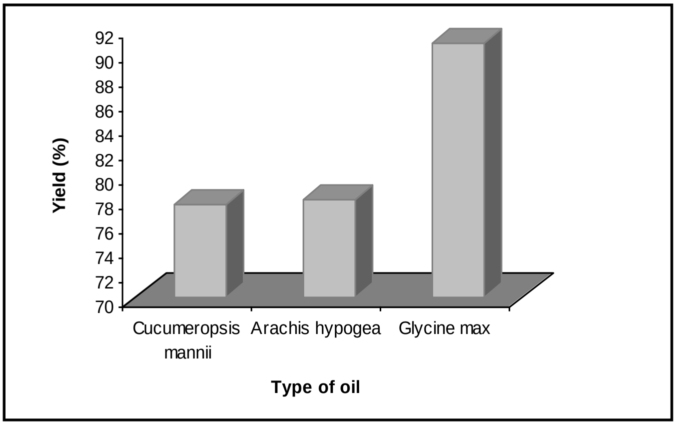

Figure 2. Comparison of yield (%) of the different types of oil

Table 1. Summary of Experimental Results

Run	Feedstock	Catalyst	Catalyst concentration (%) wt	Alcohol/oil ratio	Reaction Temperature (ºC)	Reaction time (mins)	Vol. of biodiesel (ml)	percentage yield
1	*Cucumeropsismannii*	NaOH	1	6:1	65	40	76.8	64.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	50	85.2	71.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	60	93.1	77.58
1	*Cucumeropsismannii*	NaOH	1	6:1	45	60	76.8	64.00
1	*Cucumeropsismannii*	NaOH	1	6:1	55	60	92.4	77.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	60	93.1	77.58
1	*Arachis hypogea*	NaOH	1	6:1	65	40	85.2	71.00
1	*Arachis hypogea*	NaOH	1	6:1	65	50	90.1	75.08
1	*Arachis hypogea*	NaOH	1	6:1	65	60	93.6	78.00
1	*Arachis hypogea*	NaOH	1	6:1	45	60	84.1	70.08
1	*Arachis hypogea*	NaOH	1	6:1	55	60	87.6	73.00
1	*Arachis hypogea*	NaOH	1	6:1	65	60	93.6	78.00
1	*Glycine max*	NaOH	1	6:1	65	40	99.6	83.00
1	*Glycine max*	NaOH	1	6:1	65	50	106.8	89.00
1	*Glycine max*	NaOH	1	6:1	65	60	109.2	90.83
1	*Glycine max*	NaOH	1	6:1	45	60	99.1	82.58
1	*Glycine max*	NaOH	1	6:1	55	60	103.8	86.50
1	*Glycine max*	NaOH	1	6:1	65	60	109.2	90.83

3.1. Effect of Temperature

The influence of temperature and time on the transesterification of the three feedstock kinds was investigated. Figure 3 shows the effect of temperature on biodiesel yield. The most favourable temperature was 65ºC; however, the transesterification process was not complete at 45ºC. The rise in temperature from 45ºC to 55ºC improved the yield from 64.00% to 77.00% for *Cucumeropsismannii*, from 70.08% to 73.00% for *Arachis hypogea,* and from 82.58% to 86.50% for *Glycine max*. When the temperature was increased from 55ºC to 65ºC, it increased the yield from 77.00% to 77.58% for *Cucumeropsismannii*; from 73.00% to 78.00% for *Arachis hypogea,* and from 86.50% to 90.83% for *Glycine max*. The increase in yield with an increase in temperature has also been previously reported [4]. In contrast to this finding, several researchers claim that the temperature did not affect the ultimate ester conversion. Higher temperatures, on the other hand, reduce the time it takes to reach maximal conversion [29]. Transesterification is a relatively slow process since this reaction can only take place in the interfacial region between the liquids, and because fats and alcohols are not miscible. For this reason, intensive mixing is required to enhance the contact region between the two immiscible liquids [51].

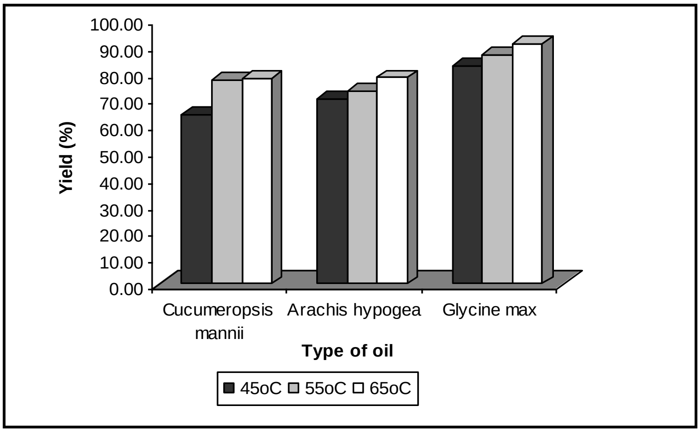

Figure 3. Effect of Temperature (°C) on yield of biodiesel

3.2. Effect of Time

The effect of time on biodiesel yield is shown in Figure 4**.** The optimum time for the transesterification reaction was 60 min; however, the process was not complete at 40 min. The transesterification process was completed at 50 min with a percentage yield of 71.00% for *Cucumeropsismannii*, 75.08% for *Arachis hypogea*, and 89.00% for *Glycine max*. When the time was increased from 50 min to 60 min, the yield increased to 77.58% for *Cucumeropsismannii*, 78.00% for *Arachis hypogea*, and 90.83% for *Glycine max*. Refaat *et al*., [4] reported that the optimum time for the transesterification process was 1hr. They also stated that raising the reaction time to 3 hours resulted in no discernible increase in yield. According to the findings, the best yield percentage was obtained utilizing a 6:1 methanol/oil molar ratio, with sodium hydroxide as catalyst (1%) at 65°C temperature for one hour.

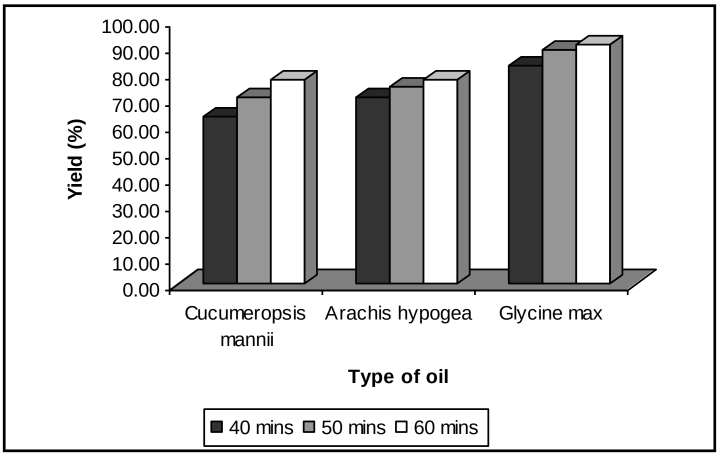

Figure 4. Effect of time (mins) on biodiesel yield

Table 2. Comparative Properties of Biodiesel from Melon (*Cucumeropsis Mannii*), Groundnut (*Arachis hypogea*) and Soya been (*Glycine Max*) Seed Oils

Feedstock	Flash point (⁰C)	Kinematic Viscosity mm^2/S	Pour Point (⁰C)	Cloud Point	Water Content (%)	Carbon Residue	Sulphated Ash	Cetane Index
CucumeropsisMannii @ 40mins	147	4.0	14	-7	0.5	0.89	Nil	24.11
CucumeropsisMannii @ 50mins	144	3.3	14	-7	0.4	0.88	Nil	24.11
CucumeropsisMannii @ 60mins	140	2.9	12	-6	0.3	0.79	Nil	23.01
CucumeropsisMannii@ 45⁰C	146	4.1	14	-7	0.4	0.88	Nil	23.99
CucumeropsisMannii @ 55⁰C	144	3.5	13	-7	0.4	0.88	Nil	24.11
CucumeropsisMannii @ 65⁰C	140	2.9	12	-6	0.3	0.79	Nil	23.01
Arachis hypogea @ 40mins	147	4.1	13	-8	0.6	0.52	Nil	23.62
Arachis hypogea @ 50mins	144	3.5	11	-9	0.6	0.42	Nil	23.62
Arachis hypogea @ 60mins	142	3.0	11	-7	0.4	0.39	Nil	20.65
Arachis hypogea @ 45⁰C	147	4.2	13	-9	0.6	0.53	Nil	23.62
Arachis hypogea @ 55⁰C	144	3.5	11	-9	0.6	0.42	Nil	23.62
Arachis hypogea @ 65⁰C	142	3.0	11	-7	0.4	0.39	Nil	20.65
Glycine max @ 40mins	146	3.6	16	-9	0.2	0.81	Nil	24.22
Glycine max @ 50mins	143	3.3	14	-9	0.2	0.81	Nil	23.58
Glycine max @ 60mins	138	2.6	09	-7	0.1	0.77	Nil	22.04
Glycine max @ 45⁰C	147	3.6	16	-9	0.2	0.81	Nil	24.22
Glycine max @ 55⁰C	143	3.5	13	-9	0.2	0.81	Nil	23.58
Glycine max @ 65⁰C	138	2.6	09	-7	0.1	0.77	Nil	22.04

4. Discussion

Laboratory investigations were carried out to ascertain the qualities and features of biodiesel produced from melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seed oils. The results are shown in Table 2. Standard viscosities stipulated by ASTM D445 are within 1.6-5.5mm^2/s. The results showed that all samples met the standard condition, indicating that they are viscous enough to generate genuine spray throughout the combustion chamber and would be adequately mixed with air [54]. All of the samples were classified as 4-D diesel fuel. The viscosity difference gives rise to the concept of viscometry, an analytical method for determining the conversion of edible fat to methyl ester[4]. The viscosity difference between the componential triacylglycerols of vegetable oils and the methyl esters produced by transesterification is about one digit [55]. Kinematic viscosity (1.9-6.0mm^2/s in EN 14214) has been incorporated into biodiesel specifications [56]. The obtained kinematic viscosities for all the samples ranged from 2.6mm^2/ to 4.2mm^2/s and this conforms to the ASTM D6751 standard. These kinematic viscosity values also denote satisfactory completion of the transesterification process [4].

The flashpoint of the samples ranged from 138^{o}C to 147^{o}C. This shows that the samples could be stored with no fire or explosion risk. The cloud point ranged from -6 to -9 and is greater than that of petroleum diesel, meaning that at low temperatures, it will form wax crystals. The pour point of the samples ranged from 9ºC to 16ºC. This conforms to the Malaysian B100 standard for biodiesel [12]. The pour point of all the samples is greater than that of petroleum dieselsince, at lower temperatures, biodiesels become a gel that cannot be pumped. The moisture content ranged from 0.1% to 0.6% for the biodiesel samples. The carbon residue ranged from 0.39 to 0.89 for all the biodiesel samples. All the samples contained no sulfated ash. The cetane index of the biodiesel sample ranged from 20.65 to 24.22. Cetane numbers are frequently estimated using the determined cetane index (ASTM D976 or D4737). The cetane number of diesel fuels is proportional to the length of the hydrocarbon chain [54].

Although biodiesel has been reported to have better lubricity characteristics as compared to diesel fuel [55]; the wear of various important parts of the engine appears to be higher during the test fuel application [56]. The lubricity issue is important since the introduction of low sulfur petrodiesel fuels, and more recently, ultra-low-sulfur diesel (ULSD) fuels, as mandated by regulations, has resulted in the failure of engine parts such as fuel pumps and injectors, which are lubricated by the fuel itself [53]. Hence, the biodiesels that blend with petrodiesel are highly recommended. The tribological issues associated with the utilization of biodiesels and also the biofuel standards and regulations are reported in [12].

5. Conclusion

Due to the declining global petroleum reserves, strict emission requirements, and climate change policies, research into alternative energy sources has grown in importance. According to the findings of the study, edible vegetable oils such as melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine Max*) seed oils are good alternatives to petrodiesel. The best percentage yield was achieved using 1% sodium hydroxide as a catalyst with a 6:1 methanol/oil molar ratio at 65°C.The optimum time for the transesterification reaction was 60 min. The maximum percentage yield of biodiesel was obtained at90.83% for *Glycine max*, 78.00% for *Arachis hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. It was determined that the temperature and time of reaction affected the percentage yield of biodiesel. *Glycine max* gave a better yield than waste vegetable oil, followed by *Arachis hypogea* and *Cucumeropsismannii*, respectively. It was evident from the data that the fuel produced met all the necessary biodiesel fuel standards.

Conflict of Interest

The authors declare no conflict of interest.

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Optimum Time and Temperature for Biodiesel Production using Melon (*Cucumeropsismannii*), Groundnut (*Arachis hypogea*), and Soybean (*Glycine max*)

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Abstract

This study investigated the optimum condition for biodiesel production at varying temperatures and time using melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seed oils. Oil was extracted from *Cucumeropsismannii*, *A. hypogea*, and *G. max* using n-hexane (67.7-69.2ºC) as the solvent. Biodiesel was produced from three different seed oils at varying temperatures of 65ºC, 55ºC, and 45ºC at varied durations of 60mins, 50mins, and 40mins. The best percentage yield was obtained at 65ºC for the duration of 60 minutes. The transesterification process was not complete at 40 min; however, at 50 min the process was completed. The process also remained incomplete at 45ºC.The maximum percentage yield of biodiesel obtained through transesterification was 90.83% for *G. max*, 78.00% for *A. hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. Fuel properties of biodiesels, such as kinematic viscosity, pour point, carbon residue, cloud point, water content, flash point, cetane index, and sulfated ash, were examined. The flashpoint, carbon residue, kinematic viscosity, and water content of biodiesels were within the standard specified for petrol diesel; however, cloud point and pour points of this product were found to be greater than that of petrol diesel. The cetane index of biodiesels was lower than the standard specified for petrol diesel. Additionally, the samples were not found to contain sulfated ash. Therefore, melon (*Cucumeropsismannii*), groundnut (*A. hypogea*), and soybean (*G. max*) are good sources of biodiesel production.

1. Introduction

Energy is the most basic requirement for human survival. According to the International Energy Outlook 2019, global energy consumption is expected to increase by 50% between the years 2018 and 2050 [1, 2].At present, consumption of global energy is heavily reliant on fossil fuels such as crude oil, natural gas, and coal, which account for over 80% of total consumption. As demand for fossil fuels grows, it is expected to reach 109.1 million barrels per day by 2045 [3]. The use of fossil fuels has expanded astronomically, and as a result, their usage has a significant environmental impact [4].

According to the analysis, based on the current daily fossil fuel usage figures, it is just a matter of time before the world's fossil resources are completely exhausted due to their depletable nature [5].The significance of this work spurs from the fact that biodiesel has been investigated as a viable alternative to fossil fuels in recent decades since it is a more sustainable way of meeting global energy demands. Recent developments in biotechnology has opened the doors to investigate diverse biodiesel sources and the work ability of the fuels generated. Energy needs are dependent on population, economy, and technological advancement, all of which are essential to the societal and economic development of a country [6, 7]. The two distinctive sources of energy are renewable and non-renewable sources. Renewable energy sources include the sun, wind, hydro, biomass, and waste; whereas, non-renewable energy sources include fossil fuels [8, 9].

The growing energy needs of our society and the ecological problems stemming from the burning of fossil fuels draws attention to our need to find alternative renewable fuels [10]. It is imperative to find acceptable alternative fuels that could be employed in engines to contest the steady depletion of the world's petroleum supplies and decelerate the impact of environmental contamination from rising carbon emissions from various man-made sources [11]. The increased awareness of greenhouse gas emissions and global warming necessitates the implementation of more stringent environmental legislation around the world [12].

Biodiesel is a clean-burning, oxygenated mono-alkyl ester fuel manufactured from natural renewable sources, such as new/used vegetable oil and animal fat [12]. Biofuels are fuels generated from biological sources, such as plants, animals, and microbes, that are biodegradable, renewable, reasonably clean, and environmentally safe [13]. Furthermore, biodiesel is a sulfur-free, superior lubricant that has significant socioeconomic benefits [14]. Biodiesel is proven to have better properties compared to petroleum. Due to these factors, the use of biodiesel has become more appealing since it can minimize the number of carcinogens emitted into the environment. In recent years, the production of biodiesel has increased. This could be due to the fact that it is considered an acceptable alternative to fossil fuels as more and more people and communities are seeing the need for a paradigm shift towards alternative and renewable energy sources. Biodiesel can be made from any fatty acid source; however, in recent studies, transesterification reactions are studied for several vegetable oils like rapeseed [15], pomace [16], sunflower [17], safflower [18], canola [19], palm [20] as well as fish oil [21]. Because edible vegetable oils like soybean oil are more expensive than diesel fuel, waste vegetable oils [22–25] and non-edible crude vegetable oils such astiger nut oil [26] and *Pongamia pinnata* [27] are intensively being investigated as possible cost-effective biodiesel sources.

It was estimated that biodiesel made from these feedstocks would be more cost-effective than biodiesel made from refined vegetable oil [28]. The process of making biodiesel from both sources is similar [29]. Vegetable oils have been shown to have substantial potential as a fuel for diesel engines in short-term engine performance testing [30,31, 28].

In one study, the effects of temperature on biodiesel in the range of 45-60ºC were investigated, and the quantity of methyl esters was evaluated using GC-MS. It was noted that the reaction's temperature has a considerable impact on the transesterification reaction, with the best biodiesel conversion of waste cooking oil occurring at 55 ºC having a methyl ester level of 81.19% [32]. Valentinoh *et al.*, [33] investigated biodiesel production using beef tallow. The greatest yield of 82.43% beef tallow methyl ester was obtained under ideal conditions by applying a 9:1 molar ratio of methanol to beef tallow at 55 ºC for 90 minutes in the presence of 3 wt% CaO catalyst. According to Abba *et al.*,[34], the greatest ester conversion of neem seed oil was attained at a reaction period of 40-50 minutes, a methanol oil ratio of 6:1, a temperature of 65°C, and a stirring speed of 350rpm.

Therefore, this article inspects and evaluates the production of biodiesel from edible vegetable seed oils such as melon (*Cucumeropsismannii*), groundnut (*Arachis hypogea*), and soybean (*Glycine max*) seed oils with special emphasis on identifying optimum temperature and time to get the best transesterification reaction.

2.1. Sample Collection

Melon (*Cucumeropsismannii*), groundnut (*A. hypogea*), and soybean (*G. max*) seeds were collected from a neighbourhood market in Okigwe, Imo State. Okigwe Local Government Area (Figure 1) is made up of twelve (12) communities and numerous villages. It lies between the longitudes of 7º44¹ and 7º26¹E and latitudes of 5º30¹ and 5º57¹N. Okigwe LGA encompasses 360km^2 and has a population of 132,237 [35]. It is bordered on the north by Umuahia South LGA, Abia State, on the east by Onu-imo LGA, Imo State, on the south by Umunneochi LGA, Abia State, and on the west by Isuikwuato LGA, Abia State. The climate is tropical, with annual rainfall ranging from 1800 to 2000 mm, mean temperature of 28 to 42 ºC, and relative humidity of 65%. The dry season (November-April) and the rainy season (May-October) are the two main seasons in the area [36]. The samples were appropriately identified at the Department of Plant Science and Biotechnology, Abia State University. The seeds were separated from all contaminating impurities and crushed using an electrical blender.

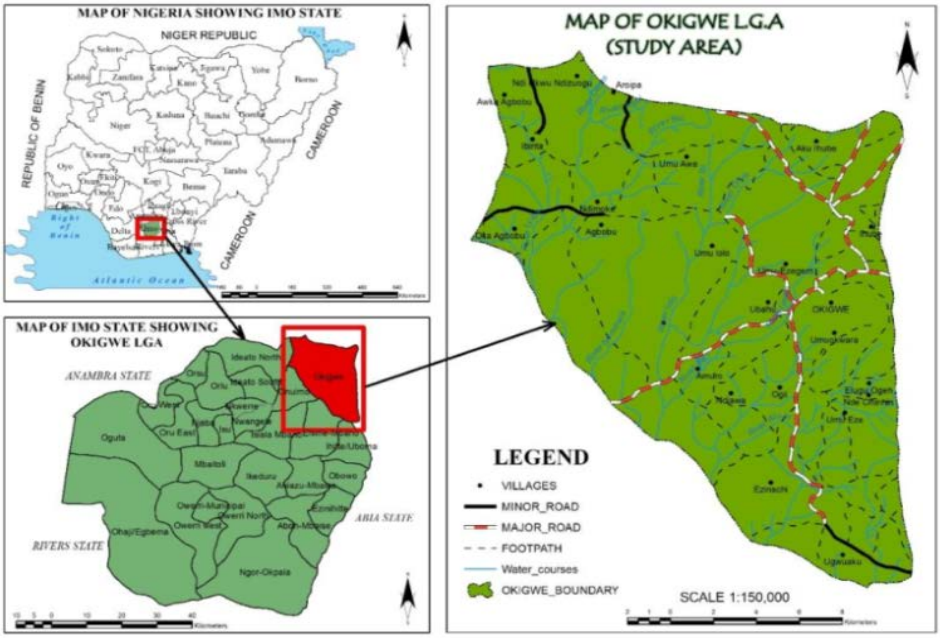

Figure 1. Map of Okigwe, Imo State

2.2. Extraction of Oil

The crushed seeds were sun-dried for three days and weighed. The crushed samples were separately put into a porous thimble and were properly covered with cotton wool. The thimble and its contents were inserted into the tube of reflux extractor connected to a round bottom flask containing 400 ml of n-hexane. The oil was extracted from the seeds using the Soxhlet extraction technique and the American Oil Chemists Society method [37]. n-hexane (67.7ºC–69.2ºC) was utilized as the extraction solvent.

2.3. Preparation of Methyl Ester (Biodiesel)

To remove any remaining water molecules, the extracted oil was filtered and heated to around 65ºC for 60 minutes. The temperature of the measured sample of oil was maintained at 65ºC to make sure that solid fats melted if present. Sodium methoxide solution was freshly prepared by the addition of a preset amount of methanol (28.39%) by weight of oil, with (100%) by weight of methanol in a container. Methyl ester (biodiesel) was produced using a modified method reported by Refaat *et al.* [4]. The transesterification process was examined at constant catalyst loading (1% of NaOH) and constant alcohol-to-oil molar ratio (6:1) at three reaction temperatures (45ºC, 55ºC, and 65ºC) and three reaction time intervals (40mins, 50mins, and 60mins).

2.4. Analysis of the Samples

The extracted samples were analyzed to identify the properties of primary fuel such as flash point, carbon residue, pour point, kinematic viscosity, total acid number (acid value), sulfated ash, moisture content, and cetane index. The flashpoint was determined by the American Standard Test Method (ASTM No. D92) [38]. Carbon residue was determined by ASTM D6271 [39]. The other parameters were determined as follows: Pour Point (ASTM D751) [40], Kinematic Viscosity (ASTM D445) [41], Sulphated ash (ASTM D874) [42], Moisture content (ASTM D6751) [43], and Cetane index (ASTM D4737) [44].

3. Results

The percentage yield of biodiesel from the oil extracted was calculated using the equation below.

Percentage yield = (Vol. of oil used/Vol. of biodiesel produced) x100 (1.0)

Figure 2 depicts the percentage yield of biodiesel. The maximum percentage yield of biodiesel obtained was 90.83% for *Glycine max*, 78.00% for *A. hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. These findings compare favourably with the percentage yield of biodiesel obtained from waste vegetable oil [4]. This means that *Glycine max* gave a higher yield than waste vegetable oil, followed by *A. hypogea* and *Cucumeropsismannii* seed oils, respectively.

The summary of the experiment is shown in Table 1. Sodium hydroxide was used as the catalyst at a catalyst loading of 1% wt/wt. Refaat et. al reported an elevated percentage yield for a catalyst loading of 1% when compared to a catalyst loading of 0.5%[4].It has been reported that potassium hydroxide was used as a catalyst to produce biodiesel with the finest characteristics [45-48], but several other studies achieved better results using sodium hydroxide [49-52]. Catalyst loading greater than 1% has been reported to favour backward reactions [48]. The alcohol-to-oil molar ratio is another crucial determinant in methyl ester production. In this study, a molar ratio of 6:1 was used which has been used in other studies [47, 48, 49, 53]. Other alcohol-to-oil molar ratios have also been reported such as (3:1) and (9:1) [4]; 10:1 [45, 50].

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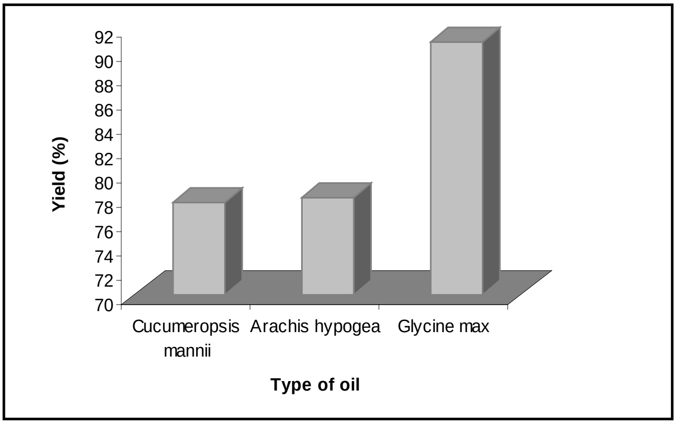

Figure 2. Comparison of yield (%) of the different types of oil

Table 1. Summary of Experimental Results

Run	Feedstock	Catalyst	Catalyst concentration (%) wt	Alcohol/oil ratio	Reaction Temperature (ºC)	Reaction time (mins)	Vol. of biodiesel (ml)	percentage yield
1	*Cucumeropsismannii*	NaOH	1	6:1	65	40	76.8	64.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	50	85.2	71.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	60	93.1	77.58
1	*Cucumeropsismannii*	NaOH	1	6:1	45	60	76.8	64.00
1	*Cucumeropsismannii*	NaOH	1	6:1	55	60	92.4	77.00
1	*Cucumeropsismannii*	NaOH	1	6:1	65	60	93.1	77.58
1	*Arachis hypogea*	NaOH	1	6:1	65	40	85.2	71.00
1	*Arachis hypogea*	NaOH	1	6:1	65	50	90.1	75.08
1	*Arachis hypogea*	NaOH	1	6:1	65	60	93.6	78.00
1	*Arachis hypogea*	NaOH	1	6:1	45	60	84.1	70.08
1	*Arachis hypogea*	NaOH	1	6:1	55	60	87.6	73.00
1	*Arachis hypogea*	NaOH	1	6:1	65	60	93.6	78.00
1	*Glycine max*	NaOH	1	6:1	65	40	99.6	83.00
1	*Glycine max*	NaOH	1	6:1	65	50	106.8	89.00
1	*Glycine max*	NaOH	1	6:1	65	60	109.2	90.83
1	*Glycine max*	NaOH	1	6:1	45	60	99.1	82.58
1	*Glycine max*	NaOH	1	6:1	55	60	103.8	86.50
1	*Glycine max*	NaOH	1	6:1	65	60	109.2	90.83

3.1. Effect of Temperature

The influence of temperature and time on the transesterification of the three feedstock kinds was investigated. Figure 3 shows the effect of temperature on biodiesel yield. The most favourable temperature was 65ºC; however, the transesterification process was not complete at 45ºC. The rise in temperature from 45ºC to 55ºC improved the yield from 64.00% to 77.00% for *Cucumeropsismannii*, from 70.08% to 73.00% for *A. hypogea*, and from 82.58% to 86.50% for *G. max*. When the temperature was increased from 55ºC to 65ºC, it increased the yield from 77.00% to 77.58% for *Cucumeropsismannii*; from 73.00% to 78.00% for *A. hypogea*, and from 86.50% to 90.83% for *G. max*. The increase in yield with an increase in temperature has also been previously reported [4]. In contrast to this finding, several researchers claim that the temperature did not affect the ultimate ester conversion. Higher temperatures, on the other hand, reduce the time it takes to reach maximal conversion [29]. Transesterification is a relatively slow process since this reaction can only take place in the interfacial region between the liquids, and because fats and alcohols are not miscible. For this reason, intensive mixing is required to enhance the contact region between the two immiscible liquids [51].

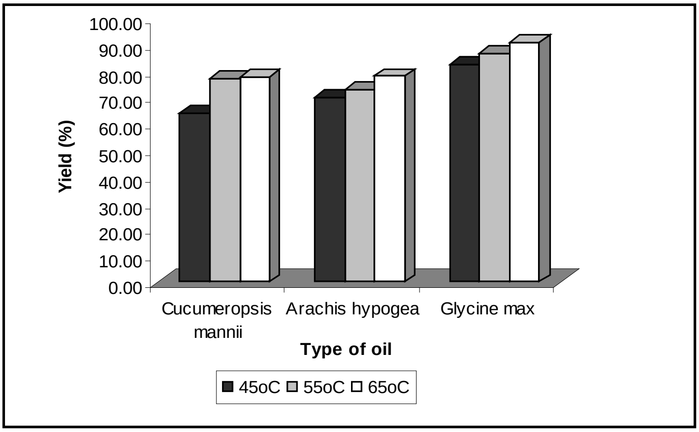

Figure 3. Effect of Temperature (°C) on yield of biodiesel

3.2. Effect of Time

The effect of time on biodiesel yield is shown in Figure 4**.** The optimum time for the transesterification reaction was 60 min; however, the process was not complete at 40 min. The transesterification process was completed at 50 min with a percentage yield of 71.00% for *Cucumeropsismannii*, 75.08% for *A. hypogea*, and 89.00% for *G. max*. When the time was increased from 50 min to 60 min, the yield increased to 77.58% for *Cucumeropsismannii*, 78.00% for *A. hypogea*, and 90.83% for *G. max*. Refaat *et al*., [4] reported that the optimum time for the transesterification process was 1hr. They also stated that raising the reaction time to 3 hours resulted in no discernible increase in yield. According to the findings, the best yield percentage was obtained utilizing a 6:1 methanol/oil molar ratio, with sodium hydroxide as catalyst (1%) at 65°C temperature for one hour.

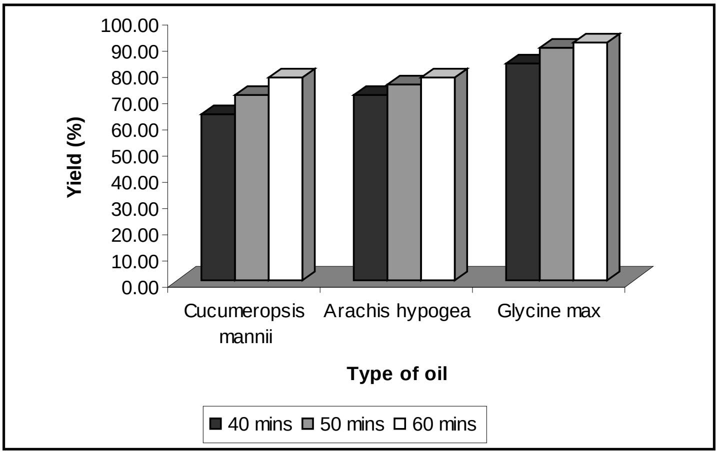

Figure 4. Effect of time (mins) on biodiesel yield

Table 2. Comparative Properties of Biodiesel from *Cucumeropsis Mannii*, *Arachis hypogea* and *Glycine Max* Seed Oils

Feedstock	Flash point (^{0}C)	Kinematic Viscosity mm^2/S	Pour Point (^{0}C)	Cloud Point	Water Content (%)	Carbon Residue	Sulphated Ash	Cetane Index
CucumeropsisMannii @ 40mins	147	4.0	14	-7	0.5	0.89	Nil	24.11
CucumeropsisMannii @ 50mins	144	3.3	14	-7	0.4	0.88	Nil	24.11
CucumeropsisMannii @ 60mins	140	2.9	12	-6	0.3	0.79	Nil	23.01
CucumeropsisMannii@ 45^{0}C	146	4.1	14	-7	0.4	0.88	Nil	23.99
CucumeropsisMannii @ 55^{0}C	144	3.5	13	-7	0.4	0.88	Nil	24.11
CucumeropsisMannii @ 65^{0}C	140	2.9	12	-6	0.3	0.79	Nil	23.01
Arachis hypogea @ 40mins	147	4.1	13	-8	0.6	0.52	Nil	23.62
Arachis hypogea @ 50mins	144	3.5	11	-9	0.6	0.42	Nil	23.62
Arachis hypogea @ 60mins	142	3.0	11	-7	0.4	0.39	Nil	20.65
Arachis hypogea @ 45^{0}C	147	4.2	13	-9	0.6	0.53	Nil	23.62
Arachis hypogea @ 55^{0}C	144	3.5	11	-9	0.6	0.42	Nil	23.62
Arachis hypogea @ 65^{0}C	142	3.0	11	-7	0.4	0.39	Nil	20.65
Glycine max @ 40mins	146	3.6	16	-9	0.2	0.81	Nil	24.22
Glycine max @ 50mins	143	3.3	14	-9	0.2	0.81	Nil	23.58
Glycine max @ 60mins	138	2.6	09	-7	0.1	0.77	Nil	22.04
Glycine max @ 45^{0}C	147	3.6	16	-9	0.2	0.81	Nil	24.22
Glycine max @ 55^{0}C	143	3.5	13	-9	0.2	0.81	Nil	23.58
Glycine max @ 65^{0}C	138	2.6	09	-7	0.1	0.77	Nil	22.04

4. Discussion

Laboratory investigations were carried out to ascertain the qualities and features of biodiesel produced from

Cucumeropsismannii, *A. hypogea*), and *Glycine max* seed oils. The results are shown in Table 2. Standard viscosities stipulated by ASTM D445 are within 1.6-5.5mm^2/s. The results showed that all samples met the standard condition, indicating that they are viscous enough to generate genuine spray throughout the combustion chamber and would be adequately mixed with air [54]. All of the samples were classified as 4-D diesel fuel. The viscosity difference gives rise to the concept of viscometry, an analytical method for determining the conversion of edible fat to methyl ester[4]. The viscosity difference between the componential triacylglycerols of vegetable oils and the methyl esters produced by transesterification is about one digit [55]. Kinematic viscosity (1.9-6.0mm^2/s in EN 14214) has been incorporated into biodiesel specifications [56]. The obtained kinematic viscosities for all the samples ranged from 2.6mm^2/ to 4.2mm^2/s and this conforms to the ASTM D6751 standard. These kinematic viscosity values also denote satisfactory completion of the transesterification process [4].

The flashpoint of the samples ranged from 138°C to 147°C. This shows that the samples could be stored with no fire or explosion risk. The cloud point ranged from -6 to -9 and is greater than that of petroleum diesel, meaning that at low temperatures, it will form wax crystals. The pour point of the samples ranged from 9°C to 16°C. This conforms to the Malaysian B100 standard for biodiesel [12]. The pour point of all the samples is greater than that of petroleum diesel since, at lower temperatures, biodiesels become a gel that cannot be pumped. The moisture content ranged from 0.1% to 0.6% for the biodiesel samples. The carbon residue ranged from 0.39 to 0.89 for all the biodiesel samples. All the samples contained no sulfated ash. The cetane index of the biodiesel sample ranged from 20.65 to 24.22. Cetane numbers are frequently estimated using the determined cetane index (ASTM D976 or D4737). The cetane number of diesel fuels is proportional to the length of the hydrocarbon chain [54].

Although biodiesel has been reported to have better lubricity characteristics as compared to diesel fuel [55]; the wear of various important parts of the engine appears to be higher during the test fuel application [56]. The lubricity issue is important since the introduction of low sulfur petrodiesel fuels, and more recently, ultra-low-sulfur diesel (ULSD) fuels, as mandated by regulations, has resulted in the failure of engine parts such as fuel pumps and injectors, which are lubricated by the fuel itself [53]. Hence, the biodiesels that blend with petrodiesel are highly recommended. The tribological issues associated with the utilization of biodiesels and also the biofuel standards and regulations are reported in [12].

5. Conclusion

Due to the declining global petroleum reserves, strict emission requirements, and climate change policies, research into alternative energy sources has grown in importance. According to the findings of the study, edible vegetable oils such as *Cucumeropsismannii*, *A. hypogea*, and *G. Max*) seed oils are good alternatives to petrodiesel. The best percentage yield was achieved using 1% sodium hydroxide as a catalyst with a 6:1 methanol/oil molar ratio at 65°C.The optimum time for the transesterification reaction was 60 min. The maximum percentage yield of biodiesel was obtained at90.83% for *G. max*, 78.00% for *A. hypogea*, and 77.58% for *Cucumeropsismannii* seed oils. It was determined that the temperature and time of reaction affected the percentage yield of biodiesel. *G. max* gave a better yield than waste vegetable oil, followed by *A. hypogea* and *Cucumeropsismannii*, respectively. It was evident from the data that the fuel produced met all the necessary biodiesel fuel standards.

Conflict of Interest

The authors declare no conflict of interest.

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