Production and characterization of biofuel production from Egusi (citrullus lanatus) vegetable oil

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Abstract: Green house effect and ozone layer depletion due continuous environmental pollution from fossil fuel has speed up the quest for search of alternative energy fuel. In recent year, biofouls has attracted much attention as a reliable substitute to fossil fuel. The objective of this study was to evaluate and characterize biofuel produced from Egusi vegetable oil by applying standard method of transesterification. This study was carried out at Processing and Storage Engineering Departmental (PSED) laboratory of National Centre for Agricultural Mechanization (NCAM), Ilorin Kwara State, Nigeria. The results of the proximate characterization of the produced Egusi vegetable oil shows crude protein, crude fibre, ether extract, moisture content, ash content and carbohydrate composition of 20.6%, 13.3%, 50.6%, 4.3%, 3.0% and 8.2% respectively. The transesterification of Egusi vegetable oil in this study yielded 63.7% of methyl ester. The characterization results of the biofuel produced shows kinematic viscosity, density, cloud point, flash point, pour point, fire point, acid value, iodine value, saponification and specific gravity values of 4.6, 0.714, 5, 210, -3, 250, 0.54, 0.69, 0.26 and 0.915 respectively. The results were compared with the American Society for Testing Materials (ASTM 6751) for standard. Information from this study will expand the scope of knowledge on the search for an alternative fuel to fossil fuel. Also, this will serve as a guide in both policy and management of global warming.

Keywords: Egusi vegetable oil, characterization, transesterification, methyl esters, biofuel

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1 Introduction

Green house effect and ozone layer depletion due continuous environmental pollution from fossil fuel has speed up the quest for search of alternative energy fuel. Likewise, the fact that fossil fuel reserve is limited has lead researchers to discovering of an alternative source of energy fuel. In Nigeria, as of 2011, there are about 5.91×109 m^3 of proven oil reserves, ranking Nigeria as the largest oil producer in Africa and the 11th largest in the world, averaging 362×103 m^3/d in 2006. However, the Nigeria's oil reserve is predicted to drying up in the next 25 to 30 years. Other key factors leading to search for alternative sources to petroleum-based fuels (fossil fuel) are the concern about environmental pollution and diminishing supply of petroleum-derived fuels. Alternative fuels from domestic sources are evolving as solution to the diminishing reserves of fossil fuels, and the environmental unfriendliness resulting from the combustion of fossil fuels. Among different possible alternative resources, biofuels has attracted much attention as a reliable substitute to fossil fuel for combustion engines. The fact that biofuels is renewable, non-toxic, environmentally acceptable and can be domestically produced make it widely accepted (Meher

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et al., 2006). Also, the invention of renewable biofuels production has given room for further research studies.

Most plants have being demonstrated of having the capability of producing biofuels. Some of these plants include oilseeds, algae, soyabeans, sugarcane, melon, cornet, but there are other promising sources that aren't food crops such as corn stover, lawn and tree waste, wood chips, switchgrass and miscanthus respectively.

There are types and classes of biofuel depending on their parent materials such as those of *ethanol* (made from corn, sugarcane), *biodiesel* (made from vegetable oils and liquid animal fats), green diesel (made from algae and other plant sources) and biogas (methane derived from animal manure and other digested organic material.

Since biofuels are made from renewable resources, they cause less pollution to the environment as compared to the fossil fuel. However, this is not the only reason why the use of biofuels is being encouraged. They also release lower levels of carbon dioxide and other emissions when burnt and as well as mitigating the effects of global warming produced by fossil fuels. Using biodiesel as a vehicle fuel increases energy security, improves air quality and the environment, and provides safety benefits.

Despite there are many advantages of biofuel, there are also some disadvantages to this energy source, among which include they have a lower energy output than traditional fuels. It therefore requires greater quantities to be consumed in order to produce the same energy level as fossil fuel and it uses land that could be used to grow food (www.wikipedia.com).

Biodiesel is an animal or vegetable oil based biofuel that burns without the emission of much soot, carbon IV oxide and particulate matter. Demshemino et al. (2013) in their study reported that biofuel is an alternative fuel that is obtained from renewable resources that burns in diesel engines with less environmental pollutants. In recent years, the acceptance of biofuel as an alternative energy fuel is increasingly becoming popular.

Literature review showed that the physical properties between biofuel and fossil fuel are alike but not identical. Sanjay (2013) reported that, biofuel can be used as a direct alternative to fossil petroleum and it is technically called B100. Research study conducted by Ramadhas et al. (2005) deduced that the use of high viscous oils on the combustion engines as a fuel leads to adverse pollution. Thus, for these high viscous oils to be compatible with existing combustion engines, it must be bederivatized, this process is to reduce viscosity in oil. One of the possible ways to achieve this purpose is conversion of large, branched triglycerides into smaller, straight-chain molecules of monoalkylester through a process called transesterification (Piyanuch and Sasiwimol, 2009). Transesterification is a relatively simple process that yields high conversion of vegetable oil with glycerol as the only byproduct. For this reaction to occur, it is necessary to accelerate the transesterification of the vegetable oil with a short chain of alcohol such as methanol, ethanol, butanol or propanol as a catalyst. A catalyst is usually required because the transesterification reaction is a very slow reaction, and can be achieved by using acid catalysis or base catalysis (Meher et al., 2006).

Thompson et al. (1998) in their study reported that, in Africa and Nigeria in particular, there is a huge potential for the development of biofuels as an alternative energy source, this is due to the fact that there is wide variety of plants produced in the country that could be used as biofuel sources. Oils from Jatropha, melon, palm oil, soybean, sugar cane, and used oil can be used to make biodiesel (Folaranmi, 2012).

In recent year, research has shown that Egusi (*Citrullus lanatus*) plant could be a new contender as a potential feedstock because of its high oil content. Egusi (*Citrullus lanatus*) is the biological ancestor of the watermelon now found all over the world, but originated from West Africa (Ojieh et al., 2007). Egusi melon belongs to the Cucurbitaceae. Unlike the familiar watermelon, whose flesh is sweet and red, the Egusi melon's juicy flesh is pale yellow or green, and also has bitter tastes. A creeping annual herb, the Egusi melon has hairy stems, forked tendrils and three-lobed hairy leaves. Ojieh et al. (2007)

reported that Egusi melon comprises 50% oil and 35% protein. However, the Egusi seeds have economic, nutritional and cosmetic significance. Lazos (1986) reported in his work that Egusi seeds contain vitamin C and B2, minerals, riboflavin, fat, carbohydrates and protein.

Biofuels productions have being receiving attention from researchers in recent years. A method of producing fuel from plants or other sources could potentially decrease the dependence on fossil fuels as well as mitigating the effects of global warming. Energy crop such as Egusi melon is perhaps an area that needs to be exploring based on its potentials of producing quality vegetable oil for biofuel production. Despite the vast economic, nutritional and medicinal values of Egusi melon, little details on production of biofeul from Egusi vegetable oil and its compositional characteristic are available in literature. This study is therefore aimed at investigating the biofuel produced from Egusi vegetable oil. Information from this study will expand the scope of knowledge on the search for an alternative fuel to fossil fuel. Also, information guarded from this study will serve as a guide in both policy and management of global warming.

The objective of this study was to evaluate and characterize biofuel produced from Egusi vegetable oil by applying standard method of transesterification.

2 Material and methods

2.1 Study area and sample collection

This research study was carried out at Processing and Storage Engineering Departmental (PSED) laboratory of National Centre for Agricultural Mechanization (NCAM), Ilorin Kwara State Nigeria.

NCAM showing PSED laboratory

Figure 1 Google Earth Arial view Map of NCAM showing PSED laboratory

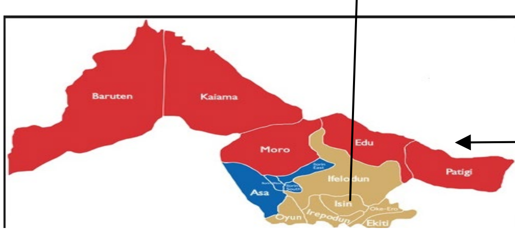

Figure 2 Map of Kwara State Showing Oyun River Basin

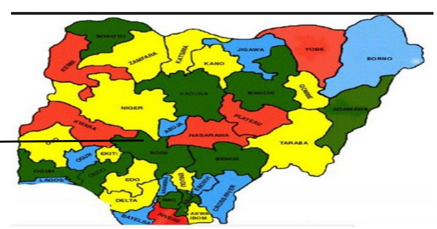

Figure 3 Map of Nigeria showing location of Kwara State

NCAM is about 20 km to Ilorin the Kwara State capital. NCAM has an estimated terrain elevation of 370 m above sea level and lies between Latitude 9^{o}50' and 8^{o}24'North and Longitudes 4^{o}38' and 4^{o}03' East (Awu et al., 2007). Rain normally starts falling in April and stop late October, with June and September recording the highest rainfall values while the dry season lasts from November to March. The mean annual rainfall values of the study area is about 1700 mm while the mean monthly maximum and minimum temperature values in the area are 31^{o}C and 29^{o}C respectively with the highest temperature values recorded in the months of February through April. The potential Evapotranspiration of the area is between 1500 to 1700 mm per annum (Manta et al., 2010). Figure 1, 2 and 3 shows map of Nigeria, Kwara States and NCAM PSED Laboratory, respectively.

All reagent used in this study were all of analytical grade and were all available at Processing and Storage Engineering Departmental laboratory of NCAM.

The Egusi seeds used in this study were purchase from Amaoyo market, Ilorin, Kwara State and were identified as citrullus lanatus by an agronomist in the department. Amayo market is one of the conventional open market in Kwara State that operates in every five day of the week.

2.2 Production of Egusi vegetable oil

The purchased Egusi seeds were screened to get rid of bad ones and good ones were chosen as the true Egusi seed for the biofuel production. The good Egusi seeds were likewise shelled and winnowed manually. The Egusi seeds were further dried in an oven at 70°C and were grounded very well with a mechanical blender. The blended Egusi seeds was put in an air-tight container and stored in desiccators for further analysis. The blended Egusi seeds were characterized for moisture content, ash content, crude protein, crude fibre and ether extract using standard methods described by Ojieh et al. (2007). The characterization test was tested in triplicate and average value was taken. The average value of the characterization result stands as the true value for that parameter under examination. The samples nitrogen was determined and converted to protein by multiplying by factor of 6.25.

The blended Egusi seed was further soaked in hexane and ether solutions to extract the oil. The mixture was then kept 24 hours for settling. The oil-solvent mixture was decanted after 24 hours. The decanted mixture was allowed to concentrate at a temperature of 65ºC in a rotary evaporator to release hexane and ether solutions. Therefore**,** the resultant biomass was collected after filtration and drying. The oil yield was evaluated as the ratio of the weight of the extracted oil to the weight of the blended Egusi seed sample using Equation 1

$$\%\, oil\ yield = \frac{weight\ in\ grams\ of\ oil\ extracted}{weight\ in\ gram\ of\ oil\ sample} \quad (1)$$

However, Figure 4 shows the flow chart of steps taken in the production of biofuel from Egusi vegetable oil

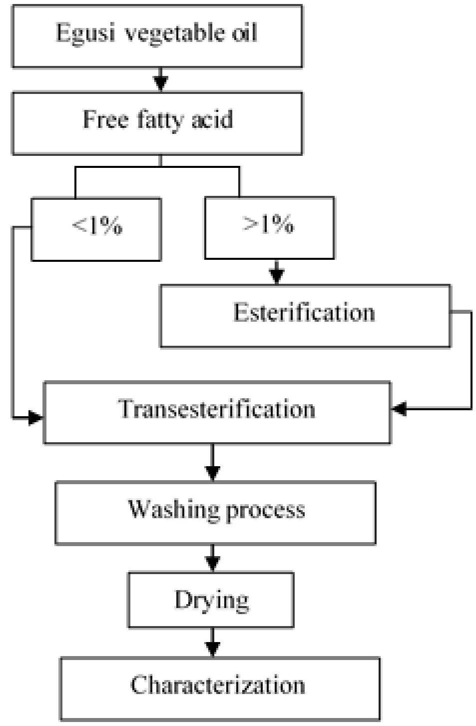

Figure 4 Flow chat of unit operation for biofuel production

The free fatty acid (FFA) composition of vegetable oil plays significant role when producing biofuel for diesel engines (Ramadhas et al., 2005). Ramadhas et al. (2005) investigated the physicochemical properties and fatty acid profile of Egusi vegetable oil from supercritical carbon dioxide extraction and found out that the fatty acid composition of Egusi vegetable oil analysed using gas chromatography showed a high linoleic acid approximately 53% and oleic acids value of 19%. Thus, in this study, the FFA content of Egusi vegetable oil was established to be 56%, therefore, the biodiesel production by transesterification was carried out using standard experimental method.

A heterogeneous reaction of mixing catalyst and methanol was employed. 1 g of zinc oxide (ZnO) and calcium oxide (CaO) was mixed with 60 mL of methanol and stirred properly for about 5min for proper dissolution of the catalyst. The reaction process is called transesterification. The mixture of the catalyst with methanol was poured into the Egusi vegetable oil in a conical flask in ratio of 1:6:1 for catalyst, methanol and Egusi vegetable oil, respectively. The conical flask containing the mixture was stirred and heated for 60 minutes at a temperature of 60ºC using a magnetic stirrer regulatory hotplate.

After stirring the solution for 60 minutes, it was allowed to settle under gravity for 24 hours in a flask separator. Two layers were clearly observed. The bottom layer consists of glycerin, catalyst, impurities and traces of unreacted oil. The upper layer consists of biofuel and excess alcohol.

The biofuel was separated from the residue layers which consist of glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil by flask separator.

After the separation, Egusi methyl ester was mixed and washed with warm distilled water to remove the impurities and allowed to settle under gravity. This was done until the clear water was seen below the biofuel in the separating funnel. The washed sample was dried by placing it on a hot plate and excess water in the biodiesel was removed. The Biodiesel production was measured using measuring cylinder and stored for analysis

2.3 Evaluation of the biofuel yield

The percentage methyl ester yield was evaluated as the ratio of the weight of the biofuel produced to the volume of the Egusi vegetable oil used using Equation 2.

$$Methyl\ ester\ yield = \frac{\text{volume}\ of\ methyl\ ester\ produced}{\text{volume}\ of\ oil} \quad (2)$$

The fuel properties were determined according to standard methods of American Society for Testing Materials (ASTM 6751). The kinematic viscosity of the fuel samples was determined by the method in ASTM D445 using Cannon-Fenske Capillary Viscometer tube. The specific gravity of the fuel samples was determined by means of pyconometer according to the method described in ASTM D1298. The flash point of the fuel samples was determined by heating the sample of the fuel in a stirred container and passing a flame over the surface of the liquid according to the method described in ASTM D93 by using the Pensky Martens flash point closed apparatus. As described in ASTM D97, the pour point of the fuel samples was determined by cooling the sample at a specified rate and the sample was examined at 3º C intervals for flow. The lowest temperature in which sample movement was observed is noted as the pour point. Also, as described in ASTM D2500, the cloud point of the fuel sample was determined by visually inspecting for a haze in the normally clear fuel, while the fuel was cooled under carefully controlled conditions. The acidic value was determined according to the ASTM D 664 test method using a pH sensitive probe. The saponification value, iodine value, and acid value of the oil samples were determined according to the method described in the American Oil Chemists Society (AOCS) official and tentative method.

3 Results and discussion

3.1 Proximate characterization of Egusi vegetable oil

In this study, results were produced based on the production of biofuel from Egusi seed. Hence, proximate characterization of the vegetable oil extracted from Egusi seed was carried out. Results of the proximate characterization of Egusi vegetable oil are shown in Table 1.

Table 1 Proximate characterization of Egusi vegetable oil

S/No.	Composition	Weight by percentage (%)
1	Crude protein	20.6
2	Crude fibre	13.3
3	Ether extract	50.6
4	Moisture content	4.3
5	Ash content	3.0
6	Carbohydrate	8.2

Results from Table 1, shows that the crude protein, crude fibre, ether extract, moisture content, ash content and carbohydrate composition of Egusi vegetable oil are 20.6%, 13.3%, 50.6%, 4.3%, 3.0% and 8.2% respectively. The moisture content value of Egusi seed (4.3%) recorded in this study agrees very close to the reports of Ojieh et al. (2007) for Egusi but appears to be low compared for legumes ranging between 7.0% and 10% as reported by Aykroyed and Doughty (1964). Also, the ash content value of 3.0% recorded in this study is mathematically above the range of 1.5% – 2.5% recommended for seeds and tubers for animal feed formulation (Ojieh et al., 2007). Therefore, this result shows that perhaps Egusi seed is not suitable for animal feed production but is a very good asset to biofuel production because of its high level of oil content. The ether extract (crude fat) content of 50.6% obtained in this study agrees to the reported of Ige et al. (1984) for varieties of melon oil seeds which ranged between 47.9% and 51.1%. They concluded that processing conditions and size of the material may be responsible for effects in the yield of oil from the seeds. The proximate values recorded in this study may be attributed to differences in varieties, genetic, environment, ecology, harvesting conditions of the Egusi crop and also the extraction method employed.

3.2 Egusi methyl ester yield

The transesterification process of Egusi vegetable oil in this study yielded 63.7% of methyl ester on a volume basis as shown in Table 2. This value is lower than the 78.80% obtained by Sahoo et al. (2007) for the production of biodiesel from *Hibiscus Cannabinus*. The low yield obtained in this study may be attributed to difference in production process such as; molar ratios of alcohol/oil, catalyst used, reaction time, temperature, presence of moisture and FFA. The methyl ester yield experiment was replicated trice and average value was taken as the true value for the parameter under examination.

Table 2 Egusi methyl ester yield

Experiment No.	Mass of milled Egusi seed sample, M_i (g)	Mass of Egusi seed oil, Mx_i (g)	Percentage oil yield, $\frac{Mxi}{Mi} X\ 100\%$
1	250	186.9	62.3
2	300	187.7	62.57
3	350	198.3	66.1
Average	300	190.967	63.7

3.3 Characterization of Egusi methyl ester

The characterization of the biodiesel produced was carried out at the laboratory of food processing and storage engineering Department of national centre for agricultural mechanization, ilorin, and the biofuel properties of Egusi methyl ester results obtained are presented in Table 3. The results are placed with the corresponding limit set of ASTMD6751 for biofuel standard.

Table 3 Characterization of biofuel produced from Egusi vegetable oil and biofuel production Standard by ASTM

Property	Unit	Limit(ASTMD6751)	Egusi oil methyl ester
Kinematic viscosity (40^{0}C)	$mm^2\ s^{-1}$	1.9–6.0	4.60
Density (15°C)	$g\ cm^{-3}$	860- 900	0.714
Cloud point	°C	nd	5
Flash point	°C	>130	210
Pour point	°C	nd	-3
Fire point	°C	nd	250
Acid value	mg KOH/g	<0.80	0.54
Iodine value	G I_2/100 g	nd	0.69
Saponification value	mg KOH/g	nd	0.26
Specific gravity (29°C)		<0.95	0.915

Note: nd =Not defined.

Source: Standard values of Biodiesel were extracted from the ASTM

Results from Table 3 shows the characterization of Egusi methyl ester values of kinematic viscosity, density, cloud point, flash point, pour point, fire point, acid value, iodine value, saponification value and specific gravity for 4.6 m^2/s, 0.714 g/cm^3, 5°C, 210 °C, -3 °C, 250 °C, 0.54mg, 0.69mg, 0.26mg and 0.915 g/cm^3 respectively.

The flash point and fire point of the biofuel produced were between 210°C and 250°C respectively. Flash point and fire point are important temperatures specified for safety during transport, storage and handling. The biofuel produced from Egusi vegetable oil has higher flash point of 210°C above the ASTM biofuel standard (>130°C), therefore, the Egusi biofuel would be safe for use and storage.

Cloud and pour points are criterion used for low temperature performance of fuel. The cloud point and pour point obtained in this study were 5°C and -3°C. These values are well in agreement with the ASTM biofuel standard and agreed closely with the values reported by Folaranmi (2012) on Production of biofuel from Jatropha oil using sodium hydroxide as catalyst recorded a cloud point value of 3ºC. However, Oniya and Bamgboye (2014) reported that the higher cloud and pour points of the biofuel than the reference ASTM standard may incur some complications for their use in diesel engine during cold weather. Therefore, the test results of cloud and pour point obtained shows that the produced biofuel could indeed be used as a fuel in cold-weather conditions. Another important parameter value obtained from the characterization of the biofuel produced is the kinematic viscosity of the fuel which measures its resistance to flow. The kinematic viscosity value was recorded to be 4.60 mm^2 s^{-1} which falls within the ASTM limit for biofuel. The viscosity of a fuel is an important parameter because it affects the atomization of the fuel being injected into the engine combustion chamber. High values of kinematic viscosity give rise to poor fuel atomization, incomplete combustion, and carbon deposition on the injectors. Therefore, the biodiesel viscosity must be low for effective performance. The biofuel density obtained was 0.714 g cm^{-3}. This value is within the range specified by ASTM D1298. Knowing the density of a fuel is very essential in the manufacturing, storage, transportation and distribution process of biofuel as it is an important parameter to be taken into account in the production of biofuel (Barabás and Todorut, 2011). The specific gravity of the Egusi biofuel was observed as 0.915. This is also falls within the range specified by ASTM D1298 standard shown in Table 3. The acid value for Egusi methyl ester was observed as 0.54 mg KOH/g which fall within the ASTM standard. The acid value is a parameter that shows the degree of fuel ageing during storage, as it increases gradually due to degradation of biodiesel.

More so, the iodine number for the Egusi methyl ester was observed as 0.62 g I_2/100 g. The iodine value is a parameter used to measure the chemical stability property of substance against oxidation. Adebayo et al. (2011) in their studies reported that the higher the iodine value the higher the number of double bond and hence lesser stability. The iodine value highly depends on the nature and feedstocks used in the biofuel production (Barabás and Todorut, 2011).

4 Conclusion

Egusi seeds, although having some vast economic, nutritional and medicinal significance, it has found its fit in sustainable biofuel production due to its high oil content. This study has demonstrates that biofuel can successfully be produced from Egusi vegetable oil using Stanadard method of transesterification. Some of the properties of the Egusi methyl ester investigated in this study showed a good results falling within ASTM standard. It is therefore concluded that the biofuel produced from the Egusi vegetable oil is a potential substitute to fossil fuel. It is believed that information guarded from the production of biofuel from Egusi seed will serve as a guide to government and agencies both in policy and management of the production of biofuels.

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