International Scientific Organization
http://iscientific.org/
Chemistry International
www.bosaljournals.com/chemint/

Mango (*Magnifera indica*) seed oil grown in Dilla town as potential raw material for biodiesel production using NaOH- a homogeneous catalyst

Tsegay Hiwot

Department of Chemistry, College of Natural and Computational Sciences, Adigrat University, Adigrat, Ethiopia
*Corresponding author's E. mail: tsegayhi@gmail.com

ARTICLE INFO

Article type:
Research article
Article history:
Received January 2018
Accepted June 2018
October 2018 Issue
Keywords:
Mango seed oil
Biodiesel
Transesterification
Homogeneous catalyst
n-Hexane
FAME
GC-MS

ABSTRACT

Biodiesel produced by transesterification process from vegetable oils or animal fats is viewed as a promising renewable energy source. Now a day's diminishing of petroleum reserves in the ground and increasing environmental pollution prevention and regulations have made searching for renewable oxygenated energy sources from biomasses. Biodiesel is non-toxic, renewable, biodegradable, environmentally benign, energy efficient and diesel substituent fuel used in diesel engine which contributes minimal amount of global warming gases such as CO, CO_2, SO_2, NO_X, unburned hydrocarbons, and particulate matters. The chemical composition of the biodiesel was examined by help of GC-MS and five fatty acid methyl esters such as methyl palmitate, methyl stearate, methyl oleate, methyl linoleate and methyl linoleneate were identified. The variables that affect the amount of biodiesel such as methanol/oil molar ratio**,** mass weight of catalyst and temperature were studied. In addition to this the physicochemical properties of the biodiesel such as (density, kinematic viscosity, iodine value high heating value, flash point, acidic value, saponification value, carbon residue, peroxide value and ester content) were determined and its corresponding values were 87 *Kg/m³*, 5.63 *Mm²/s*, 39.56 g I/100g oil, 42.22 MJ/Kg, 132°C, 0.12 mgKOH/g, 209.72 mgKOH/g, 0.04%wt, 12.63 meq/kg, and 92.67 wt% respectively. The results of the present study showed that all physicochemical properties lie within the ASTM and EN biodiesel standards. Therefore, mango seed oil methyl ester could be used as an alternative to diesel engine.

Capsule Summary: The biodiesel production efficiency from mango seed oil was evaluated. methylpalmitate, methyl stearate, methyl oleate, methyl linoleate and methyl linoleneate were the main components of the biodiesel and mango seed oil methyl ester could be used as an alternative energy resource in diesel engine.

Cite This Article As: T. Hiwot. Mango (*Magnifera indica*) seed oil grown in Dilla town as potential raw material for biodiesel production using NaOH- a homogeneous catalyst. Chemistry International 4(4) (2018) 198-205.

INTRODUCTION

Increasing energy demands, depletion of fossil fuels and environmental pollution make the world under crises now a day's. This is because of many countries worldwide are still heavily dependent on petroleum as their main source of electricity and transportation fuel. The only possible solution to solve this crisis is to find a sustainable (renewable), economically feasible and environmentally friendly source of alternative energy is necessary. There are many alternative energy sources such as hydropower, wind, solar, geothermal

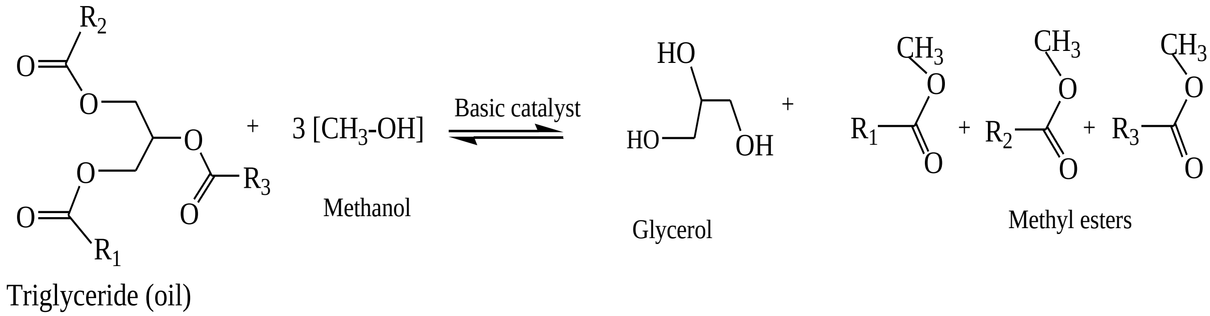

Fig. 1: base catalyzed transesterification processes

Table 1: Experimental treatments

Methanol to oil molar ratio(T_1)	Temperature in ^oC (T_2)	%w/w of NaOH to oil (T_3)
3:1	45, 55,60 and 65	0.5
6:1		1
9:1		1.5

Where: T = treatment

and biomass. Biodiesel fuel is a renewable energy resource which is made from vegetable oils available around us (Kondamudi et al., 2008; Lebedevas et al., 2006; Nebel and Mittelbach, 2006).

Mango seed (*Magniferaindica*) is a waste where so many people are throwing away after using the fruit flesh. It is one of the most popular fruit in gedeo zones as a result there is a significant rise in mango fruit consumption and consequently an increase in the mango seed waste generation. Therefore, alternative routes are needed for this waste management.

This waste can be used for various applications. The presence of nitrogen allows it to be directly used as fertilizer or as soil improver (or compost) (Lebedevas et al., 2008).On the other hand, waste mango seed have oil content in the order of 9-13wt% depending upon its varieties which very less to compare other oil seeds. The oil is high in unsaturated fatty acid such as oleic acid with 46.22 % (Nzikou et al., 2010).

Biodiesel is a clean, renewable, biodegradable, environmentally benign, energy efficient and diesel substituent fuel used in diesel engine. It is a carbon neutral fuel because there is no overall increase in CO_2 in the atmosphere due to recycling by the growing plants used to feed the biodiesel industry (Lebedevas et al., 2008; Ma and Hanna, 1999). Emissions of SO_2, SO_3, CO, unburnt hydrocarbons and particulate matter are lower than that of petroleum diesel (Coronado et al., 2009; Ma and Hanna, 1999).The most common process used to produce biodiesel is through transesterification, a reaction between triglycerides and an alcohol with a low molecular weight (ethanol or methanol) in the presence of a basic catalyst (NaOH or KOH), to obtain esters and glycerol (Knothe et al., 2006; Mata et al., 2010 and 2011).Transesterification is a three-step reversible reaction of vegetable oils or animal fats with a methanol to form fatty acid methyl esters (FAMEs) and glycerol as a final product (Morais et al., 2010).

The reaction mechanism for the formation of fatty acid methyl esters (FAME) is described as follows (Fig. 2).

MATERIAL AND METHODS

Chemicals and reagents used

Methanol (99%), sodium hydroxide,), n-hexane, sodium thiosulfate, phenolphthalein, ethanol (96%), anhydrous sodium sulphate and mango seed oil.

Instrumentations

Soxhlet apparatus, Rotary evaporator, GC-MS, bomb calorimeter, viscometer, hot plate, thermometer, round bottom flask, separatory funnel and grinder were used.

Experimental design

A basic catalysts (NaOH) was used to study at which methanol/oil molar ratio**,** mass weight of catalyst and temperature an optimum biodiesel is produced from the oils of waste mango seed oil. Finally the physicochemical properties of the biodiesel were determined and compared with a set of parameter according to European Standard, EN 14214 and American standard test and material, ASTM6751.

Seed material preparation

Undamaged thrown mango seeds were collected from Dilla town, cleaned and oven dried at 105^oC for 1 hour to remove

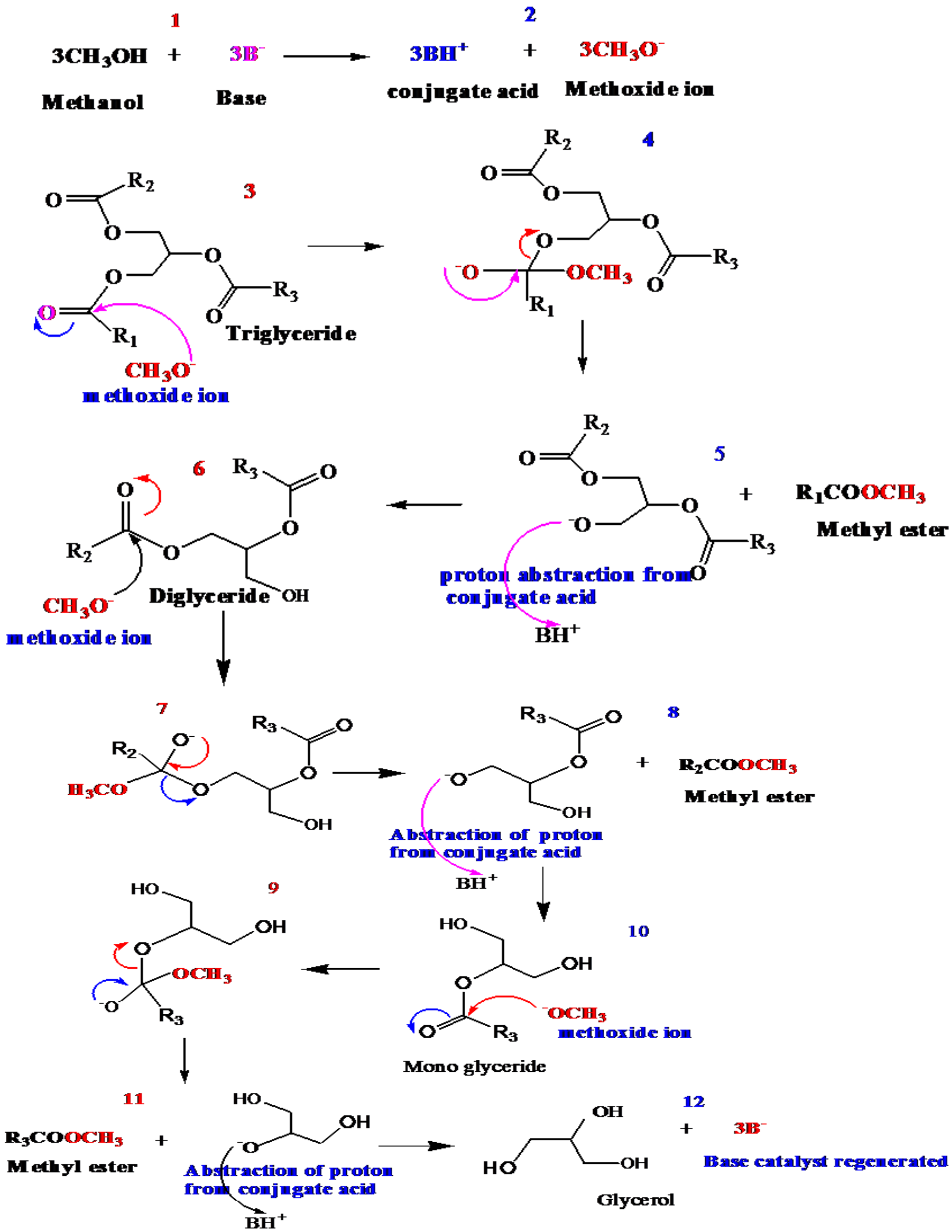

Fig. 1: Reaction mechanism for base catalyzed transesterification

the water content. After that the dried mango seeds were grounded using grinder and stored in sealed plastic bag for further use.

Oil extraction

Oven dried mango seeds were grounded in to powder by using grinder. After that 100g of the sample were loaded in to thimble in Soxhlet apparatus. Next to that extraction was carried out using 500 ml normal hexane at 68°c (boiling temperature of hexane) for 12hours in an electrical heater. The mixture of the extracted oil and the hexane was

Table 2: Physiochemical properties of biodiesel prepared from mango seed oil, Petroleum diesel and biodiesel Standards (ASTM D6751& EN 14214)

Fuel Properties	Biodiesel	Standards(USA&EU)		Petroleum diesel.	unit
		ASTM D6751	EN 14214		
Specific gravity	0.87	0.88		0.845	------
Density at 15^{o}c	87	------	860 – 900	845	*Kg/m³*
Kinamatic viscosity at 40^{o}C	5.63	1.9 -6.0	3.5 - 5.0	2.86	*Mm²/s*
Acid value	0.12	≤ 0.8	≤ 0.5	-----	mgKOH/g
Saponification value	209.72	-------	------	-----	mgKOH/g
Flash point	132	≥ 120	≥ 130	67.5	^{o}C
Higher heating value	42.22	-------	-------	45.5	MJ/Kg
Peroxide value	12.63	------	-----	-----	meq/kg
Iodine value	39.56	-----	≤ 120	-----	g I/100g oil
Carbon residue	0.04	0.05 max	--------	0.15Max	%wt
Ester content	92.67	-------	≥ 96.5	------	-----

Table 3: Methyl ester content, as function of mass weight of catalyst at methanol/oil molar ratio, 3:1, 6:1 and 9:1; reaction temperature, 60 ^{0}C; reaction time of 3 hours

Methanol/oil molar ratio,	Mass weight of catalyst, wt.%	Temperature in ^{0}C	Methyl ester content, w/w%
			Dilla Town
3:1	1%wt NaOH	60	84.65
6:1		60	92.67
9:1		60	89.57

Table 4: Methyl ester content, as function of mass weight of catalyst at methanol/oil molar ratio,6:1; reaction temperature, 45 ºC, 55 ºC,60 ºC and 65 ºC; reaction time of 3 hours

Methanol/oil molar ratio,	Mass weight of catalyst, wt.%	Temperature in ºC	Methyl ester content, w/w% Dilla Town
6:1	1%wt NaOH	45	88.78
6:1		55	91.83
6:1		60	92.67
6:1		65	86.45

separated by vacuum rotary evaporator (RE-52A, 220 V/50Hz) machine and the percentage of the oil was calculated by using the formula: % Oil = Mass of Oil x 100/ sample

RESULTS AND DISCUSSION

The biodiesel characterization shows similarities to that of fossil diesel. The Physiochemical properties of the biodiesel were determined. Several tests of the properties of biodiesel such as specific gravity, density, kinematic viscosity, iodine value, high heating value, flash point, acidic value, saponification value, carbon residue, peroxide value and ester content profile were determined and all the result were lie within the ASTM and EN standards except the percentage amount of ester produced (92.67%) which is less by 3.87% from its minimum value (96.5%) in EN standard as shown in Table 2.

Kinematic viscosity is a measure of resistance of fluid to flow under the influence of gravity (Gerpen et al., 2004). The result from this work shows a kinematic viscosity of 5.63 which is quite in agreement with the ASTM biodiesel standard but it is slightly higher than the European Standard and Petroleum diesel. Viscosity of a fuel is related to the fuel lubricity. Low viscosity fuels are unlikely to provide satisfactory lubrication in fuel injection pumps; these often lead to seepage and increase in wear (Raja et al., 2011). High viscosity in fuel are responsible for atomization of fuel, incomplete combustion and increased exhaust emissions, choking of the injections thereby forming larger droplets on injector, ring carbonization and accumulation of the fuel in the engine (Wang et al., 2006).

Specific gravity of the fuel is very important in diesel engine because fuel injection system operates on a volume metering basis. The values of specific gravity obtained for mango seed oil methyl ester was 0.87 with a corresponding density value of 87kg/m^3. This value lies within the ASTM standards and also in close proximity to the findings of other studies. The carbon residue is an indicator of residual carbon after combustion. The carbon residue for this study is measured to be 0.04 % wt which is less than the maximum value of ASTM standard (0.05% wt). (Gerpen*et al.*, 2004) reported that the major cause of surplus carbon residue in biodiesel is due excessive total glycerin present in it. The low value obtained in this study is due the complete separation and effective removal of glycerol after the tranesterification process.

Flash point is the minimum temperature at which a fuel must be heated for it to ignite air -vapor mixture. The U.S.Department of Transportation specified 90 ^{0}C as the flash point for non-hazardous fuel (Kenneth and Bruce. 2010). The flash point for this work is 132^{0}C. This result shows appreciable consistency with both ASTM, EN standard for biodiesel and works of other researchers. The high value obtained in this study clearly signifies that the biodiesel produced is basically free from methanol; this is because even small quantity of methanol can reduce the flash point reasonably and also negatively affects diesel engine parts such as fuel pumps, seals and elastomers. The acid value obtained in this work is very small (0.12) to compare with the ASTM and EN standard (≤ 0.8 and ≤ 0.5) respectively and reported work of (Enweremadu and Alamu., 2010). Acid value measures directly the free fatty acids content of the methyl ester. It clearly helps to state the corrosive nature of the fuel, its filter clogging tendency and the amount of water that may be likely present in the biodiesel. This parameter can also be used to measure the freshness of the biodiesel. The higher the acid value the lower the quality of the fuel. Generally from the physiochemical properties of the biodiesel produced from mango seed oil table 2 above it can be used as diesel substituent fuel.

Effect of different variables in the amount of biodiesel produced

Several variables which affect the yield of FAMEs were studied. These are mass weight of catalyst, methanol to oil molar ratio and temperature. Their effect of each variable was shown in Tables 3-5.

Effect of variation of methanol/oil molar ratio in the amount of biodiesel produced

The amount of methyl ester in the transesterification process activity depends on the molar concentrations of methanol to oil (Table 3). Large excess methanol is required to shift the equilibrium favorably during transesterification for better yields of biodiesel (Sree et al., 2009). When the methanol/oil molar ratio was increased from 3:1 to 6:1, an increase in methyl ester content was observed but further increasing methanol/oil molar ratio from 6:1 to 9:1 a decrease in methyl esters content was observed. This is because the higher alcohol molar ratio interferes with the separation of glycerol from the biodiesel due to an increase solubility of glycerol in the alcohol (Table 3).

Effect of variation temperature in the amount of biodiesel produced

Temperature plays an important role during biodiesel production; this is because the rate of reaction is strongly influenced by the reaction temperature (Devanesan et al., 2007, Bajpai and Tyagi., 2006). Table 4 above shows the amount of biodiesel varies with temperature variation from 45^{0}C to 65^{0}C at a catalyst concentration of 1 % wt. As the temperature increase from 45 - 60 ^{0}C the conversion yields of biodiesel also increases considerably. Further increase in temperature results in decrease in the yield of biodiesel.Literatures have reported that alkaline transesterification are conducted close to the boiling point of the alcohol used and that temperature higher than this burns the alcohol resulting into lower yield. Patil and Deng (Patil and Deng, 2009), reported that alkaline transesterification at temperature above 60 ^{0}C cause excessive methanol loss due to evaporation and significantly reduce overall biodiesel yield. And that saponification of glycerides by alkali catalyst is much faster than the transesterification reaction above 60^{0}C. This may be another plausible reason for the observed low conversion at 65^{0}C.

Effect of variation of mass weight of catalyst in the amount of biodiesel produced

From the result obtained as shown in table 5 above, as the mass weight of catalyst increase from 0.5 to 1 %wt a progressive increase in percentage conversion in the reaction was achieved and thereafter experienced a decrease in the yield above this concentration (1 % wt of NaOH). It was obvious that increase in catalyst concentration beyond 1 % wt of NaOH results in a decrease in biodiesel yield. Hence the yield at 1.5 % wt (85.92%) was lower than the yield obtained at 0.5%wt (89.87%). This can be clearly explained by the reversible nature of transesterification reaction. The findings from this studies is very consistent with opinion of Darnoko and Munnir 2000), who reported that catalyst concentration greater than 1 % wt may have favored the backward reaction, thereby shifting the equilibrium from the right to the left, hence the formation of glycerol. In comparing to results of this findings with that of previous researchers such as (Tint and Mya, 2009) for Jatropha Curcas oil and (Oghome and Ibe, 2009) for Tiger nut oil as biodiesel resource showed efficient performance.

GC-MS analysis of biodiesel prepared from waste mango seed oil

Based on GC-MS analysis, the FAME of biodiesel prepared from waste mango seed oilsgrown in Dilla town, five compounds were identified as described in detail in Table 6.

Table 5: Methyl ester content, as function of mass weight of catalyst at methanol/oil molar ratio, 6:1; reaction temperature, 60 ºC; reaction time of 3 hours

Methanol/oil molar ratio,	Mass weight of catalyst, wt.%	Temperature in ºC	Methyl ester content, w/w% Dilla Town
6:1	0.5	60	89.87
6:1	1	60	92.67
6:1	1.5	60	85.92

Table 6: Chemical composition of FAMEs of waste mango seed oil by GC-MS analysis

Fatty acid methyl ester	Position of double bond in FAMEs	Molecular mass	Amount (%)
Methyl palmitate	----	270	9.72
Methyl linoleneate	18:3, Δ 6,9,12	292	37.45
Methyl linoleate	18:2, Δ 9,12	294	44.10
Methyl oleate	18:1 , Δ 9	296	6.79
Methyl stearate	-----	298	1.94
Saturated fatty acid methyl esters	-----	----	47.17
Unsaturated fatty acid methyl esters	------	-----	52.83

Analysis of mass fragmentation of fatty acid methyl esters prepared from mango seed oil

Based on the GC-MS analysis on chemical composition of the biodiesel produced from mango seed oil grown in Dilla town, five fatty acid methyl esters such as methyl palmitate, methyl stearate, methyl oleate, methyl linoleate and methyl linoleneate were identified. The molecular ion (parent) peaks of methyl palmitate, methyl linoleneate, methyl linoleate,methyloleate and methyl stearate were observed at 270,292, 294, 296 and 298 respectively. The saturated FAMEs detected in the biodiesel from mango seed oil(methyl palmitate and methyl stearate) show$CH_3OC(=OH^+)CH_2$ fragment and appears at m/z = 74as the base peak (100%) which is the result ofMcLafferty rearrangement due to the formation of a six member ring structure of anintermediate. In the lower molecular weight region of methyl linoleneate, hydrocarbon ions with a general formula of $[C_nH_{2n}\text{-}5]^+$ were dominated with the ion at m/z = 79 as the base peak.

Methyl linoleate shows$[CH_2{=}CHCH{=}CHCH_2]^+$ fragment which appears at m/z= 67 as the base peak (100%). Methyl oleate shows $[CH_2{=}CHCH_2CH_2]^+$ fragment which appears at m/z =55 as the base peak (100%).

The methyl palmitate base peak ion at m/z=74 undergoes McLafferty rearrangement losing the methyl ester which is fragmented between the α and β substituted carbons while the ion at m/z=87 is fragmented between C4 – C5 also loosing methyl ester and a hydrogen atom. An ion with m/z =57 is fragmented between C3 and C4 losing a methylene diol and three hydrogen atoms via McLaffertyrearrangement. methyllinoleneate molecular ion occurs at m/z = 79 and other dominant peaks in the molecule such as m/z = 93, 107, 121 and 135 are due to fragmentation of the molecule hydrocarbon ions with a general formula of $[C_nH_{2n}\text{-}5]^+$. Methyl linoleate's molecular ion occurs at 294 m/z. Both ions at m/z = 67 and 81 represent hydrocarbon fragments with general formula $[C_nH_{2n}\text{-}3]$ loosing dialkenes and a hydrogen atom. Methyl oleate's parent peak is observed at m/z= 296. The peak at m/z = 74 represents the rearranged McLafferty methyl ester fragment while the peak at m/z= 87 represents fragmented hydrocarbon ions with general formula $[CH_3OCO(CH_2)n]$. Methyl stearate's molecular ion occurs at m/z = 298. The ion present at m/z = 74 corresponds to the McLafferty rearranged methyl ester fragmented between the α and β carbons while the ion at m/z = 87 represents loss of methyl ester and a hydrogen atom fragmented between C3-C4 respectively. Molecular ion at m/z= 67 and 81 represent hydrocarbon fragments with general formula $[C_nH_{2n}\text{-}3]$ due to loss of alkenes and ahydrogen atom. Based on environmental pollution issues (Bhatti et al., 2016; Iqbal et al., 2013; Iqbal,2016; Iqbal et al., 2015; Iqbal and Bhatti, 2015; Iqbal et al., 2016; Iqbal and Nisar, 2015; Iqbal et al., 2017;Manzoor et al., 2013; Mushtaq et al., 2016; Nadeem et al., 2016; Nisar et al., 2016; Nouren et al., 2017; Rashid et al., 2016; Shoukat et al., 2017; Tahir et al., 2016a; Tahir et al., 2016b; Ullah et al., 2013) and energy needs, there is need to use renewable energy sources and mango seed oil found to be efficient for the production of biodiesel.

CONCLUSIONS

Biodiesel from mango seed oil is obtained by transesterification process using sodium hydroxide as catalyst. Optimum amount of methyl ester content (92.67%) was obtained at 60°C with methanol to oil molar ratio 6:1 and at 1%wt of NaOH. The physicochemical properties of the biodiesel were determined and compared ASTM and EN biodiesel standards and fulfills both properties. Therefore, mango seed oil methyl ester could be used as an alternative energy resource to diesel engine. Engine test and further researches are needed to be conducted to determine the amount of biodiesel produced with heterogeneous catalysts and lipase enzymes. The future prospects of this study gives direction for those investors that wants to invest in biodiesel production industry and as a reference material for other researchers.

REFERENCES

Bajpai, D., V.K Tyagi., 2006. Biodiesel: Sources, production, composition, properties and its benefits. Journal of Oleo Science 55, 487-502.

Bhatti, H.N., Zaman, Q., Kausar, A., Noreen, S., Iqbal, M., 2016. Efficient remediation of Zr(IV) using citrus peel waste biomass: Kinetic, equilibrium and thermodynamic studies Ecological Engineering 95, 216-228.

Coronado, C.R., Decarvalho, J.A., Yoshioka, J.T., Silveira, J.L., 2009. Determination of Ecological efficiency in internal combustion engines: The use of biodiesel, in Applied Thermal Engineering 29, 1887-1892.

Darnoko D. and Munnir C., 2000.Kinetic of palm oil transesterification in a batch reactor.Journal of American Oilchemist's 77, 1263-1267

Enweremadu, C.C. and Alamu O.J., 2010. Development and characterization of biodiesel from shea nut butter. International Agrophysics24, 29-34.

Gerpen, J.V, Shank, B, Pruszko, R, clement, D and Knothe, G., 2004.Biodiesel production Technology"; subcontractor report, July 2004 NREL/SR–510–36244 wwwjire/.gov. 1-10.

Iqbal, J.M., Cecil, F., Ahmad, K., Iqbal, M., Mushtaq, M., Naeem, M.A., Bokhari, T.H., 2013. Kinetic study of Cr (III) and Cr(VI) biosorption using Rosa damascenaphytomass: arose waste biomass. Asian Journal of Chemistry 25, 2099.

Iqbal, M., 2016. *Vicia faba* bioassay for environmental toxicity monitoring: a review. Chemosphere 144, 785-802.

Iqbal, M., Abbas, M., Arshad, M., Hussain, T., Khan, A.U.,Masood, N., Tahir, M.A., Hussain, S.M., Bokhari, T.H., Khera, R.A., 2015. Gamma radiation treatment for reducingcytotoxicity and mutagenicity in industrial Waste water. Polish Journal ofEnvironmental Studies 24, 2745-2750.

Iqbal, M., Bhatti, I.A., 2015. Gamma radiation/H_2O_2 treatment of a nonylphenolethoxylates: degradation, cytotoxicity, and mutagenicity evaluation. Journal of Hazardous Materials 299, 351-360.

Iqbal, M., Iqbal, N., Bhatti, I.A., Ahmad, N., Zahid, M., 2016.Response surface methodology application in optimization of cadmium adsorption by shoe waste: A good option of waste mitigation by waste. Ecological Engineering 88, 265-275.

Iqbal, M., Nisar, J., 2015. Cytotoxicity and mutagenicity evaluation of gamma radiation and hydrogen peroxide treated textile effluents using bioassays. Journal of Environmental Chemical Engineering 3, 1912-1917.

Iqbal, M., Nisar, J., Adil, M., Abbas, M., Riaz, M., Tahir, M.A., Younus, M., Shahid, M., 2017.Mutagenicity and cytotoxicity evaluation of photo-catalytically treated petroleum refinery wastewater using anarray of bioassays. Chemosphere 168, 590–598.

Kenneth R. S., Bruce A. M., 2010. Market Penetration of Biodiesel. International Journal of Energy And Environment 1, 53-68.

Knothe, G., Sharp, C.A., Ryan, T.W., 2006. Exhaust Emissions of Biodiesel, Petro diesel, neat methyl esters, and alkanes in a new technology engine, Energy and fuels 20, 403-408.

Kondamudi, N., Mohapatra, S.K., Misra, M., 2008. Spent coffee grounds as a versatile source of green energy, Journal of Agricultural and Food Chemistry 56(24), 11757-11760.

Lebedevas, S., Vaicekauskas, A., Lebedeva, G., Makareviciene,V., Janulis, P., Kazancev, K., 2006. Waste Coffee Grounds as an Energy Feedstock, Energy Fuels 20, 2274–2280.

Ma, F., Hanna, M.A.,1999. Biodiesel production: a review. Bioresource Technology 70, 1-15.

Manzoor, Q., Nadeem, R., Iqbal, M., Saeed, R., Ansari, T.M.,2013. Organic acids pretreatment effect on *Rosa bourbonia*phyto-biomass for removal of Pb(II) and Cu(II) from aqueous media. Bioresource Technology 132, 446-452.

Mata, T.M., Cardoso, N., Ornelas, M., Neves, S., Caetano, N.S.,2011. Evaluation of Two Purification Methods of Biodiesel from Beef Tallow, Pork Lard, and Chicken Fat Energy and Fuels 25, 4756-4762.

Mata, T.M., Cardoso, N., Ornelas, M., Neves, S., Caetano, N.S., 2010.Sustainable Production of biodiesel from Tallow, Lard and Poultry and its Quality Evaluation.

Morais, S., Mata, T.M.,Ferreira, E., 2010. Life Cycle Assessment of Soybean Biodiesel and LPG as Automotive Fuels in Portugal, Chemical Engineering Transactions 19, 267-272.

Mushtaq, M., Bhatti, H.N., Iqbal, M., Noreen, S., 2016.Eriobotrya japonica seed bio composite efficiency for copper adsorption: Isotherms, kinetics, thermodynamic and desorption studies. Journal of Environmental Management 176, 21-33.

Nadeem, R., Manzoor, Q., Iqbal, M., Nisar, J., 2016.Biosorption of Pb (II) onto immobilized and native Mangiferaindica waste biomass. Journal of Industrial and Engineering Chemistry 35, 185-194.

Nebel, B. A.; Mittelbach, M., 2006. Biodiesel from extracted fat out of meat and bone meal. European Journal of Lipid Science and Technology 108, 398–403.

Nisar, J., Sayed, M., Khan, F.U., Khan, H.M., Iqbal, M., Khan, R.A., Anas, M., 2016. Gamma– irradiation induced degradation of diclofenac in aqueous solution: Kinetics, role of reactive species and influence of natural water parameters. Journal of EnvironmentalChemical Engineering 4, 2573-2584.

Nouren, S., Bhatti, H.N., Iqbal, M., Bibi, I., Kamal, S., Sadaf, S.,Sultan, M., Kausar, A., Safa, Y., 2017. By-product identification and phytotoxicity of biodegraded Direct Yellow 4 dye. Chemosphere 169, 474-484.

Nzikou, J. M., Kimbonguila, A., Matos, L., Loumouamou, B.,Pambou-Tobi, N. P. G., Ndangui, C. B., Abena, A. A., Silou, Th.,Scher, J. and Desobry, S., 2010. Extraction and characteristics of seed kernel oil from mango (*Mangiferaindica*). Research Journal of Environmental and Earth Sciences 2(1), 31-35.

Oghome; P. Ibe, E.C., 2009. An Investigation into properties of Biodiesel from locally made groundnut oil. Global Journal of Engineering and Technology 21, 651–659.

Patil P.D; Deng S., 2009.Optimization of biodiesel production from edible and non–edible vegetable oils. Fuel 7(88), 1302–11306.

Raja Antony S., Robinson smart D.S. and C. Lindon Robert Lee., 2011.Biodiesel Production from Jatropha oil and its Characterization. Research Journal of Chemical Sciences 1(1), 81–87.

Rashid, A., Bhatti, H.N., Iqbal, M., Noreen, S., 2016. Fungal biomass composite with bentonite efficiency for nickel and zinc adsorption: A mechanistic study. Ecological Engineering 91, 459-471.

Shoukat, S., Bhatti, H.N., Iqbal, M., Noreen, S., 2017. Mango stone bio composite preparation and application for crystal violet adsorption: A mechanistic study. Microporous and Mesoporous Materials 239, 180-189.

Sree, R.; SeshuBabu, N.; Sai Prasad, P.S.; Lingaiah, N., 2009. Transesterification of edible and non-edible oils over basic solid Mg/Zr catalysts, in Fuel Processing Technology 90, 152-157.

Tahir, M.A., Bhatti, H.N., Iqbal, M., 2016. Solar Red and Brittle Blue direct dyes adsorption onto Eucalyptus angophoroides bark: Equilibrium, kinetics and thermodynamic studies. Journal of Environmental Chemical Engineering 4, 2431-2439.

Tahir, N., Bhatti, H.N., Iqbal, M., Noreen, S., 2016. Biopolymers composites with peanut hull waste biomass and application for Crystal Violet adsorption. International Journal of Biological Macromolecules 94, 210-220.

Tint T. k., Mya M. O., 2009. Production of Biodiesel from Jatropha Oil (*Jatropha Curcas*) in pilot plant.In Proceedings of World Academy of Science, Engineering and Technology.

Ullah, I., Nadeem, R., Iqbal, M., Manzoor, Q., 2013.Biosorption of chromium onto native and immobilized sugarcane bagasse waste biomass. Ecological Engineering 60, 99-107.

Wang, Y.Z., Shemmeri. T., Eames. P., McMullan. J., Hewitt, N., and Huang.Y., 2006. An Experimental Investigation of the performance and gaseous exhaust emission of adiesel using blends of a vegetable oil. Applied Thermal Engineering 26, 1684-1691.

Visit us at: http://bosaljournals.com/chemint/
Submissions are accepted at: editorci@bosaljournals.com