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Bio-lubricating base oil from castor oil (*Ricinous communus*)

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Abstract

Production and characterization of bio lubricating base oil from non-edible castor seed oil has been studied. Castor oil was extracted from castor seed by solvent extraction method. KOH catalyzed transesterification process was used to produce bio-lubricating oil. Ethanol was used as alcohol in the transesterification process. Optimum condition for bio-lubricating base oil production was 40% ethanol, 0.45% KOH at 75°C for reaction time of 90 min. and the yield was 98%. Important properties of produced bio-lubricating oil like acid value (0.58 mg KOH/g), flash point (235°C), density (0.890 g/cc), pour point (-15°C) and viscosity (131.90 and 16.5 cSt at 40 and 100 °C respectively) etc. were analyzed. The properties were found to be analogues to conventional commercial lubricating oil. This renewable base oil from castor seed could be an attractive and environment friendly alternative to base oil from petroleum sources.

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Introduction

Lubricants are using to reduce friction, reduce the risks of cutting failure and to smoother the machine operations. Lubricating oil consists of a base oil mixing with different additives to maintain the desired properties (Battersby *et al.,* 1992). The additives are added to improve some of their properties. The base oil is petroleum oil, vegetable, or synthetic oil. About 95% lubricating oil comprise of petroleum oil as base stock. Lubricating oil compositions mainly containing 60–99% base liquid along with additives. Additives are using depends on the machineries or engine where it is used. Annually about 40 million tons of lubricants are consumed worldwide (Amit, 2012; Johansson *et al.,* 1979). This petroleum based lubricating oils are not biodegradable and this becomes a threat to environment. As environmental pollution increases and petroleum reserve decreases, researchers are looking for alternative base oil instead of petroleum sources which would be renewable and ecofriendly (Mungroo *et al.,* 2008). High oil containing vegetable seed which are non-edible can use as oil source and extracted oil from these seed can be transformed to bio base oil (Fox *et al.* 2007; Waleska *et al.,* 2005).

Formulations made using extracted and converted oil from vegetable seeds and corresponding additives depending on the different grade are usually known as bio-lubricating oil (Wagner *et al.,* 2001; Sinadinovic-Fiser *et al.,* 2001). It is a renewable lubricating oil, biodegradable, nontoxic and has a net zero greenhouse gases. Vegetable oils from different non-edible seeds can be converted as base oil which shows the similar performance as the base oil from petroleum resources. Castor seed is one of the sources of that kind. Lubricating base oil from vegetable sources are high in viscosity index along with greater lubricity than the base oil from petroleum. Bio lubricating base have higher flash point and lower loss of evaporation compared to base oil from petroleum (Gawrilow, 2004).

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Vegetable oil structure contains polar groups in long chains of fatty acids and because of these properties hydrodynamic lube oil could be prepared from bio base oil (Mobarak *et al*., 2014; Adhvaryu *et al.,* 2002).

Castor plants are available in Bangladesh and can grow on barren lands. The castor seeds contain 40-60% oil, compared to different non-edible seeds it is much higher oil content e.g., pithraj (40-45%), rubber seeds (38.9%), karanja seeds (31.8%) and others (Gui *et al*., 2008; Banik *et al*., 2015). Triglycerides in castor oil is high mainly ricinolein (Jumat *et al.,* 2010). Since there is no reserve or source of petroleum-based lubricant in Bangladesh, bio-lubricating oil from castor oil is an alternative to petroleum based lubricating oil which can save a lot of foreign currency. Hence the objectives of the research were preparation of bio-lubricant base oil from castor oil and optimization of the process, determination of functional groups in castor oil and produced bio-lubricating base oil, comparison of the physicochemical properties of produced bio-lubricating base oil and commercial lubricating oil.

Materials and methods

Sample preparation and extraction of oil

The castor bean sample contained some dirt and foreign materials which were separated by hand picking. Then the cleaned beans were sun dried in open air until the casing splits. Then the beans were further oven dried at 60°C for 7 h to make the weight constant. The seeds have grinded to powder using mortar and pestle. The grinded powder coarse have been separated ones and those were again grinded for homogenization of the powder. Extraction of oil from the powder was carried out using petroleum ether as solvent in a Soxhlet apparatus.

Production of bio-lubricating oil

Bio-lubricating oil was produced by based catalyzed transesterification process. At first, required amount of KOH catalyst was properly dissolved in ethanol using standard agitator. The potassium ethoxide solution was preheated to 60-65°C in a round bottom flask equipped using a condenser and magnetic stirrer with it. The

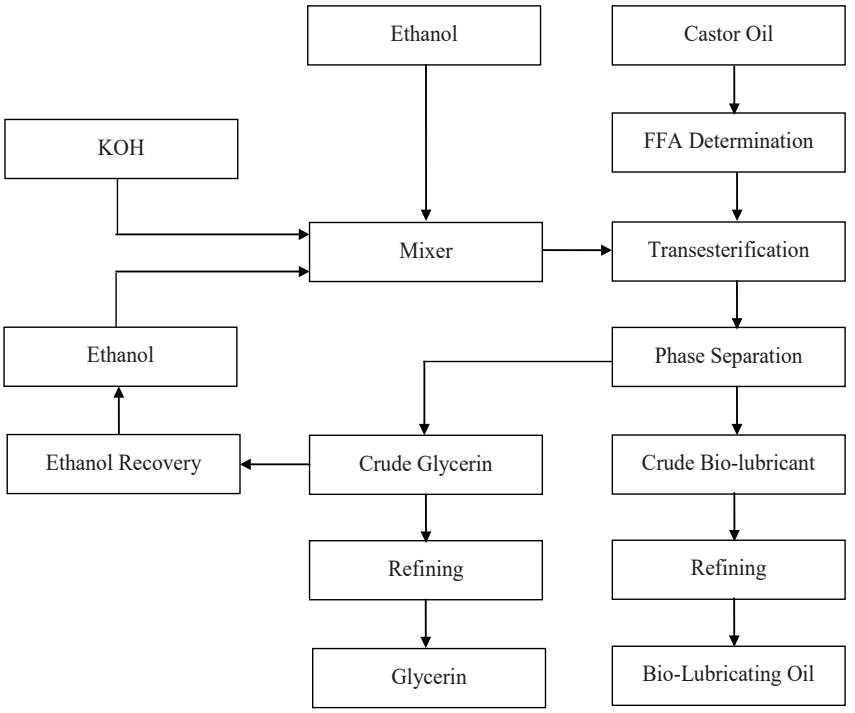

Fig. 1. Flow diagram of bio-lubricating base oil production from castor oil

pretreated oil was then added to the potassium ethoxide solution, and the system was made airtight to prevent the loss of ethanol. The reaction mixture was kept at 75°C and the reaction was carried out from 1-2 h. While reaction has completed, ethyl ester has been separated using separating funnel from the mixture where two layers were formed, in the top layer bio-lubricating oil and glycerin was in the bottom layer. Bio-lubricating oil was obtained after withdrawing the glycerin layer. Fig. 1 represents the flow diagram of bio-lubricating oil production. Using hot water spray from the top lubricating base oil was washed. After settling down the product vacuum evaporator was used at 80°C to dry out. After drying, the pure bio base oil product was obtained.

Results and discussions

Characteristics of castor oil

Characteristics of raw castor oil and produced bio-lubricating oil are presented in Table-I, where all the parameters were determined by following standard methods of ASTM and IP. Table-II compares the common lubricating oil characteristics of produced bio-lubricating oil with the commercial lubricating oil. These results shows that the properties of produced bio lubricating base oil would be a better alternative to commercial petroleum based lub base oil.

Table I. Characteristics of castor oil

Parameter	Method	Result
Density at 15°C, g/cc	IP-160/57	0.9644
Kinematic viscosity at 40°C, cSt	ASTM-D 445-65	252
Kinematic viscosity at 100°C, cSt	ASTM-D 445-65	19
Acid value, mg KOH/g	IP-1/58	2.62
Carbon residue, % (w/w)	ASTM-D 189-65	0.05
Ash content, % (w/w)	ASTM-D 482-63	0.02
Water content, %(v/v)	IP-74/57	0.025
Flash point, °C	ASTM-D 93-62	225
Pour point, °C	ASTM-D 97-57	-13
Cloud point, °C	ASTM-D 93-55	-10
Color index	ASTM & DIN 51900	Amber
Sulfur content, % (w/w)	ASTM-D 129-63	0.04
Cetane number	ASTM-D 613-86	42
Corrosion	IP 154/59	Nil

Table II. Comparison of properties of bio-lubricating base oil and commercial lubricating oil

Parameter	Produced bio - lubricating oil	Commercial lubricating oil
Density at 15 °C, g/cc	0.890	0.8942
Kinematic viscosity at 40 °C, cSt	131.90	105.10
Kinematic viscosity at 100 °C, cSt	16.5	13.64
Acid value, mg KOH/g	0.58	0.34
Carbon residue, % (w/w)	0.83	0.21
Ash content, % (w/w)	Nil	Nil
Water content,% (v/v)	Nil	Nil
Flash point, °C	235	230
Sulfur content, % (w/w)	0.002	0.001
Corrosion	Nil	Nil
Pour point, °C	-15	-10

Effect of ethanol addition on bio-lubricant base oil yield

Ethanol addition to oil with the constant KOH concentration and at fixed temperature has significant effect to the yield. Bio-lubricating base oil yield was increased with the ethanol addition to the reaction up to 40% and the highest yield of bio lubricating base oil was 95% (Fig. 2). When more than 40% ethanol was added the yield started to decrease may be because of reaction was reached at equilibrium state. Highest 95% yield was achieved when the constant KOH concentration was 1 % and reaction temperature was 75°C.

Effect of variation of catalyst concentration on bio-lubricant base oil yield

The effect of catalyst KOH on the lubricant base oil yield was studied at the reaction temperature of 75°C and kept the optimized ethanol addition in the reaction of 40%. KOH concentration was varied from 0.15-0.75% of oil taken in the reaction. Maximum yield was found at 0.45% of KOH concentration (Fig. 3). More than 0.45 % of KOH addition decreased the yield because of the soap formation. This result also was supported by other study (Dorado *et al.*, 2004).

Effect of variation of temperature

To get optimum reaction temperature, catalyst and ethanol concentration were fixed constant at 0.45% and 40% respectively and reaction temperature was varied. Fig. 4 shows that maximum yield was obtained at 75°C. When the reaction temperature increased more than 75°C, the yield was started to decrease, because at above the ethanol boiling temperature it could be separated from the

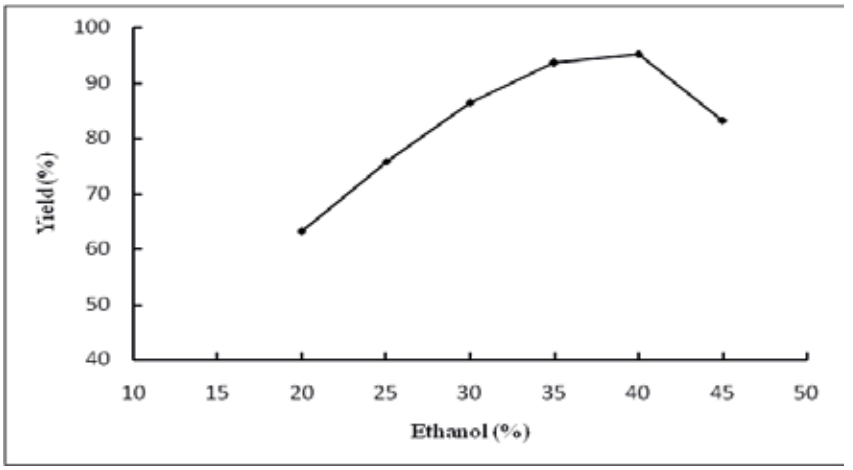

Fig. 2. Effect of ethanol percent on bio-lubricating base oil yield

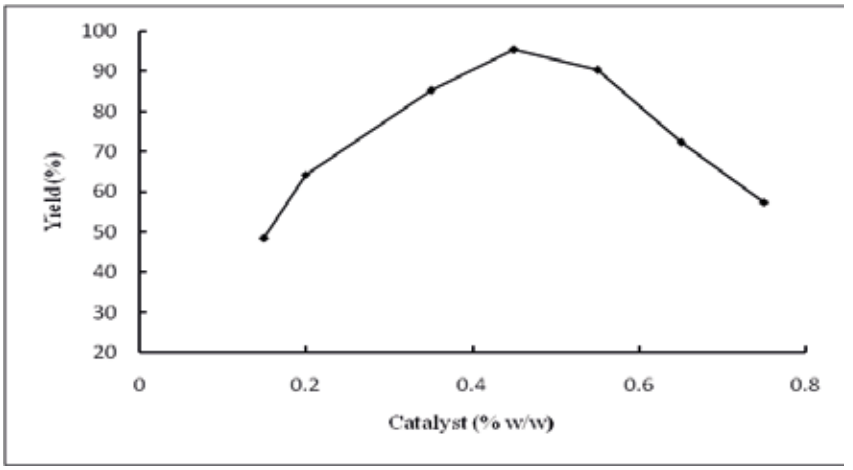

Fig. 3. Effect of catalyst concentration on bio-lubricating base oil yield

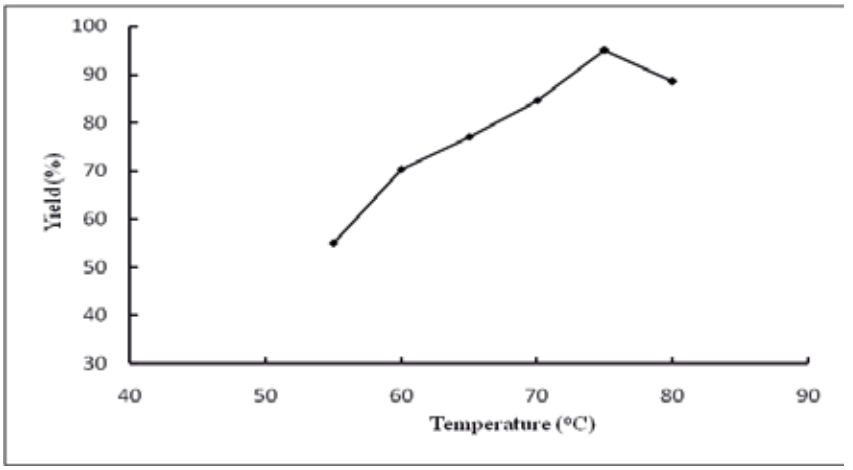

Fig. 4. Effect of temperature on bio-lubricating base oil yield

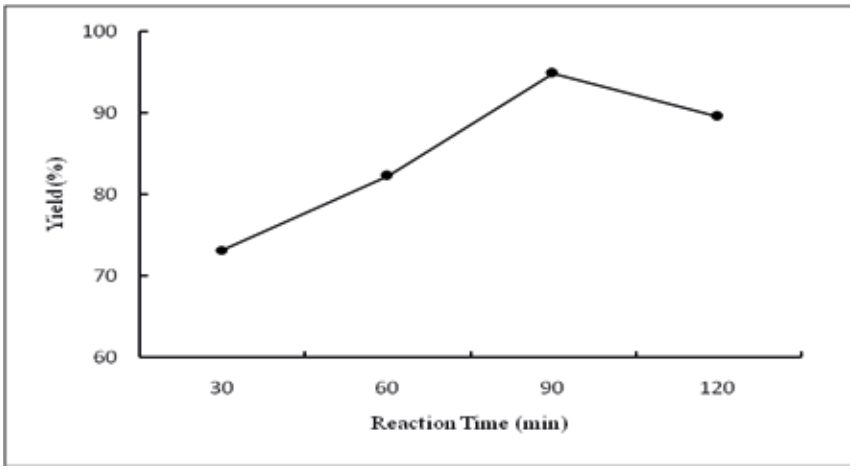

Fig. 5. Effect of reaction time on bio-lubricating base oil yield

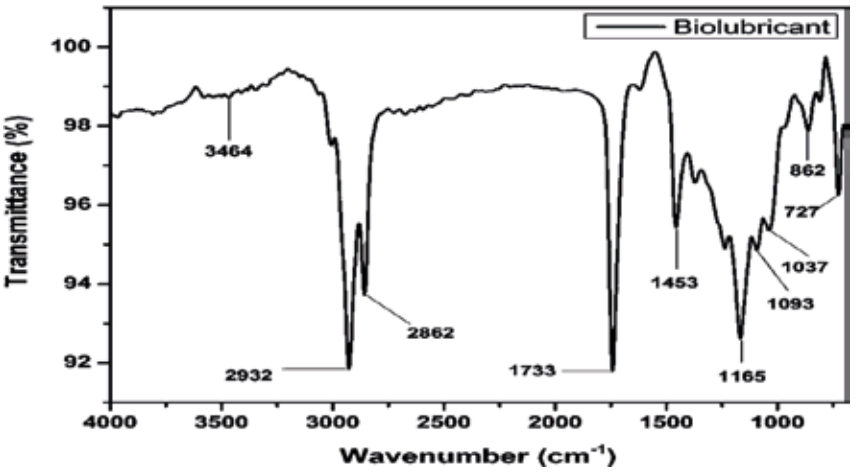

Fig. 6. FTIR spectra of bio-lubricating base oil

reaction mixture and started saponification instead of alcoholysis. Similar results also found in other studies (Dorado *et al.*, 2004).

Effect of reaction time to bio lubricant base oil yield

The variation of reaction time was studied maintaining the constant ethanol addition of 40%, KOH concentration 0.45% and reaction temperature of 75°C. Reaction time up to 90 min the product yield was increased and then started to decrease. Fig. 5 shows that the highest yield with 90 min reaction time was around 95%. Reaction time more than 90 min decreased the yield because of equilibrium shifts to reverse direction (Mayo *et al.,* 2003).

Functional group identification of bio-lubricating oil

FTIR (Shimadzu FTIR 8400S spectrophotometer) spectrum of produced bio lubricating base oil was shown in Fig. 6. Functional group was determined from this figure

recorded from 4000-700 cm^{-1} range with the resolution of 2 cm^{-1} and 30 scans. The main peaks were found in 1733.68 cm^{-1}, 2862 cm^{-1} and 2932.06 cm^{-1} region. FTIR spectroscopic results shows that the leading functional groups of bio-lubricating oil are because of ester (C=O) absorption and alkanes (C-H) which appear at 1733.68 cm^{-1} and 2800-3000 cm^{-1} region respectively (Mayo *et al.,* 2003).

Optimum condition of bio-lubricating base oil produced from castor oil

The best situations for bio-lubricating oil production from castor oil was 40% of ethanol addition to the oil; catalyst (KOH) concentration was 0.45% and the time of reaction 90 min. at the reaction temperature of 75°C with adequate stirring rate. The optimum yield was 95% and after washing yield was 98%.

Conclusion

Rapid depletion of fossil oil reserve and growing environmental pollution from excessive mineral oil use, non-edible vegetable oil would be considered as new resources for bio- lubricating oil production. Bio-lubricating base oil by transesterification of non-edible vegetable oil is superior to synthetic lubricating oil. Ethanol used in the reaction is a product from agriculture, renewable and less objectionable to environment. Transesterification of castor oil yields about 98% bio-lubricating base oil after washing. The optimum condition for transesterification of castor oil is 40% ethanol, 0.45% KOH at 75°C for 90 min. Lubricating oil properties are also comparable to commercially available lubricating oil. As Bangladesh has no of petroleum source, this type of renewable lubricant can help to meet our increasing demand of lubricating oil and can help to reduce environment pollution.

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