Journal of Phytology 2009, 1(2): 95–99
© *Journal of Phytology, 2009*

ISSN: 2075-6240
Available Online: www.journal-phytology.com

REGULAR ARTICLE

DETERMINATION OF OPTIMAL ALKALINE CATALYST CONCENTRATION FOR THE MAXIMUM PRODUCTION OF BIODIESEL FROM EDIBLE AND NON-EDIBLE OILS

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SUMMARY

The profitability of biodiesel production largely depends on the understanding of all the processes involved, especially the optimal values of the transesterification process parameters. In this study, both edible (groundnut oil and sesame oil) and non-edible oils (pongamia and madhuca oil) were used to determine the optimal catalyst concentration for the biodiesel production process. The values obtained as 1% for edible oils and 1.1 and 1.2 % for non-edible oils and these gave biodiesel yield fraction of 0.95, 0.9, 0.73 and 0.71 of groundnut oil, sesame oil, pongamia oil and madhuca oil respectively.

Keywords: Biodiesel, Transesterification, Catalyst, Alcohol, Alkaline.

K.M. Shereena and T. Thangaraj. Determination of Optimal Alkaline Catalyst Concentration For The Maximum Production of Biodiesel From Edible And Non-edible Oils. J Phytol 1 (2009) 95-99
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1. Introduction

Vegetable oils are becoming a promising alternative to diesel fuel because they are renewable in nature and can be produced locally and environment friendly as well the substitution of diesel oil by renewable fuels produced within the country generates higher foreign exchange savings. Even for the major oil exporting countries. In view of the several advantages vegetable oil has potential to replace petroleum-base fuels in the long run [1]. A sustainable biofuel has two favorable properties, which are its availability from renewable raw material and its lower negative environmental impact than that of fossil fuels. Various vegetable oil extraction and transesterification technologies are currently used in the production of biodiesel fuel. As an alternative fuel, vegetable oil is one of the renewable fuels [2].

Almost all biodiesel is produced by using base catalyzed transesterification process, as it is the simple process and requiring only low temperature. The transesterification process is the reaction of a triglyceride (fat or oil) with an alcohol to form esters and glycerol. The alcohol reacts with the fatty acids to form monoalkyl ester or biodiesel and crude glycerol [3]. In biodiesel production process the main reaction is the transesterification of vegetable oil [4, 5]. The important factor that affects the transesterification reaction is the amount of

methanol and sodium or potassium hydroxide, reaction temperature and reaction time [6].

Various authors [7-11] have reported the use of transesterification procedures to produce methyl and ethyl esters (Biodiesel) from various oils from their works, one conclusion could be drawn: every oil has its own properties and characteristics and therefore an unique set of transesterification process parameters [12]. The raw material being exploited commercially by the developed countries constitutes the edible fatty acid oils derived from rapeseed, soya bean, palm, sunflower, coconut, linseed [13]. Use of such edible oil to produce biodiesel in India is not feasible in view of a big gap in demand and supply of such oils in the country. Increased pressure to augment production of edible oil has to put limitation on the use of these oils for production of biodiesel under such condition those crops that produce non edible oils in appreciable quantities can be grown in large scale known cropped marginal lands and waste lands only considered for biodiesel production [14].

This work therefore took as its objective, the optimization of transesterification process of the groundnut, sesame, madhuca and pongamia oil for biodiesel production. Specifically, the work set out to determine the optimal catalyst concentration level that gives maximum yield of methyl ester from groundnut, sesame, madhuca and pongamia oil.

2. Materials and Methods

The seeds of groundnut, sesame, madhuca and pongamia were obtained from the Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamilnadu.

Oil extraction

The extraction procedure described by [15] using methanol and hexane at between 40-600C for 12 hours in a sohxlet apparatus was employed to obtain the quantity of oil from the seeds used for the transesterification procedure.

Transesterifification procedure

Transesterification or alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except than alcohol is used instead of water [16].This process has been widely used to reduce the high viscosity of triglycerides. The transesterification reaction is represented by the general equation as

$$\underset{\text{Ester}}{RCOOR^1} + \underset{\text{Alcohol}}{R^2OH} \overset{\text{Catalyst}}{\rightleftharpoons} \underset{\text{Ester}}{RCOOR^2} + \underset{\text{Alcohol}}{R^1OH}$$

Transesterification of triglycerides produce fatty acid alkyl esters and glycerol. The glycerol layer settles down at the bottom of the reaction vessel. Diglycerides and monoglycerides are the intermediates in this process. The overall transesterification reaction [17] is given by three consecutive and reversible equations as below:

$$\text{Triglyceride} + ROH \overset{\text{catalyst}}{\Longleftrightarrow} \text{Diglyceride} + R^{I}COOR$$

$$\text{Diglyceride} + ROH \overset{\text{catalyst}}{\Longleftrightarrow} \text{Monoglyceride} + R^{II}COOR$$

$$\text{Monoglyceride} + ROH \overset{\text{catalyst}}{\Longleftrightarrow} \text{Glycerol} + R^{III}COOR$$

The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule per mole of glyceride at each step [18, 19].

The bench scale transesterification reactions to produce methyl esters from oil of groundnut, sesame, madhuca and pongamia were carried out in a 1-litre conical flask equipped with a thermometer. 400ml of the extracted oil was poured into the reactor and heated to 45^{o} C to improve the oil's mix-ability with methanol. The catalyst, sodium hydroxide (NaOH) pellet was prepared in concentration range of 0.5% w/v to 1.2% w/v, in increments of 0.1% w/v. To achieve the first concentration level, 2.30g of the catalyst (NaOH) was dissolved in 100 ml of methanol and the mixture stirred for 20 minutes, to form sodium methoxide. This sodium methoxide was introduced gently into the heated oil in

the reactor and the entire content was brought to a temperature of 55° C at a heating rate of 5° C/min, and then held at this temperature for an hour. The reaction product mixture was allowed to separate into phases by standing for 8 hours in a separative funnel so as to separate glycerin from the biodiesel. The collected biodiesel washing with water to remove impurities. The denser soapy mixture was carefully drained from the bottom of the separative funnel, leaving behind the biodiesel. The volume of the biodiesel obtained was determined in a measuring cylinder.

The procedure described above was repeated for other catalyst concentration levels as shown in figures 1, 2, 3 & 4

Yield of Biodiesel from Edible Oils and Non-Edible Oils at Various Catalysts Concentration levels.

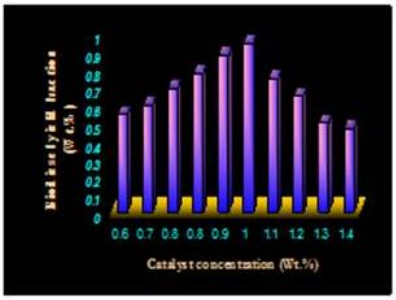

Figure 1.Yield of Biodiesel from groundnut oil at various concentration levels

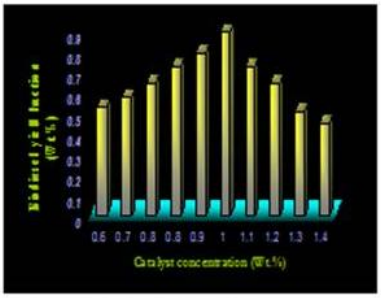

Figure 2.Yield of Biodiesel from sesame oil at various concentration levels

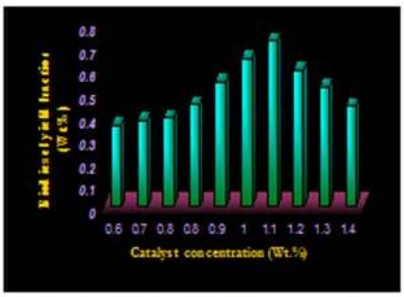

Figure 3.Yield of Biodiesel from pongamia oil at various concentration levels

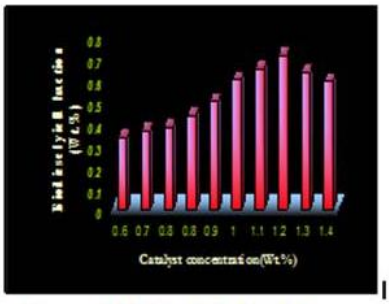

Figure 4.Yield of Biodiesel from madhuca oil at various concentration

3. Results and Discussion

The effect of sodium hydroxide concentration on the trans-esterification of the edible and non-edible oils was investigated with its concentration varying from 0.6 to 1.4 wt % (based on the weight of raw oil). The operation conditions during the whole reaction process were fixed at the optimal level: reaction temperature of 55°C, 180 and 210 ml of methanol for edible and non-edible oils, respectively. Experimental results showed changes in ester yield content with varied catalyst concentration.

As the sodium hydroxide concentration increased, the conversion of triglyceride as well as the ester content also increased. Insufficient amount of sodium hydroxide resulted in incomplete conversion of triglycerides into the esters as indicated from its lower ester content. The ester content reached an optimal value when the sodium hydroxide concentration reached 1wt % in edible oils, 1.1 and1.2 wt % in non-edible oils and further increase in catalyst concentration in all the cases, ester production amount decreased as shown in Fig.1, 2, 3 & 4. Large

amount of soap was observed in excess amount of sodium hydroxide added experiments. This is because addition of excess alkaline catalyst caused more triglycerides participation in the saponification reaction with sodium hydroxide, resulting in the production of more amount of soap and reduction of the ester yield [20]. This could be explained from the viewpoint of the reversible nature of the transesterification process as described by [9].

Although, it is possible that variation of other parameters that affect the transesterification process such as (according to Freedman [21]) stirring speed (rate of mixing), molar ratio of methanol etc, may affect reaction equilibrium time as well as improve volume yield of biodiesel, it is nonetheless, suspected that variation of these parameters would have a null effect on the optimal catalyst concentration level needed for the transesterification process.

Comparing the results of biodiesel yield obtained from these experiments and the ones obtained elsewhere [22] for the same oils biodiesel resource, it could be inferred that these oils are available biodiesel resources and the commercialization of the process of biodiesel production from these oils exceptionally non edible oils (pongamia and madhuca) not a mirage and may not be far into the future.

Conclusions

The investigation here reported has helped to establish an optimal catalyst concentration level of 1% weight in gram (KOH) per volume in milliliter in the transesterification process of groundnut and sesame oil. This concentration level gave biodiesel yield fractions of 0.95and 0.9 respectively. And the optimal catalyst concentration level of 1.1 and 1.2 %w/v in the transesterification process of non edible oils (pongamia and madhuca), these concentration levels gave biodiesel yield fractions of 0.73and 0.71 respectively.

Further work is required to fully optimize the overall transesterification process including modeling the reactions and unit operations involved in the production of biodiesel from these oils.

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