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Effects of degumming on biodiesel properties of some non-conventional seedoils

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ABSTRACT

This study examined the effect of degumming process on physicochemical and biodiesel properties of six non-conventional oils in Nigeria extracted from the seeds and flesh of *Terminalia catappa* (seed), *Irvingia gabonesis* (seed), *Glycine max* (seed), *Persea americana*(flesh), *Tithonia diversifolia* (seed), *and Dacryodes edulis*(flesh). The fruits and seeds were air-dried to constant weight and pulverized. Oil was extracted from the milled sample using Soxhlet extraction method. The oils were degummed using 300 μg/mL of NaCl solution to obtain the refined (degummed) oil. Physicochemical properties of both degummed and crude oils were carried out using the AOAC (1990) methods. The fuel properties of the biodiesel obtained were carried out using ASTM methods. Results showed that degumming process lead to high biodiesel yield and reduced the acid value and iodine value compared with the crude oils. The study therefore concluded that degummed oils were a better substitute for biodiesel fuels production.

1. Introduction

Free fatty acids, phosphatides, metal ions, waxes, oxidation products and color bodies are some of the known impurities in raw vegetable oils that impact negatively on their suitability for consumption and other uses. Thus it becomes imperative to refine vegetable oils using different treatment processes such as water degumming, alkali refining and oil bleaching to produce high quality oil that will stand the test of time and resistant to oxidative degradation (Wiedermann, 1991; Haraldsson, 1983). Refining of vegetable oils solve the problem of oil rancidity, deterioration and incomplete combustion when used as fuel. It also improves the transesterification process of vegetable oil to biodiesel (Demirbas, 2008). Arisa and Lazarus reported there is improvement in the qualities of Native Pear oil after refining process (Arisa and Lazarus, 2008). Oyekunle et al. studied the efficiency of different easy-to-come by degumming agents as cheaper refining method for the developing nations and concluded that 300 μg/mL of NaCl solution as degumming agent is efficient and capable of tremendously reducing the heavy metal levels of the oils and thus capable of increasing their shelf life (Oyekunle et al., 2013).

The imminent scarcity of conventional fossil fuels due to fast depletion in the capacity of oil and gas reserves, plus the growing emissions of combustion generated pollutants, and increasing costs has led to search for an alternative energy sources using biomass materials (Sensoz et al., 2000). To meet the rising energy demands and reduce the over dependence on petroleum reserves, experts have now suggested that the viable alternatives for compression–ignition internal combustion engines are biodiesel and bioethanol (Demirbas, 2008). Transesterification, dilution, microemulsification and co-solvent blending, and pyrolysis are methods use for obtaining diesel from vegetable oils but transesterification is the one most commonly employed (Bala, 2005). Transesterification is a process by which oil is converted into its corresponding fatty ester (biodiesel) by its reaction with methanol or ethanol in the presence of a catalyst (Demirbas, 2002). Due to the rising energy demand and the need for vegetable oils for biodiesel production, experts have calculated the economy land space that will be required to produce sufficiently reasonable amount of biodiesel for basic needs. It was reported that 2.67 hectares of soybean, 1 hectare of rape seed, and 0.14 hectare of palm seed respectively would produce 1 tonne of biodiesel (Gunstone, 2004). Apart from the economic land advantage required for biodiesel production, other advantages such as jobs creation for the teaming population, rural revitalization, low CO and hydrocarbon emissions, clean and save

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environment as compared to the conventional petroleum-based diesel cannot be overemphasized (Kaewta, 2008). Biodiesel also have added advantages of ease of ignition and, higher lubricity, and less corrosive thus making engines to undergo less wear and tear (Vasudevan and Briggs, 2008).

Several studies have reported the use of some conventional and non-conventional oils for biodiesel production (Adekunle et al., 2015; Bello et al., 2011; Betiku and Adepoju, 2013; Kumar and Kant, 2013; Sandip and Ahindra, 2008). For example, Adekunle et al. studied the potentials of some non-conventional oils (Persea Americana, (Avocado pear), Irvingia gabonenses (Dica nut) and Darcryodes edulis (Native pear)) biodiesel and suggested that they can serve as an alternative to biodiesel made from a conventional seed oil (palm kernel oil), and petroleum-based diesel (Adekunle et al., 2015). Similarly, Bello et al. reported that the performance characteristic of African bush mango Nut (Dika nut, or Irvingia gabonensis) oil biodiesel is similar to that of diesel fuel and the specific fuel consumption is 8% higher than diesel fuel, thus the oil will be a potential source of alternative fuel for diesel engine (Bello et al., 2011). It was also reported that the fuel properties of biodiesel produced from Sesame oil were found to be within the ASTM D6751 and DIN EN 14214 biodiesel specifications (Betiku and Adepoju, 2013). However none of these studies explored the effect of oil refining on the physico-chemical and fuel properties of the produced biodiesel hence the present study.

The motivation to this study is predicated on the rising demand for alternative sources of energy supply due to the increasing world population, and accelerated rate of industrial and domestic activities that require constant supply of energy. Thus, the present study investigated the effect of refining of raw oils on the biodiesel properties of some non-conventional oils using a relatively cheap and cost effective degumming process that could be used in the developing countries to effectively reduce the presence of impurities in the oils and improve their shelve life and guide against combustion engine corrosion during biodiesel application. Results showed that the degumming process gave improved biodiesel parameters that compare favorably with the presently used conventional petroleum diesel.

2. Materials and methods

2.1. Fruits and seeds preparation

The fruits and seeds were collected from various locations around in Ife Central local government, Ile-Ife, Osun State, Nigeria with an area of 111 km^2 (43 sq mi) and coordinates of 7°33′N 4°32′E. The collection was done during the month of January through March, 2013. The plants from which the fruits and seeds were obtained are *Persea americana* (Avocado pear) fruits, Terminalia *catappa* (Almond fruit) seeds, *Tithonia diversifolia* (Wild sunflower) seeds, *Dacryodes edulis* (Native pear) fruit, *Irvingia gabonensis* (Wild mango) seeds and *Glycine max* (Soya beans) seeds. The fruits were thoroughly washed and the seeds decortications and selection were manually done. The seeds and flesh removed were air-dried to a constant weight. They were milled and stored in a refrigerator prior to further analysis.

2.2. Extraction of the oils

The extraction was carried out using the Soxhlet extractor method (AOAC, 2004) in which case 20 g of the milled samples was weighed at a time and packed into a cellulose thimble prewashed with acetone/*n*-hexane mixture and allowed to dry in an oven at a temperature of 70 °C for 2 h before used. The extraction of the oils with *n*-hexane lasted 7 h on the average. After extraction, the content in the flask was concentrated by distilling off the solvent content to obtain a solvent-free crude oil. The flask was later placed in the oven maintained at 70 °C to drive off traces of the solvent left.

2.3. Degumming operation

Accurately measured 5 mL of raw oil was mixed with 1 mL of the 300 μg/mL NaCl solution. The oil and NaCl solution mixture was agitated for 60 min at 60 °C on magnetic stirrer to render fat-soluble phosphatides insoluble. These insoluble phosphatides are then separated by centrifugation at 1000 rpm for 30 min. During the agitation process, a colloidal mixture beneath the oil layer was formed. This was believed to be a mixture of the fat-soluble impurities (phospholipid lecithin complexed with metals) contained earlier in the oil. The oil was separated from the colloidal mixture by decanting (Oyekunle et al., 2013).

2.4. Transesterification process: production of biodiesel

Transesterification of all the vegetable oils (raw oils and degummed oils) was carried out with methanol in the presence of KOH as a catalyst. The method recommended by Van Gerpen et al. (2004) was employed. The biodiesels generated for the oils are represented as biodiesel of *T. catappa* (BDTC), biodiesel of *P. Americana* (BDPA), biodiesel of *I. gabonensis* (BDIG), biodiesel of *G. max* (BDGM), biodiesel of *T. diversifolia* (BDTD), and biodiesel of *D. edulis* (BDDE). The percentage biodiesel yield was calculated using the relationship:

$$\text{Biodiesel yield} = \frac{\text{Mass of biodiesel produced}}{\text{Mass of oil used}} \times 100.$$

The physico-chemical properties of biodiesel produced for both the raw and the degummed oils were carried out according to American Society for Test and Material—ASTM and Leevijit method (Leevijit et al., 2016). The parameters determined are acid value, iodine value, cetane number, kinematic viscosity, density, higher heating value, heating efficiency, pour point, cloud point, smoke point and flash point.

3. Results and discussion

3.1. Percentage oil composition and biodiesel yield

The results of percentage oil yield of the oilseeds are presented in Table 1. *T. catappa*, *P. americana*, *I. gabonensis*, *T. diversifolia,* and *D. edulis* have a high oil yield (30.33%–81.94%). *T. diversifolia* has the lowest oil yield of 30.33% while *I. gabonensis* has the highest oil yield of 81.94%. Kyari (2008) considered an oil yield of 26%–42% to be reasonable oil yield. All the non-conventional seeds were considered economical for commercial production of oil in Nigeria. *G. max* has a yield of 20.33% which falls below the considered value for oil yield, but agreed closely to 18% reported by Ene-Bong and Carnovale (1992). The oil yield of *D. edulis* (69.60%) obtained in this study was higher than that reported for *D. edulis* (50.00%) by Arisa and Lazarus (2008). This might be due to the maturity of the seed before extraction and the mode of extractions. Other factors such as soil fertility, environmental conditions, and so on, can also affect the oil yield of the materials. *T. catappa*, *P. americana*, *I. gabonensis*, *T. diversifolia*, and *D. edulis* had a high oil yield compared with the conventional oilseed (*G. max*), thus, these fixed oils can compete favorably with conventional oils thereby reducing over dependence on them.

Base catalyzed transesterification is preferred over acid catalyzed transesterification reactions for the production of biodiesel at industrial level because it provides better conversion rates and efficiencies (Fukuda et al., 2001). The percentage conversion yield of raw oils to biodiesel ranged from 63.35% in *P. americana* to 91.07% in *I. gabonensis.* However, it was observed that the conversion of degummed oil to biodiesel gave higher percentage yield