Transesterification of Various Oils and the Analysis of their Product Physical Properties

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ABSTRACT

Peanut oil and used cooking oil were chemically altered via transesterification to produce biodiesel fuels using sodium methoxide as a base catalyst. The physical properties of the products were tested by the American Standards and Testing Methods for flash point, cloud point, kinematic viscosity, and density. Both starting material oils were physically characterized by the American Standard Testing and Methods (ASTM). The physical properties of the peanut oil methyl esters resulted as: kinematic viscosity of 37.62 mm^2/s $\pm$ 0.32, a cloud point of 4.6°C $\pm$ 1.80, and a density of 0.9125g/cm^3 $\pm$ 0.00002. The results of the used cooking oil methyl esters were determined: kinematic viscosity of 15.82 mm^2/s $\pm$ 3.98, cloud point of -5.5°C $\pm$ 6.81, and density of 0.9150 g/cm^3 $\pm$ 0.0023. The statistical analysis of the fuel properties via one sample t-test of the peanut oil differed from literature fuel properties from Kaya's peanut seed oil study in 2009. Similar statistical analysis tests was used to analyze the sample cooking oil to the characteristics of methyl esters from pure soybean oil. Both samples sets differed from their respective literature values due to an incomplete transesterification process. The samples were unable to mix thoroughly while being heated during the reflux process. In regards to the used cooking oil, the sample was based at 70% soybean oil, with possible acid contaminants from the food left behind after the cooking process. The comparison of the physical properties of the products to the original oils showed no significant differences, thus the transesterification process was incomplete.

Keywords: *Biodiesel, fuel, oil, transesterification, peanut, soybean*

INTRODUCTION

Within recent years, research optimizing biofuels from different alternative sources for transportation is due to the pull of the limited amount of natural fossil fuel feedstock. Researchers in the field of fuels search for natural feedstocks that have a high energy potential in their biodiesel products, while also being able to be produced easily and readily. They also look for the efficiency of the chemical transformation of feedstock into biodiesel (Eevera, Rajendran, and Saradha, 2009). A concern with the production of biodiesel fuels form natural feedstocks is the lower efficiency of energy output compared to the energy input in the production process. (Eevera, Rajendran, and Saradha, 2009). Research has been conducted using animal fats and vegetable oils as alternative feedstock for the production of combustible fuels. Additionally, the produced biofuels can be utilized as an additive to petroleum diesel in diesel engines. Biodiesel can is primary produced from the lipids of animals or that from plants such as soy, corn, and algae. Therefore, biodiesel fuels turn towards an easy renewable resource (Atabani, *et al,* 2013).

Various biodiesel fuels are characterized by their physical properties such as flash point, cloud point, pour point, fire point, and kinematic viscosity to determine their overall efficiency and theoretical power production for diesel engines (Lapuerta, Armas, and Rodriguiz-Fernandez, 2008). Biodiesel is produced through the chemical process of transesterification, or alcoholysis, where the lipids

react with an alcohol in the presence of a catalyst, to yield the long hydrocarbon chains and glycerol as a byproduct (Mehler, *et al*, 2006). Transesterification is often done by refluxing the oil of the feedstock with methanol in the presence of a base catalyst, this produces glycerol and a form of methyl ester species to be offered as the fuel source.

Previous studies of the production of biofuels have explored the effects of temperature, catalyst concentration, and the selection of the type of catalysts for the optimization of biofuel yield from various feedstocks (Dermibas, 2005). Common feedstocks are the oils extracted from plantae such as soybeans, walnuts, and peanuts (Cho, *et al,* 2009). Studies found that the concentration of the catalyst to be the most sensitive variable in the process of producing biodiesel fuel, and that when the concentration is too high, a production of soap occurs (Burton, R, and Piedmont Biofuels, 2009).

This study utilizes used cooking oil (soybean oil) and peanut oil to produce biodiesel fuel. The used cooking oil was collected from the McPherson College cafeteria, and the Kroger peanut oil was purchased from Dillons. The oils were then processed through transesterification to produce methyl esters and glycerol. This process used a fixed mass of methanol and sodium hydroxide. The experimental products went through various physical property tests under the American Standards and Testing Methods (ASTM) for the cloud point, flash point, density, and kinematic

viscosity.

MATERIALS AND METHODS

For each sample, 600 grams of the oil was weighed into a one liter round bottom flask. Then 100 grams of methanol was added followed one and a half grams of sodium hydroxide. This 6:1 molar ratio of the oil feedstock to methanol follows the procedure conducted by Kaya's methyl ester production. The solution was then refluxed in a hot water bath for two hours at approximately 70-75°C. The mixture was allowed to cool and then each sample was placed into a separatory funnel to allow the two layers to separate. The methyl ester layer was collected and was washed four times with warm deionized water and the glycerol was collected. If an emulsion occurred during the washing of methyl esters, a saturated sodium chloride solution was added to induce separation and was allowed to sit overnight. Samples were distilled to drive off any remaining methanol within the product. Anhydrous sodium sulfate was added to dry the product. The products were analyzed for their density, cloud point, kinematic viscosity, and flash point in accordance with ASTM methods at the CHS refinery in McPherson, Kansas.

ASTM D-4052 Density
This method calls for fuel properties to fall between 860-900 kg/m^3 (0.86-0.90 g/cm^3) at 15°C. The samples were drawn in through an Anton Paar DMA 35 specific gravity meter at ~20 °C.

ASTM D-7042 Kinematic Viscosity
The standards for the kinematic viscosity falls between $3.5*10^{-6}$-$5.0*10^{-6}$ m^2/s (1.9-6.0 mm^2 s^{-1}). The testing was conducted by placing the sample through a syringe (~6 mL) into an Anton Parr SVM 3000 Stabinger Viscometer at 40°C.

ASTM D-93 Flash Point
The flash point of fuels must be at least 100°C. The samples were tested from 38°C to 121°C. The tests were ran with a Pensky Martens OptiFlash from 37.8°C to 121.1 °C.

ASTM D-2500 Cloud Point
For biodiesel, the cloud point limits its standards to 4°C for during summer and -1°C for winter. The tests were conducted with Phase Technology JFA-70XI lab analyzer.

Statistical test conducted was a one sample t-tests were conducted in the comparison of the mean physical characteristics between the peanut oil samples to that of the peanut oil methyl esters of Kaya's study. The same statistical comparison was used to quantify a statistical difference between the physical properties of a used 70% soybean cooking oil and the pure soybean oil used in Derimbas's study. Additionally, a two sample t-tests was used to analyze the properties of the products to that of the starting oil material. Tests were conducted with a 95% confidence interval and only p-values less than 0.05 were considered significant. The literature values were assumed to be the population values for the one sample t-tests, and the original oil's property values were assumed to be the true values in the two-sample t-tests. The samples were assumed to

RESULTS

The observed fuel properties were observed in respect to their standards and No. 2 petroleum diesel fuel in table 1. One sample t-tests of the used cooking oil methyl esters had p-values > 0.05, while peanut oil methyl esters had p-values <0.05. The p-values of two sample t-tests for the used cooking oil products were greater than 0.05, except the viscosity, which had a p-value < 0.05. All the p-values of the two sample t tests for the peanut oil and its products were not significant with p-values > 0.05.

Table 1. Fuel properties of products

Property	Peanut oil	Used cooking oil	ASTM D6751-06	No.2 petroleum diesel
Kinematic viscosity (mm^2 s^{-1})	37.62	15.82	1.90-6.00	2.50-3.50
Density (g cm^{-3})	0.91	0.91	0.88-0.90	0.82-0.86
Flash point (°C)	-	-	130.00 minimum	>55.00
Cloud point (°C)	4.6	-5.5	Summer 4.00 Winter -1.00	-16.00

Table 2. Fuel properties of oils

Property	Peanut oil	Used cooking oil
Kinematic viscosity (mm^2 s^{-1})	39.12	32.93
Density (g cm^{-3})	0.89	0.91
Flash point (°C)	-	-
Cloud point (°C)	4.8	0.9

DISCUSSION

The samples came out overall being heavy and thick, shown from the test results of their physical properties.

This observation is most likely due to the long hydrocarbon chains resulting from the transesterification process. The tests support this claim due to the observed physical properties in Table 1**.** An explanation in which more heat energy must be added to induce combustion; the burning of alkanes within oxygen and forms the products of carbon dioxide and water. Other traits of the biofuels being composted of long hydrocarbons are increased densities and viscosities, correlating directly to the chain length of the hydrocarbon chain.

Table 3. Comparison of fuel properties of peanut oil methyl esters.

Properties	Literature	This study
Kinematic viscosity ($mm^2 s^{-1}$)	4.42	37.62
Density ($g\, cm^{-3}$)	0.8485	0.9125
Flash Point (°C)	166.0	-
Cloud Point (°C)	0	4.6

When comparing the sample's physical properties of the peanut methyl esters to the literature values from the research by Kaya could be from the methods of the transesterification. From a statistical analysis on the peanut oil samples, a one sample t-test on gave p values < 0.05, thus the sample observations are not due to random variation, however, the observations are different from the methyl esters within the literature. In this project the samples were not able to be continuously stirred while being heated, thus could be the difference between the efficiency of the transesterification, but not of the material itself. The difference off efficiency would show a different transparency in the products. The physical property values between the No. 2 diesels from either of the samples sources differ. This difference may be from the different variations of catalytic cracking, mostly liquid, to alter the sulfur content in No. 2 diesel fuel. This conversion is mostly from the source of the liquefied petroleum gas produced through various means.

Table 4. Fuel properties of sample used cooking methyl esters to soybean methyl esters

Property	Literature value	This study
Kinematic viscosity ($mm^2 s^{-1}$)	4.08	15.82
Density ($g\, cm^{-3}$)	0.89	0.91
Flash Point (°C)	174	-
Cloud Point (°C)	-	-5.5

The used cooking oil was compared to the methyl esters yielded from soybean oil from the research of Demirbas as a template due to its composition being mostly from soybean oil. The used cooking oil was mixture composition with about a seventy percentage being from soybean oil. Thus when compared to the methyl ester fuel properties the difference can be concurred from the remainder thirty percent of the oil, plus contaminate oils from the foods cooked within the oil, as well as any oil contaminants from the foods cooked with the oil. Based on observed data from other research, the instruments used for obtaining the flash point of the methyl ester products of the peanut oil and used cooking oil were had too low parameters. A hypothesis in which the products' flash point would be above 160°C for the peanut oil and 170°C for the used cooking oil.

From the starting oils in this study in comparison to their respective products, the overall reaction did not go through. A majority of the physical properties of the products were not significantly different than that of the oils themselves.

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