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The testing of the effects of cooking conditions on the quality of biodiesel produced from waste cooking oils

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ABSTRACT

In this study, the effects of cooking conditions on the cold flow properties and kinematic viscosity of biodiesel produced from cooking oils were investigated. Sunflower, corn and canola oils were used as vegetable oils. Salt content, water content, cooking time and cooking temperature were selected as the experimental parameters. Some of the physical properties such as kinematic viscosity, density, cloud point and pour point were examined. In addition, total polar material contents, heating values and acid values of biodiesel produced from waste cooking oils were analysed. The results of the study revealed that increase in salt and water content, cooking time and temperature led to deterioration in the physical properties and cold flow properties of B100 biodiesel samples from waste cooking oils of sunflower, corn and canola oils. On the other hand, the heating values of all biodiesels were found to improve with the increasing salt content.

1. Introduction

Biodiesel is a fuel produced from the reaction of vegetable or animal oils in the presence of a catalyst with a short chain alcohol like methanol or ethanol. The world energy need is increasing, while the available sources of fossil fuels such as coal and petroleum are reducing. Moreover, the utilization of fossil fuels causes global warming by increasing the effects of greenhouse gases, significantly. Biodiesel is biodegradable, non-toxic and environmentally friendly due to low emission profiles. Contrary to these advantages, the most important disadvantage of biodiesel is its high cost [1,2]. Since vegetable oils are important raw materials in food industry, their utilization in biodiesel production is not economical and practical. Waste cooking oils are accumulated in very large quantities each year in all countries and releasing these oils into the environment can cause environmental problems and clogs inside drainage pipes. Therefore, the use of waste cooking oils for biodiesel production is one of the promising ways.

Important review studies were performed related with biodiesel production from waste cooking oils. Kulkarni and Dalai [3] said that undesired products such as free fatty acids and some polymerized triglycerides formed in vegetable oil during frying could affect negatively both transesterification reaction and the physical properties of biodiesel. Yaakob et al. suggested that waste cooking oil was a promising raw material of biodiesel production [4].

Knothe and Steidley, examined the acid values, viscosities and fatty acid profiles of used frying oils they obtained from 16 local restaurants. According to the obtained results researchers decided that used cooking oils are very heterogenous raw material source for biodiesel production [5].

Zhang et al. developed 4 different process flow charts for biodiesel production from waste cooking oil at commercial scale. Operation conditions and equipment design were obtained in detail for each process. In the research it was determined that a system with acid catalyst is technically more convenient compared to basic one [6].

Studies were also made where optimum conditions of biodiesel production from waste frying oils were researched. In these studies the conditions for reaching highest methyl ester product were determined [7–9].

In some studies various physical and chemical properties of biodiesel produced from waste frying oil were measured. In these studies the fuel quality of produced biodiesel was researched [10–14].

In the present study, the effects of cooking conditions of cooking oils on the quality of biodiesel produced from waste cooking oils were investigated. The cloud point (CP), pour point (PP), density, viscosity, heating value, acid value and total polar materials (TPM) contents were used as determining parameters of the biodiesel

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quality. Majority of the studies made examines the properties of biodiesel produced. However this study focuses on the effects of waste oil cooking conditions on biodiesel properties.

2. Materials and methods

2.1. Materials

Sunflower, corn and canola oils used in this study were obtained from a local market in Erzurum, Turkey. The fatty acid composition of these oils was obtained by GS and given in Table 1. The methanol and potassium hydroxide catalyst used for biodiesel production had 99.9% purity. They were provided from Merck and Flake, respectively. Edible salt used in the experiments was supplied from a local market.

2.2. Equipment

Cooking experiments were carried out in a 1000 mL flat-bottomed glass balloon. Hot plate magnetic stirrer was used for stirring and heating. The balloon was placed in boiling stones and a magnet to prevent the oil explosion. In addition, it was fitted with a condenser to prevent water losses and a digital thermometer was used for temperature measurement. Experimental parameters during the cooking experiments were given in Table 2.

Transesterification experiments were performed in a 1000 mL jacketed glass reactor. A mechanical stirrer, a constant temperature circulator and a condenser were utilized in order to keep the methanol amount inside the reactor constant. Experiments were carried out at atmospheric pressure. Constant parameters, reaction temperature, reaction time, oil to alcohol ratio and catalyst amount were defined as 60 °C, 1 h, 1:6 (in weight) and 1% KOH (in weight), respectively.

3. Experimental procedure

Experiments were repeated three times at different times. Averages of standard deviations (ASD) and R^2 values were calculated. R^2 values were displayed on figures and ASD were given along with the labels of figures.

3.1. Cooking experiments

The glass balloon was initially filled with vegetable oil. Water and edible salt were added in the certain amount. The balloon contents were heated to the desired temperature and kept at that temperature for the desired time. For example while examining the effect of salt content, 500 mL of vegetable oil was placed in a glass balloon with flat bottom surface. After that 2% water by volume and 0.22% salt by weight (initial value of salt amount) were added. On top of them condenser was added for preventing water loss and a thermometer for temperature control. The oil was heated at 100 °C for 5 h. The oil which is exposed to cooking conditions was transferred to a reactor for biodiesel production. The operations were repeated for other values determined for effect of salt. Same method was followed while examining the effect of each parameter. Namely while the parameter aimed to be examined was changed the parameters stated to be constant on Table 2 were not changed.

Table 2
Experimental parameters during cooking experiments.

Parameters	Values		
Salt amount (wt %)	0.22	0.44[a]	0.88
Water amount (v %)	2[a]	4	8
Time (h)	5[a]	10	15
Temperature (°C)	100[a]	160	230

[a] Constant parameters used when the effects of other parameters were tested.

3.2. Transesterification reaction

The vegetable oil exposed to cooking conditions was placed into the reactor and heated to 60 °C. KOH catalyst dissolved in methanol was added to the stirred reactor and the reaction started. At the end of the reaction, the reactor content was taken to a separator funnel and glycerol phase was separated from the bottom. After three times washing with deionized water, mixture in the separator funnel was placed on a rotary evaporator and kept there under vacuum at 80 °C in order to remove residual methanol.

3.3. Analytical methods

Physical properties of the biodiesel products obtained from waste cooking oil were determined according to related European standards (EN). After each experiment, pour point (PP), cloud point (CP) and density (at 15 °C) were measured. Kinematic viscosity (at 40 °C) and heating value of each sample were determined by using Koehler kV4000 series viscosimeter and calorimetric bomb IKA C 200, respectively. The acid values of samples were measured through the titration method using a KOH-ethanol solution and given Table 3. Additionally, the amount of total polar materials (% TPM) of each biodiesel sample (B100) at 50 °C was analysed by Testo 270 cooking oil tester. In order to achieve this the biodiesel sample in which TPM content will be determined, was heated to 50 °C. In the sample Testo 270 – the cooking oil determination device was immersed and directly the TPM percentage was read from digital screen.

Fatty acid composition of vegetable oils and Fatty acid methyl ester contents of biodiesel samples were analysed using a Gas Chromatograph system equipped with an auto-injector (Perkin Elmer Clarus 680, USA). The BPX-70 capillary column (SGE, Melbourne, Australia, 60 m × 0.25 mm i.d., 0.25) was used for the analysis of FAME. The initial oven temperature was 50 °C for 4 min, and was increased to 230 °C at a rate of 4 °C/min, then maintained for 10 min.

Table 1
Fatty acid composition (mass%) of canola, sunflower and corn oils.

Fatty acid		Canola oil	Sunflower oil	Corn oil
Palmitic	C16:0	4.85	27.35	31.72
Stearic	C18:0	1.93	60.95	52.42
Oleic	C18:1	64.38	0.50	1.17
Linoleic	C18:2	19,74	6.54	11.80
Linolenic	C18:3	7.05	3.61	2.18
Arachidic	C20:0	1.14	0.15	0.27
Behenic	C22:0	0.28	0.64	0.15