Effects of Material and Cold Air Temperature Conditions on Safflower Biodiesel Viscosity and Evaluation with Anova/Taguchi

Mustafa Taşyürek, Murat Mirik, Şerafettin Ekinci, and Mustafa Acaroğlu

***Abstract*—In this paper response surface methodology (RSM) was used to study the transesterification reaction of safflower for biodiesel production. Biodiesel is alternative fuel, *with* catalyst and alcohols reaction production, from vegetable oils, animal oils and waste fried oils. But there are fuel problems to be solved before biodiesel. These are storage time, storage conditions and cloudy and flow points which have flow peculiarity in the low heats. In this research, physical and chemical properties as a fuel of Safflower Methyl Ester (SME) which are biodiesel fuels are determined. In this research, method of transesterification is employed. Attitudes in storage time and storage conditions of SME are investigated. As a result, SME viscosity figures, according to measured dates, are below 40 Redwood min. at 40°C. Also the effects of outer temperature and fuel temperature on viscosity were found significant (*P*<0.01) by the performed variance analysis.**

***Index Terms*—Biodiesel, fuel properties, safflower methyl ester, storage, taguchi method.**

I. Introduction

Today, society is continuing its intensive search for alternative sources and research for the energy requirements. One of these alternative energy sources are biodiesel. Biodiesel is a renewable and environmentally friendly. However, there are problems of biodiesel fuel. These are storage time, storage conditions, with flow properties at low temperatures, the cloud and pour point. Cloud and pour point are flow properties at low temperatures. One of the biggest technical obstacles of biodiesel is not suitable lack of adequate flow properties especially in winter conditions.

So that the biodiesel in cold climates with high yield point that would adversely affect the availability of fuel. Therefore, this feature should be used with a pour point depressor. An additive used to improve the cold flow properties will affect positively to the degree of crystallization and clogging of the fuel filter.

As biodiesel properties can be affected by environmental conditions. This impact should be known that the circumstances in how. The environmental conditions, especially temperature are an important feature. In addition, storage time and storage features also affect the fuel properties. Klopfenstein [1], has stored to soy methyl ester in steel and plastic containers for 20 months and the peroxide value of the sample stored in steel containers have found that the higher the plastic container.

DuPlesis *et al*. [2], have examined oxidative stability of the ethyl and methyl ester produced from sunflower oil and during the 90-day test, ethyl and methyl esters were tested by storing in different containers under a variety of experimental conditions. Acaroğlu and Demirbaş [3] have investigated the effect of viscosity and density on flash point in some biodiesel fuel and investigated the methyl esters of safflower, palm, soybean, mustard, nut, and rapeseed. Erdoğan [4] examined the physical properties of vegetable oils whether or not engine fuel and stated that the viscosity is higher.

Taguchi’s technique has been popular for parameter optimization in design of experiments (DOE) for decades. Such programs in recent years have begun to be preferred in many different fields of science such as surface hardness measurements [5], biodiesel production optimization [6], [7], image deblurring [8], interrill erosion [9] study. The Taguchi method was adopted as the experimental design methodology, which was adequate for understanding the effects of the control parameters and to optimize the experimental conditions from a limited number of experiments [7]. Buasri *et al.* [10], obtain biodiesel from oil palm have optimized using the Taguchi method and they have reported on the production temperature and the amount of catalyst. Ganapathy *et al.* [11] have made the engine performance evaluation of jatropha biodiesel using the Taguchi program. In this study, duration and storage conditions of the biodiesel fuels produced from safflower oil by the transesterification process are investigated the effect on fuel properties of biodiesel and their results were determined.

The biodiesel storage conditions are depends on the fuel temperature, the storage material, storage time and ambient temperature. Instead of performing numerous experimental studies to optimize the process parameters in the Taguchi experimental design, fewer amount of test were sufficient to achieve better conditions of use of methyl ester. The primary advantage of the Taguchi method for optimization is using orthogonal arrays for design to simplify the task of planning experiments greatly.

II. Materials and Methods

In this study, safflower oil methyl ester and has used as material. The biodiesel reactor is used to safflower methyl

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ester (SME) produce from safflower oil. Methanol (CH_3OH) has 99.9 % purity, 0.791 kg/liter density, 32.04 g/mol molecule weight, 64.4-64.7 °C distillation interval. Sodium hydroxide (NaOH) has 40.00 molecule weights, 99.5 % real matter [12].

The aim of the obtaining methyl ester is to prepare accordingly of the catalyst used in reacting vegetable oil and alcohol [12]. Production scheme of biodiesel is shown in Fig. 1.

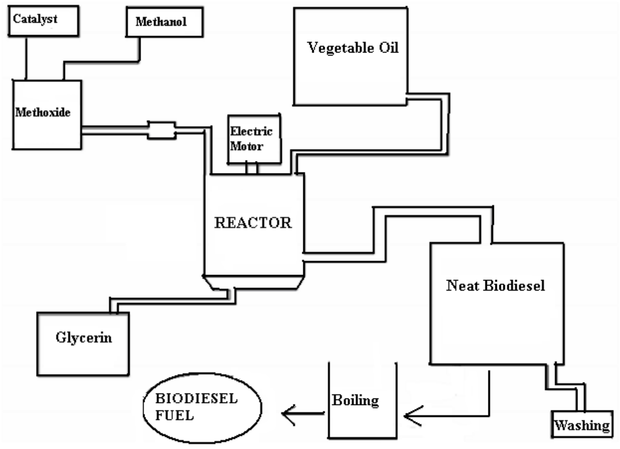

Fig. 1. Production scheme of biodiesel [4], [12], [13].

Safflower oil is placed in the reaction tank after filtration. Biodiesel is heated to 60°C. Heat treatment of the substances placed in the mixture makes it easier to stir.70 g of this catalyst was placed into a separate container during heating. The catalyst as NaOH (sodium hydroxide) was added. Addition of 4 liters of methyl alcohol is added. The resultant final mix is called methoxide. The mixture is mixed at 1000-1500 rev/min. After placing the methoxide tank mixing started immediately. Stirring is continued for 70 min. After the mixing is complete, the glycerin settles to the bottom of the container. After collapse the receiving of biodiesel is started. Separation was performed using a pump. After separation the washing is started. Washing was continued for 3 hours. Boiling temperature was set at 105°C.

Redwood No. 1 model viscometer was used for measure the fuels viscosities. The fuels put covered in glass bottles, and bottles was protected from sun by means of encircle with aluminum folio and hide at closed environment (in the sunshineless cupboard) in order to determination characteristic at storage conditions of safflower biodiesel (see Fig. 2).

Fig. 2. Safflower methyl ester.

Flash point of safflower was determinate with flash point device which is Koehler trade mark around type. Measures are at least 3 repeat.

The design of experiment used a statistical technique to investigate the effects of various parameters included in experimental study and to determine their optimal conditions. The design of the experiment via the Taguchi method uses a set of orthogonal arrays for performing of the fewest experiments. The Taguchi approach is used for the process optimization of transesterification.

The full factorial experimental parameters with factors and levels involve hundreds of experimental results. This increases the number of experimental runs correspondingly it takes time and requires a very high cost. So, firstly analysis of the material was performed. Three material numbers were reduced to 1. Later, experiments were conducted on ambient temperature and fuel temperature.

The S/N ratio indications can be separated into three groups: the smaller-the-better, the larger-the-better, and the nominal-the-best [14]. This study aimed to optimize the fuel viscosity. Hence, smaller-the-better has been debated to compute the S/N ratio.

The authors use the L18 (6^1 3^6) orthogonal array of the Taguchi method to determine the optimal (A) viscosity of biodiesel and (B) storage materials. In here A and B represents viscosity and container material respectively. Also, in B 1, 2, and 3 represents glass, plastic, and metallic material respectively. Also, in A 1, 2, 3, 4, 5, and 6 represents temperature of fuel (20°C, 25°C 40°C, 50°C, 65°C, 90°C respectively) in Table I and Table II.

TABLE I: DESIGN OF EXPERIMENTS L18 ORTHOGONAL ARRAY

Parameters	Levels																	
A	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6
B	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3

TABLE II: DESIGN EXPERIMENTS FOR PRODUCTION

Parameters	1	2	3	4	5	6
A (°C)	20	25	40	50	65	90
B	glass	plastic	metallic	-	-	-

III. DISCUSSION AND RESULTS

In this study, nowadays for use in vehicles which have diesel technology, effect of safflower methyl ester (SME) on storage time and fuel characteristic was investigated. The values obtained from biodiesel were compared with the diesel fuel. Comparing the SME based on the diesel is given in Table III. Fuel properties have started to be measured in December. Also, viscosity variation is given in Fig. 3 according to date.

TABLE III: FUEL PROPERTIES OF SME

Fuel Property	Unit	SME	Diesel	EN 14214
Density (at 15 °C)	kg/m^3	880	838	860-900
Kinematic viscosity (at 40 °C)	mm^2/s	4.02	2.4	3.50-5.00
Flash Point (FP)	°C	180	64	120 (min)
Cetane Number	---	49.8	52.1	51
Cloud point (CP)	°C	- 4	-6	--
Pour Point (PP)	°C	-6	-20	--
Freezing point	°C	-11	-29	--
HHV	MJ/kg	40.0	45.35	--
LHV	MJ/kg	37.0	41.76	--

There wasn't a great distinction about dates at the viscosity variation in SME. At the same time there wasn't variation on SME's color, after oxidation test which 240 hours and apply on Safflower Methyl Ester. Its color has light yellow. But it always been a risk for oxidation owing to it has high iodine number. The average results of SME's viscosity are given for all temperatures and all container materials in Table IV.

TABLE IV: VISCOSITY OF SME

Temp. (°C)	glass	plastic	tin
20	7,28	13,22	9,32
25	6,78	10,39	8,63
40	4,988	9,24	4,68
50	3,31	6,74	3,4
65	2,688	5,33	2,25
85	1,45	3,36	1,1
90	0,95	2,94	0,7

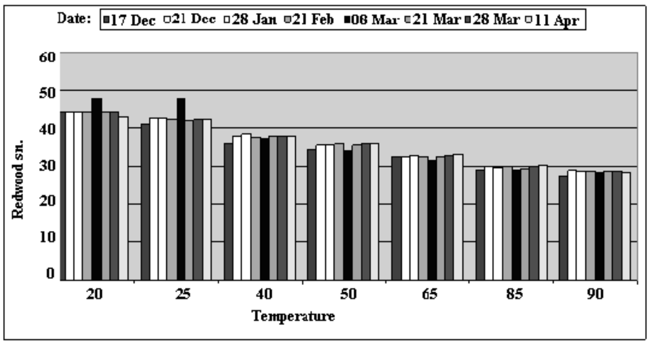

Fig. 3. Variation of AME viscosity according to dates.

IV. DETERMINATION OF OPTIMAL MATERIAL BY TAGUCHI METHOD

The experimental data are compared according to the results estimated in Taguchi program. As shown in Fig. 4 under all conditions, there is a great similarity. This is an indication that could increase the number of tests performed under real conditions and forecast the approach of the experiments.

According to the results; it is seen that plastic material has negative effect on the viscosity. But, the effect of glass and metal are positive. It is known that metallic materials be used as storage container. Not found in the literature, the work on the glass material. Thus, studies were continued for ANOVA about glass material. In addition, SN ratios for biodiesels container materials and temperatures are shown in Fig.5.

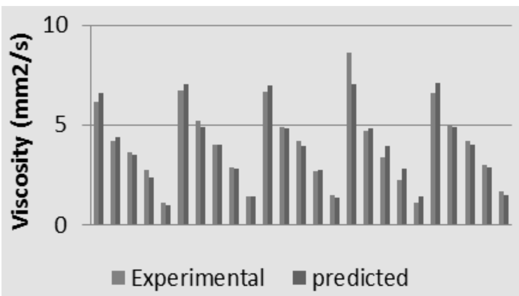

Fig. 4. Comparison of experimental and predicted data.

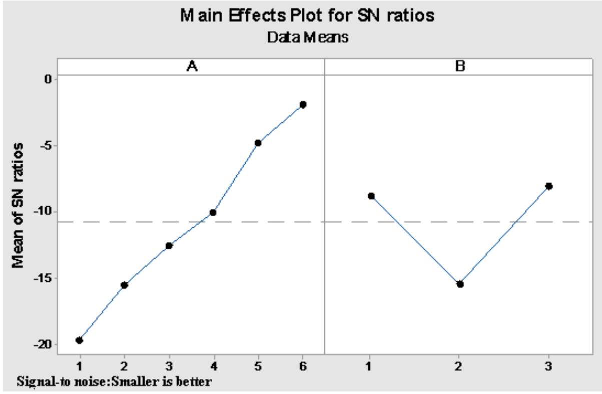

Fig. 5. Main effect plot for SN ratios.

V. ANALYSIS OF VARIANCE (ANOVA)

Variance analyses of manipulated variables such as outer temperatures and viscosity measurement temperatures were done in order to determine effects on viscosity of biodiesel from safflower methyl ester. MINITAB 14 software program was used to obtain the results of variance analysis were done via ANOVA module. Then results are given in Table V.

TABLE V. ANALYSIS OF VARIANCE FOR VISCOSITY

Source	DF	SS	MS	F
Date	7	1,364	0,195	1,17^{ns}
Temperature	6	314,845	52,474	314,02**
Error	42	7,018	0,167	
Total	55	323,227		
Date 1	7	68,055	9,722	12,12**
Temperature 1	6	630,482	105,080	130,98**
Error	42	33,696	0,802	
Total	55	732,234		
Date	2	48,526	24,2629	34,79**
Temperature 2	6	188,444	31,4073	45,04**
Error	12	8,368	0,6973	
Total	20	245,337		

** 1% level was statistically (P <0.01)^{ns} not significant.

VI. CONCLUSION

In this study, once others fuel properties keep an eye, it is certain that AME will be a good biodiesel sources with its storage conditions aspect.

1) Fuel tanks, storing cans or small amount in ready sale point plastic can are not certainly using, for preventing fuels oxidation.
2) In the diesel fuel and biodiesel, if storage conditions don't suitable, viscosity rises in the course of time.
3) Although plastic cans have more sensitive towards oxidation in biodiesel, steel and glass cans less sensitive than these. At the biodiesel should prefer to storage stainless-steel or chromium-nickel cover.
4) The conclusion reveals that container material had greater influence on viscosity. The major conclusion of Taguchi analysis exposes that the results direct to the

conclusion that combination of factors metallic material-high temperature (90°C) and glass material-high temperature (90°C) offer minimum viscosity.

5) The other major conclusion (ANOVA results) reveals that temperature of fuel had greater influence on viscosity.

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