J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (8): 329 –332, 2018

Utilization of High Voltage to Separate Glycerol during Producing Biodiesel

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ABSTRACT

Fried cocking oil from different homes were collected to produce biodiesel through trans-esterification process. It is a chemical reaction between fried cocking oil molecules and methanol alcohol in the presence of catalyst like potassium hydroxide to obtain glycerol as a by-product and biodiesel as a major product. Using gravity technique for separating is not appropriate method because it is conformed per long period; therefore, high voltage technique has been shown capable of fast causing glycerol fallout. The purpose of this research is to examine the effect of electrodes span having different high voltages on separating period between methyl ester (biodiesel) and glycerol; besides, to determine the energy consumption for this technique compared to gravity. Data indicated that the least separating period was 210 seconds at distance of 2 cm between electrodes with high voltage 7.2 kV per mixture 10 liters.

Keywords: Fried cocking oil, separating glycerol, high voltage, biodiesel.

INTRODUCTION

Egypt imports more than 90% of its need from vegetable oil, so it is not a good idea to produce fuel from edible oil for the commercial production. Therefore, advisable to use the non- edible oil like used cooking oil, jatropha oil, pongamia oil, etc. for producing biodiesel. Biodiesel is more sustainable and more friendly to the environment than fossil fuels which continues to be of a major concern by the whole world, because the high viscosity of vegetable oils (40–50 mm^2/s at 40 ^oC) establishes a major problem when used for running engine due to their poor atomization which, leads to incomplete combustion with subsequent formation of carbon deposits on the piston tip of the diesel engine, Therefore, vegetable oils should be treated to improve their properties (Tat and Van Gerpen, 1999). Trans-esterification process is the chemical method to change the oil properties to be suitable as diesel fuel. In the trans-esterification reaction triglycerides are reacted with an alcohol to form three fatty acid alkyl esters (FAAE) as a main product and glycerol as a by-product. The alcohol most commonly used is methanol and ethanol, but methanol is preferred because it is cheaper and is more easily recovered in downstream operations. The products formed when using methanol. Therefore, they referred too as fatty acid methyl esters (FAME) and glycerol (Jaichandar and Annamalai, 2011). Biodiesel fuels have received significant attention both as a possible renewable alternative fuel and as an additive to exist petroleum-based fuels. Beyond simply representing an additional fuel supply, biodiesel exhibits several advantages when compared to existing petroleum fuel (Abbaszaadeh *et al*., 2012). One of the most serious obstacles to use biodiesel as an alternative fuel is the complex and costly trans-esterification processes involved in its production. The difficulties involved in separating glycerol, non-reactive substances and byproducts require the development of new low-efficiency separations for this purpose (Hayyan *et al*. , 2010). To remove glycerol from biodiesel is important since the glycerol content is one of the most significant precursors for the biodiesel quality. Man *et al*. (2010) and Demirbas (2007) indicated that the traditional means of removing glycerol is mainly by gravity separation or centrifugation. The biodiesel/glycerol mixture is pumped to a tank and allowed to settle for 8–10 hours. Therefore, (Moussa, 2016) indicated that The gravity method is not a proper solution for biodiesel production. Graham (2015) advanced the idea of using a high voltage current to separate biodiesel from glycerol. It but this method didn't tested on conformed under the Egyptian condition. To make separation easy, fast, and less time consuming by pass the bulk of the liquid through a pair of medium voltage, converged distance. So the upward flow rate is set to suit the downward drop rate, showed the separation swift and efficient. The whole high voltage section can be isolated into one simple external module, to reduce spark ignition risk. Abbaszadeh *et al*. (2014) studied the process of coagulation particles or drops of glycerol in biodiesel- glycerol mixture from an electric field is done by the determine the effectiveness of a high voltage/low amperage a glycerin separation in a batch setting.

So, the aim of the present study is to determine the optimum conditions of utilizing high voltage for separating biodiesel/glycerol mixture such as electrodes span and different of high voltages per current intensities.

MATERIALS AND METHODS

Experiments were carried out in the laboratory of biofuel in Tractor Test Station Sabahia, Department of forces and Energy. To produce biodiesel from waste home of vegetable oil using the trans-esterification process in a prototype unit that manufactured locally.

Raw Materials

The main source of biodiesel are wastes vegetable oil (WVO) which mixed and fatty acid compositions were analyzed in laboratory. Methanol alcohol (CH_3OH) $99\%^+$ pure and Potassium Hydroxide must be dry and there were purchased from chemical company.

Manufactured prototype

A movable prototype for making biodiesel as shown in Fig.(1) consists of chemical premix tank with agitator that take power from electric motor of 100 W, processor with electric heater, an agitating pump of 0.37 kW, separating glass tank and high voltage unit to apply different voltages.

Separating unit is a cylindrical-conical tank made of glass with a thickness of 10 mm, a diameter of 22 cm with its capacity of 10 liters. Separation process is performed using high voltage to separate the glycerol from the biodiesel as in Fig. (2).

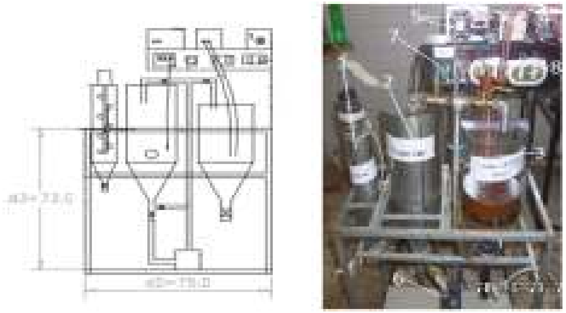

Fig. 1. Manufactured prototype for making biodiesel

1- Chemical Tank 2- Mixing Unit 3- Separating Unit
4-Power Supply 5-High Voltage Unite 6-Electric Motor
7-Temperature Controller 8- Unite Operation

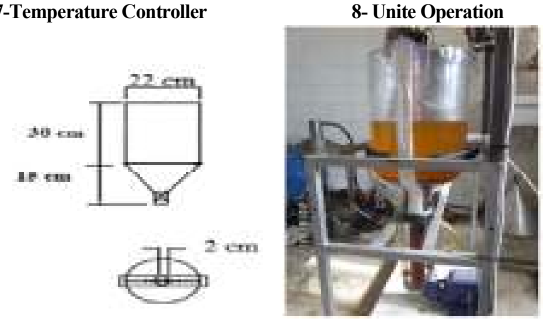

Fig. 2. Separating unit

High voltage unit consists of two main parts; power supply and high voltage components (Fig. 3):

- Power supply using to input the power of 12 – 13.5–15–18–24 and 30 Volt DC, 3A max to the high voltage part.
- The high voltage part was manufactured by a 2n3055 fly back driver circuit, Fig. (4). That having fly back transformer, 2n3055 transistor + heat sink, 220 ohm 5 watt resistor and 22 ohm 5 watt resistor.

A fly back transformer, sometimes called a line output transformer, is used in older CRT televisions and computer monitors to produce the high voltage. This consists of the primary turns with a number of laps of 10 and secondary turns with a number of laps of 3000 assuming an ideal transformer with a 1:300 turn ratio. Then, it can expect to obtain 3.6; 5.4 and 7.2 kV with low amperage AC of 38; 20 and 16 mA during input volts of 12; 18 and 24V respectively. The following simple eq. used to predict the high volts in the secondary turns:

$$\frac{v_{in}}{v_{out}} = \frac{n_p}{n_s}$$

Where:

V_{out} = V induced in the secondary V_{in} = V applied to the primary
N_s = Number of secondary turns N_p = Number of primary turns
For example:
But V_{in}=12 V, N_p=10 turns, N_p = 3000 turns
$V_{out}=\frac{v_{in}}{n_p} * n_p = \frac{12}{10} * 3000$= 3600 V

Fig. 3. High voltage unit

1-Power Supply 2-High Voltage Unite

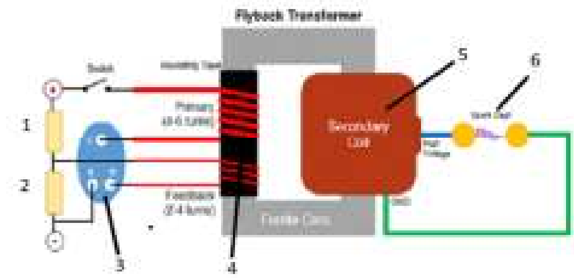

Fig. 4. 2n3055 fly back driver circuit

1- Resistor =220 ohm 5 watt 2- Resistor= 22 ohm 5 watt
3- transistor 2n3055 4- primary turns
5- secondary turns 6- spark out

Heater controller (W1209) is an incredibly low cost yet highly functional thermostat controller. This module can intelligently control power with the temperature sensed by the included high accuracy temperature sensor. Although this module has an embedded microcontroller no programming knowledge is required three tactile switches allow for configuring various parameters including on & off trigger temperatures. The on board relay can switch up to a maximum of 240V with AC at 5A or 14V with DC at 10A. The current temperature is displayed in degrees Centigrade via its 3 digit seven segment display and the current relay state by an on board LED as shown in Fig. (5).

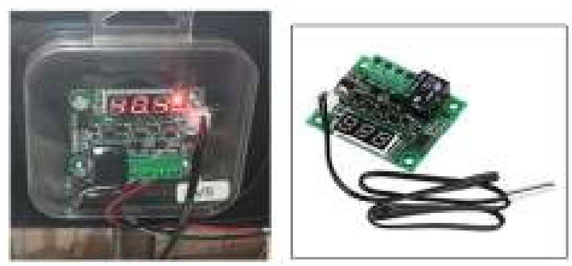

Fig. 5. Heater controller

Biodiesel Properties

Physical properties of diesel, biodiesel B100 and blended biodiesel B20 were measured in Misr Petroleum Company's lab. These characteristics were evaluated in accordance with the American Standard for Biodiesel Testing Method (ASTM D6751) these methods are shown in ASTM procedures for petroleum products.

RESULTS AND DISCUSSION

Fatty acid composition of waste vegetable oil:

A mixture of waste vegetable oil (WVO) has been poured and mixed in the processing tank. That samples contain linoleic acid (C18:0) which is the highest amount among other fatty acids recorded 47.8% followed by palmitic acid (C 16:0) of 23.1%, oleic acid (C18:1) of 22.9%, Palmitoleic acid of (C16:1) 2% and the rest is 4.2%. High levels of saturates (C14:0, C16:0, C18:0) tend to improve stability and raise Cetane number.

Separating Glycerol Via Gravity Method

The different amounts of glycerol separated per different times are illustrated in Fig. (6). Regarding to Fig. 6, it easy to shows that, the first 60 min recorded the rapidly separation which the amount of glycerol confirmed around 360mL and through the 60mim later (the second section of curve) the separation of glycerol rate decreasing by about 10% than that the first section. The third section of relation, from 180 to 360 min, recorded regular increase rate for separation. After that and during the fourth section of curve, the amount of glycerol separation conformed in irregular rate. At the end of the trans-esterification process, the mixture of biodiesel and glycerol left for 10 h for complete separation, in order to determine the total amount of glycerin-rich phase when separated by gravity method. Data indicated that the maximum time for separation was 540 min, after that the quantity of glycerol did not exceed.

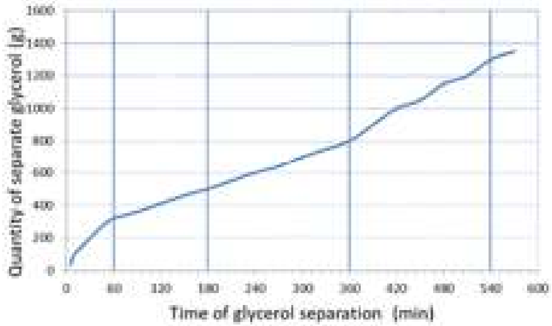

Fig. 6. Glycerol separation relative to operate time via gravity method

High voltage method for separating glycerol

The amounts of glycerol separation rate (GSR, mL) relative to operating time are recorded in Fig. 7. From Fig. (7-A), the amounts of glycerol separation rate decrement with increment the high voltage at the electrodes span of 2 cm. For example, the amount of glycerol after 10 sec were 180; 150 and 90 mL for high voltage of 3.6; 5.4 and 7.2 kV respectively. Generally, the total amount of GSR (1380mL) were found per operating times of 210; 240 and 300s for 3.6; 5.4 and 7.2 kV respectively at electrodes span of 2 cm. While, at electrodes span of 4 cm (Fig, 7-B), the total amount of GSR (1380mL) were found per operating times of 330; 390 and 450s for 3.6; 5.4 and 7.2 kV respectively. Increasing the electrodes span to 6cm (Fig. 7-C); the amount of GSR (1380mL) recorded per operating times of 480; 540 and 780s for 3.6; 5.4 and 7.2 kV respectively.

On the other side, the interaction between electrodes span and high voltage parameters was illustrated in Fig. 8. Results showed that at distance 2 cm the maximum quantity of glycerol (GSR=1380 mL) was separated at 210 sec but at electrodes span of 4, 6 cm all GSR were separating at 330 and 480 sec respectively.

The analysis trends of the GSR data per resting time were conformed as power relation with the following relations

At 2 cm electrodes span		
$GSR = 53.967\ T^{0.5976}$	$R^2 = 0.9261$	during 3.6kV
$GSR = 39.499\ T^{0.6519}$	$R^2 = 0.9394$	during 5.4kV
$GSR = 19.947\ T^{0.7772}$	$R^2 = 0.9346$	during 7.2kV
At 4 cm electrodes span		
$GSR = 58.377T^{0.5357}$	$R^2 = 0.9333$	during 3.6kV
$GSR = 40.075T^{0.5984}$	$R^2 = 0.9394$	during 5.4kV
$GSR = 19.551T^{0.7174}$	$R^2 = 0.9342$	during 7.2kV
At 6cm electrodes span		
$GSR = 32.812T^{0.5911}$	$R^2 = 0.9352$	during 3.6kV
$GSR = 20.955T^{0.6602}$	$R^2 = 0.9442$	during 5.4kV
$GSR = 7.1656T^{0.7923}$	$R^2 = 0.9913$	during 7.2kV

Investigation of voltage on separation showed that with increasing voltage from 3.6; 5.4 and 7.2 kV at current from 38 mA, 20mA, 16mA, the amount of time required to separate of glycerin and biodiesel has reduced at 10 liters mixture. This phenomenon can be explained by that increase in voltage leads to a strengthening of electrostatic field and accelerating of the coagulation particles or drops of glycerin in biodiesel- glycerin mixture.

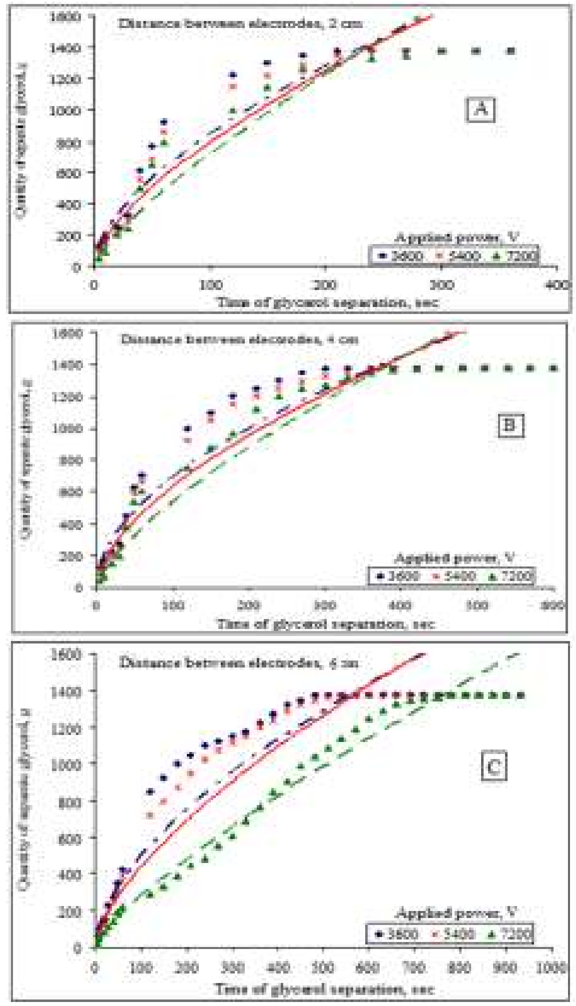

Fig. 7. Glycerol separating via high voltage method

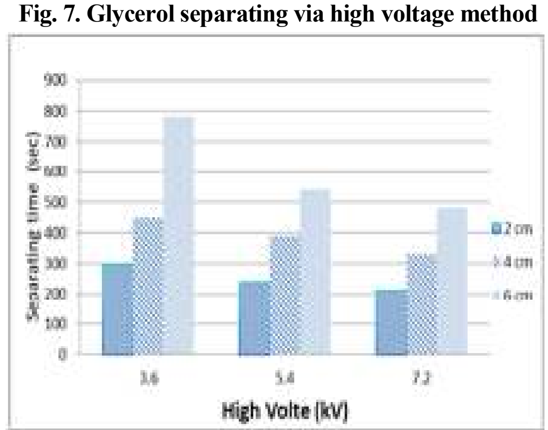

Fig. 8. The GRS as the interaction between high volte and electrodes span

Energy vs. High voltage and electrodes spans

Fig. (9) Showed that, the energy consumptions were 11.4; 7.2 and 6.72 W.h at high voltage recorded 3.6; 5.4and 7.2 kV respectively for electrodes span of 2 cm. It less from

17.1 to 11.7 and to 10.56 W.h at voltage is increased from 3.6 to 5.4 and to 7.2k V respectively at electrodes span of 4 cm. The highest of the energy consumptions were 29.64, 16.2 and 15.36 W.h at high voltage 3.6; 5.4 and 7.2kV respectively at electrodes span of 6cm. The reduction in power usage by the system seems to correlate with the separation of the glycerol in the layer between the two electrodes. Data showed that the shorter distance is reducing energy consumption and as that increase the high voltage affect positively on energy consumption.

Properties of biodiesel and diesel fuels

Table (1) reveals some physical characteristics of biodiesel and diesel fuel. Biodiesel percentages have all essential properties of diesel fuel. The parameters were checked according to the ASTM specification for diesel fuel. From the previous table it showed that the properties of B100, B20 was in the allowable limit as ASTM standard

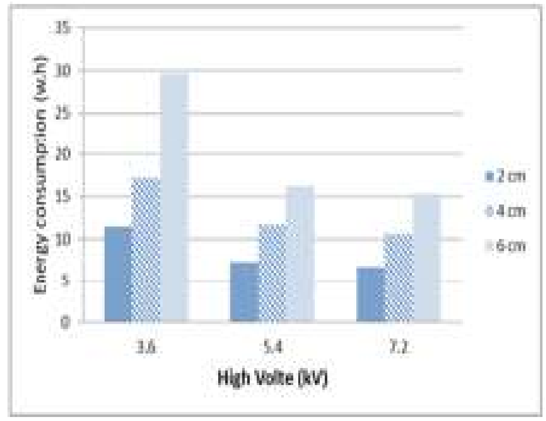

Figure 9. Effect of high volte and electrode distances to energy consumption

Table 1. Physical properties of diesel and biodiesel at 100 and 20% compared with American standard.

Properties	Diesel	Biodiesel		Standard of biodiesel	Standard methods
		B100	B20		
Density, kg/l @15 °C	0.846±	0.888	0.854	0.86 – 0.9	D287
Calorific value, MJ/l	44.3±	42.13	43.87	37.27	D240
Viscosity, mm^2/s @ 40 °C	3.3±	5.66	3.77	4 – 6	D445
Cetane No.	47±	51	48	48 – 65	D613
Pour point, °C	-3±	3	-1.8	-5 – 10	D97
Flash point, °C	52±	141	70	100 – 170	D93

CONCLUSION

The results indicated that electrode distances, voltages were important factors affecting the time required for separation process. Using high voltage method compared to gravity method to separation process in period less than minutes. Results of using various distances between electrodes (2, 4 and 6 cm) in various high voltage 3.6; 5.4 and 7.2kV proved that distance between electrodes of 2 cm and higher electrostatic field 7.2kV intensity has most effective reducing the glycerol separation period. The problem with this new method is how it used for industrial scale but seems to be applicable method in the future.

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استخدام الفولت العالي لفصل الجليسرول أثناء إنتاج الوقود الحيوي

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تم تجميع زيت مستعمل من المنازل لاستخدامه في انتاج الوقود الحيوي وذلك عن طريق عملية التحول. هذه العملية عبارة عن تفاعل كيمائي بين جزيئات الزيت المستعمل وكحول الميثانول في وجود مادة محفزة مثل هيدروكسيد البوتاسيوم للحصول علي جليسرول كمنتج ثانوي وبيوديزل كمنتج رئيسي. استخدام طريقة الفصل بالجاذبية ليست بالطريقة المناسبة للإنتاج بكفاءة لأنها تحتاج لوقت طويل في حين ان استخدام طريقة الفولت العالي قد اثبتت كفاءة عالية لفصل الجلسرول. الغرض من البحث هو دراسة تأثير المسافة بين الاقطاب والفولت المختلف علي زمن الفصل بين الجلسرول والبيوديزل ومقارنتها بالفصل بالجاذبية, بالإضافة الي حساب الطاقة المستهلكة في هذه العملية. أوضحت النتائج المتحصل عليها ان استخدام الفولت العالي عند مسافة 2 سم بين الاقطاب وفرق الجهد 7.2 كيلو فولت في حجم زيت مستعمل مقداره 10 لتر أدت الى الفصل بين الجليسرول و البيوديزل في اقل فترة زمنيه مقدارها 210 ثانيه واقل طاقة مستهلكه مقدارها 6.72 كيلو وات .ساعة