PRODUCTION OF BIODIESEL USING WASTE FAT FROM ROASTED CHICKEN

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ABSTRACT

Fossil fuels are non-renewable sources of energy which generate pollutants and are linked to global warming and climatic change. In order to overcome these problems, there is a need for an alternative for fossil fuels. The most common renewable fuel is biodiesel which is produced from vegetable oils, animal fat wastes and poultry. The aim of the present work was to study the transesterification of liquid fat resulted from chicken roasting. This fat was esterified with methanol and NaOH as a basic catalyst. Product yield of chicken fatty acid methyl Ester (CFME) was 79.1 % for liquid fat resulted from roasting. All quality control parameters for biodiesel produced (B100) were generally in agreement with ASTM standards. It can be concluded that chicken fat resulted from roasting is suitable for low cost feed stocks for biodiesel production.
Key words: biodiesel, liquid fat resulted from roasting, transesterification.

INTRODUCTION

Our society is highly dependent on petroleum for its activities. However, petroleum is a finite source and causes several environmental problems such as rising carbon dioxide levels in the atmosphere. About 90% of fossil fuels is used as an energy source for transportation, heat and electricity generation, and the remaining sources used as feed stocks in the chemical industry (Carlsson, 2009). Due to the increase in energy consumption and limitation of

fossil fuels, research is directed towards alternative renewable fuels (Bhatti *et al*., 2008).

Biodiesel fuels are attracting increasing attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines. Biodiesel consists of a mixture of fatty acid (chain length C14-C22) alkyl esters, derived from a renewable lipid feedstock, such as vegetable oil or animal fat. In the case of using methanol or ethanol is used as reactants, it will be a mixture of fatty acid methyl esters (FAME) or fatty acid ethyl esters (FAEE), respectively. Biodiesel produced by transesterification reaction by this means, three smaller molecules of ester and one molecule of glycerol are obtained from one molecule of fat or oil. Glycerol is removed as by-product and esters are known as biodiesel (Fazal *et al*., 2011). There are several reports on biodiesel production from edible oils (Aransiola *et al*., 2010). Thus; its competition with food consumption has been a global concern. About (34%) of edible oil was estimated for worldwide biodiesel production from 2004 to 2007 (Balat, 2011), and biodiesel is projected to account for more than a third of the expected growth in edible oil use from 2005 to 2017 (Balat, 2011). Consequently, using waste and nonedible oils in biodiesel production would eliminate the competition with food consumption (Kiss, 2009), it will also allow for compliance with ecological and ethical requirements for biofuel. Non-edible oil plants are well adapted to arid, semi-arid conditions and require low fertility and moisture demand to grow. Added to this, non-edible oils are not suitable for human food due to the presence of

toxic components in the oils also they solve the problem of competition with food production (Ahmad *et al*., 2011).

For all these reasons, they considered non-edible oils as good raw material for biodiesel production (Ahmad *et al*., 2011). The most important non edible oil plants are jatropha, karanja, tobacco, mahua, neem, rubber, sea mango, castor, cotton (Azam *et al*., 2005). The most common plants used for biodiesel production are jatropha, moringa and castor oils.

The production of biodiesel from waste cooking oil to partially substitute petroleum diesel is one of the ways for solving the problem of illegal dumping of waste cooking oil into rivers and landfills, which lead to environmental pollution and energy shortage (Chen *et al*., 2009). Also, in order to reduce the cost of biodiesel production, waste cooking oil would be a good choice as raw material since it is cheaper than virgin vegetable oils and other feedstocks (Hameed *et al*., 2009). The used edible oil is categorized by its free fatty acid (FFA) content. If the free fatty acid content of waste cooking oil is < 15 %, then it is called 'yellow grease'; otherwise, it is called 'brown grease' (Kulkarni and Dalai, 2006). Microalgae as a raw material for biodiesel has been reviewed extensively in recent years. Microalgae has many advantages over other traditional sources, including soybeans (Lee, 2011), sunflower and maize oils. It is grown in open ponds, exerting zero demand on arable land. It has the potential for up to one hundred times greater biodiesel yield than from soybeans (Lee, 2011). It was considered as a good raw material source, if the cost of production of algae is favorable. Gallagher (2011) reached the same conclusion that biodiesel from algae may will become an economic reality. The use of waste animal fat for the production

of biodiesel solves two problems that of sourcing a cheap raw material from a renewable resource that does not compete with food and that of tackling the waste management problems associated with meat production (Al-Zuhair, 2012). Previous researchers have effectively utilized mutton fat (Mutreja *et al*., 2011), chicken fat (Alptekin and Canakci, 2010), lard (Jeong *et al*., 2009) and beef tallow (Hoque *et al*., 2011), as alternative sources for transesterification processes. Mege *et al*., (2006) indicated that chicken can have a 30% fat content of the total poultry meat. The chicken fat can be simply and economically separated from wastes without chemical solvent treatment (Kondamudi *et al*., 2009). There are four primary ways to make biodiesel, direct use and blending, micro emulsions, thermal cracking (pyrolysis) and transesterification. The most commonly used method is transesterification of vegetable oils and animal fats (Geller and Goodrum, 2004). Transesterification or alcoholysis is the displacement of alcohol from an ester fat or oil by another in a process similar to hydrolysis, except that alcohol is used instead of water (Srivastava and Prasad, 2000). This process has been widely used to reduce the high viscosity of triglycerides. If methanol is used in this process it is called methanolysis. Methanolysis of triglyceride is represented in equation 1; transesterification is one of the reversible reactions and proceeds essentially by mixing the reactants. However, the presence of a catalyst (a strong acid or base) accelerates fatty acid conversion into ester.

Fig. (1): General Equation for transesterification of triglycerides (1)

Transesterification of triglycerides produces fatty acid alkyl esters and glycerol as by product. The glycerol layer settles down at the bottom of the reaction vessel. Diglycerides and monoglycerides are the intermediates in this process. The mechanism of transesterification is described in equation.2, the step wise reactions are reversible and a little excess of alcohol is used to shift the equilibrium towards the formation of esters. In presence of excess alcohol, the foreword reaction is pseudo-first order and the reverse reaction is found to be second order. It was also observed that transesterification is faster when catalyzed by alkali (Özcan and Aydın, 2004). The mechanism of alkali catalyzed transesterification is described in Equation.3. The first step involves the attack of the alkoxide ion to the carbonyl carbon of the triglyceride molecule, which results in the formation of a tetrahedral intermediate. The reaction of this intermediate with an alcohol produces the alkoxide ion in the second step. In the last step the rearrangement of the tetrahedral intermediate gives rise to an ester and a diglyceride (Rojer *et al*., 2008).

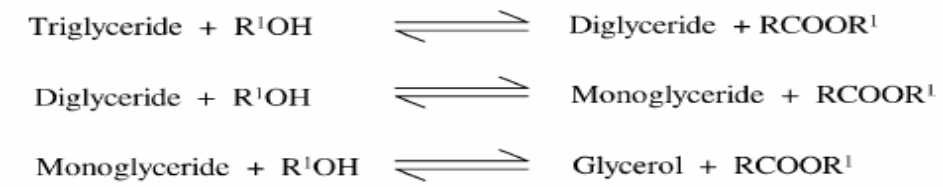

Fig. (2): Transesterification of triglycerides (2)

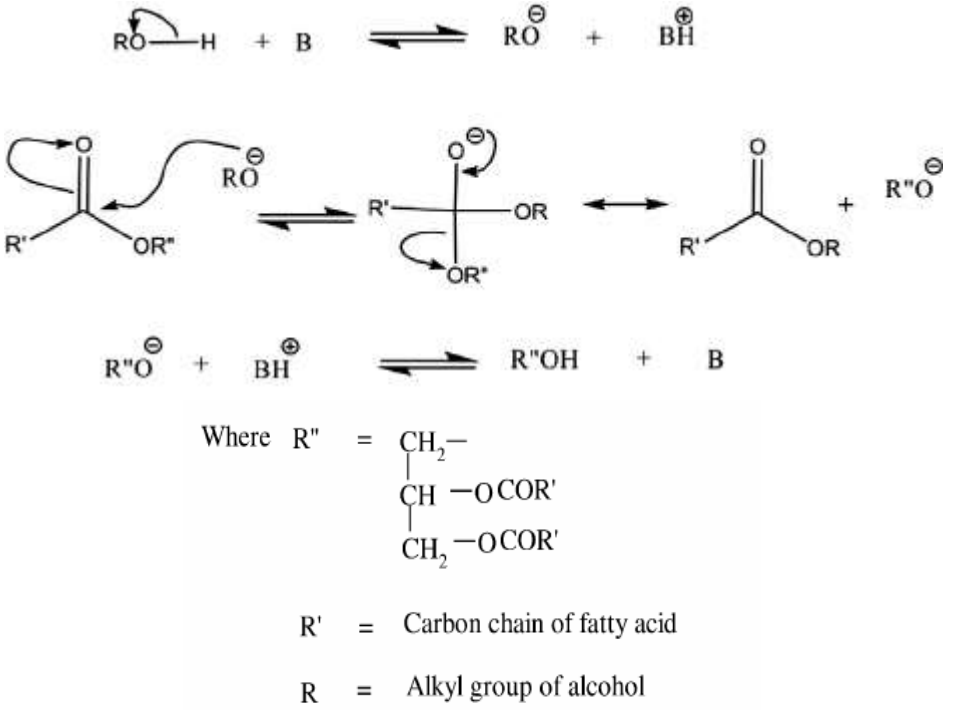

Fig. (3): Mechanism of base catalyzed transesterification (3)

The process of transesterification is affected by various factors depending upon the reaction condition used (Meher *et al*., 2006). These factors are free fatty acid content and moisture, catalyst type and concentration, molar ratio of alcohol to oil and type of alcohol, effect of reaction time and temperature, mixing intensity and the use of organic co-solvents.

In this work, the fat from chicken waste is suggested as a raw material for biodiesel.

The aim of the work is to produce biodiesel from chicken liquid fat resulted from roasting and investigate its characteristics as 100 % biodiesel and blended with 10 and 20% with fuel oil.

MATERIALS AND METHODS

Material: Chicken skins (source of roasting fat) were purchased from local market then heated in oven at100 ºC. This chicken fat is a mixture of solid and liquid phases at room temperature. Methanol (95%), hydrochloric acid, distilled water and sodium hydroxide (97%) were purchased from local chemical company.

Raw-Material Extractions and Characterization: The total mass of fat obtained from skin from market was 10kg, showing a fat extraction yield of 35% w/w. The acid value of obtained fat was 1.65 mg KOH.g-1. According to (Selva *et al.*, 2011)

Methods:

Acid Value: In order to access the quality of the raw material, the acid value was determined by volumetric titration according to NP EN ISO 660 (2002).

A test portion was dissolved in a solvent (ethanol at 70 ºC) and titrated with a 0.1 M solution of potassium hydroxide, using phenolphthalein as an indicator.

Biodiesel production: The reaction started when the mixture of solid NaOH (97%), dissolved in methanol (95%) then added to the fat sample. The following reaction conditions were considered, according to the literature review: 6:1 methanol to fat molar ratio and catalyst amount 1% (w/w). As the mass of fat considered in each reaction was 150 g, the methanol used was 42 mL and the mass of catalyst (NaOH) was 1.5 g at temperature 60° C for about 90 minutes according to (Moreira *et al*., 2009)

Biodiesel yield of each reaction was determined based on the following equation:

$$\text{biodesiel yield} = \frac{mass\ of\ biodiesel}{mass\ of\ raw\ material} \times 100$$

After the reaction is completed, the mixture of Biodiesel and glycerol was placed in a separating funnel.

Biodiesel Purification: After separation of biodiesel and glycerol, biodiesel was washed to remove the residual catalyst. First, 75 mL of a diluted solution of HCl (0.2%) was added to the biodiesel, then, the same amount of distilled water was repeatedly used to wash the biodiesel and ensure total removal of acid/base and salts. The washing process was stopped when the initial distilled water pH was similar to the pH of the water after extraction. After this washing process, biodiesel was heated at 90 ºC to evaporate the water and alcohol present. Finally, the purified product was weighed and placed in the refrigerator (Moreira *et al*., 2009).

Biodiesel Characteristics: The raw materials and the production process variables strongly influence biodiesel quality. To ensure and control product quality, standards were established and carried out according to (ASTM D6751, 2002).

RESULTS AND DISSCUSION

Biodiesel Composition: Biodiesel composition reflects the raw material composition and was determined using gas chromatography. The fatty acid profile for liquid fat resulted from roasting was as shown in table (1).

Table (1): Fatty acid profile for liquid fat resulted from roasting

Fatty acid	aC:bN	Weight %
Palmitic acid	16:0	26.4577
Stearic acid	18:0	7.2234
Plmitoliec acid	16:1	3.5379
Oleic acid	18:1	62.781

[a]C, no of carbon, [b]N, no of carbon-carbon double bond

Oleic fatty acid was the one presented in higher quantity.

Table (2): Comparison between fatty acid profile of chicken fat for present study with other previous studies

Fatty acid	Present study	Marulanda *et al.* (2010)	Arnaud et al. (2004)	Boey *et al.*(2011)	Lee and Foglia (2000)	Moreira *et al.*(2009)
Palmitic acid 16:0	26.45	21	24	24.7	25.2	24.85
Stearic acid 18:0	7.22	5.5	5.8	4.5	5.9	6.23
Plmitoliec acid 16:1	3.53	7.7	5.8	6.3	7.8	6.13
Oleic acid 18:1	62.78	48.5	38.2	44.1	40.5	41.19
Linolenic acid 18:3	Not detected	Traces	1.9	0.2	0.7	Not detected

The fatty acid profile for current work is 33.67% for saturated fatty acid while the fatty acid profile for saturated fatty acid for (Marulanda *et al*., 2010 & Arnaud *et al*., 2004 & Boey *et al*., 2011 & Lee and Foglia, 2000 and

Moreira *et al*., 2009) was 26.5 %, 29.8 %, 29.2%,31.1% and 31.08% respectively. On the other hand the fatty acid content for unsaturated fatty acid for present study is 66.31%, while that for (Marulanda *et al*., 2010,

Arnaud *et al*., 2004, Boey *et al*., 2011, Lee and Foglia, 2000 and Moreira *et al*., 2009) was 56.2%, 45.9%, 50.6%, 48.9% and 47.32% respectively with major components being palmitic, stearic, linoleic, and oleic acids like that for (Gugule *et al*., 2011).

Table (3): Quality control parameters of biodiesel resulted from liquid fat upon roasting for current work and others' work

Test	Method	ASTM D6751 Standards	CFME for current work	Kambiz *et al*., (2011)	Selva & Lima., (2011)	Moreira *et al*.(2009)
Density @ 15.56oC	ASTM D-1298	————	0.8724	0.864	0.870	0.878-0.885
Pour Point, oC	ASTM D-97	NA	0	----	----------	170-178
Flash Point, oC	ASTM D-93	130 min	190	……	……	…..
Carbon Residue, wt%	ASTM D-527	0.050 max	Nil	……	……	…..
Kinematic viscosity @ 40oC, cSt	ASTM D-445	1.9-6	4.83	5.5	4.3	4.52-6.13
Cetane Index	ASTM D-976	47min	64.65	……	……	…….
Total acid number, mg KOH/ gm	ASTM D-664	0.8 max	0.178	-----	0.16	0.091-0.24
Total Sulphur, wt %	ASTM D-4294	0.0015 max	Nil	……..	…….	……
Copper corrosion	ASTM D-130	No.3 max	1a	…….	…….	……

According to data tabulated in table (3) all results are compliance with ASTM D6751(2002) standards, Density @ 15.56^{o}C for current work was near other results for (Kambiz *et al.*, 2011,Selva and Lima, 2011 and Moreira *et al*., 2009) which were 0.864, 0.870 and 0.878 respectively ,while the value of Flash Point, ^{o}C for current work higher than that for (Moreira *et al*.,2009) which was (170-178 ^{o}C), Kinematic viscosity @ 40^{o}C, cSt value for current

work was compliance with ASTM D6751(2002) standards as that for other authors (Kambiz *et al*., 2011, Selva and Lima, 2011 and Moreira *et al*., 2009) and Total acid number, mg KOH/ gm was in agreement of with ASTM standards for current work and for (Selva and Lima, 2011 and Moreira *et al*., 2009).

Table (4): Quality control parameters of biodiesel resulted from liquid fat upon roasting after blending with petrodiesel

Test	Method	ASTM D7467 Standards	CFME from liquid fat upon roasting(B10)	CFME from liquid fat upon roasting(B20)
Density @ 15.56oC	ASTM D-1298	……	0.8315	0.9071
Total acid number, mg KOH/ gm	ASTM D-664	0.3 max	0.056	0.0594
Total Sulphur, wt %	ASTM D-4294	15max(S15) 500max(S500)	0.081	0.072
Kinematic viscosity @40oC,cSt	ASTM D-445	1.9-4.1	3.1	3.32
Pour point, °C	ASTM D-97	……	-6	-6
Flash point, °C	ASTM D-93	52 min	91	95
Carbon residue, wt.%	ASTM D-189	…….	Nil	Nil
Copper corrosion	ASTM D-130	No.3 max	1a	1a
Cetane Index	ASTM D-976	40 min	59	56

According to data tabulated in table (4) all results in are compliance with ASTM D7467 Standards.

Biodiesel Production Yield: From an economical perspective, biodiesel production yield is very important. The yield was determined considering the initial poultry fat mass (150 g) and the mass of biodiesel obtained after the reaction. The yield obtained was calculated using the following equation:

$$\text{biodesiel yield} = \frac{mass\ of\ biodiesel}{mass\ of\ raw\ material} \times 100$$

(1) The obtained yeild was 79.1% for liquid fat resulted from roasting

There are a few reasons for the low yield achieved:

- Formation of emulsions that hinder the washing process during purification;
- Drag of some biodiesel during this phase;
- Presence of water that leads to hydrolysis of triglycerides and consequently formation of FFA that react with NaOH forming soaps.

Regarding the raw material used, the results showed that biodiesel production using raw material containing free fatty acids by conventional process is possible, without any pre-treatment, contrary to the results obtained in other studies; however it brings many operational problems and difficulty for the reproducibility of the experiments. Therefore, the storage and the processing of the fat is a key issue.

CONCLUSION

Results of the present study clearly demonstrated that the use of chicken fats is very suitable as low cost feed stocks for biodiesel production as all results are compliance with ASTM standards. The optimal reaction conditions for production of methyl esters from chicken and are established as follows. The reaction time of 90 min at 60oC, 6:1 molar ratio of methanol to oil and 1% NaOH w/w of fat weight of chicken fat which is 150 gm of chicken fat.

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إنتاج الديزل الحيوى باستخدام المخلفات الدهنية الناتجة عن تحمير الدجاج

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المستخلص

يتزايد مفهوم تكنولوجيا الإنتاج الأنظف عالمياً. ويعد الوقود الأحفوري من مصادر الطاقة غير المتجددة الملوثة للبيئة والتى ينتج عنها غازات الإحتباس الحرارى وانبعاثات أخرى تسبب تغيرات مناخية وأمراض عديدة ومزمنة للإنسان لذلك قام الباحثون فى الأونة الأخيرة بعمل أبحاث كثيرة للحصول على بدائل أخرى ومصادر للطاقة من المصادر المتجددة والتى تعد صديقة وغير ملوثة للبيئة. إن المواد الخام المتجددة الأكثر شيوعًا لإنتاج وقود الديزل الحيوي هي الزيوت النباتية والنفايات الدهنية الحيوانية ودهون الدواجن. إن الهدف من هذا البحث هو دراسة إمكانية إنتاج الديزل الحيوى من مخلفات دهون تحمير الدجاج بواسطة عملية الأسترة باستخدام الكحول الميثلى فى وجود هيدروكسيد الصوديوم كعامل حفاز.

ولقد أوضحت نتائج البحث أن كمية الديزل الحيوى الناتجة من عملية تحويل دهون تحمير الدجاج ٧٩،١ % كما أن خصائص الديزل الحيوى الناتج مطابقة للمعايير الأمريكية لإختبارات الوقود كما أن معايير الوقود بعد الخلط مع السولار كانت مطابقة للمعايير الامريكية لذلك تعد دهون الدجاج من المصادر الجيدة والرخيصة لانتاج الديزل الحيوى.

الكلمات الدالة: الديزل الحيوى، الدهون المسالة الناتجة من تحمير دهون الدجاج، أسترة.