

OBTAINING OF METHYL ESTER FROM POULTRY RENDERING FAT AND FUEL PROPERTIES OF THE DIESEL - ESTER MIXTURES

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Abstract

The decrease in oil reserves and the increasing air pollution have directed studies to improve alternative fuels. One of the alternative fuels which has been studied on is biodiesel. Biodiesel is an oxygenated, sulfur and aromatic hydrocarbons-free, biodegradable, non-toxic, and environment friendly alternative to diesel fuel. In this study, methyl ester production from poultry rendering fat, which was obtained from a slaughterhouse, was carried out using sulfuric acid as the catalyst and esterification process. Methanol was used as alcohol in this process. Methyl ester and its blends with diesel are characterized. The results show that properties of blends with a percentage of the methyl ester are within the EN590 standard.

Key words: methyl ester, esterification, poultry rendering fat, waste animal fats

1. INTRODUCTION

Rapid increase in energy requirements has led to the development of new and renewable energy sources. On the other hand, diesel fuels are limited mainly by their sulfur content which causes corrosion and environmental pollution. Hence, the European Community recommends using biodiesel–diesel blends increasing ratios in member countries (Çaynak et al., 2009). There have been many researches on fuel production and fuel additives. One of renewable fuels is biodiesel which can be domestically produced from vegetable oil and animal fat. The vegetable oil or animal fat is reacted with alcohol in order to form esters. The reaction requires strong catalysts such as alkaline or acid. These esters are known as biodiesel fuels. Biodiesel can be used on its own, or mixed with petroleum diesel fuel in any unmodified diesel engine (Keskin et al., 2007).

Biodiesel can be synthesized from different varieties of feedstocks such as edible vegetable oils (e.g. canola oil, sunflower oil, etc.), non-edible vegetable oils (e.g. Jatropha oil, Pongamia oil, etc.), waste cooking oils, and animal fats (Sukhawanit et al., 2004; Karabaş, 2013; Berchmans and Hirata, 2008; Naik et al., 2008; Özbay et al., 2008; Gürü et al., 2009; Adewale et al., 2015). Although vary from one region of the world to another price and availability are important factors for determination of different types of feedstocks used for biodiesel production. Despite the current growth, sustainability of the biodiesel industries may be limited due to the industry's inability to secure cheap feedstock. Most of the current and forecasted biodiesel production in Canada comes from canola. Similarly, other biodiesel producing countries (US and Europe) depend on edible vegetable oils as feedstocks. This trend also implies the need for large supply of vegetable oils, drawn from neat edible oil sources, may lead to food security and ethical issues. Such situation, regarding diversion of food crops to biofuel production have engendered heated arguments worldwide. Investigators have sought to eschew feedstocks which might threaten food safety and produce higher quality biodiesel at a lower cost. Some of these feedstocks include tallow, lard, chicken fat, leather industry solid wastes, etc. (Shin et al., 2012; da Cunha et al., 2009; Lin and Tsai, 2015; Alptekin et al., 2012). Animal fat wastes are abundant in some regions resulting in lower feedstock cost. Using waste animal fats as feedstock for biodiesel production has the added advantages of reducing environmental damage by creating a fuel with lower or equal NO_x emission as vegetable oil biodiesel. Biodiesel from animal fat waste feed stocks also has high cetane number, an important quality parameter for diesel fuels (Adewale et al., 2015). Chicken fat is a low-cost feedstock for biodiesel production compared to high-grade vegetable oils. It is extracted from feather meal which is prepared from chicken wastes such as chicken feathers, blood, offal and trims after rendering process (Alptekin et al., 2014).

Chicken meat has become one of the most extensively consumed food products in the world (Magdelaine et al., 2008; González-García et al., 2014). In 2015, almost 9 billion broiler chickens, weighing live weight 53 billion pounds, were produced. More than 40 billion pounds of chicken product was marketed, measured on a ready-to-cook basis. The United States has the largest broiler chicken industry in the world, and about 19 percent of production was exported to other countries in 2015 (www.nationalchickencouncil.org).

Chicken fat is generated during rendering of chicken feathers and poultry by-products to produce feather meal (Fig.1). Poultry by-products consists of ground dry- or wet-rendered portion of the clean carcass (e.g. heads, feet, undeveloped eggs, and intestines, exclusive of feathers) (Kondamudi et al., 2009). The amount of fat extracted from the feather meal varies from 2% to 12%, depending on feather type (Dale, 1992; Moritz and Latshaw, 1992; Adewale et al., 2015).

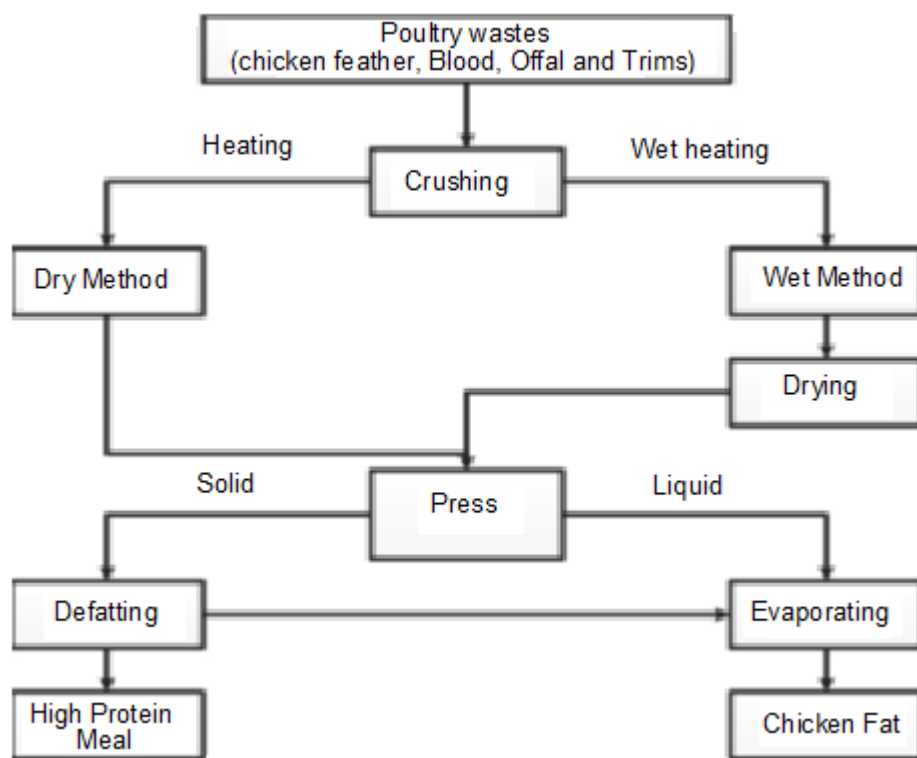


Fig. 1. Poultry wastes rendering process (Adewale et al., 2015)

In this experimental study, methyl ester production from poultry rendering fat, which was obtained from a slaughterhouse, was carried out using sulfuric acid as the catalyst and esterification process. Because the poultry rendering fat contains free fatty acid above 1%, the esterification process has been preferred. Methanol was used as alcohol in this process because of its low cost, and sulfuric acid was preferred as the catalyst. Methyl ester and its blends with diesel are characterized for their physical properties.

2. MATERIALS AND METHODS

The poultry rendering fat, which contains free fatty acids more than 1 %, was obtained from Erpilic Slaughterhouse in Bolu, Turkey. Erpilic integrated production plant's chicken slaughtering capacity is 330 thousand per day (www.erpilic.com.tr). This slaughterhouse produces many poultry rendering fat.

The rendering fat was filtered to remove inorganic residues. Then it was subjected to a heating at 110 °C for one hour to remove any remaining water. After these processes, the physical properties of poultry rendering fat were designated. In Table 1, the physical properties of poultry rendering fat sample are shown. Methanol was used as alcohol in this process because it is the most widely used alcohol for biodiesel production, it is easy to process, and is relatively low cost (Çaylı and Küsefoğlu, 2008; Reşitoğlu et al., 2005). Sulfuric acid was preferred as the catalyst because it gives very high yields in alkyl esters (Zullaikah et al., 2005, Reşitoğlu et al., 2005). Solutions of sulfuric acid in methanol were prepared by reacting at 40 °C temperature for 30 min. The esterification process of free fatty acids was repeated for different alcohol weight ratios and amounts of acid catalysts based on the free fatty acid level of the rendering fat for 1 h at 63 °C. The experiments were performed in a laboratory scale apparatus. The rendering fat was added into the reaction flask equipped with reflux condenser, magnetic stirrer and thermometer, and then it was heated. When the temperature reached to 63 °C, the methanol–sulfuric acid mixture was added into the fat. The final mixture was stirred for 1 h at 63 °C. The mixture was settled overnight and two phases was occurred. The upper phase was separated from the other phase. The upper phase consists of the alcohol–water–acid mixture and the other phase mainly consists of the esterified fatty acids and unreacted rendering fat. After the separation, samples were washed three times with pure water at 85 °C temperature to remove the catalyst effect. After this step, the lower phase was subjected to a heating at 110 °C for one hour to remove excess alcohol and water. The acid value of the fat–ester mixture was measured and recorded. A flow diagram of the biodiesel production from rendering fat process is shown in Figure 2.

Table 1. Properties of poultry rendering fat

Quality	Unit	Sample
Density	kg/m ³	0.89959
Viscosity (40 °C)	mm ² /s	37.43
Acid value	mgKOH/g	3.74

The weight ratio of alcohol, catalyst amount, and reaction time were investigated to determine the best strategy for the esterification process. In order to determine the effect of the weight ratio of alcohol on acid value of rendering fat, reactions were conducted with 3 wt% sulfuric acid amount with methanol/rendering fat weight ratio at 25%, 30%, 35%, 40% at 63°C temperature and to determine the effect of catalyst amount on acid value of the rendering fat, the reaction was carried out with the optimum weight ratio 40% at 63°C temperature with sulfuric acid amounts at 1, 3, 5, and 10 wt%. Finally, the effects of reaction time on the conversion efficiency at 60, 120, 180, and 240 min were also experienced with sulfuric acid amount at 5 wt%.

Commercially available diesel fuel was purchased from a firm to prepare the blends. The methyl ester and fuel were characterized by determining their viscosity, density, flash point, sulfur content, and water content. The fuel properties of the methyl esters and diesel fuels are presented in Table 2. The methyl esters were blended with the diesel fuels at 5%, 10%, 15%, 20%, and 25% on a volume basis. The analysis was carried out at a fuel analysis laboratory in Afyon Kocatepe University.

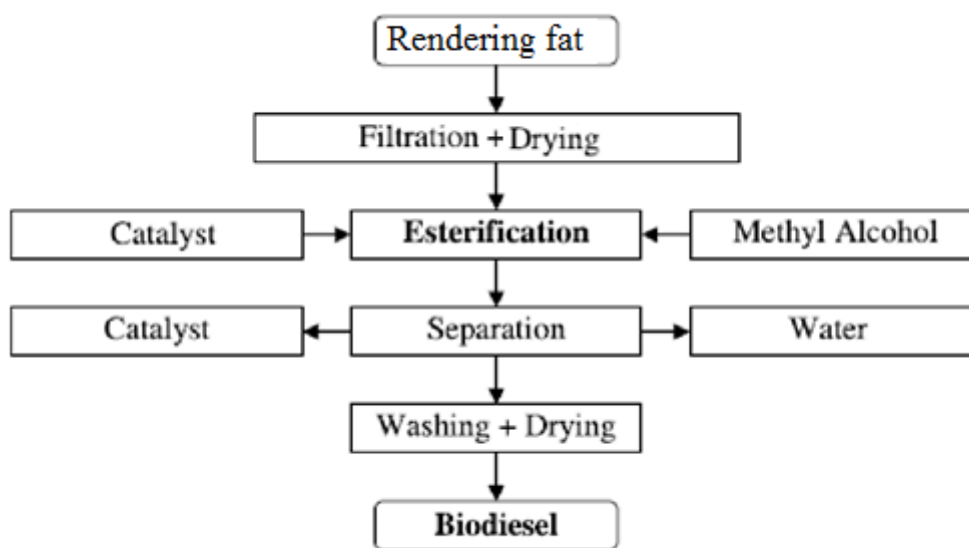


Fig. 2. Flow diagram of biodiesel production from rendering fat

3. RESULTS AND DISCUSSION

3.1. Esterification of the Poultry Rendering Fat with Methanol

3.1.1. Effect of Methanol to Fat Weight Ratio

The weight ratio of alcohol to the poultry rendering fat is one of the most important factors that influence the acid value. The changes in the acid value are shown in Figure 3. The weight ratio of methanol increases, the acid value decreases. The acid value reached a minimum of 0.35 mgKOH/g at the 40 wt% methanol ratio and 60 min. Because the acid value is smaller than 0.5 mgKOH/g, it meets the standard (EN 14214, 2014).

3.1.2. Effect of Catalyst Amount

The catalyst amount is another important factor that affects the acid value. The effect of sulfuric acid amount on the poultry rendering fat acid value is presented in Figure 4. From the ranges 0.35–0.65 mgKOH/g, the acid value decreases proportionally with increasing sulfuric acid amount. But the acid value is not changed when the acid ratio is 5 wt% and 10 wt%. Therefore, the acid ratio is selected as 5 wt%.

3.1.3. Effect of Reaction Time

Four different reaction times (60, 120, 180, and 240 min) were selected to determine the effect of the reaction time on conversion efficiency. Each reaction was run for 63 °C temperature with 5 wt% sulfuric acid catalyst and 40 wt% methanol ratio. The changes in the conversion efficiency are presented in Figure 5. The maximum conversion was observed at 60 and 240 min reaction time. Because the conversion efficiency was observed at 60 and 240 min reaction time, the reaction time is selected as 60 min.

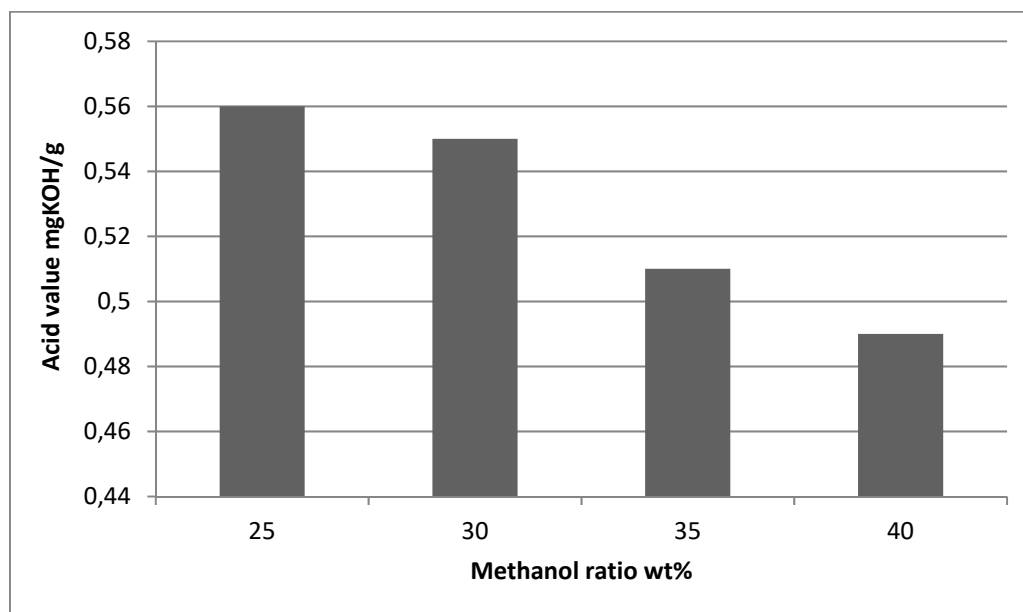


Fig. 3. The effect of the weight ratio of alcohol on the acid value at a temperature of 63 °C, 1 h, and 3 wt% sulfuric acid.

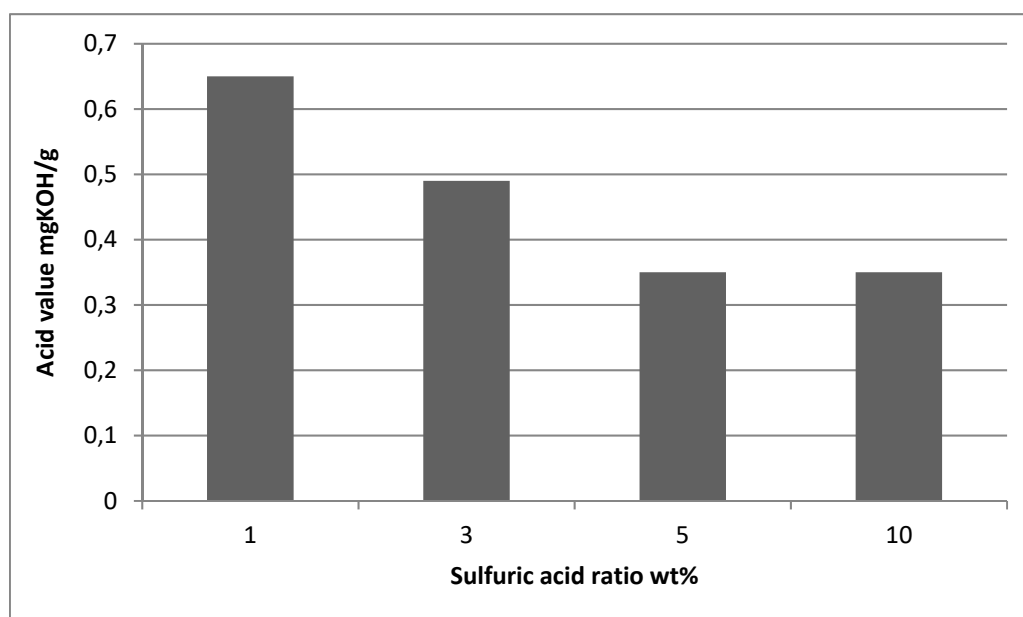


Fig. 4. The effect of the weight ratio of sulfuric acid on the acid value at a temperature of 63 °C, 1 h, and 40 wt% methanol.

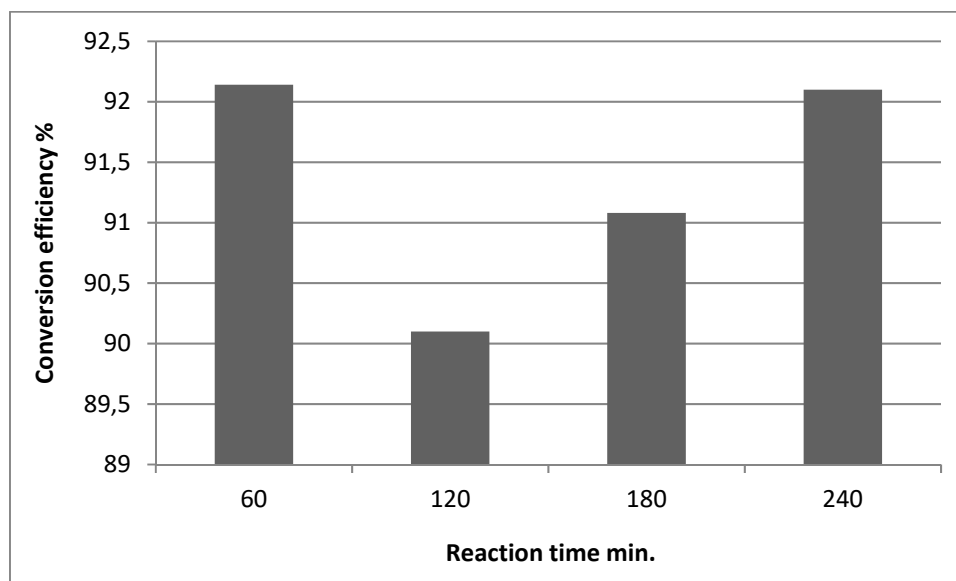


Fig. 5. The effect of the reaction time on the conversion efficiency at a temperature of 63 °C, 40 wt% methanol, and 3 wt% sulfuric acid.

3.2. Characteristics of Biodiesel and Its Blends with Diesel

Biodiesel derived from the poultry rendering fat was analyzed. Five ester-diesel blends were prepared by blending ester at proportions of 5%, 10%, 15%, 20%, and 25% by volume with diesel, which corresponded to B5, B10, B15, B20, and B25 fuels, respectively. Some properties of biodiesel and its blends with diesel are presented in Table 2. The biodiesel samples were compared according to EN590 standards for viscosity, density, flash point, sulfur content, water content (EN590, 2013).

Table 2. Some properties of biodiesel and mixtures with diesel.

Quality	Unit	B5	B10	B15	B20	B25	B100	Diesel	EN590
Density	kg/m ³	845	850	853	858	863	918	841	820–860
Viscosity (40°C)	mm ² /s	3.15	3.521	4.251	4.903	5.609	29.82	2.951	2.0–4.5
Flash point	°C	68	69	72	73	73	149	67	Min. 55
Sulfur content	mg/kg	8	8.5	8.6	8.9	9.6	14.9	7.6	Max. 10
Water content	mg/kg	44.96	69.72	86.97	106.84	128.8	462.24	37.18	Max. 200

The B100 fuel had a density of 918 kg/m³ and a viscosity of 29.82 mm²/s, these values were higher than diesel. The density and viscosity increased with the increase of the ester volume fraction in the blends. Densities of blends were linear with the volume fraction of ester. Although the viscosity of pure poultry rendering fat methyl ester was high, the B15 or lower blends could meet the specification of EN590 (2–4.5 mm²/s). Biodiesel–diesel blends constitute an alternative to improve this parameter of the biofuel. The higher viscosity of biodiesel, as compared to diesel, is due to the higher molecular mass and larger chemical structure of the biodiesel. The flash point is a parameter of practical importance, once the higher the flash point, for instance, the higher is the safety during handling, transportation, and storage. The flash point of blends was also increased with the increased biodiesel; the higher the volume fraction of biodiesel in the blend, the higher the flash point. The higher flash point compared with diesel is beneficial in the safety aspect. The sulfur content was observed in accordance with the standard values for the all blends. Low sulfur has advantages both for the

environment and the engine life. The water content in all samples was observed to be smaller than the standard specification. The optimal ester-diesel blends in the range of B5 to B15 would have a density from 845 kg/m³ to 853 kg/m³, a kinematic viscosity from 3.15 mm²/s to 4.251 mm²/s, a water content from 44.96 to 86.97 mg/kg and a sulfur content from 8 to 8.6 mg/kg.

4. CONCLUSION

Feasible methyl ester production from the poultry rendering oil that had a higher free fatty acid than 1% has been investigated. The poultry rendering oil was obtained from a slaughterhouse. Esterification process was carried out to methyl ester production by sulfuric acid catalyst. An acid catalyst is preferred over basic catalyst in esterification of free fatty acid to avoid saponification. The optimum conditions were determined to be 40 wt% methanol ratio, 5 wt% acid catalyst amount, 63 °C reaction temperature, and 60 min reaction time. The conversion efficiency was observed to be 92,1 % at these conditions. The methyl ester was mixed with diesel in different volumetric ratios and their characteristics were observed. The samples were compared to each other according to EN590 standards. The results showed that the blend down of 15% volume could be applied in diesel engines without major modification. The present study showed that the poultry rendering oil can be used as an addition fuel to diesel.

REFERENCES

- Adewale, P., Dumont, M. J., and Ngadi, M. (2015) Recent trends of biodiesel production from animal fat wastes and associated production techniques, *Renewable and Sustainable Energy Reviews*, vol 45, pp. 574-588.
- Alptekin, E., Canakci, M., and Sanli, H. (2012). Evaluation of leather industry wastes as a feedstock for biodiesel production. *Fuel*, vol 95, pp 214-220.
- Alptekin, E., Canakci, M., and Sanli, H. (2014) Biodiesel production from vegetable oil and waste animal fats in a pilot plant, *Waste Management*, vol 34, no 11, pp 2146-2154.
- Berchmans, H. J. and Hirata, S. (2008) Biodiesel production from crude *Jatropha curcas* L. seed oil with a high content of free fatty acids. *Bioresource technology*, vol 99, no 6, pp 1716-1721.
- Çaylı, G. and Küsefoğlu, S. (2008) Increased yields in biodiesel production from used cooking oils by a two step process: Comparison with one step process by using TGA, *Fuel Proc. Tech.*, vol 89, pp 118-122.
- Çaynak, S., Gürü, M., Biçer, A., Keskin, A., and İcingür, Y. (2009) Biodiesel production from pomace oil and improvement of its properties with synthetic manganese additive, *Fuel*, vol 88, no. 3, pp. 534-538.
- da Cunha, M. E., Krause, L. C., Moraes, M. S. A., Faccini, C. S., Jacques, R. A., Almeida, S. R., and Caramão, E. B. (2009) Beef tallow biodiesel produced in a pilot scale, *Fuel Processing Technology*, vol 90, no 4, pp 570-575.
- Dale N. (1992) True metabolizable energy of feather meal, *J Appl Poult Res.*, vol 1, pp 331-4.
- EN 590, Automotive fuels - Diesel - Requirements and test methods, 2013.
- EN 14214, Liquid petroleum products - Fatty acid methyl esters (FAME) for use in diesel engines and heating applications - Requirements and test methods (includes Amendment A1:2014), 2014.
- González-García, S., Gomez-Fernández, Z., Dias, A. C., Feijoo, G., Moreira, M. T., and Arroja, L. (2014) Life Cycle Assessment of broiler chicken production: a Portuguese case study, *Journal of Cleaner Production*, vol 74, pp 125-134.

Gürü, M., Artukoğlu, B. D., Keskin, A., and Koca, A. (2009) Biodiesel production from waste animal fat and improvement of its characteristics by synthesized nickel and magnesium additive, *Energy conversion and Management*, vol 50, no 3, pp 498-502.

<http://www.erpilic.com.tr/en> (Accessed 05/05/2016)

<http://www.nationalchickencouncil.org/about-the-industry/statistics/broiler-chicken-industry-key-facts/> (Accessed 05/05/2016)

Karabaş, H. (2013), Investigation of biodiesel fuel from canola oil using various reaction parameters, *International Journal of Automotive Engineering and Technologies*, vol. 2 no. 3, pp. 85-91.

Keskin, A., Gürü, M., & Altıparmak, D (2007), Biodiesel production from tall oil with synthesized Mn and Ni based additives: effects of the additives on fuel consumption and emissions, *Fuel*, vol. 86, no. 7, pp. 1139-1143.

Kondamudi N., Strull J., Misra M., and Mohapatra S.K. (2009) A green process for producing biodiesel from feather meal, *J Agric Food Chem*, vol 57, pp 6163–6.

Lin, C. W. and Tsai, S. W. (2015) Production of biodiesel from chicken wastes by various alcohol-catalyst combinations, *Journal of Energy in Southern Africa*, vol 26, no 1, pp 36-45.

Magdelaine P., Spiess M.P., and Valceschini E. (2008) Poultry meat consumption trends in Europe, *World Poultry Sci J*, vol 64, pp 53–64.

Moritz J, and Latshaw J. (2001) Indicators of nutritional value of hydrolyzed feather meal, *Poult Sci*, vol 80, pp 79–86.

Naik, M., Meher, L. C., Naik, S. N., and Das, L. M. (2008) Production of biodiesel from high free fatty acid Karanja (*Pongamia pinnata*) oil, *Biomass and Bioenergy*, vol 32, no 4, pp 354-357.

Özbay, N., Oktar, N., and Tapan, N. A. (2008) Esterification of free fatty acids in waste cooking oils (WCO): Role of ion-exchange resins, *Fuel*, vol 87, no 10, pp 1789-1798.

Reşitoğlu, İ. A., Keskin, A., and Gürü, M. (2012) The Optimization of the esterification reaction in biodiesel production from trap grease, *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol 34, no 13, pp 1238-1248.

Shin, H. Y., Lee, S. H., Ryu, J. H., and Bae, S. Y. (2012) Biodiesel production from waste lard using supercritical methanol, *The Journal of Supercritical Fluids*, vol 61, pp 134-138.

Sukhawanit, C., Srinophakun, P., and Matsumura, M. (2004) Biodiesel production from crude sunflower oil, *Engineering Technology*, vol 1, no 2, pp 141-150.

Zullaikah, S., Lai, C. C., Vali, S. R., and Ju, Y. H. (2005) A two-step acid-catalyzed process for the production of biodiesel from rice bran oil, *Bioresour. Tech.*, vol 96, pp 1889–1896.