Waste cooking oil physiochemical properties improvement via transesterification process

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ABSTRACT – Power transformers use mineral oil as an insulating liquid due to the outstanding performance in-service. Due to non-biodegradability and toxicity of mineral oil, natural ester-based oil was introduced as new insulating liquid in power transformer. Natural ester insulating oil have high flash point and breakdown voltage compared to existing mineral oils. However, it also contains high viscosity which is not suitable for the transformers cooling system. This paper proposed the used of waste cooking oil (WCO) as an alternative transformer insulating oil. Transesterification method based on the chemical reaction between WCO, methanol and catalyst sodium hydroxide (NaOH) are performed to produce waste cooking oil methyl ester (WCOME). Physiochemical properties such as water content, acidity and breakdown voltage of the developed WCOME are measured and analyzed.

1. INTRODUCTION

Mineral transformer oil is cheaper and reliable insulants for industrial, distribution and power transformers insulating system [1]. Due to good dielectric properties, mineral oil has been used as heat transfer medium and insulating liquid in the power transformers for more than 100 years [2]. However, typical mineral oil has low fire points which can increase the risk of fire occurred once the transformer's failure. On the other hand, natural ester based liquids (NEI) offers a higher fire point, breakdown voltage, and excellent biodegradable characteristics besides enhancing fire safety and environmental sustainability [3][4]. Besides that, the high viscosity of the oil will cause the liquidity becomes poor and the transformer cooling efficiency will be affected [5]. The modification required on NEI to reduce its viscosity through chemical modifications. This will enable NEI to be used in the distribution transformer [6]. An original NEI also has a higher total acid number (TAN) values which normally above than 0.3 mg KOH/g. In this research, waste cooking oil (WCO) from palm-based is chosen since its offers a cheaper price compare to others natural ester oil. However, original WCO has a problem with its physicochemical properties such as low breakdown voltage, higher acidity and water content, which not suitable to be used as an insulating oil. This is because physicochemical properties in WCO do not reach the standards. Viscosity is already carried out and it is found that WCO reaches the standard. The viscosity of WCO is 40.84 mm2/s satisfies the viscosity at 40 °C requirement as per IEEE C57.147 which it should be less than or equal to 50 mm2/s. Therefore, the aim of this research is to improve three physiochemical properties of WCO via transesterification reaction using NaOH alkali-catalyzed process with methanol.

1.1 Waste Cooking Oil

The term "waste cooking oil" (WCO) refers to the vegetable oil, which has been use after frying times in food production. The use of waste cooking oil as biodiesel oil can reduce biodiesel production costs. This is because 70-95% of total biodiesel production comes from the feedstock cost. Statistic shows that the remaining waste oil which have been used and disposed without treatment in Malaysia is about 50000 tonnes per year.

1.2 Transesterification

Transesterification reactions occur between alcohol and lipids to produce esters and by-products, glycerol, also known as glycerine. Figure 1 shows the molecular representation of the transesterification reaction. The fatty acids are mainly constituted by triglycerides and presented as R_1, R_2 and R_3.

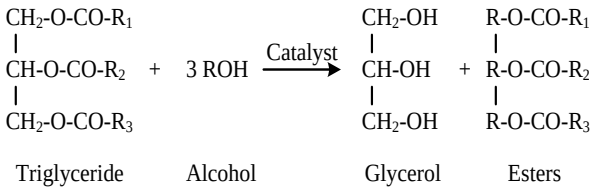

Figure 1: Molecular representation of a transesterification reaction.

2. METHODOLOGY

Preparation of Waste Cooking Oil and Transesterification Reaction

Firstly, one liter of cooking oil is heated at 120 ° C for 10 minutes to remove an existing water content in the oil. It is important to minimize water content in feedstock before transesterification process. Fatty acids, constituents of fats, and important energy sources for living organisms, are found in the form of free fatty acid esters (FFA).% FFA in WCO can be determined by using equation (1). After that, the temperature has been reduce till 60°C, and mixed with 250ml of methanol and sodium

hydroxide (NaOH), which will act as catalysts in the transesterification reaction.

$$\%FFA = \frac{Acidity}{1.99} \quad (1)$$

2.1 Chemical Properties (acidity and water content)

Total acid number or acidity is measured in accordance to ASTM D974 method by using 848 Titrino Plus (Metrohm) for evaluating the acid number of WCO. Water content in oil is measured based on ASTM D1533 by using 899 Karl Fischer coulometer (Metrohm).

2.2 Electrical Properties (breakdown voltage)

Breakdown voltage (BdV) is measured in accordance to ASTM D1816 by using OTS60PB Portable Oil Tester (Megger).

3. RESULT AND DISCUSSION

Table 1.Chemical and electrical properties of WCO and WCOME samples

Property	Specification for Mineral Insulating Oil	Specification for Natural Ester Fluids	WCO	WCOME (NaOH)
Acidity (mg KOH/g)	≤ 0.03	≤ 0.06	2.7972	0.2578
Water content (mg/kg)	≤ 35	≤ 200	1036.5	75.12
Break down voltage (kV)	≥ 20	≥ 20	7	33.4

Result in Table 1 shows that the acidity of WCO has been reduced from 2.7972 mg KOH/g to up to 0.2578 mg KOH/g (WCOME) after transesterification process which is corresponding to 90.78%. The acidity value after the transesterification process does not reach the standard specification value. Therefore, suggest that reclamation techniques will be used to reduce the acidity found in the WCO. In this case, modern reclamation technology is required as introduced by researchers introducing new adsorbents that have characteristics similar to Fuller's earth industry absorbent such as alumina, membranes, and bentonites.

Meanwhile, water content in WCO also been reduced up to 92.75%, less than 200ppm which meet the requirement stated in ASTM D6871-03 standard. The water content value after transesterification process reach the standard specification value. Besides that, the water content treatment technique will be used such as vacuum and nitrogen treatment to reduce the water content in WCO.

Result also shown the transesterification reaction affect the Breakdown voltage (BdV) in oil, which BdV of WCOME (33.4kV) is higher than WCO (7kV). The breakdown voltage value after transesterification process also reach the standard specification value. The effect of water content related to the breakdown voltage of the transformer oil. This is because the breakdown voltage remains higher when the percentage of moisture saturation is below 20% but then decreases significantly as relative when moisture saturation increases.

4. CONCLUSION

WCOME was produced based on a reaction of catalytic transesterification between WCO, methanol and alkali catalyst using sodium hydroxide (NaOH). The reaction can influence the physicochemical and electrical properties (water content, acidity and breakdown voltage) of waste cooking oil. Based on the result, WCOME using NaOH catalyst has improved the physicochemical properties of WCO, hence has potential to be electrical insulating fluid for power transformer.

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