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The synthesis of bio-lubricant based oil by hydrolysis and non-catalytic of palm oil mill effluent (POME) using lipase

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ABSTRACT

Synthesis of bio-lubricant from palm oil mill effluent (POME) using enzymatic hydrolysis and non-catalytic esterification has been investigated in this article. The effects of essential parameters, which are temperature, pH, agitation speed, enzyme loading, ratio of oil to fatty acid and alcohol to fatty acid, on the reaction rate were examined. The optimum hydrolysis rate (0.1639 mg/sec.L) was achieved at 40 °C, pH 7.0, 650 rpm, 20 U/mL of enzyme loading and 50% (v/v) of POME. As for non-catalytic esterification, the highest reaction rate attained was 0.0018 mg/sec.L at the operating conditions of 75 °C, 950 rpm, and alcohol to fatty acid ratio of 3:1. Viscosity and density of the produced bio-lubricant were also evaluated.

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1. Introduction

Malaysia is very well known for its abundant oleo-chemical industry. This is largely due to the vast availability of palm oil resources. The palm oil plantation and palm oil based industry represents one of the main incomes of Malaysia, occupying more than one-third of the total cultivated land in Malaysia [1,2]. This explains the huge amount of palm oil mill effluent (POME) present as by-product, which is a hazardous water and air pollutant if discharged untreated. Identifying a potential solution to make good use of the POME instead of just disposing it has been the interest of many researchers [3]. In this work, the potential of POME to be used in producing bio-lubricant has been investigated.

2. Literature review

The lubricants available in the market today are largely fossil-based and the rest are synthetically formulated from chemicals. It is vital to note that the availability of these mineral resources is finite and the product could emit greenhouse gases (GHG) which could increase the probability of global warming. Although the chemical lubricant has been approved to have a higher biodegradability rate, it is still restricted by its high cost and toxicity [1]. To overcome the problems, one of the most feasible choices is to replace the current lubricants with bio- lubricants which are biodegradable, economical and certainly environment friendly [4–6]. Up to this date, bio-lubricants still comprise a narrow segment; however, they're finding their way into such applications as metalworking fluids, food industry lubricants, biodegradable grease, agricultural equipment lubricants, and others. With regards to these facts, scientists started to investigate many types of natural material such as oil of plants, animal's fats, and organic waste oil as the starting material for the preparation of bio-lubricants [7,8]. It has been reported that nearly 350 oil-bearing crops, including *Jatropha, Karanja, Neem, Soybean* and *Castor* are potential to be sources for bio-lubricants [9]. A review by Fernando et al. (2007) on the lubricities of selected vegetable oils and animals fats along with their derivatives stated that most bio-based oil have superior lubricity compared to diesel [10]. Mirghani *et al.* (2012) and Balamurugan *et al.* (2010) conducted a study on *Nahar* seed oil and soybean oil, respectively. They found that both plants have an impressive value as bio-lubricants [11,12]. Other works was the production of bio-lubricant from *Castor* oil base stock which had been performed by Madankar *et al.* (n.d.) [13].

Despite their advantages, the crude oil of these bio-lubricants is mostly draws from food sources. Thus, it has to cope over the requirement for human consumption, presenting a crisis of food vs. energy. In our previous work, we had exploited the use of non-edible oil, i.e. *Jatropha curcas* as bio-lubricant. Nevertheless this seed of this fruit is actually toxic, and its advance usage need a delve consideration, since to some extent, it may bring harmful effects to humans [14]. With regard to this, we aimed to develop a newly formulated bio-lubricant from palm oil mill effluent (POME), which is the waste from palm oil mill industries. In contrast to the other bio-lubricant, this POME derived bio-lubricants will not be challenged by this dilemma since it is fully based on unwanted surplus of farm crops. Moreover, it is also expected to be a strong price-competitive against other bio-lubricants which seems to be slow-catching for market interest due to their expensive base-stocks.

The synthesis of this bio-lubricant from POME will be accomplished using enzymatic hydrolysis using lipase, followed by non-catalytic esterification. Lipase enzyme has a unique role in splitting of oil and fats. It usually functions at the oil-water interface. A high interfacial area between the oil and the aqueous phase which contains lipase enzyme will enhance the hydrolysis rate [15]. In contrast to the typical hydrolytic reactions which are facilitated by alkaline/acid, the utilization of enzymatic process has several advantages. The enzymatic hydrolysis can be operated at an ambient temperature, there is no requirement of co-factor or any chemical additive, and the enzyme is reusable. Therefore, it is gaining importance as an option for catalyst in hydrolysis [16]. Former studies, such as by Avisha *et al.* (2013) [17] have utilized lipase in bio-lubricants production from waste cooking oil (WCO) and observations appear to be promising. Another example is the work by Akerman *et al.* (2011), who retrieved bio-lubricants from vegetable oil and they found that, production process through enzymatic route using immobilized lipase contributed to the least environmental impact. The yield of hydrolysis reaction of POME was then subjected to the non-catalytic esterification process to produce bio-lubricant. Non-catalytic esterification is favored compared to catalyst-driven esterification because it could provide a higher yield, and the separation of final products is simpler since no isolation of residual catalyst is required [19,20]. For both enzymatic hydrolysis and non-catalytic esterification processes, the effects of temperature, pH, enzyme loading, oil to water ratio, and agitation speed on the reaction rate were investigated.

3. Materials and methods

3.1. Materials

POME used in this study was obtained locally from Trades Wings Resources Sdn. Bhd., Malaysia. Lipase (*Candida sp.*) was fermented in Chemical Engineering Laboratory at University of Malaya. All other chemicals (oleic acid, phenolphthalein, acetate acid, sodium hydroxide, diethyl ether, 2-propanol, glycerin), calibration buffer solutions (pH 4.0, pH 7.0 and pH 10.0) were provided by Fisher Scientific (M) Sdn. Bhd. They were of analytical grade and were used without further purifications.

3.2. Experimental methods

3.2.1. Gravity settling

The fresh POME usually consists of suspended solids such as sludge, trunks, barks and leaves. So prior to its further usage, these contaminants were separated by gravity settling using a separator funnel.

3.2.2. Enzymatic hydrolysis

The experimental design for enzymatic hydrolysis is presented in Table 1. This process was conducted in a stirred glass bioreactor. Ratio of POME to buffer (acetate) was varied from 20–50% V/V, making the final amount of 500 mL. The reactor was kept immersed in a temperature controlled water bath to maintain the reaction temperature at desired conditions. The mixture of POME and buffer was agitated and after reaction reaches the