Utilization of *Moringa oleifera* Seed as Coagulant for pretreatment of palm oil mill effluent (POME)

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Abstract

This study aims to investigate the pretreatment process of palm oil mill effluent (POME) using *Moringa oleifera* seeds as natural coagulant to remove total suspended solid. Firstly, performance of two types of *Moringa oleifera* seeds; after oil extraction (MOAE) and without oil extraction (MO) was evaluated. From the data obtained, it gave the result of total suspended solid removal higher in usage of MOAE rather than MO. The sludge volume index (SVI) was also looked at to verify the tendency of sludge to become concentrated during the settling process. The study was followed by the identification of the best dosage as well as stirring speed. The maximum suspended solid removed 89.89% was obtained at conditions of 0.2 g/L and 150 rpm while its residual conductivity was successfully reduced to 2.76%. This condition was found to be efficient and capable to increase the suspended solid removal of POME pretreatment.

Keywords: Moringa oleifera seeds; POME; Coagulation-flocculation; Suspended solid.

1. Introduction

Mass production of Crude Palm Oil (CPO) started in Malaysia since 1979 and the production was regarded as one of the vital industry for the economy growth for Malaysia ever since. Remarkable in history, the palm oil trees were introduced in early 1870s as ornament plants by the British government. The very first palm oil cultivation was done in Selangor in 1917 and the commercialization started in the early 1960s. Following that, the Malaysia government announced the spread of palm oil cultivation hence, revolutionized the nation's economy that was once focused on the rubber and tin manufacture. According to the Malaysian Palm Oil Board (MPOB), approximately 17.32 million tonnes of Crude Palm Oil (CPO) were produced in the year 2016 (Din, 2017).

Unfortunately, this growing industry has its drawback which is the effluent. Specifically, the effluent was named Palm Oil Mill Effluent (POME) and it is highly polluting and toxic as it contains suspended solids, traces of heavy metal, oil, high biological oxygen demand (BOD) as well as chemical oxygen demand (Saifuddin et al., 2011). Palm Oil Mill Effluent (POME) is a highly polluting substances that can cause pollution when it is dumped into any open water sources such as lakes, ponds and rivers. In fact, POME is highly acidic and its release to the waterways change the waters' pH hence, causing it to be not suitable for drinking and disrupt the ecosystem (Bala et al., 2014). According to Madaki & Lau, 2013 as much as 2.5 tonnes of POME is produced with every tonne of CPO. Though the industry has generated a staggering amount of profit, POME has raises concerns on the environment as well as humans' health.

As the production of CPO escalate year by year due to its high demand, an effective yet safe method to treat this effluent is urgently needed. There are few different treatments that have been reported by researcher for POME treatment since the enactment of the Environment Quality Act, 1974 (Rupani et al., 2010). Currently, the conventional ponding system is the most preferable treatment process for treating POME (Efluen et al., 2015). The other name for this method are known as biological aerobic and anaerobic digestion treatment. Unfortunately, this method only leads to severe pollution. This is due to the fact that large amount of greenhouse gases such as methane and carbon dioxide were released to the atmosphere along the process of digestion (Takriff et al., 2013). In Malaysia, the final discharge of the treated POME must follow the standards set by the Malaysia's Department of Environment (DOE) where the limit for the water turbidity should not be more than 5 NTU (Bhatia et al., 2007). Surprisingly, there are many palm oil mills failed to comply with the standard discharge limit even though they have applied biological treatment system in their mills. Therefore, finding a sustainable, clean and pollution-free treatment is an urgent matter for the palm oil industry to maintain its environmental sustainability.

Apart from digestion technique, the coagulation-flocculation technique is typically used to treat POME (Hendrawati et al., 2016). Coagulation is a process where colloids start to coagulate due to the assistance by a chemical to form flocs. Coagulant is one of the most common ways to reduce the turbidity in any effluent. Widely used coagulants in the conventional wastewater treatment processes are chemical based such as ferrous sulphate, aluminium sulphate (alum) and poly aluminium chloride (Hendrawati et al., 2016). These coagulants were used for various purposes depending on their chemical characteristics (Bhatia et al., 2007). Among these three, alum is the most widely used coagulant in wastewater treatment facilities (Bhatia et al., 2007; Hendrawati et al., 2016). Even though these chemical based coagulants were reported to be able to reduce waters' turbidity level effectively but its toxic properties remain as major health concerns. This is due to the fact that chemical based coagulant such as alum consists of aluminium that could heavily affect humans health (Efluen et al., 2015). Terrifyingly, the presence of aluminium ions as low as 0.1 ppm in water sources will increase the chances of getting neurological diseases for instance Alzheimer and pre senile dementia. The focus now has been shifted to finding a natural, sustainable and most importantly, nontoxic coagulant to human.

To date, there are reports on the utilization of organic materials that can be derived from tropical plants as coagulant for instance, *Moringa oleifera* (Hassan et al., 2005). *Moringa oleifera* is among the 14 species of trees that belong to the genus *Moringaceae*. The Moringa tree is resistant to dry and have an ability to grow well and cultivate in various regions around the world. The seeds of *Moringa oleifera* tree are used to reduce the water turbidity in the countries all around the Nile River, especially Sudan and also earlier studies have recommended the use of *Moringa oleifera* seeds extract as coagulant for water treatment in African and South Asian countries (Bhatia et al., 2007). Their use in wastewater treatment is therefore very promising. This is due to the several advantages of using *Moringa oleifera* seeds such as stated as a positive cost-effectiveness, water treated without extreme pH, and have a high level of biodegradability (Dehghani et al., 2016). Various studies have been conducted and showed that the moringa seeds are effective as biocoagulant to improve physico-chemical properties of contaminated water (Hendrawati et al., 2016). The coagulating properties in the *Moringa oleifera* seeds enable the seeds to be used in various water treatment process such as turbidity, total dissolved solid and hardness. The presence of water-soluble cationic protein in the seeds was determined to serve as a coagulant. In addition, it is possible to extract edible oil from the seeds and can be utilized as a source of edible oil for human consumption (Bhatia et al., 2007).

This study aims to investigate the effectiveness of *Moringa oleifera* seeds as a coagulant for removing turbidity from POME. The parameters that influenced the performance of *Moringa oleifera* seeds as a coagulant; dosages and rate of stirring speed will be looked at. The study will be followed by the determination of sludge volume index and residual conductivity.

2. Materials and methods

2.1 Materials

2.1.1 Palm Oil Mill Effluent (POME) collection & preparation

Samples of palm oil mill effluent (POME) used for the experiment were obtained from Bell Palm Oil Industries, Batu Pahat, Johor at temperature of 80-90°C and the sample were cooled prior to the experiment. Raw samples of POME is a brown coloured suspension, slightly acidic and consist about 94-96% of water (Bhatia et al., 2007). The sample of POME collected was characterised in Table 1:

Table 1. Characteristics of palm oil mill effluent (Average value)

pH	Conductivity (mg/L)	Turbidity (NTU)
4.98	979.67	887.83

Matured *Moringa oleifera* seeds used in this present experiment were collected from Kota Tinggi, Johor, Malaysia. The matured *Moringa oleifera* were sundried for two days. Then, the seeds were peeled as shown in Fig. 1. The good selected seeds were next grinded into smaller particles in form of fine powder of size 250 µm.

Fig. 1 : *Moringa oleifera* seeds for POME pretreatment.

2.1.3 Moringa oleifera seed oil extraction

The extraction process of *Moringa oleifera* was performed in an ultrasonic water bath which function as indirect ultrasonication. The ultrasonic bath was already equipped with a timer, heater, temperature regulator and indicator, as well as ultrasonic power regulator. Before the process started, the ultrasonic bath was set at power of 176 W and ultrasound frequency of 40 kHz. In each experiment run, the seeds was mixed with the solvent ethyl acetate at ratio 1:20. The bath was filled with water approximately 2/3 of its volume and instantly immersed the conical flask in the ultrasonic bath and the flask was fixed at the centre of the ultrasonic bath. Once process ended, the extraction carried out for duration ranging between 40 mins. The content was then centrifuged at 3000 rpm (Shan et al., 2017). As the extraction process completed, the samples were filtered by separating the liquid extract from the solid residue. The solid was taken to be used as coagulant in pretreatment POME as MOAE.

2.2 Methodology

2.2.1 Jar Test

1000 mL of POME filled into six different jar tests for each test run as shown in Fig. 2. The test was first conducted using two types of *Moringa oleifera* seeds; after oil extraction (MOAE) and non-extracted seeds (MO). The *Moringa oleifera* dosages MOAE and MO were varied from 0.1g to 0.6g (Dehghani et al., 2016). The POME sample was stirred at 150 rpm within 2 mins for fast stirring speed and before slowed down to 35 rpm for 20 mins after mixing the turbid water with *Moringa oleifera*. The samples were then left to settle for 30 mins and data on turbidity level, pH and the conductivity of the POME were recorded. The best dosage of *Moringa oleifera* was then used at different stirring speed of 30 rpm to 180 rpm respectively.

2.1.2 Moringa oleifera seed pretreatment

Fig. 2 : Six (6) jar test were filled with 1000mL of POME

2.2.2 *Turbidity removal from POME*

The suspended solids formed at the bottom of the jar test with the settling time of 30 mins so that the upper layer of the sample was filled with the supernatant water. The turbidity level of the sample POME was tested at the beginning of the experiment and as well as after the supernatant was obtained. The turbidity level of each sample from the jar test was determined by a turbidity meter, model LOVIBOND Water Testing TB 210 IR. Then the percentage of suspended solid removal (% SS Removal) for each sample was calculated to determine the best dosage. The equation is defined as bellow:

$$\text{uspended solid removal, \% (SS) Removal} = \frac{\text{Initial turbidity} - \text{Final turbidity}}{\text{Initial turbidity}} \times 100\% \quad (1)$$

2.2.3 *Sludge Volume Index (SVI)*

The setttleability parameter which is volume sludge index, SVI (cm^3/g) was determined in this study. The SVI was defined as follow:

$$\text{ludge volume index, SVI (mL/g)} = \frac{V_{30}}{(V_0 \times 100)} \quad (2)$$

Where;

V_{30} – the volume below the supernatant suspension interface after 30 mins of sedimentation (cm^3)

V_0 = the initial wastewater volume expressed in liter

TSS = total suspended solid content of the POME wastewater in grams per liter (g/L)

2.2.4 Residual Conductivity

The conductivity of the turbid water was determined using a conductivity meter, 470 Cond Meter JENWAY. The conductivity data indicates the percentage of reducing conductivity value to verify the efficiency and best dosages for each MOAE and MO coagulant during coagulation process.

3. Result and Discussions

3.1 Coagulation parameter : Optimization

3.1.1 Best Coagulant MOAE and MO dosage

In this study, the effect of dosage for *Moringa oleifera* after oil extraction (MOAE) and non-extracted seeds (MO) was identified and the result is shown in Fig 3. The coagulation-flocculation process was conducted by using MOAE and MO at different dosage, ranging from 0.1 - 0.6 g/L.

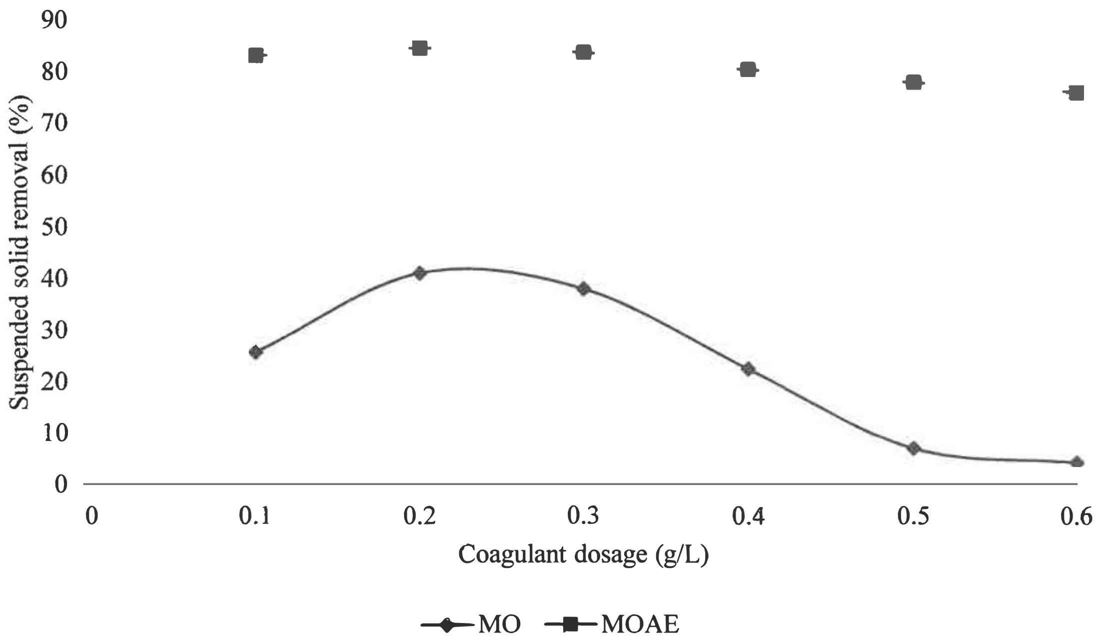

Fig. 3 : Effect of MOAE and MO dosage on the removal of suspended solids (%) in POME pretreatment.

It was observed that the total suspended solid removal increased as the dosage increased and reached its maximum 84.54% and 40.94% at dosage of 0.2 g/L for MOAE and MO respectively. The percentage of total suspended solid removal that used MOAE as natural coagulant resulting in higher value compared to MO. This is due to the presence of oil in the seeds which could form an emulsion or film coating and it inhibits the surface of reaction and thus reduces floc formation (Muyibi et al., 2009). Furthermore, the presence of primary aliphatic amines as functional group in the MOAE also helped to improve the coagulation process for suspended solid removal (Bhatia et al., 2007). In addition, the MOAE gave 25 wt% of edible oil as a side product (Muyibi et al., 1995), which made this coagulant more economical in its usage. However, when MOAE dosages exceeded the best dosage of 0.2 g/L, turbidity of POME increases as all colloids have been neutralised and precipitated with an best dosage, so the excess coagulants will has cause turbidity in water as they did not interact with oppositely charged particles (Ahmed et al., 2004). Hence, the decrease in suspended solid removal at higher dosage was expected, and the best dosage of MOAE as coagulant was determined to be at 0.2 g/L.