



**UNIVERSITI PUTRA MALAYSIA**

***APPLICATION OF PROTEIN EXTRACTED FROM WHEAT GERM AS  
NATURAL COAGULANT FOR PALM OIL MILL EFFLUENT USING  
OSCILLATORY FLOW REACTOR***

**NOR SHAZWANI BINTI DAUD**

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AS NATURAL COAGULANT FOR PALM OIL MILL EFFLUENT  
USING OSCILLATORY FLOW REACTOR**

**By**

**NOR SHAZWANI BINTI DAUD**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
Malaysia, in Fulfilment of the Requirements for the Degree of Master of  
Science**

**January 2015**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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**January 2015**

**Chair: Assoc. Prof. Tinia Idaty Mohd. Ghazi, PhD**

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This research has been concerned with coagulation process using a natural coagulant known as wheat germ to treat the palm oil mill effluent (POME). The performance of wheat germ in the coagulation process was assessed using a jar test through the study of several effects that affects the coagulation process in the jar test. The effects being studied were extractions of wheat germ using different solvent, wheat germ dosage, pH of POME, mixing speed, mixing time and sedimentation time. The wheat germ was extracted using different solvents; distilled water, tap water and salt solution (using sodium chloride (NaCl) with different molar concentration 0.25 M, 0.5 M and 1M). It was found that the wheat germ extracted with 1 molar concentration of sodium chloride (WG-1M) obtained the highest removal of investigated parameters i.e. turbidity, total suspended solid (TSS), chemical oxygen demand (COD) and colour. Following to this, WG-1M was applied throughout the whole experimentation process. The optimum condition in the jar test obtained at 12 000 mg/L of WG-1M dosage, at original pH of POME i.e. 5 with rapid mixing of 120 rpm for 1 minute and slow mixing 35 rpm for 20 minutes at mixing time of 20 minutes in the jar test and 1 hour sedimentation time.

The removals were found to be 97.7%, 93.5%, 55% and 65.2% for the turbidity, TSS, COD and colour, respectively. The coagulation process using WG-1M was then conducted in the oscillatory flow mixing reactor (OFR). The effects being studied in the OFR were the effects of baffles spacing, effect of frequency and amplitude, effect of mixing time in the OFR, sedimentation time and WG-1M dosage. The effectiveness of coagulation process in the OFR was assessed through the comparison of the result obtained in the OFR with those obtained in the jar test. The highest removal of turbidity, TSS COD and colour were obtained at frequency of 1 Hz and amplitude of 12 mm which corresponds to  $Re_0$  of 6786. This highest removal also achieved when all baffles applied in the OFR at 10 minutes mixing time and 4 hour sedimentation time with the same optimum dosage as obtained in the jar test i.e. 12 000 mg/L. The highest

removals of turbidity, TSS COD and colour were 99.5%, 96%, 81.3% and 68.9% respectively. This is higher as compared to coagulation process in the jar test. The result shows that the coagulation process which traditionally done in the jar test can be successfully applied in the OFR. It was found that the removal of investigated parameter was further improved and enhanced. The study showed that the wheat germ could be regarded as a new potential natural coagulant for the treatment of POME.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

**APLIKASI PENGEKSTRAKKAN PROTEIN DARIPADA GERMA GANDUM  
SEBAGAI PENGENTAL ASLI UNTUK SISA BUANGAN AIR PENAPISAN  
KELAPA SAWIT MENGGUNAKAN REAKTOR ALIRAN AYUN**

Oleh

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Kajian yang dilakukan adalah mengenai proses pengentalan menggunakan pengental asli yang dikenali sebagai germa gandum bertujuan merawat sisa buangan air penapisan minyak kelapa sawit (POME). Pencapaian germa gandum dalam proses pengentalan dinilai dengan menggunakan ujian balang melalui kajian beberapa kesan terhadap proses pengentalan pada ujian balang. Antara kesan-kesan yang dikaji adalah pengekstrakkan germa gandum menggunakan larutan yang berbeza, dos germa gandum, pH POME, kelajuan campuran, tempoh campuran dan tempoh pemendapan. Germa gandum diekstrakkan menggunakan larutan yang berbeza iaitu air suling, air paip dan larutan garam (menggunakan larutan natrium klorida (NaCl) yang berbeza kepekatan, iaitu 0.25 molar (M), 0.5 M dan 1M). Didapati bahawa germa gandum yang diekstrak menggunakan 1M NaCl (WG-1M), mencapai pengurangan tertinggi pada parameter-parameter yang dikaji iaitu kekeruhan, jumlah pepejal terampai (TSS), permintaan oksigen secara kimia, dan warna. Berikutan itu, WG-1M diaplikasi pada keseluruhan proses ujikaji. Keadaan optima pada ujian balang diperoleh pada 12 000 mg/L dos germa gandum, pada nilai pH POME yang asal iaitu 5 dengan campuran laju 120 rpm selama 1 minit dan campuran perlahan 35 rpm selama 20 minit, pada tempoh campuran 20 minit dan tempoh pemendapan selama 1 jam.

Pengurangan didapati sebanyak 97.7%, 93.5%, 55% and 65.2% untuk parameter kekeruhan, TSS, COD dan warna masing-masing. Proses pengentalan menggunakan WG-1M kemudiannya dilakukan di sebuah reaktor yang dikenali sebagai reaktor aliran ayun (OFR). Antara kesan-kesan yang dikaji pada penggunaan OFR ialah kesan jarak sesekat, frekuensi dan amplitud, kesan tempoh campuran dalam OFR, kesan pemendapan dan dos WG-1M. Keberkesanan proses koagulasi pada OFR dinilai melalui perbandingan keputusan pada ujian balang. Pengurangan tertinggi untuk kekeruhan, TSS, COD dan warna diperoleh pada frekuensi 1 Hz dan amplitud 12 mm menyamai nombor Reynolds iaitu 6786. Pengurangan tertinggi ini juga diperolehi

apabila semua sesekat diaplikasikan pada OFR pada 10 minit tempoh campuran, 4 jam tempoh pemendapan dengan dos optima yang sama seperti yang diperolehi pada ujian balang iaitu 12 000 mg/L. Pengurangan tertinggi untuk kekeruhan, TSS, COD dan warna masing-masing ialah 99.5%, 96%, 81.3% and 68.9%. Ini lebih tinggi jika dibandingkan dengan ujian balang. Keputusan menunjukkan proses koagulasi yang secara tradisionalnya dilakukan pada ujian balang boleh dilakukan dengan jayanya pada OFR. Kajian mendapati bahawa pengurangan parameter adalah lebih diperbaiki dan maju. Kajian ini menunjukkan germa gandum boleh dikategorikan sebagai pengental asli baru yang berpotensi untuk merawat sisa buangan air penapisan kelapa sawit.





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I certify that a Thesis Examination Committee has met on 30 January 2015 to conduct the final examination of Nor Shazwani Binti Daud on her thesis entitled “Application of Protein Extracted from Wheat Germ as Natural Coagulant for Palm Oil Mill Effluent using Oscillatory Flow Reactor” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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## LIST OF ABBREVIATIONS

APHA	American Public Health Association
Alum	Aluminum Sulfate
BOD	Biochemical Oxygen Demand
Bs	Baffle spacing
COD	Chemical Oxygen Demand
CSTR	Constant Stirred Tank Reactor
DEA	Diethanolamine
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOE	Department of Environmental
DW	Distilled Water
E.Coli	Escherichia Coli
EFB	Empty Fruit Bunches
FFB	Fresh Fruit Bunches
FPB	Fluidized Pellet Bed
HBaqs	Hibiscus Rosa-Sinensis
HRT	Hydraulic Retention Time
JCSC	Jatropha Curcas Seed Coagulant
kDa	kilo Dalton
MO	Moringa Oleifera
MOC-DW	Moringa Oleifera Coagulant Extracted with Distilled Water
MOC-S	Moringa Oleifera Coagulant Extracted with Salt Solution
MOC-S-P	Purified Moringa Oleifera Coagulant Extracted with Salt Solution
MPOB	Malaysian Palm Oil Berhad
MSP	Maize Seed Powder
MW	Molecular Weight
NC	Natural Coagulant
OBF	Oscillatory Baffled Flocculator
OBR	Oscillatory Baffled Reactor
OFR	Oscillatory Flow Mixing Reactor
PACl	Polyaluminium Chloride
PAM	Polyacryamide
PFR	Plug Flow Reactor
POME	Palm Oil Mill Effluent
Reo	Reynolds number
rpm	Revolution per Minute
SDWF	Safe Drinking Water Foundation
SS	Suspended Solid
STF	Stirred Tank Flocculator
TOC	Total Organic Carbon
TP	Total Phosphorus
TS	Total Solid
TSS	Total Suspended Solid
TSW	Tapioca Starch Wastewater
TW	Tap Water

UV	Ultraviolet
WFC	Wheat Food Council
WHO	World Health Organization
WG	Wheat Germ
WG-0.25	Wheat germ extracted with 0.25 M NaCl solution
WG-0.5	Wheat germ extracted with 0.5 M NaCl solution
WG-1M	Wheat germ extracted with 1 M NaCl solution
WG-DW	Wheat germ extracted with distilled water
WG-TW	Wheat germ extracted with tap water



## CHAPTER 1

### INTRODUCTION

Palm oil industry in Malaysia had grown since year 1920 with 400 hectares of oil palm cultivated. More cultivation areas were opened up as direct consequences of crop diversification policy by government. In 2011, five million hectares of land was cultivated with oil palm. Result from the growth of the palm oil industry, the milling and refining sectors also increased (MPOB, 2012). Besides the empty fruit bunches, mesocarp fibers and shell, palm oil mill effluent (POME) was one of the wastes resulted from processing of the oil palm fresh fruit bunches (FFB) for the production of palm oil (Er et al., 2011). It was estimated that 0.5-0.75 tonnes of POME discharged, for every tonne of fresh fruit bunches processed (Rupani et al., 2010).

POME is a viscous acidic liquid with brown in colour and it was primarily organic with unpleasant smell. It had potential to deplete the oxygen by 100 times more than the domestic sewage. Due to this reason, it is important to treat this effluent before discharge into the water course for the protection of the aquatic life. The most common treatment system for POME was the ponding system which consisted of several stages (Salihu and Alam, 2012). Due to several drawbacks such as the requirement of vast area, production of bad odor and difficulties in maintaining biogas collection, it is required to replace the ponding system with other reliable treatment system to preserve the environment (Ismail et al., 2013). The application of coagulation-flocculation process using natural coagulant was found to be a new alternative for POME treatment (Othman et. al., 2008). This coagulation process commonly conducted using a jar test method (Ni et al., 2001). However, study carried out by Ni et al., 2001 showed that coagulation can be successfully conducted in oscillatory baffled (OBF) reactor and the coagulation performance was even better than the jar test in terms of mixing and energy. Thus further studies on the treatment of POME using alternative natural coagulant using effective tools in coagulation process are needed to be explored for the safety of human, aquatic life and environment.

#### 1.1 Problem statement

Chemical based coagulants were mostly used in the water and wastewater purification. Even though these coagulants showed its effectiveness in the purification process, there were some disadvantages related to it. It produced large volume of sludge, affected the treated water pH and the main issue was harmful to human health (Yin, 2010). Chemical such as aluminum had been studied by researchers and they found that aluminum based coagulants may contribute harmful to the human nervous central system (Flaten, 2001; Polizzi et al., 2002). In addition to that, the production of Alum requires complex chemical process which caused high cost production.

As a result, more and more work have now focused on the new potential natural coagulants to replace the function of chemical coagulant. These natural coagulants have

several advantageous such as it is natural, renewable, non-toxic, and biodegradable (Saranya et al., 2013).

## **1.2 Objectives**

This research work was carried out to study the potential of wheat germ as a natural coagulant in the treatment of palm oil mill effluent (POME) using an Oscillatory Flow Mixing Reactor (OFR). The specific objectives are as below:

- 1) To investigate the potential of wheat germ as a new coagulant obtained from natural resources as an alternative coagulant for treatment of POME.
- 2) To identify the suitable solvent in extracting the wheat germ using three different solvents; (distilled water, tap water and salt solution) and study the reaction parameters such as coagulant dosage, POME pH, mixing and settling time that affects the coagulation process using jar test.
- 3) To investigate the effectiveness of coagulation process in an Oscillatory Flow Mixing Reactor (OFR).

## **1.3 Scope of study**

This study was conducted within its scopes. The scopes of this study were listed below:

- 1) The POME sample was collected directly after palm oil mill processing, before this effluent flows into the POME treatment plant. This effluent was called as raw POME.
- 2) Coagulation was used in the treatment of POME as it was found to be simple method which involved low in cost and its effectiveness in water and wastewater purification had been proved by many researchers. Wheat germ was used as natural coagulant in this study due to its availability in protein, where protein was found to be an active coagulation component. It is highly biodegradable as it is obtained from the natural resource and can reduce the reliability solely on chemical coagulant which correlates to adverse human health (Saranya et. al., 2013). Other than that, wheat germ is productive and easily available either obtained as a by product from the flour milling process or from the raw wheat without the use of complex chemical process. This also generates the value-added products (present new source of income) (Ali et. al., 2013).
- 3) The coagulation performance was assessed in terms of removal of turbidity, total suspended solid (TSS), chemical oxygen demand (COD) and colour. These parameters were common parameters measured, as good indicator to assess the coagulation performance from previous researcher's works.
- 4) The solvents used for the extraction of the active coagulation component from the wheat germ were distilled water, tap water and salt solution with different concentration (1M, 0.5M and 0.25 M). These were common solvents used by researchers in extracting the active coagulant component from natural coagulant for successful coagulation process.



5) An OFR was chosen as an equipment for coagulation process since it provides good mixing performance. This led to good contacting between particles of POME suspension and wheat germ for good coagulation process. The performance of OFR reactor was assessed through the comparison of the result obtained from the OFR with those obtained in the jar test.

#### **1.4 Construction of thesis**

There are five chapters in this thesis. Chapter 1 presents an introductory part for the overview and current scenario of palm oil industry in Malaysia. This introductory part also provides the basic discussion of the problems generated by the effluent discharged from the palm oil milling process which known as palm oil mill effluent (POME) and common treatment system for the effluent. Problem statements, objectives and scope of the study have also been outlined in this chapter.

Meanwhile, a detailed description on the palm oil milling process and the palm oil mill effluent (POME) are provided in chapter 2. These include the current treatment of POME done by many researchers, theory and detailed study of coagulation process for POME and other wastewater treatment. In addition, it contains a discussion on oscillatory flow mixing (OFM) reactor as an effective equipment in mixing purposes for coagulation process in the treatment of POME.

In Chapter 3, the experimentation methodology involved in this study is explained and interpreted in the form of a flowchart. Chapter 4 presents the results obtained from the experimentation work, in the form of graphs and tables that include the detailed explanation. Last but not least, the conclusion of the study and some recommendations for future work are provided in chapter 5.



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