UTILISATION OF OIL PALM EMPTY FRUIT BUNCH ASH AS POTENTIAL NATURAL COAGULANT FOR PALM OIL MILL EFFLUENT TREATMENT

Nur Syahira Hisham[1], Zadariana Jamil[1*]

[1] *Faculty of Civil Engineering*
Universiti Teknologi Mara UiTM Shah Alam, 40450 Shah Alam

[*] *Corresponding author: zadariana@uitm.edu.my*

Abstract

The palm oil mill industry generates massive wastes in solid and liquid forms such as Empty fruit bunches (EFB) and palm oil mill effluent (POME). These two wastes are high in fibre and organic content that may affect the environment and health without proper management. Thus, the recovery of these valuable resources from wastes is vital in order to reduce pollutions generated from palm oil production. The empty fruit bunch ash (EFBA) was investigated to determine its potential as a natural coagulant for COD and TSS removal in palm oil mill effluent (POME). The effectiveness of EFBA was determined by varying the parameters such as coagulant dosage (0 – 22 g/l) and initial pH of POME (3 – 4). The maximum removal of COD and TSS were about 39.96% and 77.09% respectively at initial POME pH of 4 and EFBA dosage of 6 g/l, suggesting EFBA as a new alternative coagulant for treating palm oil mill effluent.

Keyword: Empty fruit bunch, natural coagulant, Palm oil mill effluent

Introduction

Malaysia is one of the leading palm oil producers in the world after Indonesia. According to the Department of Statistics Malaysia (Kei, 2018), about RM 96.0 billion (8.2 per cent) of Malaysia Gross Domestic Product (GDP) 2017 gained from agricultural sectors. About 46.6 per cent of them were from oil palm. In 2018, there were about 451 oil palm mills in operation in Malaysia, showing an increment of 28.13% since 17 years ago (WWF, 2002). This shows that the demand for crude palm oil has continuously increased over the years. The crude palm oil is then processed to produce products such as cooking oil and margarine. However, during the production of crude palm oil, several biomass wastes generated in solid and liquid states such as empty fruit bunch (EFB), palm kernel shell (PKS), palm press fibre, decanter cake, palm oil mill effluent (POME), and palm oil fuel ash (POFA).

The EFB is the main constituent of solid waste produced by the palm oil industry (Prasertsan & Prasertsan, 1996), which contributes to 9% of cumulative solid wastes production in Malaysia (Othman & Sadikin, 2008). It is reported from the previous study that every kilogram of palm oil can produce approximately a kilogram of EFB (Drahansky et al., 2016). Since the EFB has high moisture content characteristic (~55%-65%) and bulky that hardly to be handled and transported, it is usually disposed by open burning or rotting naturally at the mill and plantation (Igwe & Onyegbado, 2007). In enhancing environmental sustainability during the production of crude oil palm, researches have started to study the potential of EFB for innovation and other valuable applications. Currently, EFB is also being used as mulch at the plantation areas to prevent corrosion and control the moisture of soil (Chiew & Shimada, 2013). Previous studies have shown that the EFB can be reused and recycled as fibre, fertiliser, fuel and others, including the use of EFB to treat water and wastewater (Chiew & Shimada, 2013).

It has been reported that the EFB can be used as a low-cost adsorbent to remove heavy metals in aqueous solution (Lee, Hiew, Lee, Gan, & Thangalazhy-Gopakumar, 2017; May, Thoe, Surugau, Lye, & Chong, 2019).

POME is identified as the most polluting wastewater as it contains high biological oxygen demand (~53,630 mg/L), chemical oxygen demand (~25,000 mg/L), oil and grease (8,370 mg/L) and suspended solids (19,020 mg/L) (Shak & Wu, 2015). It is also a thick brownish viscous liquid waste, slurry, high in colloidal suspension and has an unpleasant odour. The raw POME consists of 95 – 96% water, 0.6 – 0.7% oil and 4 – 5% total solids (Teh, Wu, & Juan, 2014). Thus, the discharge of untreated POME into water bodies will destruct the aquatic lives and natural ecosystem. Therefore, the palm oil industry has a big responsibility in term of environmental protection, economic viability, and sustainable development by treating the POME before releasing into the river.

The current treatment technologies of POME applied in the mill are natural aerobic and anaerobic digestion. Pre-treatment processes of advanced treatment of POME such as membrane filtration, coagulation and flocculation play an essential role in effectively removing most of the pollutants such as total suspended solids (TSS), turbidity (TUR) and chemical oxygen demand (COD) in POME. The coagulation-flocculation process requires the addition of chemicals known as coagulants to remove the organic matter and suspended particles which cause turbidity and colour of the wastewater. During the process, a coagulant is added to form large masses of particles and later removed from the wastewater. The conventional chemical-based coagulant such as aluminium sulphate (Alum) harms human health when excessive dosage used and long term exposure. Furthermore, the usage of Alum as a coagulant in wastewater contributes to an adverse effect on the environment, especially to aquatic life if the wastewater is not treated correctly. The use of Alum as a coagulant is within a limited range of pH and temperature and cost consuming (Fatah & Wahab, 2018). Hence, this study was carried out to investigate the potential of EFB as an alternative to chemical coagulants. It has been proved that EFB ash (EFBA) is a suitable adsorbent in previous studies (Chowdhury, Zain, Khan, & Ahmed, 2011; Imla Syafiqah & Yussof, 2018; Lee et al., 2017). However, the potential of EFBA as a natural coagulant has barely been explored. Therefore, in this research, the effectiveness of oil palm EFBA as a natural coagulant in order to remove chemical oxygen demand (COD) and total suspended solids (TSS) of POME was studied.

Materials and Methods

Preparation of palm oil mill effluent (POME) sample

The palm oil mill effluent (POME) samples were collected from a palm oil mill at Bukit Kerayong, Selangor. The sample collected was located before the oil trap unit process. The POME was stored in a thermal resistant plastic container and preserved in a cold room at 4°C.

Preparation of empty fruit bunch ash (EFBA)

The oil palm EFB was collected at the same palm oil mill, where POME samples were collected. The EFB was shredded into small pieces, then dried in the oven at 105°C for 48h to remove the oil and water content (Huzir et al., 2019). The dried EFB was then burnt in a muffle furnace at 550°C for 2h to form amorphous ash, as shown in **Figure 1**. The EFB ash is then stored in a plastic container at room temperature before further analysis.

Figure 1 The EFB ashes after burned in the furnace at 550ºC

Jar Test

POME was poured into 500ml of beakers, and its initial pH was adjusted to 3 and 4 using hydrochloric acid (HCl) (1M) and sodium hydroxide (1M) solutions. The pH of POME was measured using a pH meter (HACH, USA). The EFBA was then added to each of the beakers with different dosage of 0, 6, 14 and 22g/L. The mixed POME and EFBA samples were agitated at rpm of 250 rpm (rapid mixing) for 3 mins and then changed to 30rpm for 30 mins for slow mixing. The change of mixing speed from rapid to slow mixing allows the particles in the POME to coagulate and flocculate respectively. Then the mixture was left for 60 mins to allow the agglomerated particles to settle down (Huzir et al., 2019). After the agglomerated particles settled down, the treated POME was analysed for COD and TSS. The effects of dosage and pH on the removal of COD and pH using EFBA as the coagulant were studied in this research. The pH and dosage were varied within (3-4) and (0-22g/L), respectively. The rapid and slow speeds were remained constant at 250 and 30 rpm respectively.

Chemical Oxygen Demand (COD) Analysis

The COD concentration of POME was measured using High Range (500-2000 mg/L) COD Reagent (HACH, USA). Prior to the COD analysis, the POME sample was diluted (10 times) using distilled. Then, 2 ml of the diluted POME was then added into the high range COD reagent that contains K_2CrO_7, H_2SO_4 and Hg. 2 ml of distilled water was added into another reagent vial as a blank sample. The sample and the reagent were mixed by turning the vial upside down several times. Then the mixed sample vials were placed in the pre-heated reactor for digestion for 2h at 150°C. After the vials cooled down to room temperature, they were placed in a spectrophotometer (HACH DR 2800) for COD concentration measurement. All samples were analysed in duplicate. **Figure 2** shows the layer of settled particles and treated POME after the coagulation-flocculation process. The sample for COD analysis was taken from Layer 1.

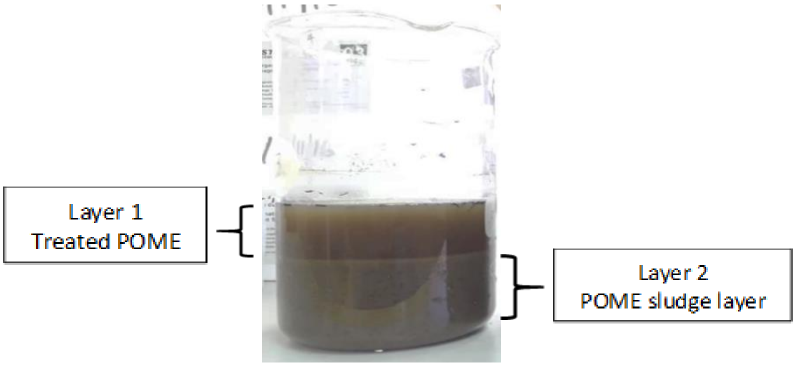

Figure 2 The layer of settled particles and treated POME after the coagulation-flocculation process

Total Suspended Solid (TSS) Analysis

The total suspended solids (TSS) was determined using a spectrophotometer (HACH DR 2800). The POME sample (same layer as taken for COD determination) was diluted (10 times) as described in the previous section. The diluted POME was stirred and quickly poured into a sample cell (10ml). A blank sample used in this study was distilled water. The sample was mixed, and the bottom of the cell was tapped in order to remove gas bubbles, before placing it in the cell holder of spectrophotometer for TSS measurement. All samples were analysed in duplicate. The removal of TSS and COD of POME were calculated using **Equation (1)**.

$$\text{Removal efficiency (\%)} = \left(1 - \frac{\text{final concentration}}{\text{initial concentration}}\right) \times 100 \qquad (1)$$

Results and Discussion

Characteristic of Palm Oil Mill Effluent (POME)

The physical and chemical properties of POME obtained in this study are tabulated in **Table 1**. These properties were compared with the POME properties reported in previous studies

Table 1 The initial characteristics of POME used in the study and previous study

Parameter	POME used in the current study	(Trisakti, Manalu, Taslim, & Turmuzi, 2015)	(Huzir et al., 2019)	(Fatah & Wahab, 2018)	(Shak & Wu, 2015)	(Bhatia, Othman, & Ahmad, 2007)	(Idaty & Ghazi, 2014)
pH	3.95	3.70-4.70	4.51	4.47	4.86	4.5	4.78
COD (mg/L)	29,300	48,300	54, 867	97, 400	30, 000	40,200	48, 000
TSS (mg/L)	9, 210	2,080-27,040	24, 840	32, 050	67, 700	17, 927	18, 400

It is shown that the pH of POME obtained in this study was within the range obtained from previous studies (~ 3.8 – 4.7). The POME has high in acidity due to its complex forms of organic acids that are produced during fermentation processes (Madaki & Seng, 2013). The COD and TSS obtained in this study were 29,300 mg/L and 9, 210 mg/L respectively. Many factors may influence the characteristics of POME in the mill, such as the season (low and high crop seasons), sampling point and time (production time). The low crop season starts in December until May and June marks the beginning of a high harvest season and ends November. Moreover, the parameter values are also varied due to different batches, days and factories, processing techniques and the age or type of the fruit (Madaki & Seng, 2013).

Effect of dosage on COD and TSS removal using EFBA

The effect of palm oil EFBA dosage in the coagulation-flocculation process to remove COD and TSS of POME was studied. The dosage of EFBA was varied from 0 to 22 g/L. The other parameters such as initial pH of POME and the speed of rapid mixing were remained constant at 4 and 250 rpm respectively. **Figure 3** shows that the COD removal was slightly changed, about 30 – 40% after the coagulation-flocculation treatment. The maximum removal of COD was about 39.96% when 6 g/L of EFBA ashes were added. It is shown that the addition of EFBA removed another ~ 10% of COD as compared to the blank. This shows that the effect of EFBA dosage on COD removal of POME is very minimal. However, the TSS was removed at the maximum level (77.09%) at the same conditions. Further increment of dosage did not show any increment in the removal of both COD and TSS. It is shown that the EFBA required higher dosage to remove COD and TSS compared to other natural coagulants such as rice husk ash, wheat germ and *Moringa Oleifera* (Table 2). The maximum removal of COD was 39.96% at 6 g/L of EFBA while rice husk ash able to remove COD as much as 52.38% using similar dosage. This is due to the capabilities of different materials to act as natural coagulant efficiently based on its chemical characteristics.

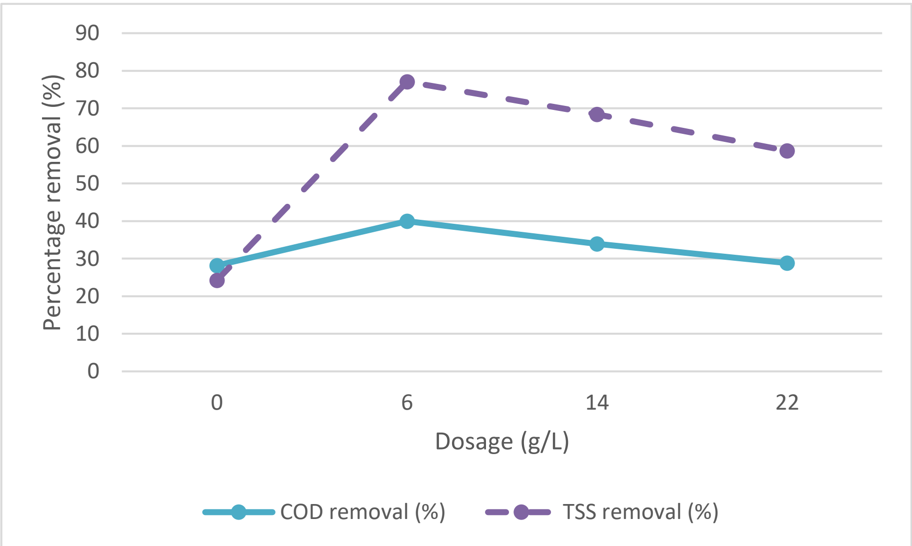

Figure 3 The percentage removal of COD and TSS for different dosages

The selection of material for natural coagulants is based on its chemical composition (Bhatia et al., 2007). The EFB has high silica content. Silica is the cationic elements that were reportedly suitable for adsorbing negatively charged particles in wastewater such as POME and potentially removes contaminants such as COD and TSS in POME (Huzir et al., 2019). However, EFBA contains lower silica content that might affect the neutralisation of the anionic elements of the EFBA. It has been reported in the previous study that the used of rice husk ash

as (RHA), which had over 90% of silica content, was able to remove 52.38% of COD and 83.88% of TSS (Huzir et al., 2019).
Additionally, the content of active protein compounds and polysaccharides in the coagulant material also affects its performance on the removal of COD and TSS (Choong Lek et al., 2018). EFB has a lower content of protein which only has 11% of crude protein (Widyastuti & Rakhmawati, 2010). It is reported that wheat germ with 27% of protein content has removed COD and TSS in POME as much as 61.7% and 95.6%, respectively (Idaty & Ghazi, 2014).

Effect of pH on COD and TSS removal using EFBA

The initial pH of POME is one of the factors that plays an essential role in removing contaminants such as COD and TSS. The pH is responsible for influencing some of the mechanism, such as a bridging mechanism during the coagulation-flocculation process (Choong Lek et al., 2018). Furthermore, pH will affect the surface charge of coagulants and stabilisation of the particle suspension. Thus, it is crucial to study the effect of pH on removing COD and TSS in POME.
Figure 4 shows the removal percentage of COD and TSS when the initial pH of POME was c hanged from 3 to 4. Since the maximum removal of COD and TSS using various types of natu ral coagulants in previous studies were within acidic range, thus, the pH values selected in thi s study was in the range of 3 to 4. The effect of alkaline range to the COD and TSS removal i n POME will be studied in the future for verification.
Figure 4 shows that the COD removal was slightly increased from 33.75 % to 39.96 % when the initial pH of POME changed from 3 to 4. The TSS removals were about 67.97% and 77.09% at pH 3 and 4 respectively. This agrees well with the range of operating pH of POME (pH 3-5) for maximum removal using different types of natural coagulants (**Table 2**).

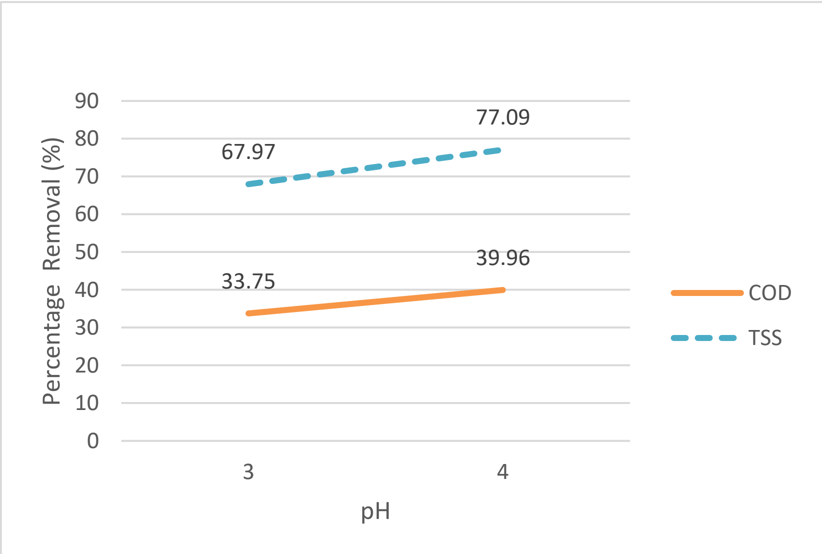

Figure 4 The percentage removal of COD and TSS at pH 3 and 4 with dosage of EFBA of 6g/L

Table 2 shows the comparison between results obtained in this study and previous studies. EFBA worked well on the removal of COD and TSS under a similar condition as RHA and u nmodified rice starch. The removal of COD and TSS using EFBA are comparable with the va lues obtained by other natural coagulants. Thus, the EFBA shows a very promising natural co agulant.

Table 2 The operating pH values at maximum COD and TSS removals of current and previous studies

Type of natural coagulant	Coagulant dosage (g/L)	pH at operating condition	Removal		Reference
			COD	TSS	
EFBA	6	4	39.96	77.09	Current study
Rice husk ash (RHA)	3	3.6	52.38	83.88	(Huzir et al., 2019)
Unmodified rice starch	0.28	4.45	49.23	86.65	(Teh et al., 2014)
Wheat germ	12	2	61.7	95.6	(Idaty & Ghazi, 2014)
Moringa Oleifera	3.49	5	NA	87	(Bhatia et al., 2007)

Conclusion

The EFBA has shown promising results as an alternative natural coagulant for COD and TSS removal from POME. It is shown that the EFBA removes TSS (77 %) better than COD (~40%) in acidic condition due to the abundance negatively charged of particles that are likely attracted more to EFBA to form coagulates. This is suitable with the nature of POME, which acidic (pH 3-4), thus no further pH adjustment is needed. Furthermore, the treatment of POME using EFBA will minimise solid wastes problems generated by palm oil industries and eventually reduce the operational cost.

Acknowledgement

The most profound gratitude goes to the team member and FCE laboratory assistants, who assisted in the sampling processes, experiments and analysis.

Conflict of interests

The authors hereby declare that there is no conflict of interest with any organisation of finance body for supporting this research.

References

Bhatia, S., Othman, Z., & Ahmad, A. L. (2007). Coagulation-flocculation process for POME treatment using Moringa oleifera seeds extract: Optimisation studies. *Chemical Engineering Journal*, *133*(1–3), 205–212. https://doi.org/10.1016/j.cej.2007.01.034

Chiew, Y. L., & Shimada, S. (2013). Current state and environmental impact assessment for utilising oil palm empty fruit bunches for fuel , fiber and fertiliser - A case study of Malaysia. *Biomass and Bioenergy*, *51*, 109–124. https://doi.org/10.1016/j.biombioe.2013.01.012

Choong Lek, B. L., Peter, A. P., Qi Chong, K. H., Ragu, P., Sethu, V., Selvarajoo, A., & Arumugasamy, S. K. (2018). Treatment of palm oil mill effluent (POME) using chickpea (Cicer arietinum) as a natural coagulant and flocculant: Evaluation, process optimisation and characterisation of chickpea powder. *Journal of Environmental Chemical Engineering*, *6*(5), 6243–6255. https://doi.org/10.1016/j.jece.2018.09.038

Chowdhury, Z. Z., Zain, S. M., Khan, R. A., & Ahmed, A. A. (2011). Equilibrium kinetics and isotherm studies of CU (II) adsorption from waste water onto alkali activated Oil palm Ash. *American Journal of Applied Sciences*, *8*(3), 230–237. https://doi.org/10.3844/ajassp.2011.230.237

Drahansky, M., Paridah, M. ., Moradbak, A., Mohamed, A. ., Owolabi, F. Abdulwahab Taiwo, Asniza, M., & Abdul Khalid, S. H. . (2013). The oil palm wastes in Malaysia. In *Biomass Now-Sustainable Growh and Use*: *Vol. i* (pp. 75–100). https://doi.org/http://dx.doi.org/10.5772/57353

Fatah, A., & Wahab, A. (2018). Performance study of dragon fruit foliage as a plant- based coagulant for treatment of palm oil mill effluent from three-phase decanters. *Peer-Reviewed Article*, *13*(2), 4290–4300.

Huzir, N., Aziz, M. A., Ismail, S. B., Azmi, N., Mahmood, N., Umor, N. A., … Muhammad, S. (2019). Industrial crops & products optimization of coagulation-flocculation process for the palm oil mill effluent treatment by using rice husk ash. *Industrial Crops & Products*, *139*(June), 111482. https://doi.org/10.1016/j.indcrop.2019.111482

Idaty, T., & Ghazi, M. (2014). Wheat germ as natural coagulant for treatment of palm oil mill effluent *(POME)., International Journal of Chemical and Environmental Engineering, 5*(2), 111-115.

Igwe, J. C., & Onyegbado, C. C. (2007). A review of palm oil mill effluent (pome) water treatment. *Global Journal of Environment Research, 1*(2), 54–62.

Imla Syafiqah, M. S., & Yussof, H. W. (2018). Adsorption of mercury from aqueous solutions using palm oil fuel ash as an adsorbent - Batch studies. *IOP Conference Series: Materials Science and Engineering*, *334*(1), 1-8. https://doi.org/10.1088/1757-899X/334/1/012039

Kei, Ho Mei. (2018). *Selected agriculture indicators, Malaysia*. https://www.dosm.gov.my/v1/index.php?r=column%2FcthemeByCat&cat=72&bul_id=UjYxeDNkZ0xOUjhFeHpna20wUUJOUT09&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09. [31 December 2018].

Lee, X. J., Hiew, B. Y. Z., Lee, L. Y., Gan, S., & Thangalazhy-Gopakumar, S. (2017). Evaluation of the effectiveness of low cost adsorbents from oil palm wastes for wastewater treatment. *Chemical Engineering Transactions*, *56*, 937–942. https://doi.org/10.3303/CET1756157

Madaki, Y. S., & Seng, L. (2013). Palm oil mill effluent (pome) from Malaysia Palm oil mills : Waste or resource. *International Journal of Science, Environment and Technology*, *2*(6), 1138–1155.

May, J., Thoe, L., Surugau, N., Lye, H., & Chong, H. (2019). Application of oil palm empty fruit bunch as adsorbent : A review. *Transactions on Science and Technology, 6(1),* 9-26.

Othman, N., & Sadikin, A. N. (2008). Lignocellulostic fiber media filters as a potential technology for primary industrial wastewater treatment. *Jurnal Teknologi, 49(F),* 149-157.

Prasertsan, S., & Prasertsan, P. (1996). Biomass residues from palm oil mills in Thailand: An overview on quantity and potential usage. *Biomass and Bioenergy*, *11*(5), 387–395. https://doi.org/10.1016/S0961-9534(96)00034-7

Shak, K. P. Y., & Wu, T. Y. (2015). Optimised use of Alum together with unmodified Cassia obtusifolia seed gum as a coagulant aid in treatment of palm oil mill effluent under natural pH of wastewater. *Industrial Crops and Products*, *76*, 1169–1178. https://doi.org/10.1016/j.indcrop.2015.07.072

Teh, C. Y., Wu, T. Y., & Juan, J. C. (2014). Optimisation of agro-industrial wastewater treatment using unmodified rice starch as a natural coagulant. *Industrial Crops and Products*, *56*, 17–26. https://doi.org/10.1016/j.indcrop.2014.02.018

Trisakti, B., Manalu, V., Taslim, I., & Turmuzi, M. (2015). Acidogenesis of palm oil mill effluent to produce biogas: Effect of hydraulic retention time and pH. *Procedia - Social and Behavioral Sciences*, *195*, 2466–2474. https://doi.org/10.1016/j.sbspro.2015.06.293

Widyastuti, Y., & Rakhmawati, A. (2010). Fermentation of palm oil waste by Aspergillus oryzae and Rhizopus oryzae. 567–573.

WWF. (2002). The palm oil industry in Malaysia: From seed to frying pan. *Wwf*, (November), 145. Retrieved from http://www.senternovem.nl/mmfiles/WWF_palm_oil_industry_Malaysia_tcm24-195179.pdf