CHAPTER 3

AEROBIC AND ANAEROBIC BIODEGRADATION OF PALM OIL MILL EFFLUENT

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3.1 INTRODUCTION

Malaysia has abundant and diverse tropical crops due to its geographical location, evenly distributed temperature (25–33 °C), and plenty of rainfall making it ideal for oil palm (How et al., 2019). Currently, the country is the world's second-largest palm oil producer and exporter after Indonesia, with about 18.45 million tons of crude palm oil (CPO) processed in 2022 (MPOB, 2023). However, despite the advancement of the oil palm industry and its high economic returns to the country, the production process is accompanied by the generation of massive wastes. About 100 million tons of fresh fruit bunches (FFBs) are processed annually, with the final palm oil products usually constituting only about 10% of the processed FFBs. The remaining 90% are fibre and cellulosic biomass (Ong et al, 2021). Among the different types of waste generated, palm oil mill effluent (POME) is the most abundant, with about 3.75 tonnes of wastewater produced for every tonne of CPO extracted (Arisht et al., 2022). The wastewater is released from three stages of the extraction process: the sterilization of the fresh fruit bunches, crude palm oil clarification, and hydrocylone separation, in the ratio of 9:15:1 (Cheng et al., 2021a).

POME, in its raw state, is a thick, acidic brownish colloidal wastewater which comprises 95 – 96% water, 0.6 – 0.7% residual oil, and organic pollutants, such as carbohydrates (ranging from complex to simple sugars), proteins, lipids, free organic acids, nitrogenous compounds, and minerals (Sani et al., 2021). Other properties of POME reported includes high biological oxygen demand (BOD) (≥ 25,000 mg/L) and chemical oxygen demand (COD) (≥ 50,000 mg/L) (Ding et al., 2020). POME in itself might be non-toxic due to the chemical-free wet milling extraction process used, but the high organic content can result in the consumption of dissolved oxygen in waterways, inducing aquatic hypoxia (Albarracin-Arias et al., 2021; Garritano et al., 2018). The significant level of macronutrients in the POME can promote algal growth (Tan et al., 2017), and could also contain precursor compounds, which can form aromatic amines that might be hazardous if discharged untreated (Abdulsalam et al., 2018). Hence, to control and minimize the impacts towards the environment, the Department of Environment (DOE) Malaysia enacted the Environmental Quality Act (EQA) in 1974 and the discharge standards for POME into the environment was set. This required all mills to adopt POME treatment methods in order to meet the standards.

The most adopted treatment methods are the microbial-based processes, due to the rich biodegradable high-energy compounds, and the macro- and micronutrients it contains which supports the microbial-catalysed metabolic processes (Cheng et al., 2021b). Over 85% of the palm oil mills in Malaysia employs the conventional ponding systems due to its cost effectiveness, simple design and construction, low maintenance costs, and energy efficiency (Hazman et al., 2018). The process utilizes the action of native microbes to synergistically oxidize the complex organic matter in the wastewater, under anaerobic and aerobic conditions (Dominic & Baidurah, 2022). This chapter summarizes the anaerobic and aerobic treatment utilized for POME treatment, including the microorganisms and the pathways involved in the degradation process. The current challenges associated with the treatment methods and the future prospects are also highlighted.

3.2 PONDING TREATMENT SYSTEM

The ponding treatment system generally consists of two distinct phases: waste stabilization (anaerobic) and oxidation (aerobic) process, which is carried out in a multitude of open ponds (Liew et al., 2015). The raw POME is pumped through a series of ponds, which consists of cooling, mixing, anaerobic, facultative, aerobic, and polishing ponds, having different design and treatment requirements before its final discharge (Albarracin-Arias et al., 2021; Cheng et al., 2021a).

3.2.1 Anaerobic Treatment Process

Raw POME from the wet mill extraction process is first discharged into the cooling pond where it is retained for about a week, and the temperature (75 – 90 ℃) of the POME decreased to mesophilic (35 – 38 ℃) in preparation for the anaerobic ponds (Cheng et al., 2021b; Liew et al., 2015). The initial high temperature also facilitates thermal hydrolysis of the complex polymers contained in the POME (Mohammad et al., 2021). The microbial community structure in these ponds is typically undefined, however the predominance of air and soil-borne microorganisms mostly of the family *Clostridiaceae*, *Lactobacilli*, *Prevotella*, and *Veillonella* was reported in the cooling ponds. These group of microorganisms are usually associated with plant materials (Mohd-Nor et al., 2019). The anaerobic treatment phase is the most important of the treatment processes, due to its innate ability to degrade the high organic content present (Vijayan et al., 2024). The high-strength wastewater is bio-converted into methane (CH_4) and carbon dioxide (CO_2) in a multi-step enzymatic and biochemical process (Naran et al., 2016). Anaerobic digestion (AD) can be carried out by three different methods: open ponds, open anaerobic tank digesters, and closed anaerobic tank digesters, followed by the aerobic treatment process (Cheng et al., 2021b; Vijayan et al., 2024). The open ponding methods is carried out in multiple anaerobic ponds constructed to about 5–7m of depth and operated under the hydraulic retention time (HRT) of 54–66 days. The tank digesters offer a shorter