OPTIMIZATION OF FACTORS AFFECTING BIOGAS PRODUCTION FROM POME

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ABSTRACT: *This paper documents a study on biogas production from palm oil mill effluent (POME) by anaerobic digestion. The study aims to optimize biogas production from POME by employing the effect of optimal level of inputs and to develop an appropriate model to predict its processes. In this study, the continuous-stirred reactor was used to treat POME, where the inputs monitored, were Organic Loading rate, Hydraulic Retention Time and Sludge Retention Time. Waste fruit-based inoculum and NaOH were used to adjust Carbon to Nitrogen ratio and pH value. The novelty of this research was to harness the biogas production potential of hazardous POME in line with the waste to energy [WtE] concept. In order to come up with credible research design and analysis, DOE software was used. The findings in surface response diagrams of DOE manifested that the optimum inputs for maximum biogas production of* $3.8L.d^{-1}$ *are;* $5g\ L^{-1}d^{-1}$ *for OLR, 28 for C/N and 6.5 days for HRT. The validation results of the developed model affirm that the overall error in model prediction is 1.51 percent with respect to actual outputs from the anaerobic reactor. Thus, this study justifies that further research on POME should be done at economic scale CSTR reactor using the optimum value of inputs for maximum productivity of biogas in order to contribute to achieving economic and environmental sustainability*.

Keywords: Hydraulic Retention, Sludge Retention, Biogas Production, Anaerobic Reactor, Production Optimization

1.0 INTRODUCTION

Biogas is an output of a biological process from anaerobic digestion of organic waste including biomass-enrich wastewater, manure, sewage sludge, municipal solid waste, and biodegradable feedstock [1–4]. The stages of decomposition of biosolids to biogas are hydrolysis, acidogenesis, acetogenesis, and methanogenesis [5, 6]. Raw biogas contains 50-65% biogas (CH_4), 30-45% carbon dioxide (CO_2), hydrogen sulphide (H_2S) and other impurities [7, 8].

With Malaysia being one of the largest palm oil producers in the world, which accounts for 17.73 million tons of crude palm oil (CPO) and 2.13 tons of palm kernel oil a year [8, 9]. Consequently, a huge amount of palm oil mill effluent (POME) produced to be known as a toxic and hazardous effluent for environment and health. The POME contains organic compounds (COD) and biomass-based volatile suspended solids (VSS) which both become the sources of biogas (CH_4) emission [9, 10]. It has been reported that the COD and VSS in POME are biogas potential elements [4]. In conventional POME treatment, the biogas is produced and emitted to atmosphere as GHG emission. It has also been reported that biogas emission is about 25-times higher global warming potential (GWP) compare to CO_2 [8, 11]. Despite, being POME a hazardous element to environment and health; it could be converted to biogas as a resource, which would contribute to achieving economic and environmental sustainability [9, 12]. The composition of POME-based biogas is listed in Table 1 [4, 13, 14], which reflects its biogas and methane potentials for capture and use for generating energy.

Table 1: Composition of Bio-gas [4, 13]

Element	Formulae	Composition (Vol. %)
Methane	CH_4	50 – 75
Carbon dioxide	CO_2	25 – 45
Water vapor	H_2O	2 – 7
Hydrogen Sulphide	H_2S	< 2.5
Other Gases	-	< 2

In this research, a two-stage anaerobic digester has used for optimizing biogas production by using waste fruit to inoculate the digestion process. Though several types of researches have been conducted for biogas production from POME; the optimization of factors that maximize productivity as well as inoculation of the digestion process with waste fruit had never been reported in published journals; ***in this regard, this research is Novel*.**

1.1 The Chemistry of Biogas Production from POME

Thee digestion process begins with bacterial hydrolysis for breaking down insoluble long-chain polymers of fats, proteins, and carbohydrates into short-chain polymers. Then, acidogenic bacteria reduce the fatty acids, amino acids, and sugars into CO_2, H_2, NH_2, and organic acids. The acetogenic bacteria later convert these organic acids into acetic acid. Finally, methanogenic bacteria transform these products into gases which are mostly CH_4 and CO_2 [15], [16].

In order to have efficient biodegradation, the required nutrients shall be made available in the anaerobic reactor for microorganisms to build cells that produce biogas. The main chemical elements that would be utilised by microorganisms are carbon, oxygen, nitrogen, hydrogen, Generation of biogas requires an appropriate carbon-to-nitrogen ratio of at least 25:1 [17]. These stages are shown in Figure 1.

1.1.1 Biogas Production from POME

Hydrolysis Process - In this stage, the water of POME is broken down to form H^+ cations and OH^- anions. Water reacts with long-chain organic polymers including polysaccharides, fats, and proteins to form soluble shorter-chain polymers, such as Fatty Acids, Amino Acids and Sugars [19, 20]. The rate of breakdown depends on the composition of the substrate used in the anaerobic process [21–25]. Equation (1) shows the hydrolysis step of anaerobic digestion:

$$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + H_2 \quad \text{(Eq. 1)}$$