CHAPTER

4

BIOETHANOL PRODUCTION FROM OIL PALM WASTES

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4.1 INTRODUCTION

At the moment, the world is facing serious problems as a result of high reliance on fossil fuels as the energy source including fossil fuel depletion, greenhouse gases emissions, and global warming. Bioethanol is believed to be a rapid and significant answer to those problems. According to the United States Department of Energy (Rani et al., 2010), one for every unit of energy required for bioethanol production, three units of energy are returned. Besides, bioethanol is also used as a feedstock for various applications in food, pharmaceutical, cosmetic, and petrochemical industry. Furthermore, its renewable and biodegradable nature makes bioethanol a promising alternative for achieving sustainable energy development.

Bioethanol is produced by microorganisms (usually yeast or bacteria) through fermentation process of simple sugar. In this study, bioethanol was produced by yeast, *Saccharomyces cerevisiae* from oil palm trunk sap (OPT sap) supplemented with nutrients from palm oil mill effluent (POME). Both are oil palm residues. The economical lifespan of an oil palm tree is 25 years to 30 years. For every 100,000 hectares of replanted oil palm, around 13.6 million of trunks were generated (Teh et al., 2024). Although some of the OPTs are used for burning in stack, most of them were dumped or used as mulch. Samsudin and Don, (2014) reported that OPT sap contained glucose up to 86.9%, hence, can be used as a potential carbon source for the bioethanol fermentation. Since it contained higher simple sugars, no pretreatment is needed as it is in the lignocellulosic materials. Meanwhile, in oil palm mill, at the end of oil extraction process POME is generated in very large amount. Currently, POME is considered as waste and discarded into water stream after being treated. However, it has been reported that, POME contained high concentration of protein, carbohydrate, nitrogenous compounds, lipids and minerals (Low et al., 2021). In fact, POME also contained high organic materials. Therefore, in this study, OPT sap was utilized as the carbon source and POME was exploited to be the nutrient supplier to the bioethanol fermentation by yeast, *Saccharomyces cerevisiae.*

However, a fermentation performance of *Saccharomyces cerevisiae* as well as other microorganisms depend on the environmental conditions and every factor gives different effect on the microbial growth. According to Jung et al. (2024), an increase in temperature will improve the fermentation performance due to increase of microbial metabolisms. However, according to Zhang et al. (2024), higher temperature may lead to reduction in fermentation performance due to denaturation of ribosomes and enzymes of cells. In addition, Zhou et al. (2024) mentioned that every organism worked best at its own optimum pH. By controlling the pH at optimum level, the best fermentation performance could be expected. Besides, fermentation performances also depend on the availability of substrates and nutrients for the microorganism's growth (Hafeez et al., 2025). As in this study, POME contained larger amount of total suspended solids, and hence, caused mass transfer limitations. Agitation system might improve the mass transfer, and consequently improved the fermentation performance. However, an extensive agitation might introduce cell to other stress namely the shear force stress, consequently reduce the fermentation performance. Therefore, in this study, the effects of temperature, pH, and agitation speed on the volumetric growth rate of *Saccharomyces cerevisiae* were investigated.

4.2 PROXIMATE COMPOSITION OF OIL PALM TRUNK SAP AND PALM OIL MILL EFFLUENT

Oil palm trunk sap (OPT sap) contained higher glucose (49.12 g/L) as compared to POME (3.04 g/L). In addition, POME contained inorganic ions including nitrogen, potassium, magnesium, calcium, phosphorus, iron, boron, zinc, manganese, and copper. These ions are essential for bioethanol fermentation. The characteristics of POME was consistent with works done by Wong et al. (2009) and Sumathi et al. (2008). Therefore, in this study, POME was used mainly as a nutrient supplier for the production media, OPT sap.

4.3 BIOETHANOL FERMENTATION PROCESS

Batch bioethanol fermentations of OPT sap and POME were carried out in a 2.5L stirred-tank bioreactor (Minifors, Infors HT, Switzerland) with a working volume of 2.0L. Bioreactor containing mixture of OPT sap and POME at a ratio of 63:37 was sterilized (SELECTA Germany) at 121°C (around 1.5 bar) for 15 minutes. After sterilization, the yeast cell (at 4.3% inoculum size) was inoculated into the bioreactor in a sterile condition. The fermentation was done at 33°C, controlled pH at 7.0, and agitation speeds 120 rpm. The fermentation process was then repeated at different temperature (27°C, 30°C, 36°C, and 39°C), controlled pH (pH 6.0, pH 6.5, pH 7.5, and pH 8.0), and agitation speeds (40 rpm, 80 rpm, 160 rpm, and 200 rpm).

4.4 FERMENTATION KINETIC MODELS

In literature, fermentation process behavior was described by various kinetic models. In this study, the cell growth, bioethanol formation, and glucose consumption data was fitted to the logistic, Luedeking–Piret and Luedeking–Piret–like model, respectively. The models were previously used by other researchers to describe various fermentation processes. The models were proven to provide a reasonable description of each