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Improving biogas production with application of trimetallic nanoparticle using response surface methods

Pramod Jadhav [a,b], Santhana Krishnan [c], Reshma Patil [d], Prakash Bhuyar [e], A.W. Zularisam [h], Vigneswaran Narayanamurthy [f,g], Mohd Nasrullah [h,*]

[a] Centre for Advanced Intelligent Materials, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Gambang, Kuantan, Malaysia
[b] Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Gambang, Kuantan, Pahang, Malaysia
[c] Department of Civil and Environmental Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla, 90110, Thailand
[d] Bioaromatic Centre of Excellence, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Gambang, Kuantan, Malaysia
[e] International College (MJU-IC), Maejo University, Chiang Mai, 50290, Thailand
[f] Advance Sensors and Embedded Systems (ASECs), Centre for Telecommunication Research and Innovation, Fakulti Teknologi Kejuruteraan Elektrik Dan Elektronik, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, 76100, Melaka, Malaysia
[g] Department of Biotechnology, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, India
[h] Faculty of Civil Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300, Gambang, Kuantan, Malaysia

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ABSTRACT

The potential of trimetallic nanoparticles (TMNPs) to enhance biogas production through microbe-to-microbe interactions and boost biogas yield is evident. This present study employed the central composite design (CCD) of response surface methods (RSM) to determine the optimal conditions of iron-cobalt-zinc TMNPs influenced anaerobic digestion for higher biogas yield. The impact of initial pH (6.6–7.4), TMNPs concentration (0–30 mg L^{-1}), temperature (25-45 °C), and hydraulic retention time (HRT) (0-4 days) were modelled for improved biogas production. The results indicated that the linear model terms of pH and TMNPs concentration, and quadratic model terms of temperature and HRT, significantly affect the biogas production. Linear model terms of TMNPs, temperature, pH, and HRT have significant interactive effects and the numerical analysis identified the best conditions for the evaluated parameters. Ideal anaerobic process settings generated a maximum cumulative biogas production of 3700 mL^{-1}_{POME} than blank (2000 mL^{-1}), corresponding to an 85 % yield. Optimizing the initial pH, TMNPs concentration, temperature, and HRT can significantly improve biogas yield and could be helpful for developing more efficient AD processes at large volume and commercial biogas plants. Promoting TMNPs as catalysts positively improves an AD process towards sustainable biogas production.

1. Introduction

In many developing countries (such as Malaysia, India, Indonesia, and Thailand), organic waste is mainly collected for disposal with little emphasis on resource recovery. However, organic waste has high organic content and moisture valuable content for biogas production by anaerobic digestion (AD) process. AD consists of four metabolic stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Several factors can affect these metabolic stages, such as the nature of the substrates, accumulation of volatile fatty acids, and ammonia inhibition. Due to these reasons, a different optimization strategy is needed for higher biogas production with a well-optimized AD process [1]. Biogas production from organic wastes could be significantly enhanced by optimizing main parameters like TMNPs, temperature, pH, and HRT that affect biogas yield (Menon et al., 2017; Nordell et al., 2016). The critical variables that affect the AD process are feedstock composition, inoculum-to-feed ratio, temperature, biomass substrate mixing and substrate concentration. If these variables are not in the proper range, methane production would be reduced. Previous studies have often optimized biogas production by changing a single factor while other factors remained fixed at a specific condition. These methods are time-consuming, laborious, and uncertain to reach the optimum conditions due to ignoring the interactions between variables. Statistical programs are widely used as optimization approaches in the literature to

* Corresponding author.
E-mail address: nasrul.ump@gmail.com (M. Nasrullah).

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