



ELKAWNIE
Journal of
Islamic Science and Technology



P-ISSN : 2460-8912
E-ISSN : 2460-8920
Accredited by Kemendiknas - DIKTI
No. 28/E/KPT/2019
Vol. 5 No.1, 2019 - Vol 9 No.1, 2023

HOME ABOUT LOGIN REGISTER SEARCH CURRENT ARCHIVES ANNOUNCEMENTS EDITORIAL TEAM EDITORIAL POLICIES

REGISTER**PUBLICATION ETHICS****OPEN ACCESS POLICY****PEER-REVIEW****REVIEWERS****FORM OF STATEMENT****JOURNAL STATISTICS****MANUSCRIPT STATISTICS****AUTHOR FEE**

Scopus[®]
Citation Tracker

Register as a Reviewer

**Register as a Reviewer**

9 772460 891016



9 772460 892006

KEYWORDS

Aceh Adsorbent BET BSLT c.
curvignathus Chitinolytic actinobacteria HAPS
Inong Balee Fort M. brunneum
Mikrokontroler TiO₂-anatase XRF
anthocyanin characteristics chitinolytic index
compressive strength isolation katalis
lactic acid bacteria restoration tofu liquid
waste

Supported by :**INFORMATION**

- ▶ For Readers
- ▶ For Authors
- ▶ For Librarians

JOURNAL CONTENT

Search

Search Scope
All

Browse

- ▶ By Issue
- ▶ By Author
- ▶ By Title
- ▶ Other Journals

Home > [Elkawnie: Journal of Islamic Science and Technology](#)

Elkawnie: Journal of Islamic Science and Technology



Journal Title : Elkawnie: Journal of Islamic Science and Technology
ISSN : 2460-8920 (online) | 2460-8912 (print)
DOI Prefix : Prefix 10.22373/ekw by Crossref
Editor in Chief : Muhammad Ridwan Harahap
Managing Editor : Abd Mujahid Hamdan
Publisher : Universitas Islam Negeri Ar-Raniry
Frequency : 2 issues per year (June and December)
Citation Analysis : [Index Copernicus](#) | [Sinta](#) | [Google Scholar](#)

Elkawnie is a journal of Integration Science and Technology with Islam. It's covering research and technology in the field of study of Architecture, Biology, Chemistry, Environmental Engineering, ICT, Physical Engineering, and other science and technology fields. In particular, Elkawnie's journal discusses research and technology development in contributing to development as part of Muslim scientists in the academic sphere.

The History of Elkawnie Journal was started by switching the status of IAIN Ar-Raniry to UIN Ar-Raniry while the Faculty of science and technology of UIN Ar-Raniry was formed on October 13, 2013. As a form of institutional commitment to the tri dharma of higher education for lecturers, lecturer writing was formed in a Journal. This journal is named Elkawnie. The name Elkawnie itself comes from Arabic, namely Kauniyah, which means verses that prove the signs of the existence of Allah SWT in human life. The Elkawnie Journal was formed on December 12, 2014, and began releasing the first time in Volume 1 Number 1 June 2015.

In 2018 Elkawnie has been **accredited** by the Decree of the *General Director of Strengthening Research and Development, Ministry of Research, Technology, and Higher Education of the Republic of Indonesia* **Number 34/E/KPT/2018**. This accreditation is valid from 10 December 2018 to 10 December 2023. In 2019, Elkawnie returned to re-accreditation to obtain a higher rank, namely **SINTA 2**, with certificate **Number 28/E/KPT/2019**.

Office Address: Faculty of Science and Technology Building, Universitas Islam Negeri Ar-Raniry, Darussalam, Banda Aceh, 23111.

Email: elkawnie@ar-raniry.ac.id

The authors can ask about the status of the article process through the official email.

Announcements

LETTER OF STATEMENT

We are accepting in SINTA - Science and Technology Index. Please submit your article using our online journal system.



Posted: 2020-07-23

CALL FOR PAPERS

Dear Colleagues,

On behalf of Elkawnie: Journal of Islamic Science and Technology, it is our pleasure to thank you for your support for our journal.

Currently, the journal is now open for submission. We invite you to submit articles on topics that are part of the journal's editorial calendar as well as additional topics of interest to our journals.

The journal is published bi-annually (June and December). In June, 15 Articles for the June edition and 15 Articles for December

Important Dates
Manuscript Submission **Now**
Manuscript Review Feedback **February-May for June Edition, September-November for December Edition**
Manuscript Publication online in June and December

Please submit your paper in MS Word format by only the online submission process by following our template

We will highly appreciate your kind helps to circulate this announcement to your related academic circles.

Regards Us,

Elkawnie: Journal of Islamic Science and Technology

**USER**

Username

Password

Remember me



Reference Manager by:
MENDELEY

Plagiarism Checker by:



Indexed by:



Online	2
Vis. today	43
Visits	87 405
Pag. today	100

NOTIFICATIONS

- ▶ View
- ▶ Subscribe

Posted: 2020-12-31

[More...](#)

[More Announcements...](#)

P-ISSN : 2460-8912
E-ISSN : 2460-8920

ELKAWNIE



This work is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](#).

Elkawnie: Journal of Islamic Science and Technology in 2020. Published by Faculty of Science and Technology in cooperation with Center for Research and Community Service (LP2M), UIN Ar-Raniry Banda Aceh, Aceh, Indonesia.

00274110

[View full page view stats report click here](#)





P-ISSN : 2460-8912
E-ISSN : 2460-8920
Accredited by Kemenristek - DIKTI
No. 28/E/KPT/2019
Vol. 5 No.1, 2019 - Vol 9 No.1,2023

[REGISTER](#)[PUBLICATION ETHICS](#)[OPEN ACCESS POLICY](#)[PEER-REVIEW](#)[REVIEWERS](#)[FORM OF STATEMENT](#)[JOURNAL STATISTICS](#)[MANUSCRIPT STATISTICS](#)[AUTHOR FEE](#)**Register as a Reviewer**

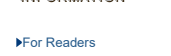
9 772460 891016



9 772460 892006

KEYWORDS

Aceh Adsorbent BET BSLT c.
curvignathus Chitinoalytic actinobacteria HAPS
 Inong Balee Fort M. brunneum
 Mikrokontroler TiO₂-anatase XRF
 anthocyanin characteristics chitinoalytic index
 compressive strength isolation katalis
 lactic acid bacteria restoration tofu liquit
 waste

Supported by :**INFORMATION**

- ▶For Readers
- ▶For Authors
- ▶For Librarians

JOURNAL CONTENTSearch Search Scope All Search

Browse

- ▶By Issue
- ▶By Author
- ▶By Title
- ▶Other Journals

[Home](#) > [About the Journal](#) > [Editorial Team](#)

Editorial Team

ADVISOR

Hendri Ahmadian, (SINTA ID: 6003098) Department of Information Technology, Universitas Islam Negeri Ar-Raniry Banda Aceh, Indonesia

EDITOR IN CHIEF

Muhammad Ridwan Harahap, (Scopus ID: 57443545800) Department of Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia

MANAGING EDITOR

Abd Mujahid Hamdan, (Scopus ID: 57205452806) Department of Environmental Engineering, Universitas Islam Negeri Ar-Raniry Banda Aceh, Aceh, Indonesia

SECTION EDITORS

Ghufran Ibnu Yasa, Department of Information Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Aceh, Indonesia
 Cut Nuzlia, (Scopus ID: 55711333200) Organic Chemistry, Department of Chemistry, State Islamic University of Ar-Raniry
 Arif Sardi, Department of Biology, State Islamic University of Ar-Raniry, Banda Aceh, Indonesia, Indonesia
 Fathul Mahdariza, (Scopus ID: 56545835300) Department of Aquatic Environmental Engineering, Karlsruhe Institute of Technology, Germany
 Bustami Yusuf, Department of Information Technology, Faculty Science and Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Aceh, Indonesia
 Zya Dyena Meutia, (Scopus ID : 57194827662), Department of Architecture, Faculty of Sciences and Technology, State Islamic University of Ar Raniry, Indonesia
 Ima Dwitawati, Department of Information technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Aceh, Indonesia
 Husnawati Yahya, Department of Environmental Engineering, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Aceh, Indonesia
 Hadi Kurniawan, Department of Physics Engineering, State Islamic University of Ar-Raniry, Banda Aceh Indonesia, Indonesia

INTERNATIONAL EDITORIAL BOARDS

Kuwat Triyana, (Scopus ID: 8597558700, H-Index: 11) Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Gadjah Mada (UGM), Indonesia
 Mustanir Yahya, (Scopus ID: 57210705476, H-Index: 8) Department of Chemistry, Syiah Kuala University, Indonesia
 Renjith Thomas, (Scopus ID: 55481779800, H-Index: 12) Department of Chemistry, St Berchmans College, Mahatma Gandhi University, Changanassery, Kerala, India
 Saluma Samanman, Scopus ID: 41662125300, H-Index: 7) Faculty of Science and Technology, Princess of Naradhiwas University, Narathiwat, Thailand
 Saharman Gea, (Scopus ID: 23004491900, H-Index: 9) Department of Chemistry, Universitas Sumatera Utara, Indonesia
 Anurita Selvarajoo, (Scopus ID: 56941851700, H-Index: 4) Department of Chemical and Environmental Engineering, Faculty of Science and Engineering, University of Nottingham, Malaysia
 Adri Huda, (Scopus ID: 57195939115, H-Index: 6) Environmental Engineering, UNESP-Universidade Estadual Paulista, Sao Paulo, Brazil, Brazil
 Nayeem Asif, (Scopus ID: 56800474400, H-Index: 2) Department of Architecture, Kulliyah of Architecture and Environmental Design, International Islamic University Malaysia, Malaysia
 Reisyah Ichwani, (Scopus ID: 57205114974, H-Index: 2) Worcester Polytechnic Institute, Worcester, Massachusetts, United States, United States
 Zahidah binti Zulkifli, (Scopus ID: 571933372860) Kulliyah of Information and Communication Technology, International Islamic University Malaysia, Malaysia
 Brij Mohan Upreti, (Scopus ID: 55962671000, H-Index: 2) Jayoti Vidyapeeth Women's University Jaipur, Rajasthan, India
 Mohamed Alaa Mandour, (Scopus ID: 36932863000) Department of Architecture, Helwan University, Cairo, Egypt
 Mohammad Arif Kamal, (Scopus ID: 56921383300) Architecture Section, Aligarh Muslim University, India
 Lidervan de Paula Melo, (Scopus ID: 12141546800, H-index: 6) Analytical Chemistry, Universidade do Estado de Minas Gerais (UEMG), Uba, MG., Brazil

LAYOUT EDITOR

Nasrullah Nasrullah, State Islamic University of Ar-Raniry, Banda Aceh, Indonesia

WEB AND OJS MANAGER

Saiful Hadi, State Islamic University of Ar-Raniry

PROOFREADERS

Nanda Syahputra, Faculty of Science and Technology, State Islamic University of Ar Raniry, Indonesia

ADMINISTRATION OFFICER

Teuku Ade Vidyan Maqfirah, Official library Faculty of Science dan Technology State Islamic University of Ar-Raniry, Indonesia

P-ISSN : 2460-8912
 E-ISSN : 2460-8920

ELKAWNIE



This work is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](#).

Elkawnie: Journal of Islamic Science and Technology in 2020. Published by Faculty of Science and Technology in cooperation with Center for Research and Community Service (LP2M), UIN Ar-Raniry Banda Aceh, Aceh, Indonesia.

00274116View full page view stats report [click here](#)**USER**Username Password Remember meLogin 

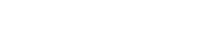
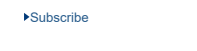
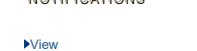
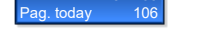
Reference Manager by:



Plagiarism Checker by :



Indexed by :



REGISTER**PUBLICATION ETHICS****OPEN ACCESS POLICY****PEER-REVIEW****REVIEWERS****FORM OF STATEMENT****JOURNAL STATISTICS****MANUSCRIPT STATISTICS****AUTHOR FEE**

**Register as a Reviewer**

9 772460 891016



9 772460 892006

KEYWORDS

Aceh Adsorbent BET BSLT c.
 curvignathus Chitinoalytic actinobacteria HAPS
 Inong Balee Fort M. brunneum
 Mikrokontroler TiO₂-anatase XRF
 anthocyanin characteristics chitinoalytic index
 compressive strength isolation katalis
 lactic acid bacteria restoration tofu liquid
 waste

Supported by :**INFORMATION**

- For Readers
- For Authors
- For Librarians

JOURNAL CONTENTSearch

Search Scope

All Search **Browse**

- By Issue
- By Author
- By Title
- Other Journals

Home > Archives > Vol 7, No 1 (2021)

Vol 7, No 1 (2021)**Full Issue**

View or download the full issue

[FRONT MATTER](#) [BACK MATTER](#)**Table of Contents****Articles**

- Mineralogical, Microstructural and Compressive Strength Characterization of Fly Ash as Materials in Geopolymer Cement** PDF 1-18
 10.22373/ekw.v7i1.7787
Cut Rahmawati, Sri Aprilia, Taufiq Saidi, Teuku Budi Aulia
- The Endophytic Actinobacterial Toxicity Test of Ginger (*Zingiber officinale* Roscoe) Used The BSLT (Brine Shrimp Lethality Test) Method** PDF 19-29
 10.22373/ekw.v7i1.8027
Sri Rahayu, Lenni Fitri, Yulia Sari Ismail
- The Implementation of The Open-Plan Concept In The Muslim Residential** PDF 30-40
 10.22373/ekw.v7i1.7733
Maysarah Bakri
- Treatment of Well Water Using Biosorbent Derived From Areca Fiber Waste** PDF 41-51
 10.22373/ekw.v7i1.8503
Devie Novallyan, Wiji Utami, Risnita Risnita, Atik Sahara, Malia Sabrina
- Isolation and Cytotoxic Activity of The β -Carotene Combination of Trigona Honey and Namnam Leaves Extract (*Cynometra cauliflora*)** PDF 52-66
 10.22373/ekw.v7i1.8696
Ahmad Fathoni, La Ode Sumarlin, Fuady Hanief, Dede Sukandar
- Biometric Condition of Seurukan Fish (*Osteochillus Vittatus Valenciennes, 1842*) Exposed to Mercury in Krueang Sabee River Aceh Jaya Indonesia** PDF 67-83
 10.22373/ekw.v7i1.8258
Ilham Zul Fahmi, Yunina Rahmi, Arif Sardi, Mahyana Mahyana, Yusrizal Akmal, Rumondang Rumondang, Epa Paujjiah
- The Computer Program Development to Determine The Shares of Inheritance for Three Types of Heir** PDF 84-95
 10.22373/ekw.v7i1.7777
Salmawaty Arif, Rahmi Muliana, Syarifah Meurah Yuni
- Evaluation of Antioxidant Activities From Ethyl Acetate Fraction of Curry Leaf Using DPPH Method** PDF 96-106
 10.22373/ekw.v7i1.8059
Ulil Amna, Halimatussakdiah Halimatussakdiah, Furqan Nur Ihsan, Puji Wahyuningsih
- Development of Kinetic Models For Biogas Production From Tofu Liquid Waste** PDF 107-118
 10.22373/ekw.v7i1.8296
Lukhi Mulia Shitophyta, Anisa Salsabila, Firanita Angraini, Siti Jamilatun
- Characterization of Organic Polymer Monolith Columns Containing Ammonium Quarternary As Initial Study For Capillary Chromatography** PDF 119-130
 10.22373/ekw.v7i1.8764
Aster Rahayu, Siti Jamilatun, Joni Aldilla Fajri, Lee Wah Lim
- Spatial Temporal Condition of Recent Seismicity In The Northern Part of Sumatra** PDF 131-145
 10.22373/ekw.v7i1.8797
Inna Nurana, Andrean Vesalius Hasiholan Simanjuntak, Muksin Umar, Djati Cipto Kuncoro, Syamsidik Syamsidik, Yusran Asnawi
- Synthesis and Characterization of Bagasse (*Saccharumofficinarum* L.) Silica Gel Modified Diphenylcarbazon** PDF 146-155
 10.22373/ekw.v7i1.9239
Rismawaty Sikanna, Dwi Nur Assyifah Rajmah, Kurnia Ramadani, Musafira Musafira, Arfiani Nur, Amalyah Febryanti
- Zonation Drives The Abundance of Understory Exotic Plant Species in Ir. Djuanda Forest Park, West Java** PDF 156-171
 10.22373/ekw.v7i1.6950
Tri Cahyanto, Billy Nabil Yuni, Muhammad Efendi
- Effect of Time and Voltage on Pollutant Remover in Gold Treatment Wastewater With Electrocoagulation Batch Reactor** PDF 172-181
 10.22373/ekw.v7i1.8226
RR Dina Asrifah, Titi Tiara Anasstasia, Mia Fitri Aurilia
- Black Cumin (*Nigella sativa*) Against *Mycobacterium tuberculosis* Strain H37RV And MDR-TB** PDF 182-196
 10.22373/ekw.v7i1.9335
Makbul Mardiyah, Dwi Nur Assyifah Rajmah, Kurnia Ramadani, Musafira Musafira, Arfiani Nur, Amalyah Febryanti

USERUsername Password Remember meLogin Reference Manager by: **MENDELEY**

Plagiarism Checker by :



Indexed by :



Online	3
Vis. today	43
Visits	87 405
Pag. today	112

NOTIFICATIONS

►View

►Subscribe

Mashun Masri, Cut Mutiaain, Masita Masita, In Canyanto, Lianan Lianan, Kusny Kusny, Siska Tridesianti

Identification Secondary Metabolites From Callus Piper retrofractum Vahl
10.22373/ekw.v7i1.8630

PDF
197-214

Fahrauk Faramayuda, Jaka Permana, Akhirul Kahfi Syam, Elfahmi Elfahmi

P-ISSN : 2460-8912
E-ISSN : 2460-8920

ELKAWNIE



This work is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/).

Elkawnie: Journal of Islamic Science and Technology in 2020. Published by Faculty of Science and Technology in cooperation with Center for Research and Community Service (LP2M), UIN Ar-Raniry Banda Aceh, Aceh, Indonesia.

00274122

[View full page view stats report click here](#)



DEVELOPMENT OF KINETIC MODELS FOR BIOGAS PRODUCTION FROM TOFU LIQUID WASTE

Lukhi Mulia Shitophyta*, Anisa Salsabila*, Firanita Anggraini*, Siti Jamilatun*

*Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan,
Yogyakarta, Indonesia, lukhi.mulia@che.uad.ac.id, anisasalsabila40@gmail.com,
firanita1700020024@webmail.uad.ac.id, sitijamilatun@che.uad.ac.id

Email Correspondence : lukhi.mulia@che.uad.ac.id

Received : November 27, 2020

Accepted : May 5, 2021

Published : June 30, 2021

Abstract: Biogas promises bioenergy to be developed as a renewable fuel to reduce the fossil energy crisis. Biogas raw material can be derived from tofu liquid waste. Biogas is processed by anaerobic digestion. This study aimed to develop a simulation of the kinetic model variations of biogas production from tofu liquid waste. The results showed that the ascending limb of the exponential equation had a greater coefficient ($R^2 = 1$) than the ascending limb of the linear equation ($R^2 = 0.9574$). The descending limb of the linear equation had a better coefficient ($R^2 = 0.9574$) than the descending limb of the exponential equation ($R^2 = 0.95$). The Gaussian model had the greatest R^2 of 0.9937. Logistic growth had the greatest coefficient ($R^2 = 0.9951$) compared to modified Gompertz ($R^2 = 0.9817$) and exponential rise to maximum ($R^2 = 0.9852$) in the simulation of cumulative biogas production. The fit model for kinetic biogas production from tofu liquid waste is Gaussian Model.

Keywords: anaerobic digestion, biogas, tofu liquid waste, kinetic model

Abstrak: Biogas merupakan salah satu bioenergi yang menjanjikan untuk dikembangkan dalam mengurangi krisis energi fosil. Bahan baku biogas dapat berasal dari limbah cair tahu yang diolah secara *anaerobic digestion*. Penelitian ini bertujuan untuk mengembangkan variasi model simulasi kinetika produksi biogas dari limbah cair tahu. Hasil penelitian menunjukkan bahwa persamaan eksponensial untuk grafik kenaikan memiliki koefisien yang lebih besar ($R^2 = 1$) dibandingkan grafik kenaikan dengan persamaan linier ($R^2 = 0,9574$). Grafik penurunan pada persamaan linier memiliki nilai koefisien lebih besar ($R^2 = 0,9574$) dibandingkan grafik penurunan pada persamaan eksponensial ($R^2 = 0,95$). Model Gaussian menghasilkan nilai koefisien tertinggi $R^2 = 0,9937$. *Logistic growth* menghasilkan nilai R^2 terbesar (0,9951) dibandingkan modified Gompertz ($R^2 = 0,9817$) dan *exponential rise to maximum* ($R^2 = 0,9852$) pada simulasi produksi biogas kumulatif. Model yang paling cocok untuk kinetika produksi biogas dari limbah cair adalah model Gaussian.

Kata kunci: *anaerobic digestion*, biogas, limbah cair tahu, model kinetika

Recommended APA Citation :

Shitophyta, L. M., Salsabila, A., Anggraini, F., & Jamilatun, S. (2021). Development of Kinetic Models For Biogas Production From Tofu Liquid Waste. *Elkawnie*, 7(1), 107-118. <https://doi.org/10.22373/ekw.v7i1.8296>

Introduction

The use of fossil fuels can harm environmental conditions such as greenhouse gas emissions and carbon gas accumulation that cause the global energy crisis. Renewable energy has been developed to reduce fossil fuel consumption (Winquist et al., 2019). Every year, around 220 million tonnes of renewable biomass are produced in the world. It is equivalent to 4500 EJ of solar energy per year. Energy production from biomass will meet the bioenergy market demand of 270 EJ in a year. The bioenergy market potential is estimated to increase by 10-50% in 2050 (Kumar et al., 2018).

Biogas is bioenergy that gains attention increasingly as renewable and sustainable energy technology (Budzianowski, 2016). Biogas technology is cost-effective and potential in organic waste management (Yu et al., 2019). The biogas production process is carried out by anaerobic digestion, a process that breaks down organic materials into biogas (Shitophyta et al., 2020). Anaerobic digestion processes help to reduce greenhouse gas emissions, carbon dioxide, and eutrophication (Kainthola, Kalamdhad, & Goud, 2019b). The anaerobic digestion stage consists of four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis ((Kovacs et al., 2018). The digestion is carried out by different microorganisms, such as acidogens and methanogens (Kainthola et al., 2019).

The main composition of biogas is methane (CH_4) and carbon dioxide (CO_2) with other impurities such as hydrogen sulfide (H_2S), ammonia (NH_3) and water vapor (Ge et al., 2016). The combustion of methane produces relatively environmentally friendly gases such as carbon dioxide and water vapor (Liu et al., 2019). Biogas raw materials can be obtained from various kinds of organic wastes, such as tofu waste. Tofu waste is generated from tofu manufacture, and soybeans wash. Tofu liquid waste contains organic compounds in the form of protein, carbohydrates, fats, and oils. If the amount of waste increased and buried for a long time, the waste substances will be difficult to be degraded by microbes. Tofu liquid waste also contains methane and carbon dioxide. The methane content in tofu liquid waste is suitable for the raw material of biogas production. (Shitophyta et al., 2019). Several studies on biogas production from tofu liquid waste have been done previously, but no study discusses the kinetics of biogas production from tofu liquid waste. Therefore, this study aimed to develop variations in the kinetics model of biogas production from tofu liquid waste.

Other researchers have offered the previous simulation models of biogas. Still, the models needed simultaneous solutions of mass balance equations for each substrate and microbial population, generating equations with copious unknown factors. Thus a simple model is required to express the anaerobic biogas digestion process (Das & Mondal, 2015). The main goal of this study focuses on the kinetic models of biogas using linear, exponential, and gaussian equations. Linear and exponential equations can illustrate the biogas production rate as the phase of microbial growth by an increasing and a decreasing curve (Kafle &

Chen, 2016). Cumulative biogas production was also simulated in this study using a logistic growth model, an exponential increase to maximum, and a modified Gompertz equation. These three models provide a better correlation coefficient to calculate the cumulative biogas. Besides, Logistic and Gompertz equations give the potential biogas production, maximum biogas production, and production delay time under various conditions based on the cumulative biogas production (Ali et al., 2018). Modified Gompertz also widely signifies the basis structure for biogas kinetic simulation (Oyejide et al., 2018).

Material and Methods

Material

Tofu liquid waste was obtained from a tofu industry in Banguntapan, Yogyakarta, Indonesia. Solution of NaOH 2 N was used to neutralize pH.

Methods

Biogas production was carried out using a batch digester 2 L. Tofu liquid waste (800 mL) was mixed and stirred with water (800 mL) (1: 1 ratio), then put into a digester. The initial pH in the digester was 7 by adding a solution of NaOH 2 N. The experiment was carried out at room temperature. The daily biogas volume was measured by the water-displacement method every 3 days. This measurement method has also been done by Dababat & Shaheen (2019). Biogas production was run until 45 days. The experimental setup of biogas production is presented in Figure 1.

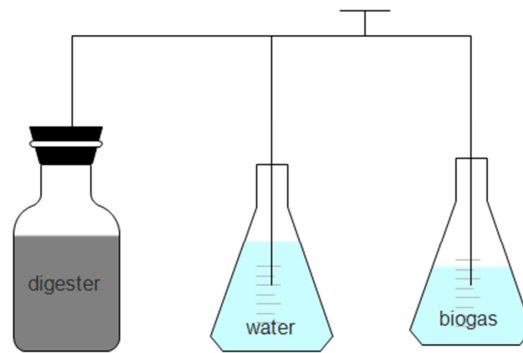


Figure 1. The scheme of biogas production from tofu liquid waste

Kinetic Models of Biogas Production

Linear equation

The kinetics of biogas production using a linear equation model was simulated with the biogas production rate increasing linearly with an increasing time, reaching the peak point and decreasing linearly to zero. The linear equation is stated as follows (Das & Mondal, 2015; Lukhi Mulia Shitophyta, 2020; Okewale et al., 2018)

$$y = a + b(t) \dots \dots \dots (1)$$

Where y is biogas production rate (mL/g VS), t is hydraulic retention time (days), a and b are constants obtained from the intercept and slope (mL/g VS/day). In the ascending limb, " b " is positive, while the descending limb, " b " is negative.

Exponential equation

The exponential model was assumed by increasing the biogas production rate exponentially with an increase in time and achieving the peak value, then decreases exponentially until zero value. The exponential equation is expressed as follows (Shitophyta & Maryudi, 2018).

$$y = a + b \exp(c.t) \dots \dots \dots (2)$$

Where y is biogas production rate (mL/g VS), t is hydraulic retention time (days), a , b (mL/g VS/day), and c (day⁻¹) are constants. In the ascending limb, " c " is positive, while in the descending limb, " c " is negative.

Gaussian equation

The Gaussian model can be simulated both as ascending and descending plots. The Gaussian equation also has been used previously by Ahmed & Kazda, 2017; Choi, Ryu, & Lee, 2020; Lukhi Mulia Shitophyta 2020 to model biogas kinetic rate. Equation 3 represents the Gaussian equation.

$$y = a \exp \left[-0,5 \left(\frac{t - t_0}{b} \right)^2 \right] \dots \dots \dots (3)$$

Where y is biogas production rate (mL/g VS), t is hydraulic retention time (days), a (mL/g VS/day), b (day) are constants, t_0 is the time when the maximum biogas production rate occurred.

$$y = \frac{a}{1 + b e^{-kt}} \dots \dots \dots (4)$$

Where, y is cumulative biogas production (mL/g VS), k is rate constant (day⁻¹), a , b are constants, and t is hydraulic retention time (days) (Ugwu & Enweremadu, 2019)

$$y = A \exp \left\{ -\exp \left[\frac{\mu_m e}{A} (\lambda - t) + 1 \right] \right\} \dots \dots \dots (5)$$

Where, y is cumulative biogas production (mL/g VS), A is potential biogas production (mL/g VS /day), μ_m is maximum biogas production rate (mL/g VS/day), λ is the minimum time required to produce biogas or lag phase (day) t is hydraulic retention time (days)

$$y = A(1 - \exp(-kT)) \dots \dots \dots (6)$$

Where, y is cumulative biogas production (mL/g VS), A is potential biogas production (mL/g VS/day), k is rate constant (day^{-1}), t is hydraulic retention time (days)

Results and Discussion

Biogas production was carried out for 45 days until no more biogas produced. The biogas production is presented as daily biogas yield in Figure 2.

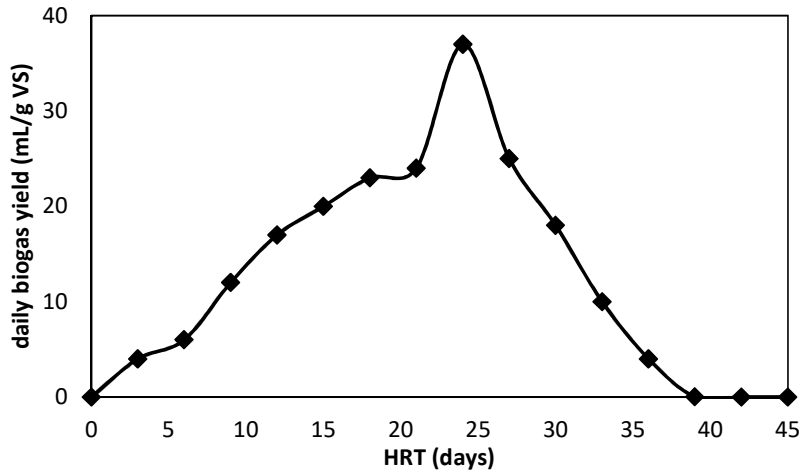


Figure 2. Daily biogas yield of biogas production from tofu liquid waste

Biogas production started on the second day with a biogas yield of 4 mL/g VS. Biogas production increased slowly until it reached the peak value on the 24th day with a biogas yield of 37 mL/g VS. After attaining the peak point, the biogas production gradually decreased until it reached a constant value on the 42nd to 45th day. The kinetics model of biogas production with linear equations was simulated in ascending and descending plots, which can be seen in Figures 3(a) and 3(b), respectively.

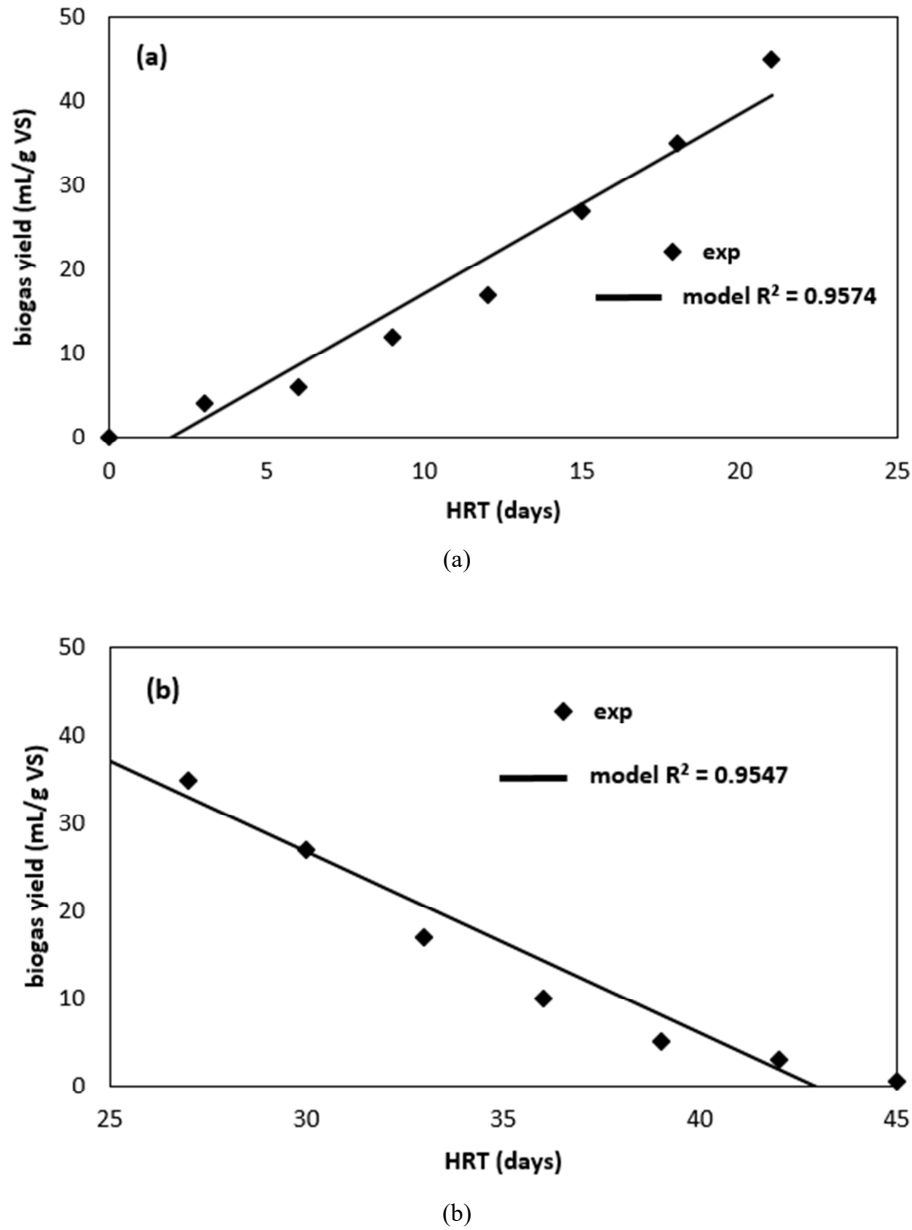


Figure 3. Exponential plots of biogas production rate from tofu liquid waste (a) ascending limb;
 (b) descending limb

As seen in Figures 3(a) and 3(b), both ascending and descending limbs have the same value of regression coefficient ($R^2 = 0.9547$). The $R^2 > 0.9$ indicated that the linear equation could be modeled on the biogas production rate. Figures 4(a) and 4(b) show the exponential equation's ascending and descending limbs. The coefficient of R^2 for the ascending limb was 1, while the descending limb had the R^2 value of 0.95. This model denotes that the biogas production rate increased exponentially with time and achieved a peak value. It decreases linearly

with time until it reached a very low or zero value (Das & Mondal, 2015). The result signifies that the exponential equation gives a better correlation for the ascending limb, while the linear equation is better for the descending limb. A similar study reported by (Ejimofor, et al., 2020) stated that the ascending limb of the exponential equation had more higher R^2 than the ascending limb of the linear equation on kinetic biogas production from post coagulation sludge.

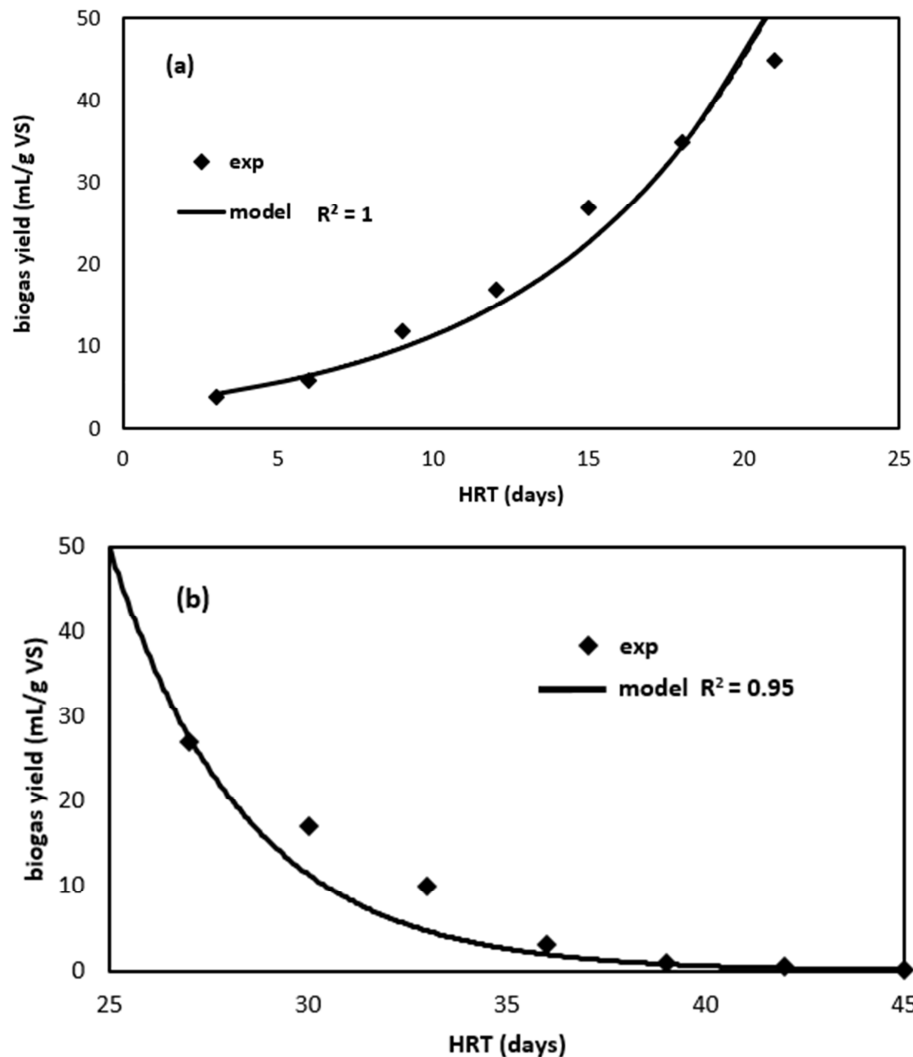


Figure 4. Exponential plots of biogas production from tofu liquid waste: (a) ascending limb; (b) descending limb

The kinetics model of biogas production with the Gaussian equation is shown in Figure 5. The coefficient of R^2 (0.95) in the Gaussian equation was greater than $R^2 > 0.9$. Compared to Figure (3) and Figure (4), the Gaussian equation was suitable to be applied both on the ascending and descending limb because it had the highest R^2 value compared to the linear and exponential

equations, even though the ascending limb of the exponential equation had the highest R^2 . However, the descending limbs on linear and exponential equations have a small R^2 . The prior study, which was reported by Das et al. (2017), also stated that coefficient R^2 was higher for the Gaussian model (R^2 0.992) as compared to the linear (R^2 0.895-0.987) and the exponential models (R^2 0.945-0.961) on a kinetic model of biogas production from pretreated rice husk.

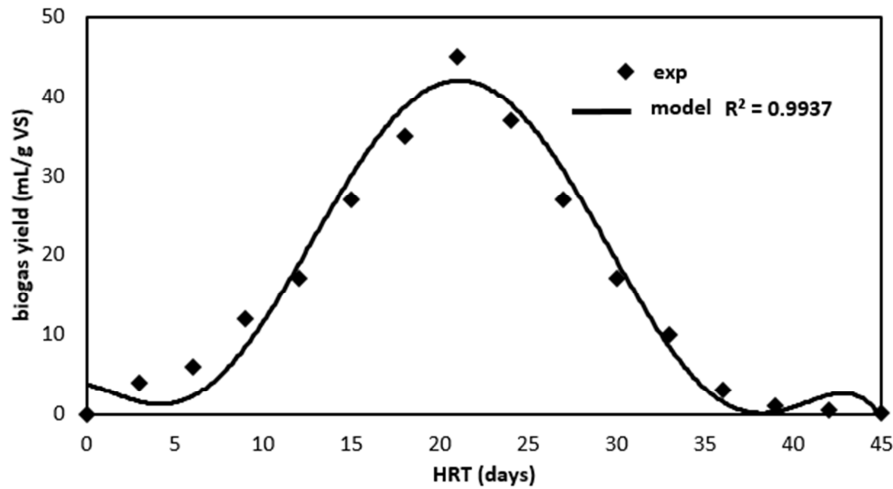
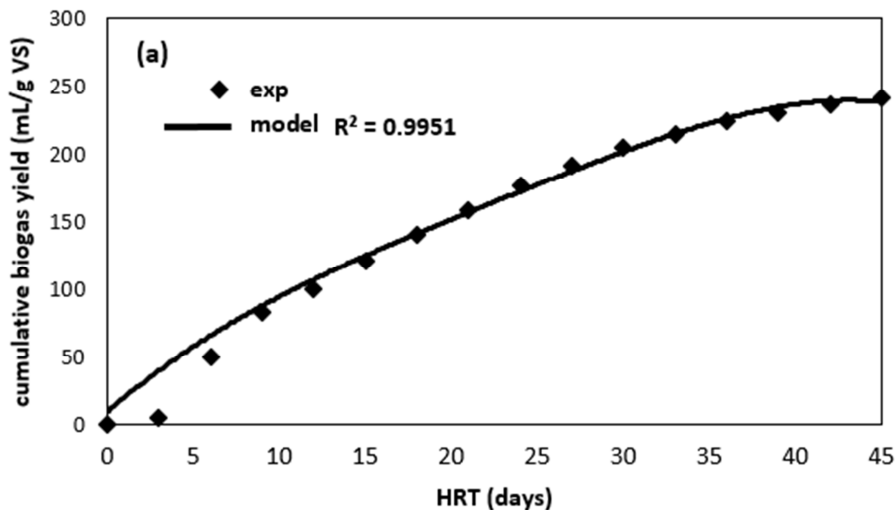


Figure 5. Gaussian plot for biogas production from tofu liquid waste

Cumulative biogas production was simulated using the logistic growth model, modified Gompertz, and exponential rise to maximum, which are shown in Figures 6(a), 6(b), and 6(c), respectively.



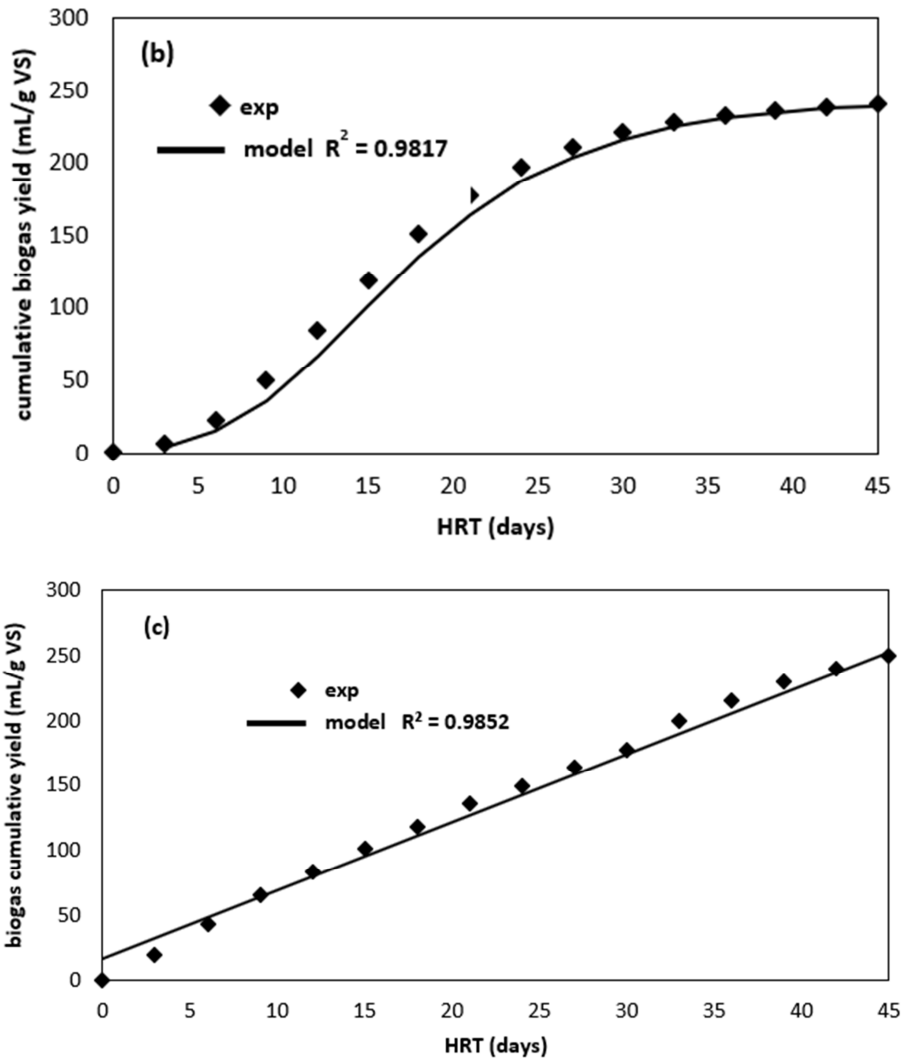


Figure 6. (a) logistic growth plot, (b) modified Gompertz plot, (c) exponential rise to a maximum of cumulative biogas production from tofu liquid waste

The coefficient of R^2 (0.9951) in logistic growth had the greatest value among the modified Gompertz ($R^2 = 0.9817$) and the exponential rise to maximum ($R^2 = 0.9852$). The logistic growth equation is ideal for the simulation of cumulative biogas production. The k value in logistic growth was 0.1 day^{-1} , while the k value in the exponential rise to maximum was 0.02 day^{-1} . In the modified Gompertz equation, the biogas production potential (A) was 243 mL/g . The biogas production rate (μ_m) and the lag phase period (λ) were 12 mL/g/day and 5 days, respectively.

This result is equivalent to the previous study, which was conducted by Ejimofor et al. (2020), who found that the regression coefficient of the logistic model ($R^2 = 0.997$) was higher than modified Gompertz ($R^2 = 0.64$) and exponential rise to maximum ($R^2 = 0.966$) on the biogas kinetic of biogas

production from paint wastewater. Therefore, the logistic growth equation is a fit model to simulate cumulative biogas production.

Conclusion

The biogas production rate with the exponential model has a better correlation than the ascending limb of the linear equation. In comparison, the descending limb of the linear equation has a better correlation than the descending limb of the exponential equation. The Gaussian equation has a higher coefficient R^2 than the linear equation and the ascending limb of the exponential equation. Logistic growth has the highest correlation compared to modified Gompertz and exponential rise to maximum in the simulation of cumulative biogas production. Therefore, this study concludes that the Gaussian equation is a suitable model to predict the kinetic of biogas production from tofu liquid waste. In contrast, the logistic growth equation is a good alternative model to simulate the cumulative biogas production from tofu liquid waste.

Acknowledgment

The author would like to thank to Lembaga Penelitian dan Pengabdian Masyarakat (LPPM), Universitas Ahmad Dahlan for the fundamental research grant number contract No. PD-233/SP3/LPPM-UAD/2020 in 2020.

References

- Ahmed, S., & Kazda, M. (2017). Characteristics of on-demand biogas production by using sugar beet silage. *Anaerobe*, 46, 114–121. <https://doi.org/10.1016/j.anaerobe.2017.04.016>
- Ali, M. M., Dia, N., Bilal, B., & Ndongo, M. (2018). Theoretical models for prediction of methane production from anaerobic digestion: A critical review. *International Journal of Physical Sciences*, 13(13), 206–216. <https://doi.org/10.5897/IJPS2018.4740>
- Budzianowski, W. M. (2016). A review of potential innovations for production, conditioning, and utilization of biogas with multiple-criteria assessment. *Renewable and Sustainable Energy Reviews*, 54, 1148–1171. <https://doi.org/10.1016/j.rser.2015.10.054>
- Choi, Y., Ryu, J., & Lee, S. R. (2020). Influence of carbon type and carbon to nitrogen ratio on the biochemical methane potential, pH, and ammonia nitrogen in anaerobic digestion. *Journal of Animal Science and Technology*, 62(1), 74–83.
- Dababat, S. S. B., & Shaheen, H. Q. (2019). Biogas Production Using Slaughterhouse Wastewater Co-digested with Domestic Sludge. *Journal of Civil Engineering and Construction*, 8(1), 34–40.
- Das, A., & Mondal, C. (2015). Comparative Kinetic Study of Anaerobic Treatment of Thermally Pretreated Source-Sorted Organic Market Refuse. *Journal of Engineering*, 2015, 1–14.
- Das, A., Mondal, C., & Roy, S. (2017). Kinetic Study of Biogas Recovery from Thermo-chemically pre-treated Rice Husk Kinetic Study of Biogas

- Recovery from Thermo-chemically pre-treated Rice Husk. *Indian Chemical Engineer*, 0(0), 1–17. <https://doi.org/10.1080/00194506.2017.1374218>
- Ejimofo, M. I., Ezemagu, I. G., & Menkiti, M. C. (2020). Biogas production using coagulation sludge obtained from paint wastewater decontamination: Characterization and anaerobic digestion kinetics ". *Current Research in Green and Sustainable Chemistry*, 3(May), 100024. <https://doi.org/10.1016/j.crgsc.2020.100024>
- Ge, X., Xu, F., & Li, Y. (2016). Solid-state anaerobic digestion of lignocellulosic biomass: Recent progress and perspectives. *Bioresource Technology*, 205, 239–249. <https://doi.org/10.1016/j.biortech.2016.01.050>
- Jijai, S., & Siripatana, C. (2017). Kinetic model of biogas production from of thai rice noodle wastewater (Khanomjeen) with chicken manure. *Energy Procedia*, 138, 386–392. <https://doi.org/10.1016/j.egypro.2017.10.177>
- Kafle, G. K., & Chen, L. (2016). Comparison on batch anaerobic digestion of five different livestock manures and prediction of biochemical methane potential (BMP) using different statistical models. *Waste Management*, 48, 492–502. <https://doi.org/10.1016/j.wasman.2015.10.021>
- Kainthola, J., Kalamdhad, A. S., & Goud, V. V. (2019a). A review on enhanced biogas production from anaerobic digestion of lignocellulosic biomass by different enhancement techniques. *Process Biochemistry*, 84, 81–90. <https://doi.org/10.1016/j.procbio.2019.05.023>
- Kainthola, J., Kalamdhad, A. S., & Goud, V. V. (2019b). A review on enhanced biogas production from anaerobic digestion of lignocellulosic biomass by different enhancement techniques. *Process Biochemistry*, 84, 81–90. <https://doi.org/10.1016/j.procbio.2019.05.023>
- Kovács Veszélovszki, P., Keszthelyi-Szabó, G., & Szendrő, P. (2018). Enhancing Biogas Production Kinetic of Meat Industrialwastewater by Microwave Pretreatment. *Hungarian Agricultural Engineering*, 7410(34), 44–48. <https://doi.org/10.17676/hae.2018.34.44>
- Kumar, S., Paritosh, K., Pareek, N., Chawade, A., & Vivekanand, V. (2018). Deconstruction of major Indian cereal crop residues through chemical pretreatment for improved biogas production: An overview. *Renewable and Sustainable Energy Reviews*, 90, 160–170. <https://doi.org/10.1016/j.rser.2018.03.049>
- Li, P., Li, W., Sun, M., Xu, X., Zhang, B., & Sun, Y. (2019). Evaluation of Biochemical Methane Potential and Kinetics on the Anaerobic digestion of vegetable crop residues. *Energies*, 12(26), 1–14.
- Liu, Y., Fang, J., Tong, X., Huan, C., Ji, G., Zeng, Y., ... Yan, Z. (2019). Change to biogas production in solid-state anaerobic digestion using rice straw as substrates at different temperatures. *Bioresource Technology*, 293, 122066. <https://doi.org/10.1016/j.biortech.2019.122066>
- Moujanni, A., Qarraey, I., & Ouattmane, A. (2018). Anaerobic codigestion of urban solid waste fresh leachate and domestic wastewaters: Biogas production potential and kinetic. *Environmental Engineering Research*, 24(1), 38–44.
- Oyejide, J. O., Orhororo, E. K., & Atadious, D. (2018). Mathematical Modeling Of Biogas Yield From Anaerobic Co- Digestion Of Organic Waste And

- Pig Dung. *International Journal of Engineering Science Invention*, 7(5), 30–38.
- Shitophyta, L.M., & Maryudi. (2018). Comparison of kinetic model for biogas production from corn cob. *IOP Conference Series: Materials Science and Engineering*, 345, 1–6. <https://doi.org/10.1088/1757-899X/345/1/012004>
- Shitophyta, Lukhi Mulia. (2020). Model Kinetika Produksi Biogas dari Limbah Makanan. *Jurnal Rekayasa Bahan Alam Dan Energi Berkelanjutan*, 4(1), 15–18.
- Shitophyta, Lukhi Mulia, Hanafi, M., & Nugroho, Y. E. (2020). Optimization of biogas from corn stover using liquid and solid-state anaerobic digestion. *Jurnal Program Studi Teknik Mesin*, 9(1), 1–5.
- Shitophyta, Lukhi Mulia, Purwanti, S., & Maryudi. (2019). Pemanfaatan Limbah Cair Tahu menjadi Biogas di Industri Tahu Murni Pak Min Jombang, Banguntapan, Yogyakarta. *Jurnal Pengabdian Pada Masyarakat*, 4(4), 541–546. <https://doi.org/10.30653/002.201944.191>
- Taghinazhad, J., Abdi, R., & Adl, M. (2017). Kinetic and Enhancement of Biogas Production for The Purpose of Renewable Fuel Generation by Co-digestion of Cow Manure and Corn Straw in A Pilot Scale CSTR System. *Int. Journal of Renewable Energy Development*, 6(1), 37–44.
- Ugwu, S., & Enweremadu, C. (2019). Biodegradability and kinetic studies on biomethane production from okra (*Abelmoschus esculentus*) waste. *S Afr J Sci.*, 115(7), 1–5.
- Ware, A., & Power, N. (2017). Modelling methane production kinetics of complex poultry slaughterhouse wastes using sigmoidal growth functions. *Renewable Energy*, 104, 50–59. <https://doi.org/10.1016/j.renene.2016.11.045>
- Winqvist, E., Rikkonen, P., Pyysiäinen, J., & Varho, V. (2019). Is biogas an energy or a sustainability product? - Business opportunities in the Finnish biogas branch. *Journal of Cleaner Production*, 233, 1344–1354. <https://doi.org/10.1016/j.jclepro.2019.06.181>
- Yu, Q., Liu, R., Li, K., & Ma, R. (2019). A review of crop straw pretreatment methods for biogas production by anaerobic digestion in China. *Renewable and Sustainable Energy Reviews*, 107, 51–58. <https://doi.org/10.1016/j.rser.2019.02.020>