

**Bioethanol based on Aquatic Biomass (*Ipomoea Aquatica*) as a Renewable Energy Solution to Achieve the 2030 SDGs**

Arini Sucia<sup>1\*</sup>, Raphael Yori Sutjipto<sup>2</sup>, Farrel Fernando Kwok<sup>2</sup>

<sup>1</sup>Chemical Engineering, Faculty of Engineering, Sriwijaya State Polytechnic, Jl Srijaya Negara, Bukit Besar, Palembang, Sumatera Selatan 30139, Indonesia

<sup>2</sup>Technical Science, Faculty of Science, Ignatius Global School, Jl. Mayor Ruslan No. 118, Palembang, Sumatera Selatan 30113, Indonesia

\*Corresponding Author: arinisucia@polsri.co.id

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**Abstract**

Indonesia has a constantly increasing energy demand. One energy source similar to fossil fuels is biomass. Biomass is organic material derived from living organisms. Indonesia has a constantly increasing energy demand. One energy source similar to fossil fuels is biomass. Biomass is organic material derived from living organisms. Water spinach (*Ipomoea aquatica*) contains cellulose fibers, which can be broken down into glucose through fermentation with yeast (*Saccharomyces cerevisiae*), then converted into bioethanol. This study used an experimental method involving a fermentation process carried out over 3, 4, 5, 7, and 10 days. The yeast mass used varied from 5, 6, and 7 grams. The bioethanol content produced from the distillation process was analyzed using a pycnometer and Gas Chromatography (GC). The highest bioethanol content was obtained in a 5-day fermentation process and a yeast mass of 7 grams, namely 28%. This result is not much different from the GC analysis result of 28.52%. Statistical analysis using ANOVA yielded a p-value of 0.021 (< 0.05), indicating that fermentation time and yeast dosage significantly influenced bioethanol content. The results of this study show that water spinach has the potential to be used for bioethanol production. This supports the goals of the 2030 SDGs, especially points 7, 8, 12, 13, and 15.

*Keywords: Bioethanol, Water Spinach, Fermentation, SDGs, Renewable Energy*

**INTRODUCTION**

Indonesia, as the world's largest archipelagic country, faces increasing energy demand driven by rapid economic and population growth (Mahmud & Fajar, 2023). For the past few decades, fossil fuels, particularly crude oil, natural gas, and coal, have been the main sources of energy fulfillment in Indonesia (Solikah & Bramastia, 2024). To this day, issues related to energy and natural resources remain inadequately addressed. Society remains highly dependent on non-renewable fossil fuels, which are limited and continue to be depleted. (Kementerian PPN/Bappenas, 2017) Additionally, fossil fuels produce significant amounts of greenhouse gases, including CO<sub>2</sub>. The demand for alternative energy sources continues to increase as non-renewable natural resources decline (Desti, 2022).

One of the energy sources that is similar to fossil energy is biomass. Biomass is organic material derived from living organisms that is available in the form of both products and residues (Sahara et al., 2015).

Compared to fossil energy, biomass does not undergo geological processes that take a very long time, up to millions of years, to be utilized as an energy source (Siagian et al., 2023). Biomass is produced through an environmentally friendly carbon cycle and can be used as renewable energy and sustainably and continuously (Sustainable Energy) (Ramayanti & Giasmara, 2017). In Indonesia, the potential of biomass as an energy provider is quite large because the raw materials in the form of plant and animal waste are abundant (Wijaya & Syam, 2021).

Bioethanol is one of the energy sources derived from plants. The raw materials for producing bioethanol (first generation bioethanol) are abundant in Indonesia, such as cassava, sweet potatoes, maize, yams, and sugarcane, which are biomass rich in carbohydrates and come from carbohydrate or starch-producing plants. However, the raw materials for this generation of bioethanol are ineffective because they rely on food sources used by people (Rilek et al., 2017). One of the bioethanol raw materials in Indonesia that

is very plentiful is water spinach (*Ipomoea aquatica*). As we know, in most areas of Indonesia, wetlands, agriculture, and flooded roads are often overgrown with wild plants such as water spinach (Baroroh & Irwanto, 2016)

Water spinach (*Ipomoea aquatica*) is relatively easy to cultivate. Water spinach can be used as a feedstock for bioethanol production due to its cellulose fiber content, especially in the stems, which can be hydrolyzed to glucose via enzymatic hydrolysis and subsequently fermented into ethanol (Rahman, 2023). Cellulose is the main component of plants and is a polysaccharide made up of sugar units (glucose) linked by glycosidic bonds that create long cellulose chains. Water spinach growing in swampy or aquatic areas is not suitable for consumption because it can absorb heavy metals from surrounding water (Sucia et al., 2022). The heavy metals that can be absorbed by wild water spinach include cadmium (Cd), chromium (Cr), and lead (Pb) (Juhri, 2017). Moreover, water spinach, as an effective raw material for bioethanol, will efficiently serve as a renewable energy solution to achieve the SDGs 2030, especially points 7, 8, 12, 13, and 15, which focus on advancements in clean and affordable energy.

The SDGs 2030 are a series of sustainable development goals set by the United Nations (UN) to be achieved by all participating countries by 2030. Indonesia is one of the countries that has signed and agreed to achieve the SDGs along with other member countries. Achieving the SDGs by 2030 will bring significant benefits to Indonesia, improving the quality of life of its people. Based on the above background, this research will focus on the production of bioethanol using water biomass as a raw material to realize Indonesia's SDGs 2030.

## METHODOLOGY

### Materials and Instrumentals

The materials used in this study included water spinach stalks, aquades, and yeast *Saccharomyces cerevisiae*. The instrumental tools used included a pycnometer to measure the density of water spinach bioethanol and gas chromatography (GC) to determine the bioethanol content.

### Methods

**Pretreatment.** Pretreatment is the initial stage in the bioethanol production process, aimed at preparing biomass for more efficient and effective conversion into bioethanol. Water spinach is cleaned, then cut into small pieces. The water spinach is then dried in the

oven at 100 °C and blended into water spinach powder (Sucia et al., 2022).

**Fermentation.** Fermentation is an important process in which simple sugars are converted into ethanol using the yeast *Saccharomyces cerevisiae*. After the kale undergoes pretreatment, 5, 6, and 7 grams of yeast are added to the fermenter and fermented for 3, 4, 5, 7, and 10 days.

**Distillation.** Distillation is the process of separating and purifying ethanol from a fermented solution to produce bioethanol for fuel, and of testing the ethanol content. The distillation of fermentation results is carried out at a temperature of 70-80 °C (the temperature is kept constant) (Waluyo et al., 2018).

**Bioethanol density analysis.** The obtained bioethanol was analyzed for density using a pycnometer and gas chromatography.

### Data Analysis

The concentration of bioethanol is calculated using density measurements with a pycnometer, specifically by weighing the empty and dry pycnometer. Then, the pycnometer is filled with water of known specific gravity. Next, the pycnometer is weighed using Equation 1 (Wiyono, 2020).

$$\text{Bioethanol Density} = \frac{A - B}{C - B} \times \text{Water Density} \quad (1)$$

A: Weight of Ethanol Pycnometer

B: Empty Pycnometer Weight

C: Weight of the Water Pycnometer

The calculation of bioethanol density is based on the calculation of the density of distilled bioethanol compared to the density of water (1 g/ml) (Andana et al., 2020). After the specific weight of bioethanol is known, the concentration of bioethanol is calculated using the ethanol density conversion table. Furthermore, bioethanol concentration is analyzed by GC, comparing the chromatogram of the standard solution (96% ethanol) with that of the sample solution.

## RESULTS AND DISCUSSION

The density of the ethanol that has been obtained is then calculated by matching the density table of ethanol against its concentration (%v). The ethanol concentration data are presented in Table 1 below.

Table 1. Results of the Ethanol Content Calculation Using a Pycnometer

Sample	Yeast (g)	Fermentation Time (Day)	Ethanol Content (%v)
1	5	3	11
2	5	4	18
3	5	5	18
4	5	7	21
5	5	10	0
6	6	3	15
7	6	4	21
8	6	5	19
9	6	7	24
10	6	10	2
11	7	3	20
12	7	4	27
13	7	5	28
14	7	7	25
15	7	10	4

### The Effect of Fermentation Duration on Bioethanol Content

The duration of fermentation significantly affects the ethanol content produced. In the fermentation process, yeast plays a role in reproduction, making timing critical for bioethanol production. The effect of fermentation duration on bioethanol content (%) is shown in Figure 1.

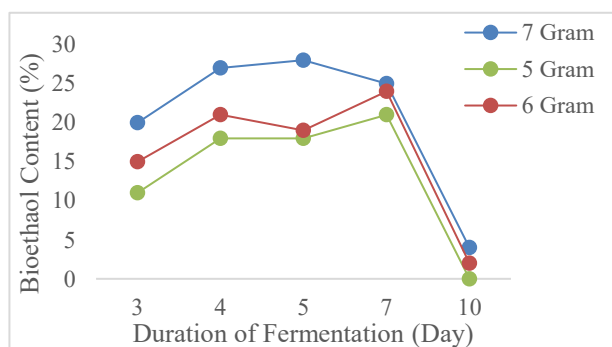


Figure 1. The effect of fermentation duration on bioethanol content

Based on Figure 1 above, the best fermentation time is 5 days, producing the highest bioethanol content of 28%. At a yeast mass of 7 grams, there is an increase in bioethanol content from day 3 to day 7 of fermentation. This indicates that at this time, a lot of glucose is produced, allowing it to be converted into ethanol. The fermentation time, combined with the

appropriate yeast dose, will result in the maximum ethanol content (Lazuardi, 2024). Conversely, for fermentation times exceeding 7 days up to day 10, the bioethanol content actually decreases. This is because a longer fermentation time increases the release of inhibitory chemicals such as furfural and HMF (Hydroxymethylfurfural), which form after reaching saturation, resulting in a significant reduction in the released sugars and, consequently, a decrease in the ethanol content produced (Maharani et al., 2021). The results of this study are better compared to the research below:

Table 2. Comparison of Bioethanol Content Based on Fermentation Time

Source	Biomass	Fermentation Time (Day)	Bioethanol Content (%)	Method
This research	<i>Ipomoea aquatica</i>	5	28%	Fermentation
(Suda et al., 2015)	<i>Typha latifolia L. (Cattails)</i>	5	0,997	Fermentation, NaOH
(Rana et al., 2021)	<i>Spirodela polyrrhiza (Duckweed)</i>	4,33	6.292	Fermentation, $\text{KH}_2\text{PO}_4$ , KCl, $\text{Mg}_2\text{SO}_4$
(Wahyudi, 2021)	<i>Eichhornia Crassipes (Water Hyacinth)</i>	7	0,528	Fermentation, Pupuk Urea, NPK
(Telussa et al., 2023)	<i>Navicula sp (Microalgae)</i>	5	6,35	Fermentation, NaOH
(Kolo et al., 2021)	<i>Ulva reticulata (Seaweed)</i>	5	5,02	Fermentation, HCl

From Table 2 above, it can be concluded that water spinach has a higher bioethanol content than other types of biomass. In this research, bioethanol was produced by fermentation without the addition of catalysts or nutrients, yet the resulting bioethanol concentration was higher.

### The Effect of Yeast Dose on Bioethanol Content

The yeast dosage significantly affects the bioethanol content produced (Nasrun et al., 2015). *Saccharomyces cerevisiae* yeast can assist in converting cellulose into glucose, which is then fermented into ethanol (Wusnah et al., 2019). In the production of water-based biomass bioethanol, *Saccharomyces cerevisiae* is chosen because it is a yeast capable of converting glucose into ethanol with high efficiency and spontaneity (Mahira et al., 2024). *Saccharomyces cerevisiae* yeast has also been used commercially in beer production, as it is a strong fermentative agent (Riswanto et al., 2017). In this study, the effect of yeast mass on bioethanol content

varied. Figure 6 below shows the effect of yeast mass on bioethanol content.

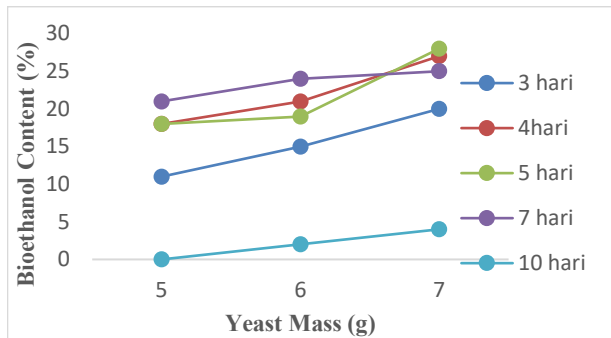


Figure 2. The effect of yeast mass on bioethanol content

Based on Figure 2 above, the highest bioethanol concentration is produced with a yeast mass of 7 grams, corresponding to 28%. Meanwhile, the lowest bioethanol concentration is obtained with a yeast mass of 5 grams, which is 0%. From Figure 2, it can be observed that a yeast mass of 5 grams produces the lowest combined ethanol concentration at fermentation times of 3, 4, 5, 7, and 10 days. A yeast mass variation of 6 grams produces a higher combined ethanol concentration than a yeast mass of 5 grams. Increasing the yeast mass to 7 grams yields the highest combined ethanol concentration across the other two mass variables at fermentation times of 3, 4, 5, 7, and 10 days. From the analysis above, it can be concluded that the greater the yeast mass used, the higher the ethanol concentration produced, up to a certain time limit, after which it will decrease (Saragih et al., 2024).

This can occur because the glucose in water spinach is converted by the zymase enzyme in *Saccharomyces cerevisiae*, reaching peak production at a specific time and yeast concentration. With a yeast mass of 7 grams, the amount of glucose converted reaches a maximum, and the greater the yeast mass, the more ethanol is produced (Maryana et al., 2020). Then, the ethanol content decreases again because the glucose has been fully converted. This shows that the yeast mass and ethanol content are directly proportional in the production of water spinach-based bioethanol. These results are better compared to the studies below in Table 3 :

From Table 3, this study is superior to previous studies using different biomass. The yeast dosage significantly impacts the bioethanol yield. The bioethanol yield in this study was higher and more optimal than those reported in studies using other aquatic biomass,

without the need for a catalyst, thereby reducing production costs.

Table 3. Comparison of Bioethanol Content to Yeast Mass

Source	Biomass	Yeast Mass (g)	Bioethanol Content (%)	Method
This Reaserch	<i>Ipomoea aquatica</i> (Water Spinach)	7	28%	Fermentation
(Whangchae, t al.,2021)	<i>Pistia stratiotes</i> (Water Lettuce)	1,24	1,53	Fermentation, NaOH dan HCl
(Aparicio et al., 2021)	<i>Sargassum sp</i> (Algae)	8	1,814	Fermentation
(Firmansyah et al., 2022)	<i>Eichhornia crassipes</i> (Water Hyacinth)	6	0,528	Fermentation, H <sub>2</sub> SO <sub>4</sub>
(Tozluoglu, 2018)	<i>Phragmites australis</i> (Common Reed)	5	13,2	Fermentation, NaOH
(Pilavtepe et al., 2012)	<i>Zostera marina</i> (Common Eelgrass)	0,5	8,72	Fermentation, Peptine, (NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub> , CaCl <sub>2</sub>

**Statistical Analysis Results of Ethanol Content**

The statistical data processing in this study used the Statistical Package for the Social Sciences (SPSS) method and Microsoft Excel. The data presented in Table 1 were used to create a model of the effect of fermentation duration (X1) and yeast dosage (X2) on bioethanol content (Y). The results of the ANOVA analysis are presented in Table 4.

Table 4. ANOVA

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	521,939	2	260,970	5,383	,021 <sup>b</sup>
Residual	581,794	12	48,483		
Total	1103,733	14			

Based on the ANOVA (Analysis of Variance) test in Table 4, it can be seen that the p-value is smaller than alpha ( $\alpha = 0.05$ ), which is 0.021. This indicates statistically significant results, meaning that these results are unlikely to have occurred by chance. Fermentation time and the dose of *Saccharomyces cerevisiae* yeast significantly affect the bioethanol content produced. Based on these results, H0 is rejected and H1 is accepted.

## GC (Gas Chromatography) Analysis Results

Bioethanol with the highest concentration, based on calculations using a pycnometer, namely bioethanol from a 5-day fermentation process with 7 grams of yeast, was analyzed by GC. Figure 3 below shows the chromatogram from the GC analysis.

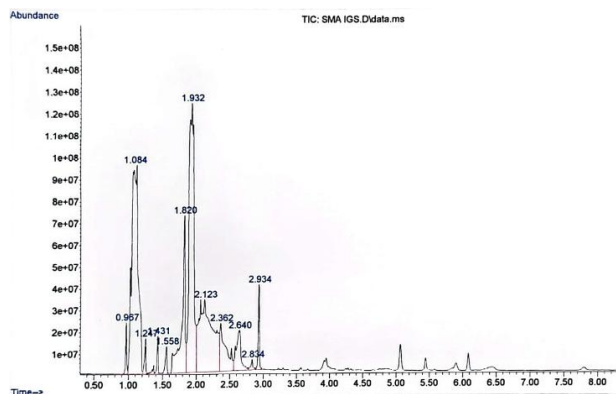


Figure 3. Bioethanol Analysis Results Graph Using Gas Chromatography (GC)

GC analysis is one of the methods used to determine volatile compounds such as ethanol (Marampung et al., 2024). In GC analysis, additional compounds are required as standards. In this study, the standard compound in question is 96% ethanol (Kolo et al., 2023). 96% ethanol was used as a comparison to determine the bioethanol content based on the area. Based on Figure 7 at the retention time (RT) of 1.084, an area (%) of 27.49 was obtained which was ethanol (ethyl alcohol). Furthermore, at RT 1.247, 1.431, and 1.558, methanol compounds were identified with (%) areas of 0.85, 1.11, and 0.94, respectively. Then the bioethanol content was determined by comparing the area of ethanol read on the chromatogram with the area of standard ethanol (96%) (Sudarma & Parwata, 2017), so that the ethanol content was obtained using the following equation 2:

$$\text{Ethanol \%} = \frac{\text{Area of Ethanol Sample (27.49)}}{\text{Area of Ethanol Standard (92.52)}} \times \text{Standard (96\%)} \quad (2)$$

After the bioethanol content was calculated using equation 2 above, the comparison results of bioethanol content using pycnometer analysis and GC are presented in Table 5 below:

Bioethanol Content by Pycnometer	Bioethanol Content by GC
28%	28,52%

In Table 5 above, it can be seen that the bioethanol content based on calculations using a pycnometer is not much different from that obtained based on GC analysis.

## Bioethanol to Realize the 2030 SDGs

Bioethanol is an energy source proven to be efficient in reducing exhaust gas emissions from combustion when blended with gasoline (Aprilyanti et al., 2020). Water spinach-based bioethanol can be categorized as an environmentally friendly energy source and supports the SDGs 2030 goal, specifically point 7, Clean and Affordable Energy (Estevão & Lopes, 2024). In the processing of water biomass-based bioethanol, the raw material used is water spinach that grows wild in Indonesian waters and can absorb heavy metals. Therefore, wild water spinach cannot be consumed as food (Fahlevi et al., 2018). Furthermore, its processing does not require additional costs in bioethanol production and reduces production costs, making water spinach-based bioethanol an affordable energy source. Blending bioethanol into gasoline can save fuel consumption by 1.65%, and specific fuel consumption by 4.66% (Helmi, 2018). Therefore, bioethanol indirectly reduces dependence on the use of fossil fuels, which is also in line with point 7 of the 2030 SDGs to substantially increase the production of renewable energy in the global energy mix (Azmi et al., 2023).

The burning of fossil energy, such as petroleum, natural gas, and coal, produces greenhouse gases in the form of CO<sub>2</sub>, CO, hydrocarbons, and NO<sub>x</sub>, which have a detrimental impact on increasing the global surface temperature (Kurnia & Sudarti, 2021). CO<sub>2</sub> emissions in Indonesia are among the largest in the world, ranking third in the category of fossil energy combustion (Santhyami et al., 2020). Research conducted by (Finahari et al., 2017) states that the amount of CO<sub>2</sub> gas emissions produced by coal-fired power plants increased by 14.7% within just one year, resulting in 271,348 tons of CO<sub>2</sub> emissions from the combustion of 100 tons of coal. Considering the air pollution caused by the combustion of fossil energy, concrete actions are needed to reduce the production of greenhouse gases and hazardous gases originating from the fossil energy carbon cycle (Adistia et al., 2020). Point 13 of the SDGs, Climate Action, focuses on addressing greenhouse gases (Thapa et al., 2023), which aligns with the production of water spinach bioethanol. When ethanol is added to gasoline, it is found that the higher the ethanol percentage, the greater the reduction in exhaust gas emissions: CO<sub>2</sub>

(21.05%), CO (17.25%), HC (14.25%), and NO<sub>x</sub> (9.55%) (Ramly et al., 2020). Based on this research, bioethanol as a renewable energy source can be an efficient solution to reduce pollutants produced from fossil fuels.

In the production of water spinach-based bioethanol, the ethanol obtained from the distillation process will leave behind a residue consisting of water spinach and fermented yeast. Generally, the remaining distillation residue is discarded because it cannot be reused. However, water spinach bioethanol residue is not polluting because it does not contain hazardous compounds such as H<sub>2</sub>SO<sub>4</sub>, HCl, etc., as found in several previous studies. Therefore, the production of water spinach-based bioethanol is in accordance with point 12, Responsible Consumption and Production (Franco & Newey, 2020). However, organic waste from the distillation residue requires further treatment. If left untreated, organic waste will decompose and produce methane gas (CH<sub>4</sub>) (Pratama & Kunci, 2019). According to previous research conducted by (Haryanto & Thalib, 2019), the concentration of methane originating from the degradation process of organic matter has increased significantly, namely 152% compared to the pre-industrial era and will continue to increase along with industrial development which contributes greatly to the greenhouse effect, which is one of the causes of global warming. In addition, methane gas has the ability to absorb heat 25 times greater than CO<sub>2</sub> gas so that the energy value re-emitted by CH<sub>4</sub> is greater than CO<sub>2</sub> (Vlaming, 2018).

Renewable energy such as biogas, which consists of 55% - 75% methane, can be one of the solutions for utilizing the residue from water spinach bioethanol for further processing (Shitophyta et al., 2022). The concentration of methane gas affects the energy contained in biogas, where the higher the methane concentration, the greater the energy in the biogas (Soebagia et al., 2021). One application of biogas utilizing methane gas is the production of LPG. In a study conducted by (Sujono & Kusuma, 2022), methane gas present in cow manure was converted into biogas, which was then interpreted as LPG, proving its use as an energy source for cooking and demonstrating that methane can be utilized to produce biogas. Therefore, the problems arising from the by-products generated from water spinach bioethanol can be addressed through biogas production.

In this study, water spinach samples were taken manually by researchers who directly observed the actual conditions of the environment where the water

spinach plants grow. Water spinach is widely distributed in the cultivation area, so precise logistical information is not needed for harvesters to obtain water spinach (Dong & Nguyen, 2019). Likewise, water spinach bioethanol can open up new job prospects, namely for harvesting and collecting samples, which indirectly supports the 2030 SDGs goal 8, Decent Work and Economic Growth (Rai et al., 2019). Water spinach is a plant with a relatively fast growth period, taking only 4 - 6 weeks (Putri et al., 2024). Seeing this, water spinach cultivation can become an opportunity to open up job opportunities not only as a food source, but also for the utilization of cellulose for the production of bioethanol that is effective and efficient (Littlejohns et al., 2018), as well as supporting sustainable farming practices and good land management by reducing the use of fossil energy sources in accordance with point 15 of the 2030 SDGs, namely Protecting Terrestrial Ecosystems and Natural Resources (Huan et al., 2021).

## CONCLUSION

The conclusions obtained after conducting this research are:

1. Water biomass (*Ipomoea Aquatica*) can be one of the solutions as a renewable energy source, namely bioethanol with a content of 28%, thereby contributing to the realization of the 2030 SDGs, covering SDG points 7, 8, 12, 13, and 15.
2. The best fermentation time was obtained with a 5-day variation, resulting in 28% bioethanol.
3. The yeast mass significantly affects the bioethanol content produced; the larger the yeast mass used, the higher the bioethanol content obtained. In this study, the highest content was achieved with a yeast variation of 7 grams, which amounted to 28% bioethanol.

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