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Morphology and Bioethanol Potential of *Amorphophallus muelleri* Blume Variants Found in East Java

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Abstract: *Amorphophallus muelleri* Blume (porang) is a high-economic value plant widely found in Indonesia, particularly in East Java. The morphological variations of this plant play a significant role in selecting superior seeds and adapting to environmental conditions. Additionally, porang has potential in the energy sector, particularly in biomass energy conversion from its tubers, which are rich in glucomannan. This study aims to analyze the morphological differences of A. muelleri from various regions in East Java and its potential for biomass energy utilization. The observed parameters include the pattern and color of petioles, the shape and color of tubers, and glucomannan content as the main indicator of energy potential. The results indicated three main groups based on petiole patterns: (1) large prismatic, (2) small prismatic, and (3) striped prismatic. The tuber morphology also showed significant differences in shape, color, and water content, which affect energy conversion efficiency. Higher glucomannan content in certain variants suggests their potential as raw materials for bioethanol or renewable energy biomaterials. This emphasizes that morphological variation is not only crucial for selecting superior seeds but also for optimizing energy utilization from porang tubers.
Keywords: *Amorphophallus muelleri* Blume, petiole morphology, tuber morphology, energy conversion, glucomannan.

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Introduction

Amorphophallus muelleri Blume (*porang*) is a tuber plant with high economic value due to its glucomannan content, which is used in various industries, including food, pharmaceuticals, and cosmetics. Glucomannan is a natural polysaccharide that serves as a thickener, emulsifier, and stabilizer, making it a valuable commodity in both domestic and international markets. According to Hui (2006), glucomannan is a type of hemicellulose polysaccharide consisting of galactose, glucose, and mannose chains. Wahyuni et al. stated that porang (*A. muelleri*) can serve as an alternative food source due to its high glucomannan content, reaching up to 67%.

Indonesia, particularly East Java, is one of the regions with significant potential for porang cultivation. The types of iles-iles commonly found in Indonesia include *A. companulatus* (Roxb.) Blume, *A. variabilis* Blume, and *A. oncophyllus* Prain ex Hook. f., synonymous with *A. muelleri* Blume. In several regions, iles-iles is known by various local names such as walur or suweg (Java), acung (Sunda), and kruwu (Madura) (Sugiyama and Edi 2015). However, until now, porang cultivation and production in Indonesia, especially in East Java, have not reached optimal results.

This condition is attributed to several factors. According to Kurniati et al., some domestic factors include farmer's limited experience in handling porang cultivation challenges, low economic conditions due to insufficient availability of fertilizers, seeds, credit, and agricultural tools, as well as limited non-formal education, making farmers less enthusiastic about attending training and workshops. In addition, price fluctuations in the Chinese market pose a serious challenge for Indonesian farmers. This issue arises due to China's policy of restricting export access from Indonesia as the porang produced has not met their standards. Consequently, porang farmers face difficulties in marketing their products internationally, directly impacting price stability and the sustainability of their businesses.

As a strategic step to address these problems, diversifying porang utilization into bioethanol production can be a potential solution. Porang contains carbohydrates that can be processed into bioethanol, serving as a renewable and eco-friendly energy source. Developing a domestic bioethanol industry based on porang not only reduces dependency on exports to China but also enhances the local added value of the product. Moreover, utilizing porang as a raw material for bioethanol can support national energy security programs and open up new industrial opportunities that contribute to Indonesia's economy. However, research on morphological variations among porang variants and their potential as a bioethanol source remains limited.

Bioethanol is an alcohol produced by the fermentation of carbohydrates such as sugars, starches, and lignocellulose by microorganisms (Rahayu et al. 2012). The selection of microorganisms in the fermentation process leads to safe, environmentally friendly, cost-effective, and efficient technology. The main advantage of bioethanol is that it is a renewable fuel and does not contribute to the increase of greenhouse gases (Walker, 2010). According to Rahayu et al., substituting gasoline with bioethanol as a vehicle fuel can reduce carbon dioxide emissions. This is possible because increasing bioethanol production promotes the cultivation of plants, which in turn fixes carbon dioxide emissions through the photosynthesis process of biomass-producing plants (Millan 1997).

The recent fuel crisis in Indonesia and the high demand for fuel underscore the urgent need for alternative fuel sources to meet the rising demand for fuel.

Although *A. muelleri* has been widely cultivated, few studies specifically address the morphological diversity of this plant in various regions. Several environmental factors such as soil type, humidity, and light intensity can influence plant growth as well as the morphology of leaves, stems, and tubers. Additionally, the relationship between morphological characteristics and glucomannan content in tubers has not been fully understood.

To address these issues, this study aims to identify the morphological differences of *A. muelleri* in several main regions in East Java and determine if there is a correlation between morphological variations and glucomannan content in the tubers.

This study aims to:

1. Analyze the morphological variations of *A. muelleri* from various regions in East Java.
2. Classify porang variants based on their phenotypic characteristics, particularly petiole patterns and tuber shapes.
3. Determine the relationship between morphological characteristics and glucomannan content in the tubers.
4. Explore the potential of *Amorphophallus muelleri* as a raw material for bioethanol based on its morphological characteristics and carbohydrate content.
5. Analyze the feasibility of developing porang-based bioethanol as an alternative utilization of agricultural products to support national energy security.

This study is beneficial for providing insights into the morphological variations of *Amorphophallus muelleri* and their correlation with glucomannan content, thereby assisting farmers in selecting superior variants for more optimal cultivation. In addition, the findings of this study can serve as a foundation for the development of porang as a source of bioethanol, supporting the diversification of agricultural product utilization and contributing to national energy security. These findings can also be utilized by industries and the government in designing policies and strategies for more sustainable and economically valuable porang management.

Method

1. Plant Samples

   Samples of *A. muelleri* were collected from four main regions in East Java:
   - Blitar (B1, B2)
   - Madiun (M1, M2)
   - Nganjuk (N1, N2)
   - Jember (J1, J2)

   Two samples with differences in leaf and tuber morphology were taken from each region for further analysis.
2. Observed Morphological Parameters

   Tuber Morphology
   - Shape: Round or elongated
   - Color: Orange or yellowish-orange
   - Water Content (%): Tested using the oven method at 105°C for 24 hours
   - Glucomannan Content (%): Tested using the method of Chairul & Chairul, S.
3. Evaluation of Energy Conversion Potential

   A study of the energy conversion potential of porang into bioethanol was conducted based on literature reviews from various relevant sources. The bioethanol test was performed as follows:

   a. Carbohydrate Extraction from Tubers
   - Tubers were dried and ground into fine flour.
   - Enzymatic hydrolysis was carried out using α-amylase and glucoamylase enzymes to convert polysaccharides into simple sugars.

   b. Bioethanol Fermentation Process
   - The hydrolysis solution was fermented for 72 hours using *Saccharomyces cerevisiae* at 30°C.
   - The pH of the solution was maintained at 4.5 to optimize yeast activity.
   - Ethanol content was tested using GC-MS (Gas Chromatography-Mass Spectrometry).
4. Measurement of Bioethanol Fermentation Efficiency

   Fermentation efficiency was calculated based on the percentage of sugar conversion to ethanol using the following formula:

$$\text{Efficiency} = \frac{Amount\ of\ Ethanol\ Produced}{Initial\ Sugar\ Content} x100\%$$

   The data were then analyzed to determine the relationship between tuber water content, glucomannan content, and bioethanol fermentation efficiency.

Results and Discussion

Leaf Morphological Variations

Table 1. Leaf Morphology of *A. muelleri*

Variant	Petiole Pattern	Petiole Color	Venation Pattern	Petiole Diameter (cm)
B1	Large prismatic	Dark green	Distinct	3.2
B2	Small prismatic	Light green	Indistinct	2.8
J1	Large prismatic	Dark green	Distinct	3.5
J2	Striped prismatic	Light green	Indistinct	3.0

Based on observations, it was found that variants with large prismatic petioles have thicker diameters and more distinct venation patterns compared to small and striped prismatic variants. This is suspected to be related to better water storage capacity and resistance to environments with high light intensity. A previous study by Liepman and Cavalier mentioned that thicker petiole structures can enhance photosynthesis efficiency and water retention, which supports plant growth in drier environmental conditions.

Meanwhile, variants with small and striped prismatic patterns showed slimmer and more flexible growth, allowing adaptation to soils with higher water content. According to Yin et al., petiole morphology has a correlation with water and nutrient distribution patterns within the plant, which can subsequently affect the size and quality of the produced tubers.

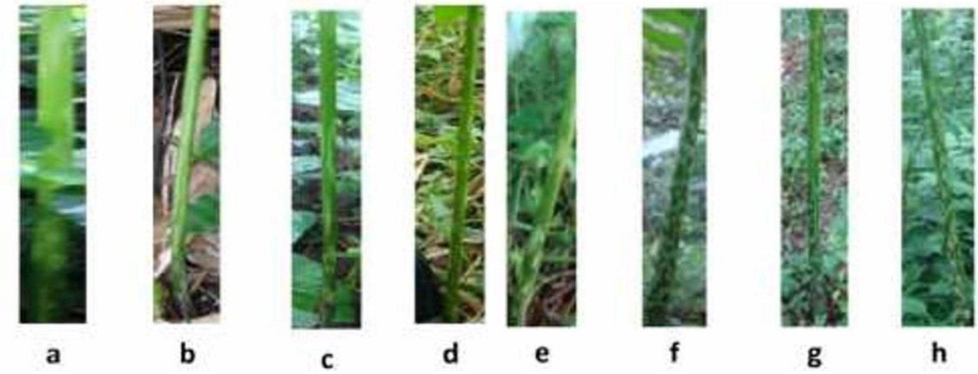

Figure 1. Variations in Leaf Morphology of Porang

Relationship between Tuber Morphology and Bioethanol Fermentation Efficiency

Table 2. Tuber Morphology and Bioethanol Efficiency

Variant	Petiole Pattern	Petiole Color	Venation Pattern	Petiole Diameter (cm)
B2	Elongated	Orange	68	5.47
J2	Elongated	Yellowish-orange	70	4.0
M1	Round	Orange	78	2.5
N1	Round	Orange	76	2.9

The study found that variants with elongated tubers have lower water content compared to those with round-shaped tubers. This contributes to higher bioethanol fermentation efficiency, as lower water content allows more optimal glucomannan extraction. A study by Wahyuni et al. stated that water content in tubers has a direct impact on the fermentability of substrates in bioethanol production, supporting these findings.

Variant B2, with a water content of 68% and glucomannan content of 5.47%, showed the highest fermentation efficiency of 89.3%, suggesting that tubers with lower water content tend to be more suitable for bioethanol production. On the other hand, tubers with higher water content (M1, 78%) showed lower fermentation efficiency (75.2%), indicating that tubers with high water content are more suitable for solid biomass or biochar feedstock than for bioethanol production.

These findings align with the research by Megazyme, which stated that glucomannan with lower water content has a more stable structure during enzymatic hydrolysis, thereby enhancing bioethanol production during fermentation.

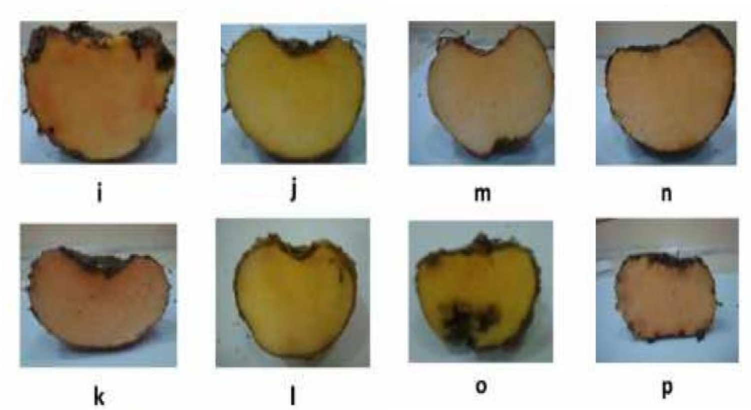

Figure 2. Relationship between Tuber Water Content and Bioethanol Efficiency

Implications for the Selection of Porang Varieties for Renewable Energy

The results of this study provide a basis for selecting porang varieties that are more optimal for renewable energy production. Key considerations in selecting superior varieties are as follows:

- Tubers with low water content are more efficient for bioethanol production. Variants B2 and J2, which have water content ≤70%, are more suitable for bioethanol production due to lower energy requirements for drying and fermentation processes.
- Tubers with high water content are more suitable for solid biomass. Variants with higher water content, such as M1 and N1, can be used as feedstock for biochar or solid biomass, which is efficient for combustion energy due to more stable energy release.
- Petiole structure influences growth efficiency. Large prismatic petioles with dark green color show higher photosynthesis efficiency, supporting larger tuber growth and increased biomass production.
- Variants with high glucomannan content have greater economic value. Higher glucomannan content not only enhances bioethanol fermentation efficiency but also opens market opportunities in the food, pharmaceutical, and cosmetic industries. Thus, selecting the right porang varieties will not only improve bioethanol production but also expand opportunities for renewable energy and other biomass-based industries.

Conclusion

This study shows that the morphological variations of leaves and tubers in *Amorphophallus muelleri* significantly influence its energy conversion potential. Key findings include:

1. Large prismatic petioles are associated with slower growth but result in larger tubers with higher water retention capacity. In contrast, small prismatic petioles are slimmer and more efficient in nutrient absorption.
2. Variants with low water content are more efficient for bioethanol fermentation, with variant B2 showing the highest efficiency (89.3%).
3. Tubers with high water content are more suitable for solid biomass applications, while those with low water content are ideal for bioethanol production.
4. This study provides a foundation for selecting porang varieties for both cultivation purposes and biomass-based energy production.

The results emphasize that morphological characteristics are crucial not only for selecting superior varieties but also for optimizing the utilization of porang tubers for renewable energy.

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