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Processing Tofu Liquid Waste into Liquid Organic Fertilizer With the Addition of Lamtoro Leaves as an Effort Prevention of Environmental Pollution

Pengolahan Limbah Cair Tahu menjadi Pupuk Organik Cair dengan Penambahan Daun Lamtoro sebagai Upaya Pencegahan Pencemaran Lingkungan

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ABSTRAK

Penambahan daun lamtoro (Leucena leucocephala) dalam pengolahan limbah tahu menjadi pupuk organik cair (POC) merupakan salah satu upaya proteksi lingkungan. Tujuan penelitian ini adalah untuk mengetahui pengaruh penambahan daun lamtoro terhadap kandungan unsur hara seperti nitrogen, fosfor, kalium (NPK), dan karbon pada POC dari limbah industri tahu di wilayah Bengkulu, Indonesia. Limbah tahu mengandung kadar BOD, COD, dan gas-gas seperti oksigen (O_2), hidrogen sulfida (H_2S), karbon dioksida (CO_2), dan amoniak (NH_3) yang tinggi melebihi baku mutu lingkungan. Daun lamtoro mengandung 3,84% N, 0,2% P, 2,06% K, 24,7% protein, dan 53,71% karbohidrat yang berpotensi untuk meningkatkan kadar NPK dan karbon dari POC untuk mencegah pencemaran lingkungan dan meningkatkan kualitas tanah. Metode penelitian ini adalah eksperimen semu (Quasi experiment) dengan rancangan pre-post and control grup design. Uji Kruskal Wallis digunakan dalam analisis data secara statistik. Hasil uji statistik menunjukkan bahwa terdapat pengaruh yang signifikan penambahan daun lamtoro terhadap peningkatan nilai N (α=0,049), K (α=0,044), C (α=0,019), dan tidak ada pengaruh untuk unsur P (α=0,136). Penelitian ini menunjukkan bahwa penambahan daun lamtoro meningkatkan unsur hara di dalam tanah dan pemenuhan nutrisi tanaman secara alami sehingga memperbaiki daya dukung dan kualitas tanah sebagai salah upaya dalam perlindungan ekosistem, pencegahan pencemaran lingkungan, dan kesehatan masyarakat.

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ABSTRACT

Adding lamtoro leaves (*Leucaena leucocephala*) in the wastewater treatment of tofu into liquid organic fertilizer (LOF) is one of the efforts to protect the environment. This study investigated the effect of adding lamtoro leaves on the nutrient content, specifically nitrogen, phosphorus, potassium (NPK), and carbon, of LOF derived from tofu industry waste in Bengkulu, Indonesia. Tofu wastewater contains high levels of BOD, COD, and gases such as oxygen (O_2), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and ammonia (NH_3), exceeding environmental quality standards. Lamtoro leaves contain 3.84% nitrogen, 0.2% phosphorus, 2.06% potassium, 24.7% protein, and 53.71% carbohydrates, making them a promising additive to enhance LOF's NPK and carbon content. This study employed a quasi-experimental design using a pre-post and control group format. Data were statistically analyzed using the Kruskal-Wallis test. The statistical analysis showed that the addition of lamtoro leaves significantly increased the levels of nitrogen (α = 0.049), potassium (α = 0.044), and carbon (α = 0.019). At the same time, the change in phosphorus content was not statistically significant (α = 0.136). These findings indicate that incorporating lamtoro leaves improves soil nutrients and provides natural plant nutrition, enhancing soil quality and carrying capacity, contributing to ecosystem protection, environmental pollution prevention, and public health improvement.

1. INTRODUCTION

1.1 Background

Tofu waste comes from the waste or residue of processing soybeans into tofu, which is wasted into the environment as a pollutant. Tofu waste consists of two types, namely liquid waste and solid waste. Liquid waste is the largest part that has the potential to pollute the environment (Suhairin et al., 2020). Disposing of liquid waste from tofu factories that continues to flow into the river is a serious problem because it significantly impacts water quality. These impacts include discoloration and increased water quality parameters, which can damage ecosystems and endanger public health. This waste disrupts the biological, chemical and physical balance of water, which in turn affects the survival of aquatic organisms and the people who depend on these water resources (Nasrul et al., 2024).

Most tofu factories in the Kepahiang area of Bengkulu Province do not treat their liquid waste. They are directly discharged into the river so that they can pollute the aquatic environment (My, 2023). The impact of environmental pollution by the presence of tofu waste in waters can affect the physical, chemical and biological properties of water, so that it disrupts the activities of aquatic biota that live in it. Tofu waste contains C-organic materials that affect biological oxygen demand (BOD) and chemical oxygen demand (COD) levels. Tofu factory waste also contains gases such as oxygen (O_2), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and ammonia (NH_3), with high levels, exceeding environmental quality standards (Pagoray et al., 2021). High levels of BOD and COD in waters are important indicators of water pollution, resulting in decreased oxygen. Microorganisms in the water cannot decompose existing waste, which can reduce water quality. Other impacts include changes in the environment (Atima, 2015).

Tofu industry liquid waste can be reprocessed or recycled into liquid organic fertilizer, because it still contains 40–60% protein, 25–50% carbohydrates, and 10% fat. The nutrients in the tofu waste and the tofu liquid waste can be used as liquid organic fertilizer for agricultural cultivation (Hikmah, 2016).

Tofu liquid waste has the potential to be used as organic fertilizer because it contains macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and organic carbon (C-Organic). A fermentation process involving microorganisms can be used to optimize its utilization (Widari et al., 2020).

Research conducted by Dai et al. (2023) showed that soybean wastewater serves as a nitrogen source to replace urea on soil NH_3 volatilization, dissolved organic matter components, and cherry tomato quality. Soybean wastewater as a liquid organic fertilizer reduced soil NH_3 volatilization by 18.65–25.27% and fertilization costs by 25.94–51.87% compared to fertilization using 100% urea. This research provides a promising option with economic and environmental benefits for soybean effluent utilization and cherry tomato production, contributing to the effectiveness of mutually beneficial sustainable production for the soybean products industry and agriculture.

Long-term use of organic fertilizers increases land productivity and can prevent land degradation. The provision of organic fertilizers in various forms began to be produced on a household and industrial scale (Warintan et al., 2021). Liquid organic fertilizer can provide nutrients that match the needs of plants in the soil because of its liquid form. So if there is excess fertilizer capacity in the soil, the plants will easily regulate the absorption of the required fertilizer composition. Liquid organic fertilizer in fertilization is more evenly distributed; there will be no accumulation of fertilizer concentration in one place. This is because liquid organic fertilizer is 100% soluble (Marjenah et al., 2018).

Utilization of tofu liquid waste for making liquid organic fertilizer (POC) by adding lamtoro leaves. Lamtoro leaves contain 3.84% N, 0.2% P, 2.06% K, 24.7% protein and 53.71% carbohydrates (Tanti, 2019). Adding lamtoro leaves to the tofu waste is expected to increase the liquid organic fertilizer's nitrogen, phosphate, potassium, and carbon content. Based on research by Hasan et al. (2021), lamtoro leaf liquid organic fertilizer (POC) generally significantly affects plant height growth, the number of leaves and plant production. Lamtoro leaf POC with a concentration of 30% increases plant production.

1.2 Research Objective

This study's purpose was to determine the effect of adding lamtoro leaf extract (Leucena leucocephala) on NPK and C nutrients in tofu liquid waste's POC (liquid organic fertilizer).

2. METHODS

2.1 Tools and Materials

The tools used in this research include 24 10-liter plastic jars, 4 15-liter buckets, filters, cutting boards, knives, blenders, scales, and 1000 ml measuring cups. The main ingredients in this study were 120 liters of tofu liquid waste, 27 kg of lamtoro leaves, and microorganism inoculant (EM4).

2.2 Research Procedure

This type of research is a quasi-experiment with a pre-post and control group design. This research method was chosen because establishing a fixed source of waste is difficult, and controlling all external variables is limited. With a pre-test and post-test or control group design, this method allows measuring the effectiveness of the liquid waste utilization process, for example, in the manufacture of liquid organic fertilizer (POC) or the waste treatment process using microorganisms.

Table 1. Research design

Pre test	Treatment	*Post test*
O1	X1	O′1
O2	X2	O′2
O3	X3	O′3
OK	-	O′K

Description:
O1, O2, O3, and OK are the results of pre-test measurements of N, P, K, and C levels of tofu waste.
X1, X2, and X3 are the treatments for adding 1 kg, 1.5 kg, and 2 kg of lamtoro leaves, respectively.
O'1, O'2, O'3, and O'K are the results of post-test measurements of N, P, K, and C levels of tofu waste after treatment.

The population in this study was all the tofu liquid waste in the West Ring of Bengkulu. The sample in this study was 120 L with repetition calculated based on the formula (t-1) (r-1) ≥ 15 ", t is the number of treatments and r is the number of repetitions, where t = 4 and r = 3, so that the repetition was obtained 6 times with a fermentation time of 21 days. Each tofu wastewater was added with EM4 as much as 100 mL, stirred until evenly distributed, and the pH and temperature were checked daily.

This research was conducted from April 22 to May 22, 2024, in the Workshop room of the Environmental Health Department of the Poltekkes Kemenkes Bengkulu.

Data analysis in this study was univariate and bivariate. Univariate analysis involved describing the characteristics of each research variable, while bivariate analysis used the Kruskal-Wallis Test with a confidence level of 0.05 (α = 0.05). The Kruskal-Wallis test was chosen over other statistical tests because it does not require normality assumptions, can be used for ordinal scales, is more flexible for many groups, and is more suitable for data that is not homogeneous or has a small sample size.

3. RESULTS AND DISCUSSION

3.1 Result

Processing of tofu liquid waste as an ingredient for making POC with the addition of lamtoro for the parameters of nitrogen, phosphate, potassium, and carbon with the average of each parameter as follows: nitrogen is greatest in the addition of 2 kg lamtoro with a result of 1.11%; phosphate is greatest in the addition of 1 kg and 1.5 kg lamtoro with a result of 1.45%; potassium is greatest in the addition of 1 kg lamtoro with a result of 3.84%; carbon is greatest in the addition of 2 kg lamtoro with a result of 4.27% (in full in Table 2).

Table 2. Average results of POC parameter examination on the addition of lamtoro leaf variations in tofu liquid waste

Lamtoro Variation	Parameters			
	Nitrogen	Phosphate	Potassium	Carbon
0	0.73	1.02	0.64	2.11
1 Kg	0.91	1.45	3.84	3.70
1.5 kg	0.90	1.45	0.97	3.20
2 kg	1.11	0.29	1.02	4.27

Statistical test results show that there is an effect of lamtoro leaf addition on increasing the value of N (α=0.049), K (α=0.044) and C (α=0.019); while for the element P (α=0.136), there is no effect (in full in Table 3). The increase in N, K, and C elements may be due to the different weights of lamtoro leaves added to the tofu wastewater.

Table 3 Kruskal-Wallis statistical test results of N, P, K and C parameters with lamtoro leaf variations 1 kg, 1.5 kg, and 2 kg of tofu liquid waste POC

Test Statistics[a,b]				
	Value N	Value P	Value K	Value C
Chi-Square	7.840	5.538	8.087	9.963
df	3	3	3	3
Asymp. sig.	.049	.136	.044	.019

a. Kruskal Wallis Test

b. Grouping Variable: Lamtoro leaf variation

Figure 1 shows in full that the highest N content in experiment X1 was 0.935, the highest P content in experiment X2 was 1.453, the highest K content in experiment X1 was 3.84 and the C content in experiment X3 was 4.271.

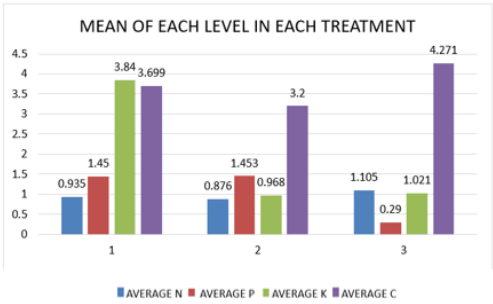

Figure 1. Mean of each treatment level

3.2 Discussion

Liquid waste is the largest part and has the potential to pollute the environment. Pollution of tofu factory waste in the environment damages environmental quality, especially waters, as it affects one of mankind's needs of mankind, ecosystems and human health problems. Tofu waste contains hazardous and toxic materials when discharged into the environment continuously. Factors that cause liquid waste management to not run properly in accordance with Law number 32 of 2009 are ignorance factors from the entrepreneurs themselves, education level factors, economic factors of entrepreneurs, government participation and law enforcement, community role factors and the role of the community in managing the environment.

Tofu waste contains C-organic materials that affect biological oxygen demand (BOD) and chemical oxygen demand (COD) levels. Tofu factory effluents also contain gases such as oxygen (O_2), hydrogen sulfide (H_2S), carbon dioxide (CO_2), and ammonia (NH_3), with high levels, exceeding environmental quality standards (Pagoray et al., 2021). High levels of BOD and COD in waters are important indicators of water pollution, resulting in decreased oxygen. Microorganisms in the waters cannot decompose existing waste, which can reduce water quality. Other impacts that occur include changes in the environmental ecosystem. High levels of BOD and COD in waters also indicate the presence of nutrients from tofu waste. This situation can cause an algae bloom or an explosion of algae growth in the waters, resulting in siltation of the river and inhibiting oxygen circulation (Atima, 2015).

Applying POC to the soil increases the nutrients needed for plant growth and production. Liquid organic fertilizer (POC) is useful for making plants grow lush because it

encourages the formation of chlorophyll substances in leaves and the formation of root nodules for legumes. In addition, liquid organic fertilizer is also rich in potassium, which is needed for plant survival (Claudia, 2022). Nutrients for growth include plant height, number of leaves, and greater fruit production. Plant growth and production are maximized by the presence of N, P, K, and C elements in POC (Mustadir et al., 2023). The standard for measuring POC parameters is by the Decree of the Minister of Agriculture Number 261 / KPTS / SR.310 / 4/2019 concerning Minimum Technical Requirements for Organic Fertilizers, Biofertilizers, and Soil Improvers for a minimum nitrogen parameter of 0.5%; phosphate 2–6%; potassium 2–6%; carbon 10%). Based on the research results of processing tofu liquid waste with the addition of lamtoro leaves, the parameters that qualify as liquid organic fertilizer are nitrogen, phosphate and potassium elements. In contrast, those that do not qualify are carbon.

This condition is made possible by the presence of nutrients in tofu waste, among others: N = 1.24%, P_2O_5 = 5.54%, K_2O = 1.34% and C-organic = 5.803% which are essential nutrients needed by plants, which can affect the concentration of phosphorus, nitrogen, and sulfur in water (Marian & Tahuteru, 2019). Lamtoro leaves are one of the legume plants containing nutrients of 3.84% nitrogen, 0.2% phosphorus, 2.06% potassium, 1.31% Ca and 0.33% Mg. All nutrients contained are essential for plants' growth and development. As a liquid organic fertilizer material, lamtoro leaves contain relatively high nitrogen and are also relatively easier to compost, so that the provision of nutrients is faster (Stefanie & Wally, 2022).

The results of another study on the effect of the fermentation time of tofu liquid waste, POC, and lamtoro leaves with the addition of EM4 bioactivator on total phosphorus and potassium content showed that variations in fermentation time did not significantly increase phosphorus content. This indicates that the addition of lamtoro leaves and variations in fermentation time are not sufficient to significantly increase phosphorus levels in POC (Purba, 2019).

Nitrogen (N) is the main nutrient for plant growth. Nitrogen makes up many important molecules, including proteins, nucleic acids, hormones and chlorophyll. Nitrogen deficiency causes stunted plant growth and chlorosis on the leaves. The nutrient element K in plants has a small role as a constituent of plant components, but also functions in regulating mechanisms such as photosynthesis, carbohydrate translocation and protein synthesis. In contrast, the nutrient element phosphorus (P) is a constituent of several proteins, coenzymes, nucleic acids and metabolic substrates (Mastur et al., 2015).

Using POC can increase the potassium (K) element in plants, affecting plant height growth, number of leaves, plant dry weight and rooting. Potassium elements in the soil also affect the composition and circulation of carbohydrates in plants, accelerate the absorption process of nitrogen elements in plants, prevent the shedding of flowers and fruits, help the absorption of water and nutrients from the soil by plants, help the passage of assimilation products from leaves to plant tissues, increase starch production, physiological processes in plants, increase plant resistance to disease and improve fruit quality (Rahma et al., 2019).

Soil microorganisms need carbon nutrients in POC as a food source. C-organic elements in the soil increase microorganism activity and accelerate soil decomposition and the reaction of organic matter. Low levels of C-organic elements in the soil impact poor plant growth. Improving soil quality requires C-organic elements obtained from POC (Sari et al., 2023).

Processing tofu liquid waste with lamtoro leaves to prevent environmental pollution and provide benefits in the provision of liquid organic fertilizer (POC). The benefits of POC in the agricultural system are nutrients needed by plants and an increase in the source of soil organic matter (Cahyani et al., 2021). However, the application of liquid organic fertilizer Lamtoro leaf (*Leucaena leucocephala*) on sugarcane seedlings (*Saccharum officinarum L.*) variety VMC does not affect all parameters (Suprayogi & Salim, 2024).

The advantages of tofu liquid waste POC with the addition of lamtoro leaves increase nutrients in the soil so as to prevent nutrient diffusion and accelerate the addition of soil nutrients. The function of POC is to improve the carrying capacity of the soil and prevent environmental pollution by tofu liquid waste (Arifan et al., 2022).

POC can be interpreted as a fertilizer made naturally through a fermentation process to produce a solution of decay products from plant residues and animal or human waste. The use of POC is better because it is environmentally friendly, does not use chemicals/synthetic materials and has a good impact on health. The use of POC is more beneficial for the ecosystem and the environment in order to fulfill plant nutrients naturally. Making POC using liquid waste is also one way to reduce waste in the environment, so that the environment is free from waste that pollutes it.

A study of wastewater from a tofu factory on Jalan Sultan Serdang, Tanjung Morawa Subdistrict, showed both positive and negative impacts. Tofu solid waste provides benefits as it can be sold to cattle farmers as animal feed, contributing to an increase in the income of tofu business owners. However, liquid waste causes water pollution. The waste is dumped directly into the area of large trees before eventually flowing into the river, potentially causing unpleasant odors if not managed properly. In addition, the lack of adequate use of personal protective equipment (PPE) can also increase the risk of disease for workers (Muharrahmi et al., 2023).

4. CONCLUSION

Variations in the addition of lamtoro leaves affect the content of nitrogen (N), potassium (K), and organic carbon (C) elements in liquid organic fertilizer (POC) produced from tofu liquid waste. However, the addition of lamtoro leaves did not significantly affect the phosphorus (P) content in the POC. Overall, treating tofu liquid waste with the addition of lamtoro leaves not only contributes to reducing environmental pollution but also provides benefits to the agricultural sector by increasing the nutrient content in the soil. Therefore, this method can be a sustainable alternative in managing tofu industry waste while supporting environmentally friendly agriculture.

Recommendations that can be given for further research and practical applications, namely by conducting further research on the effect of dosage and fermentation method of lamtoro leaves in POC of tofu liquid waste to optimize the increase in nutrients, especially phosphorus (P), and encouraging the tofu industry to apply liquid waste treatment with this method to reduce environmental pollution and produce useful products. This implementation is expected to increase the effectiveness of tofu wastewater utilization as a liquid organic fertilizer and minimize its negative environmental impact.

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