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Training on making Liquid Organic Fertilizer from tofu whey waste to reduce environmental pollution

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ABSTRACT

The utilization of tofu whey waste is crucial due to its environmental impact and the lack of proper waste management by tofu and tempeh producers in Tengaran, Salatiga. Currently, liquid waste is still discharged into nearby water bodies, affecting both the environment and surrounding agricultural areas. These areas are dominated by rice fields where farmers heavily rely on chemical fertilizers such as Urea and Ponska. This community service program aims to convert tofu and tempeh liquid waste into liquid organic fertilizer (LOF) to reduce chemical fertilizer usage and minimize environmental pollution. The implementation involved training and mentoring members of the Barukan Farmer Group (Poktan Barukan) in LOF production through simple biotechnological methods. The initiative led to several key outcomes: the independent availability of LOF, improved agricultural practices, and enhanced farmer group management. The LOF has proven effective as a bioremediation agent, promoting healthier rice growth characterized by vigorous plants, greener leaves, and earlier panicle development. Additionally, the LOF has commercial potential and can be scaled up for broader use. Around 80% of farmers showed active participation and a strong commitment to continuing LOF use, supporting a more sustainable farming system and contributing to the local green economy.

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1. INTRODUCTION

Barukan Village, located in Tengaran District, Semarang Regency, shares a border with the City of Salatiga. The village is predominantly agricultural, with vast rice fields that have earned it the reputation of being an "Agricultural Village." Most residents work as farmers, cultivating their own land. The Rukun Santoso Tani Farmers' Group consists of 70 members, 11 of whom are actively engaged in farming. They primarily cultivate *Oryza sativa* var. Inpari 32 on approximately 32,050 m^2 of land, producing around 3.3 tons of dry harvested grain per season and generating about IDR 20,000,000 in revenue.

During a meeting with the head of the Farmers' Group on Saturday, March 10, 2024, concerns were raised regarding the long-term use of chemical fertilizers. Farmers have been seeking organic

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alternatives to improve soil quality but have yet to identify a viable solution. Meanwhile, the utilization of tofu whey waste has become a pressing issue for tofu producers, local communities, and the surrounding environment. In Tengaran, Salatiga, many tofu and tempeh producers still dispose of their whey waste into nearby water bodies due to the lack of proper waste management facilities and technologies.

The surrounding rice fields are largely dependent on chemical fertilizers such as Ponska and Urea. A standard fertilization method includes applying 250 kg/ha of SP-36 one day before planting, followed by 150 kg each of Urea and Ponska per hectare 14 days after planting, and another 150 kg of each 45 days later. Prolonged use of chemical fertilizers without organic supplementation leads to nutrient imbalances, soil structure degradation, and a decline in beneficial microbial populations. Organic fertilizers are not merely supplements but are essential for maintaining sustainable soil health and crop productivity (Amalia, et al., 2022; Taha et al., 2020; Bintari et al., 2024). Additionally, the difficulty in accessing chemical fertilizers has driven farmers to seek self-reliant organic solutions and reduce dependence on synthetic inputs. Effective production management is key to achieving sustainable industrial innovation and infrastructure. Integrating organic fertilizers into farming practices ensures ongoing agricultural productivity while preserving environmental sustainability.

The combination of organic and inorganic fertilizers is necessary for effective rice cultivation. On a broader scale, this program fosters a green economy within farming communities by utilizing soybean-based industrial waste—particularly from tofu and tempeh production in Tengaran District, Salatiga Regency. Despite the abundance of small and medium-sized soybean processing enterprises (MSMEs) in Indonesia, most artisans have not prioritized sustainable liquid waste management. Currently, whey and soybean soaking water are often discarded into drains and nearby water channels.

This is unfortunate, as such waste materials are rich in organic compounds like carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), and phosphorus (P). Proteins in the waste can be broken down through microbial fermentation to produce liquid organic fertilizer (LOF) (Roidah, 2013; Sajar, 2023; Yoseva et al., 2023). Introducing LOF to farmer groups is expected to cultivate a unique social ecosystem that supports food security and, in the long term, strengthens the local green economy (Herdiyanto & Setiawan, 2015; Kementerian Pertanian, 2019).

Wider adoption of LOF promotes household-level self-sufficiency and environmental stewardship. This initiative seeks to improve community welfare by empowering farmers to produce organic fertilizer from soybean processing waste, complemented by other enriching materials. The biotransformation of this wastewater into biofertilizer is vital due to its high content of organic compounds, making it ideal for the proliferation of beneficial microbes. Moreover, the production of LOF offers a promising business opportunity for farmer groups and local communities.

The management of tofu and tempeh industry wastewater should involve not only producers but also the broader community, farmer organizations, academics, and relevant institutions. Until now, such wastewater has not been managed professionally. Converting this waste into LOF through spontaneous fermentation technology offers a sustainable, profitable solution aligned with green economy principles.

This program aims to empower rural farming communities by introducing sustainable organic fertilizer production using tofu and tempeh wastewater, thereby enhancing agricultural productivity, reducing environmental pollution, and promoting a circular green economy at the local level.

2. METHODS

This activity method is carried out in five stages. This method can provide solutions to partner problems related to increasing agricultural productivity and reducing environmental pollution. These stages include those in Figure 1.

Figure 1. Problem solving solution framework

Visits and Socialization to Activity Locations

The agricultural fields of Desa Barukan, Tengaran, Kabupaten Semarang, served as the primary location for discussions with the head of the farmer group. During the visit, direct observations and conversations were conducted to understand the challenges faced by farmers in rice cultivation and their perspectives on agricultural land conservation as part of initiating a green economy concept.

Additionally, a visit was made to a local tofu/tempeh small business, specifically the Pabrik Tahu Kuring in Desa Bener, Tengaran, Semarang Regency. A community outreach program was conducted to align the vision regarding the benefits of utilizing tofu/tempeh production waste as raw material for liquid organic fertilizer (liquid organic fertilizer) while promoting soil conservation in agricultural areas.

Focus Group Discussion

The program began with a discussion and information-sharing session covering the following topics: (a) Building sustainable agriculture and synergy. (b) The concept of green inflation for environmental sustainability. (c) Perceptions of liquid organic fertilizer based on soybean processing waste. The session also included discussions on the benefits and application methods of combining organic and inorganic fertilizers in rice fields. Three experts from the community service program team served as speakers. The discussion was followed by a hands-on training session.

Training

The training consisted of the production of liquid organic fertilizer (LOF) or *Pupuk Organik Cair (POC)* and its application technology in paddy fields. The regulation of organic fertilizer application, specifically liquid fertilizers, alongside chemical/inorganic fertilizers, was designed with reference to the concept of Green Inflation to ensure a smoother impact on both the environment and the economy.

Green inflation refers to changes in the prices of goods and services driven by environmental factors, particularly in the context of sustainable economic drivers. This concept was introduced as an essential discourse for the community service participants, emphasizing the importance of combining chemical fertilizers with liquid organic fertilizers for the continuous cultivation of rice crops.

Assistance and Evaluation

The assistance was provided to ensure the proper and accurate application of chemical fertilizers alongside liquid organic fertilizers. This support was given during the early vegetative growth phase of rice plants in the demonstration plot and during the final stage of the vegetative phase. Additionally, an evaluation was conducted to assess the feasibility of liquid organic fertilizer as a complementary supplement to chemical fertilizers such as Urea and Ponska.

Program Sustainability

The continuation of the program is a necessity, as the green economy initiative cannot be a one-time effort; it requires ongoing and extensive implementation. Therefore, this program includes periodic

visits from the community service team until the harvest period in mid-November 2024. Subsequently, the results of the monitoring and evaluation will be discussed with agricultural extension officers, the farmer group, and the community service team.

Table 1. Training activity meeting schedule

Meeting 1	
Activities	- Meet the Head of the Farmer Group and see and hear up close the problems of farmers in rice cultivation and their views on agricultural land conservation to initiate the concept of a green economy
Objectives	- To determine the time of activities and compile a rundown during the service
Meeting 2	
Activities	- Discussion of information on Building Sustainable Agriculture and Synergy, the Concept of Green Inflation on a micro scale for sustainable rice fields, and Perceptions on Liquid Organic Fertilizer based on Soybean Processed Waste
Objectives	- To align perceptions on the implementation of organic fertilizer use - To prepare a plan for making liquid organic fertilizer by members of the farmer group
Meeting 3	
Activities	- Training in making liquid organic fertilizer and its application technology in rice fields
Objectives	- Providing skills in making liquid organic fertilizer to members of the Barukan farmer group
Meeting 4	
Activities	- Advanced training on making liquid organic fertilizer and its application technology in rice fields
Objectives	- To provide information on the technique of applying liquid organic fertilizer to rice plants and others.
Meeting 5	
Activities	- Assistance in the application of liquid organic fertilizers that are carried out correctly and precisely. - Assistance during the initial growth of the vegetative phase of rice plants in demonstration plot rice fields.
Objectives	- To determine the time for administering organic fertilizers (liquid organic fertilizer) and chemical fertilizers on rice fields that receive combined fertilizers - To determine the time for administering organic fertilizers (liquid organic fertilizer) on land that is only given organic fertilizer
Meeting 6	
Activities	- Liquid organic fertilizer application activities - Assistance during the final application of the vegetative phase - Evaluation of the feasibility of liquid organic fertilizer to accompany the application of chemical fertilizers, namely urea and ponska.
Objectives	- Provide liquid organic fertilizer according to the schedule given by the head of the farmer group (done every 2 weeks)

3. RESULTS AND DISCUSSION

The primary growth medium materials used include soybean processing waste from the coagulation process known as whey, dried eggshells, and dried banana peels. Additional carbon sources

are obtained from molasses, while microbial diversity balance is maintained using the EM4 starter (Azis et al., 2018; Laohavisuti et al., 2021). The first set of materials consists of eggshells, molasses, and water, as specified in Figure 2.

Figure 2. Material preparation activities

The primary equipment used as a fermentor includes used mineral water gallons, a stirrer, a bucket, a funnel, a measuring jug, a scale, a filter cloth, and pH paper. The spontaneous fermentation process is carried out by shaking the gallon and periodically opening its cap to release gas, then sealing it again. At the beginning of fermentation, the pH of the liquid organic fertilizer suspension is measured as an indicator of its acidity level.

Figure 3. Tool preparation activities

The activities in Figure 4 sequentially include: the preparation of drying banana peels, which were previously sliced thinly until they darken in color; the mixing of liquid organic fertilizerT (egg) and liquid organic fertilizerP (banana), which are then inoculated into liquid organic fertilizerLOG (soybean processing waste) with the addition of whey wastewater up to 16 liters. This process can be observed in Figure 5.

Figure 4. Material processing activities

Figure 5. Results of material processing and product finishing/product result

The innovative product produced, known as liquid organic fertilizer LOK (Soybean Processing Waste), is a mixture of liquid organic fertilizerT and liquid organic fertilizerK with a volume of 4 liters. A 6% EM4 starter is then added, followed by whey water until the final volume reaches 16 liters in the gallon fermenter. The product will initially appear brown, and after undergoing fermentation for 21 days, it will be considered mature when it reaches a pH of around 6.0. Maturity is also indicated by the presence of a white layer, a characteristic alcoholic aroma typical of organic fertilizer, and a liquid, lightweight texture. Liquid organic fertilizer products made by farmer groups are labeled or given white background stickers with a picture of a farmer holding rice with a rice field background with the words "*Kelompok Tani Desa Barukan Rukun Santoso Tani, Kec. Tengaran Kab. Dati II Semarang*".

The key issue is ensuring that liquid whey waste from tofu production consistently transforms into liquid organic fertilizer (LOF) and serves as an alternative to reducing chemical fertilizer use among farming communities. Until now, liquid organic fertilizer derived from soybean processing waste (whey) has not been widely promoted, trained, or applied to rice cultivation in paddy fields.

Utilizing tofu whey waste with additional enrichment materials such as dried banana peels and crushed eggshells to create liquid organic fertilizer provides additional nutrients for plants during the vegetative phase. The implementation of this organic fertilizer on rice fields in the Barukan Farmers Group has shown promising results. Rice plants treated with a combination of chemical fertilizers (urea and Ponska) and liquid organic fertilizer exhibited a trend of being greener, taller, and producing more tillers, with a longer root profile compared to those treated with chemical fertilizers alone.

The training and mentoring activities for producing liquid organic fertilizer (LOF) using the primary ingredient of liquid tofu waste from the coagulation stage (whey) were conducted effectively and successfully. Operationally, the members of the Rukun Santoso Tani farmers group participated actively

in the sessions, which employed discussion, Q&A, and knowledge-sharing methods in a conducive learning environment. A total of 10 farmers took part in the training and will serve as peer tutors for other group members in the future.

Figure 7. Active participants as a supporting factor in activities

Several key questions emerged during the discussions, particularly regarding the cost of production (HPP) of LOF and whether it would help reduce production expenses compared to conventional chemical fertilizers like NPK and Ponska. The current community engagement program has resulted in 10 trained individuals who fully understand LOF production, in line with the granted copyright No. EC00202476438. Each participant successfully produced two gallons of ready-to-use liquid organic fertilizer.

One key takeaway from this initiative is the positive attitude of the farmers' group, reinforced by the program, toward understanding the role of LOF as a complement to chemical fertilizers. The farmers hope that using liquid organic fertilizer will allow them to reduce their reliance on chemical fertilizers. During the discussions, some participants also expressed their intention to use LOF for home gardening, particularly for growing vegetables and fruits. For the continued use of LOF within the farmers' community, participants committed to independently producing the fertilizer using household waste such as banana peels and eggshells, along with the main ingredient—liquid soybean waste—sourced from local tofu-making small businesses in the Tengaran area.

Table 2. Implementation of liquid organic fertilizer in rice planting in the Barukan area

Activities	Plant age	Day	Time
Inpari 32 Variety	-	-	-
Spread Seeds	-	Tuesday	July 23, 2024
Land Watering (liquid organic fertilizer)	-	Friday	August 9, 2024
Planting	-	Monday	August 12, 2024
Land Spraying (liquid organic fertilizer) I	14	Monday	August 26, 2024
Land Spraying (liquid organic fertilizer) II	28	Monday	September 9, 2024
Land Spraying (liquid organic fertilizer) III	42	Monday	September 23, 2024
Land Spraying (liquid organic fertilizer) IV	56	Monday	October 7, 2024

The implementation of liquid organic fertilizer on new farmers' rice fields is carried out using the following procedures in Table 2. Rice cultivation with liquid organic fertilizer (LOF) with the application pattern of 1) pouring, 2) planting rice, and application of LOF by spraying during the 14th, 28th, 42nd and 56th days after planting, each treatment 3 L (2 tanks)/ha.

Discussion

In this community service activity, farmers' skills were produced in making liquid organic fertilizer, a biofertilizer product from soybean processing waste which has the characteristic of a dark brown liquid fertilizer made by members of the Barukan Farmer group. This has also been done by Amalia et al. (2022), Aranda et al. (2023), and Pariyanto et al. (2023), where the fertilizer products produced have different compositions, as biofertilizers successfully applied to vegetable plants. The enthusiasm of farmers is very great in making and using LOF results to fertilize their rice plants. This includes the materials used, namely banana peels and eggshells, which are available and easy to obtain. On the other hand, farmers can prepare raw materials, manage them scientifically and mix banana peels and eggshells into LOF (Figure 5). The technology applied to produce this LOF is very easy and can be disseminated to farmer groups on a large scale. The use of eggshells has been familiar as a fertilizer ingredient, this has been reported by Taha et al. (2022), Marlina et al. (2023), and Utami & Singkam (2023).

Rice planting using two rice fields each with an area of 376 m2 for land with mixed fertilizers, namely LOF and chemical fertilizers, in the tiling test area of 2.5 m2 showed a dry harvest yield of 7.97 kg, dry milling 6.76 kg and rice yield of 4.7 kg. Furthermore, for the implementation of LOF alone on an area of 423 m2, with a tiling test showing a yield of 5.68 kg of dry harvested rice, 5.02 kg of dry milling and 3.6 kg of rice. In the protein test, it turned out that the rice cultivated with a mixture of chemical fertilizers and LOF was up to 10%, while for organic fertilizers alone it showed a figure of 8%. This is relevant to what has been produced from the research of Herdiyanto & Setiawan (2015) that with the addition or combination of organic fertilizers there is an element of improving nutrient absorption by the help of microbes. The results of community service have currently produced 10 people who are ready and understand the manufacture of LOF in accordance with the Copyright that has been granted with No. EC00202476438, with 2 gallons of ready-to-use LOF each. What can be taken from this activity is the positive attitude of the farmer group through the habits of the farmer group leader which is strengthened by community service activities is an understanding of the role of liquid organic fertilizer as a balancer for the use of chemical fertilizers. Farmers hope that the use of liquid organic fertilizer can reduce the amount of chemical fertilizers that have been used in full. In the discussion and Q&A during the training on making liquid organic fertilizer, it was stated that farmers would also use this liquid organic fertilizer for household plants, namely vegetables and fruits. For the sustainability of liquid organic fertilizer in the farmer group environment, farmers are willing to make their own by managing kitchen waste, namely banana peels, egg shells and the main ingredient, namely liquid waste from processed soybeans obtained from tofu-making SMEs in the Tengaran area. The sustainability of rice LOF production depends on the presence of related agencies and academics, especially in the provision of liquid organic fertilizers, because fertilizers have become a necessity, improper application of fertilizers can cause soil degradation. One way that can be done to restore fertility to degraded soil is to provide additional nutrients in the form of organic fertilizers (Roidah, 2013; Rahmawati, et al. 2021; Ramlan & Masrianih, 2022). Meanwhile, processed soybean waste, egg shells and banana peels can be collected from fried rice traders and fried banana sellers. It is hoped that these organic and biological fertilizers can provide sufficient nutrients in land that has long used chemical fertilizers according to the direction of the Minister of Agriculture of the Republic of Indonesia Number 261/KPTS/SR.310/M/4/2019.

4. CONCLUSION AND RECOMMENDATIONS

The conclusion of the community-based service activity on the innovation of making liquid organic fertilizer (LOF) from soybean processing waste for farmer groups in Kec. Barukan has had a positive

impact on the management and skills of farmers in providing liquid organic fertilizer as a supplement to chemical fertilizers. Furthermore, the rice profile up to 58 days showed relatively better morphological characteristics compared to those using full chemical fertilizers. The aspect of sustainable development will be observed until the rice reaches 110 days of age at mid-November.

One key takeaway from this activity is the positive attitude of the farmer group, reinforced by the community service program, in understanding the role of liquid organic fertilizer as a balancing agent for chemical fertilizers. Farmers hope that the use of liquid organic fertilizer can reduce the amount of chemical fertilizers that have been used entirely.

During the discussion and Q&A session in the liquid organic fertilizer production training, farmers expressed interest in using this fertilizer for household plants, such as vegetables and fruits. To ensure the continuity of liquid organic fertilizer in the farmer group environment, farmers are willing to produce it themselves by managing kitchen waste, including banana peels, eggshells, and the main ingredient, soybean processing liquid waste obtained from tofu production SMEs in the Tengaran area.

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