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Utilization of Biogas Energy for Pasteurization in Sembalun Mushroom Initiative

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Abstract: The Sembalun Mushroom Initiative aims to strengthen food security and resilience to disasters in Sembalun Bumbung and circumstance villages through the utilization of biogas energy for the pasteurization process of mushrooms. These areas are prone to disasters, making the supply of food and sustainable energy a major challenge. The project utilizes cow dung waste as an environmentally friendly biogas source to support pasteurization and mushroom cultivation. Traditionally, mushroom pasteurization processes still use firewood, which triggers deforestation, high carbon emissions, and health risks from smoke. The community service team from the University of Mataram has developed biogas technology as an alternative solution. The biogas installation at the At-Tazkiyah Islamic Boarding School was completed in May 2024 and began operating in July 2024, thereafter a mushroom house has been built for mushroom cultivation in early 2025. During this community service project, a gas pasteurization system is installed and used for pasteurization, followed by training and capacity building for the community in utilizing green energy sources. The aim is to introduce a transition to environmentally friendly technologies, as well as to support innovation, sustainability, and community engagement. The activities are an international collaboration between the Postgraduate Program and the Faculty of Engineering at University of Mataram and the Fatoni University in Thailand. It is expected to expand Unram's international exposure and strengthen cooperation between countries.

Keywords: Mushrooms, Biogas, Pasteurization, Disaster Resilience, Sembalun.

Introduction

The Sembalun Mushroom Initiative aims to address critical issues of food security and disaster resilience in Sembalun Bumbung Village through the innovative use of biogas energy for pasteurization. **Figure 1** shows the location of Sembalun Bumbung village. Located in a region prone to natural disasters, the community of Sembalun Bumbung faces significant challenges in maintaining a stable food supply and sustainable energy sources. This community service project seeks to leverage the potential of biogas energy, derived from cow dung, to support the cultivation and pasteurization of mushrooms, thereby enhancing local food security and promoting green energy solutions.

In the villages of Lombok Island, nestled at the foot of Mount Rinjani, mushroom cultivation has been a longstanding tradition. For generations, the villagers have relied on the rich, fertile soil and favorable climate to grow a variety of mushrooms, which have become a staple in their diet and a source of income. However, the traditional method of pasteurizing mushrooms has posed significant challenges to both the environment and the community's health.

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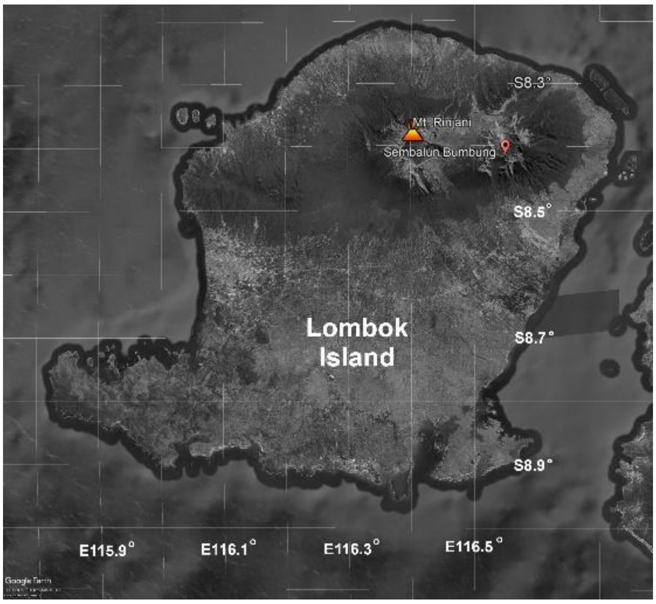

Figure 1. Map of Lombok Island, showing location of Sembalun Bumbung, nestled at the foot of Mount Rinjani.

The process of pasteurization, essential for ensuring the mushrooms are free from harmful pathogens, has traditionally been carried out using firewood. Large quantities of wood are gathered from the surrounding forests, and the mushrooms are subjected to intense heat for several hours. While effective in pasteurizing the mushrooms, this method has several detrimental effects.

Firstly, reliance on firewood has led to deforestation, threatening the delicate ecosystem of the region. The continuous harvesting of wood has resulted in the loss of trees, which play a crucial role in maintaining soil stability, regulating water cycles, and providing habitat for wildlife. As the forests shrink, the risk of landslides and soil erosion increases, endangering the very land that supports the villagers' livelihoods.

Secondly, the use of firewood for pasteurization generates significant carbon emissions. The burning of wood releases carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change. The smoke produced during the process also poses health risks to the villagers, particularly those involved in the pasteurization process. Prolonged exposure to smoke can lead to respiratory problems and other health issues.

Recognizing these challenges, the community service team from Postgraduate Program and Engineering Faculty of University of Mataram has begun exploring alternative methods to make mushroom cultivation more sustainable. One promising solution is the use of biogas technology. By converting cow dung and organic waste into biogas, the villagers can generate a renewable and clean energy source for pasteurization. This not only reduces their reliance on firewood but also helps manage waste and lower carbon emissions.

The transition to biogas technology represents a significant step towards a more sustainable and environmentally friendly approach to mushroom cultivation. It offers the promise of preserving the natural beauty of Sembalun Bumbung while ensuring the health and well-being of its residents. As the community embraces this new technology, they are paving the way for a greener and more resilient future.

Utilizing biogas energy for pasteurization is an efficient and environmentally friendly solution. Biogas, produced from the fermentation of organic materials such as cow dung and agricultural waste, can be used as an energy source to heat water or steam required in the pasteurization process.

Here are some benefits of using biogas for mushroom pasteurization:

1. Reduction of Carbon Emissions: Using biogas as an energy source reduces dependence on fossil fuels and lowers greenhouse gas emissions.
2. Waste Management: The biogas production process helps manage organic waste more effectively, reducing environmental pollution.
3. Energy Efficiency: Biogas can be produced locally and used on-site, reducing transportation and distribution costs.
4. Sustainability: Biogas is a renewable energy source that can be produced sustainably from continuously available organic waste.

The following are the results of previous studies related to the use of biogas for pasteurizing mushrooms. Substrate sterilization is a crucial step in mushroom cultivation that ensures optimal mycelium growth and quality yields. Innovative methods have the potential to replace traditional methods, although they require further research for optimization (Rathod et al., 2024). A study aims to evaluate the method of pasteurization of substrate through water immersion as a cheaper alternative to autoclave sterilization for in vitro cultivation of *Pleurotus ostreatus* fungi. The substrates used include larch wood shavings, corn straw, and rice straw. Pasteurization is carried out by soaking the substrate for 7 (seven) days under water before aeration. Although mycelium growth was found on all substrates after pasteurization, the growth yield was lower than that of conventional sterilization methods (Magaña and Shimizu, 2022). Another study explores the impact of the pasteurization stage on the production of straw mushroom (*Volvariella volvacea*). The pasteurization method was carried out using goat and rabbit manure at a temperature of 60-70°C with a humidity of 80-90%. The results showed that the temperature and duration of pasteurization affected the success of fungal growth (Bermuli et al., 2022).

A study discusses the pasteurization method of substrate for the cultivation of *Pleurotus ostreatus* mushrooms, which is a crucial step in the mushroom growth process. Compared to other methods of disinfection of substrates, thermal pasteurization was identified as the best option. This method can eliminate major pathogenic microorganisms, preserve essential nutrients, and allow beneficial microbes to stay alive. Among the existing methods, heating at 80°C for a short period of time has been identified as the optimal approach. The use of "tunnel pasteurization" is also considered ideal for efficiency and high yields (González et al., 2022). Another study evaluates various methods of pasteurization and sterilization of substrates for the cultivation of oyster mushrooms (*Pleurotus ostreatus*) in terms of crop yield, energy efficiency, and water. The study compared four main methods: hot air pasteurization (HAP), hot water pasteurization (HWP), pasteurization with hydrated lime (HLP), and autoclave. Although autoclaves provide the highest yield (50% more than other pasteurization methods), HAP is found to be more energy and water efficient (Grimm et al., 2024).

A study discusses the various nutritional and medical benefits of rice fungus (*Volvariella volvacea*), which is native to tropical and subtropical regions. This mushroom is rich in bioactive compounds such as antioxidant enzymes, terpenes, polypeptides, sugars, phenolics, and flavonoids. These compounds have a wide range of therapeutic properties, including anti-tumor, anti-microbial, anti-inflammatory, antioxidant, and others. Nutritionally, these mushrooms contain protein, carbohydrates, fiber, and essential amino acids that make them an excellent source of functional food (Javed et al., 2024).

Another study highlights the process of mushroom production from straw to substrate, mushroom harvesting, and the utilization of residual biomass as a valuable soil conditioner. This process minimizes waste, reduces the use of mineral fertilizers, and has a positive impact on the environment and the agricultural economy. The biotransformation of organic matter in straw with the addition of nitrogen (poultry manure) and calcium (gypsum) produces highly morphological biomass with high fertilizer value, which contributes to environmentally friendly carbon agriculture (Pisarek, 2024).

The development of mushroom cultivation can be improved through the provision of up-to-date information by research institutions and the establishment of farmer cooperatives to expand access to loans. In addition, training on cultivation techniques and quality control is urgently needed (Olawale et al., 2024).

Method

The implementation of a biogas system for mushroom pasteurization in Sembalun Bumbung Village aims to address key challenges related to energy costs, waste management, and production efficiency. The fixed-dome digester, constructed from reinforced concrete, processes organic waste to produce biogas, which is then stored in a high-density polyethylene gas holder. The biogas is used to fuel a low-pressure burner, providing a renewable energy source for the steam pasteurizer. A functional biogas unit has been installed at designated locations, and mushroom pasteurization systems are designed using biogas as an energy source, as illustrated in **Figure 2**. Specifications and sizes of the design system are as follows:

1. Biogas Digester
   - Type: Fixed-dome digester
   - Material: Reinforced concrete
   - Size: 8 m^3
   - Capacity: Processes up to 200 kg of cow dungs per day
   - Output: Produces approximately 4 m^3 of biogas per day
2. Biogas Storage
   - Type: Gas holder
   - Material: High-density polyethylene (HDPE)
   - Capacity: Stores up to 12 m^3 of biogas
3. Biogas Burner
   - Type: Low-pressure biogas burner
   - Material: Stainless steel
   - Size: Standard burner size
   - Capacity: Consumes 0.5 m^3 of biogas per hour
4. Pasteurizer Installation
   - Type: Steam pasteurizer
   - Material: Stainless steel pipes
   - Size: 20 m^3
   - Capacity: Pasteurizes up to 200 kg of mushrooms media per batch

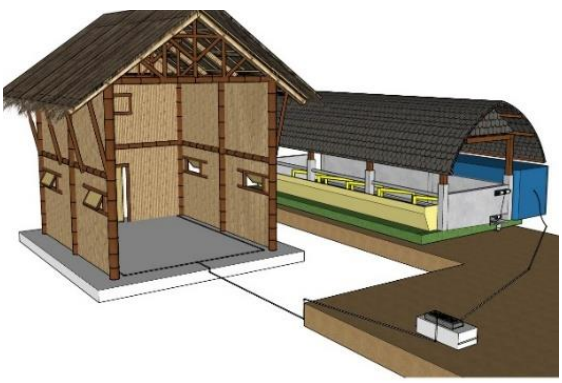

Figure 2. Design of mushroom pasteurization system using biogas as an energy source.

Result and Discussion

A. Construction of biogas pasteurization installation
The installation of biogas mushroom pasteurizer has been constructed, consisting of 8 m^3 of Biogas Digester (Figure 3), 12 m^3 of Biogas Storage (Figure 4), and two Biogas Burners for tunnel steam pasteurizer installation (Figure 5).

Figure 3. The biogas digester with a capacity of 8 m^3.

Figure 4. Biogas storage with a capacity of 12 m^3

(a)

(b)

Figure 5. Biogas burners for tunnel steam pasteurizer installation (a) initial construction, and (b) after modifications.

B. The pasteurization process of straw mushrooms
Mushroom pasteurization has been carried out in May 2025 by placing substrates made of rice straw on all shelves in the mushroom house, with a total capacity of 800 kg. The straw has been fermented beforehand for ten days to ensure that all the nutrients needed for mushroom growth can be perfectly absorbed. Pasteurization was conducted in two stages, the first stage lasting for 5 hours from 4 PM to 10 PM. Due to the increasingly cool weather, pasteurization continued the next morning for 8 hours from 7 AM to 3 PM. During pasteurization, the temperature could only reach a maximum of 30 °C. The process was temporarily hindered due to a leak in the pipes and the accumulation of water due to boiling water overflow, necessitating pipe cutting for steam drainage.
The pasteurization process in this first experiment can be said to be less successful, as evidenced by the results of mushroom growth, where wild mushrooms still grew and did not produce straw mushrooms as expected. Figure 7 shows the results of mushroom growth in the first pasteurization experiment.

Figure 7. Mushroom growth after 15 days of cultivation.

C. The pasteurization process of button mushrooms

The pasteurization experiment was repeated in July 2025 by improving the pasteurization installation, specifically by bringing the combustion furnace closer and aligning it straight with the mushroom house to reduce the possibility of heat loss due to the length of the pipe, and to minimize the risk of pipe leaks caused by bends. The system was also designed with elevated inlet and outlet valves to reduce the likelihood of boiling water overflowing into the pipe. Additionally, adding a steam pipe network with a valve system to ensure that steam can better reach the substrate placed on the upper rack. The pasteurization installation after modification are shown in **Figure 5(b)**.

The pasteurization process in the second experiment used the volume of substrate limited to only 200 kg and the room used is only a quarter of the mushroom house's capacity, i.e. only about 20 cubic meters. This was done by partitioning the room using thick tarpaulin wrapped around the shelves' walls. The temperature that could be maintained during pasteurization reached 70-80 °C. The time needed totally is around 9 hours, beginning on 2 PM until ended on 11 PM. Button mushrooms were chosen because they are considered more suitable to grow in cold air temperatures, needing a temperature of 18 – 20 °C. This is different from straw mushrooms which require warm temperatures, around 30 °C.

The pasteurization process in the second experiment was successful, as evidenced by the results of mushroom growth, where only limited wild mushrooms grew and started to produce button mushrooms as expected. **Figure 8** shows the results of mushroom growth in the second pasteurization experiment.

(a) (b)

Figure 8. Mushroom growth after (a) 15 days and (b) 30 days of cultivation.

However, it should be noted that pasteurization processes still use LPG, and biogas could not be used in this pasteurization process due to extreme environmental temperatures. Figure 9 shows the daily temperature in the mushroom chamber, during May – July 2025, which are below 25 °C, and in some coldest days the temperature reached below 20 °C. To anticipate these environmental constraints, modifications will be made to the heating furnace system, or alternatively, an autoclave system will be used.

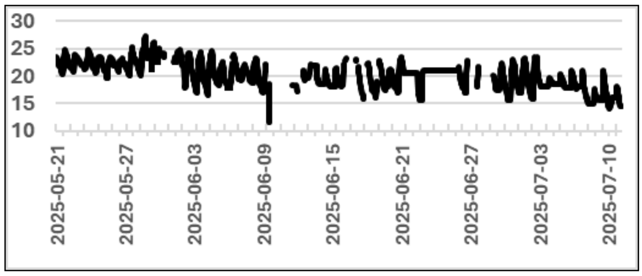

Figure 9. Daily temperature in the mushroom chamber during May – July 2025.

Conclusion

The biogas installation for mushroom pasteurization has been successfully constructed, consisting of an 8 cubic meter of Biogas Digester, a 12 cubic meter Biogas Storage, two Biogas Burners, and a 20 cubic meter tunnel steam pasteurizer installation. The installation has been tested two times to pasteurize straw substrates for cultivating straw mushroom and button mushroom.

The pasteurization process of straw mushrooms was less successful due to the large room volume used (about 600 cubic meters) and directly heating 16 shelves containing about 800 kg of substrate. The temperature that could be maintained during pasteurization only reached 30 ºC. The pasteurization process of button mushrooms was successful because the volume of the room used was smaller (about 20 cubic meters) and only heated of 4 shelves containing about 200 kg of substrate, in accordance with the capacity of the made pasteurizer. The temperature that could be maintained during pasteurization only reached 70-80 ºC. Pasteurizations still use LPG, and biogas could not be used in this pasteurization process due to extreme environmental temperatures (during some coldest days they are below 20 ºC). Modifications will be made to the heating furnace system, or alternatively, an autoclave system will be used.

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