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Innovation of Hybrid Solar and Gas-Powered Maggot Dryer Machine as a Solution for Dry Feed

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Abstract. Sugihmanik Village, a major tofu production center, produces substantial amounts of organic waste, particularly wastewater that contaminates local rivers and disrupts the surrounding ecosystem. A community service program has been developed to convert tofu waste sludge into maggot feed, followed by drying using a hybrid solar and gas-powered maggot drying machine. Initial activities involved program outreach and technical training on maggot cultivation and the drying process. A drying trial demonstrated that 200 grams of wet maggots were reduced to 114 grams within seven minutes. Monthly drying operations required only four 3-kg LPG cylinders, resulting in 81 kilograms of dry maggots and a potential monthly income of IDR 4.050.000. Environmental degradation caused by tofu waste has been significantly mitigated, while local economic productivity has improved. The drying machine enhances the commercial value of maggots as durable livestock feed. The initiative strengthens the operational sustainability of the Krida Manik Waste Bank and offers a scalable model for resource-based environmental solutions.

Keywords: tofu waste; maggot feed; maggot dryer machine; waste bank; waste management

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INTRODUCTION

Sugihmanik Village, located in Grobogan Regency, Central Java, encompasses an area of approximately 1.286.600 hectares and consists of eight hamlets (Wahyuningsih, 2024). The majority of the population engages in tofu production as the primary economic activity (Hulu, Afriani, & Hasan, 2022). However, tofu manufacturing processes have triggered a range of environmental challenges, particularly concerning waste disposal and pollution control.

Daily production in Sugihmanik generates substantial volumes of organic sludge characterized by high protein content (Ayu, Amini, & Rohayat, 2023). Unmanaged disposal of such waste contributes to the degradation of river water quality, marked by excessive biological oxygen demand (BOD) and chemical oxygen demand (COD) levels that exceed safety thresholds (Silmina, Edriani, & Putri, 2010). River pollution in the surrounding area has not only led to ecological damage and foul odors but has also posed serious public health concerns (Production et al., 2016).

To address environmental issues, the Krida Manik Waste Bank was established in 2018 as a local facility dedicated to sustainable waste management. The waste bank previously collaborated with PT Semen Grobogan to process organic waste (Cicilia & Susila, 2018). Following the termination of this partnership, significant operational constraints emerged. The facility experienced an overflow of accumulated waste, including plastic and non-biodegradable materials, which surpassed available storage capacity (Febry Ferdiyanto Purba et al., 2023; Nabila Noor Qisthi et al., 2023).

Beside these limitations, tofu sludge contains valuable nutrients that offer opportunities for repurposing. Organic residues may serve as feed for *Hermetia illucens* (Black Soldier Fly) larvae, which are widely recognized as a sustainable protein source for animal husbandry (Rosyadi et al., 2024; Suciati et al., 2017). Indriyanti, Widiyaningrum, & Setiati (2023) demonstrated that maggot cultivation using tofu waste can generate high-value feed products while simultaneously reducing environmental burdens.

To ensure the viability of maggot-based feed, appropriate post-harvest handling is essential. A dedicated drying machine allows larvae to be processed into durable and transportable animal feed. Solar and gas-based hybrid drying technology offers an innovative solution by utilizing renewable energy to maintain product quality while minimizing operating costs (Febiola et al., 2024).

The development of a hybrid solar and gas-powered maggot dryer represents a strategic intervention to improve tofu waste management efficiency in Sugihmanik Village. The machine aims to enhance feed preservation, ensure long-term storability, and increase market value. This community service program seeks to integrate technological innovation with ecological stewardship and local economic empowerment, offering a replicable model for waste conversion and sustainable development.

METHODS

The community service activities began with a preliminary site survey in Sugihmanik Village to collect both primary and secondary data. The survey aimed to evaluate the operational condition of the Krida Manik Waste Bank and the availability of tofu waste sludge as potential maggot feedstock. Data collection provided a foundation for planning appropriate interventions and identifying suitable technologies.

Following the initial assessment, program implementation was initiated through socialization sessions directed at the Krida Manik Waste Bank management and local residents. The purpose of these sessions was to increase awareness regarding the environmental and economic benefits of utilizing tofu sludge for maggot cultivation and the introduction of hybrid drying technology. Training was then conducted, covering the complete cycle of *Hermetia illucens* (Black Soldier Fly) cultivation, from egg hatching, larval care, and harvesting to post-harvest processing using a solar and gas-powered maggot dryer.

Facility construction included the development of BSF cages and hatcheries, as well as the installation of a hybrid drying machine designed to convert maggots into durable animal feed. The machine employed a roasting system powered by LPG and a DC servo motor driven by solar panels. Operational steps included material preparation (cleaning harvested larvae), temperature adjustment (maintaining 50–60°C), activation of the rotating mechanism, uniform drying with continuous monitoring, and final packaging.

To evaluate the success of the program, several performance indicators were used: (1) daily quantity of maggot feedstock processed, (2) reduction in organic waste observed at the waste bank, (3) weight output of dried maggots, (4) energy consumption per drying cycle, and (5) monthly income generated from maggot sales. Periodic mentoring sessions and field observations were carried out to ensure proper operation of cultivation units and drying equipment, while feedback from the community served as a qualitative measure of acceptance and sustainability.

RESULTS AND DISCUSSION

The community of Sugihmanik Village in Grobogan Regency has long relied on tofu production as a major source of household income. Since 2018, micro, small, and medium enterprises (MSMEs) in the area have consistently produced tofu in significant quantities. However, extensive production has contributed to a growing environmental concern, particularly the indiscriminate discharge of wastewater containing high concentrations of organic matter into nearby rivers (Yogafanny, 2015). Observations conducted during the program confirmed the presence of dark, stagnant water in open drainage channels adjacent to tofu production sites. This water carried an unpleasant odor and showed signs of biological contamination, such as algae growth and sediment accumulation.

The presence of high BOD and COD levels in the river, previously documented by environmental studies (Kesuma, 2016), supports the conclusion that unprocessed tofu wastewater adversely affects aquatic ecosystems. Overflowing mud was also found at the inlet and outlet of local wastewater treatment installations **(Figure 1).** The plant design consisted of simple sedimentation tanks, which appeared to function inadequately due to limited maintenance and an overcapacity of sludge.

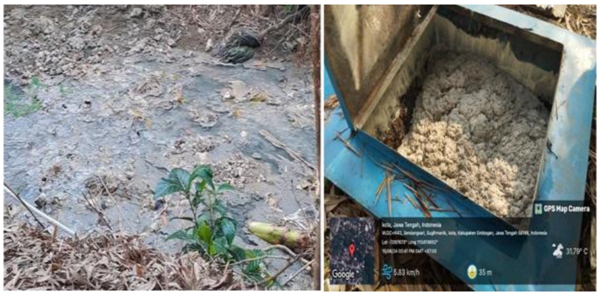

Figure 1. Condition of the River in Sugihmanik Village and Overflowing Mud at IPAL UKM Tahu

To mitigate pollution, the community had constructed a wastewater treatment facility (IPAL) to channel and store tofu waste into sedimentation tanks (Sukindrawati & Kartika, 2022). The acidic nature of the sludge prompted the application of fermentation techniques to generate methane gas, later used for basic electrical needs (Rajagukguk, 2020; Jannah, 2010). The physical condition of the tofu waste treatment area, including the covered sedimentation tanks and inspection platforms, is illustrated in **Figure 2.** However, a significant volume of solid waste byproduct remained unused after the liquid fermentation process. That unused organic sludge presented an opportunity for productive reuse, especially due to its protein content.

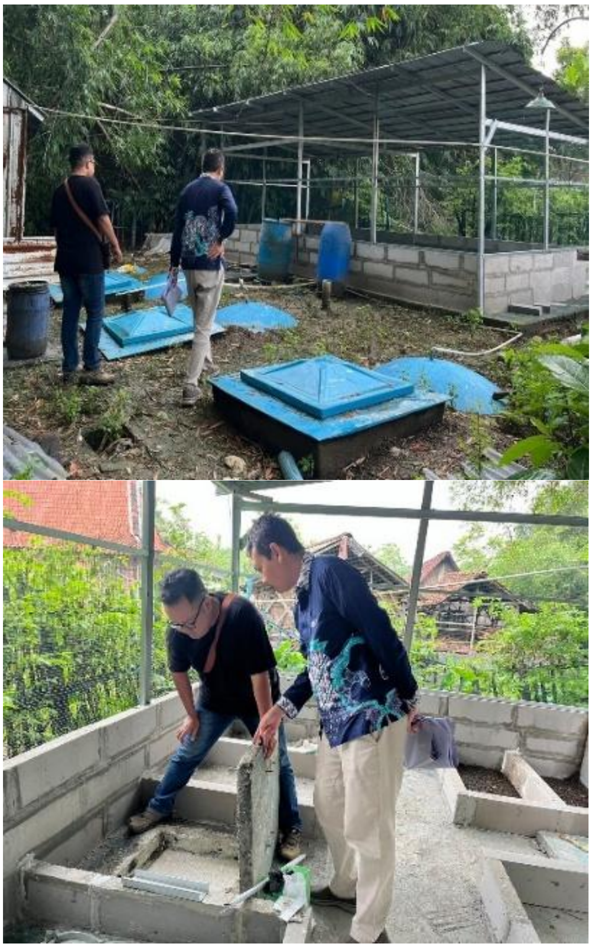

Figure 2. Tofu waste slurry collection site

To transform this problem into a resource, the program team from Semarang University initiated an intervention that proposed the use of tofu waste sludge as a substrate for maggot cultivation. Black Soldier Fly (BSF) larvae were selected for their rapid decomposition capacity and ability to convert organic waste into protein-rich biomass (Rosyadi et al., 2024). Maggot cultivation infrastructure, including netted cages and stackable trays, was installed within the Waste Bank facility **(Figure 3).**

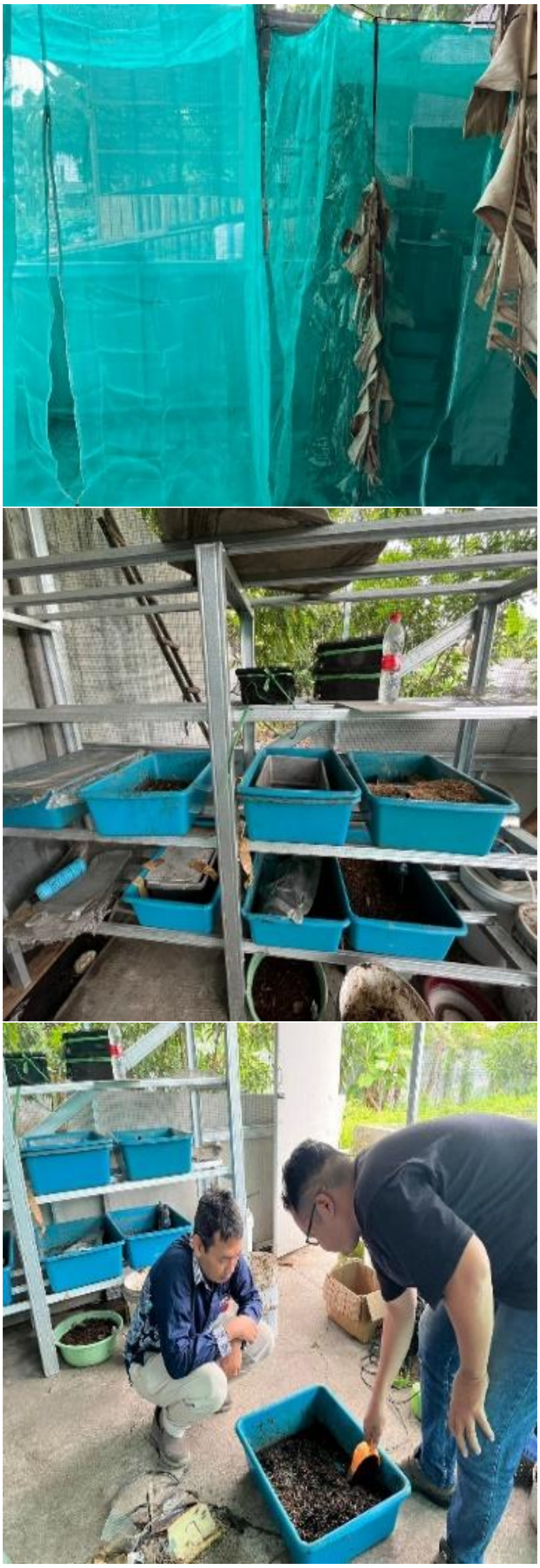

Figure 3. Maggot cultivation cage

The cage measured 2x3x2 meters and was equipped with adequate ventilation, shading, and

Figure 4. The process of drying maggots with a drying machine. The initial weight of 200 grams (center) becomes 114 grams (right)

water drainage systems to support the BSF life cycle.

Training sessions were conducted with Krida Manik Waste Bank managers and local MSME representatives. The training covered BSF egg incubation, larval feeding, harvesting techniques, and hygiene protocols. The cultivation process began with the inoculation of BSF eggs onto tofu sludge mixed with dry organic residue to improve moisture balance. The larvae developed within six to ten days, depending on environmental conditions, and reached optimal harvesting size within two weeks.

A critical post-harvest challenge was the need to convert wet larvae into durable animal feed. Wet maggots contained high moisture content, limiting storage time and increasing the risk of microbial contamination. To address this, a hybrid solar and gas-powered drying machine was introduced as an appropriate technological solution (Febiola et al., 2024). The machine featured a stainless-steel roasting basket rotated by a 30-watt DC motor powered by solar panels. A 3-kg LPG gas burner served as a constant heat source, maintaining a drying temperature of 50–60°C.

Drying trials were performed to evaluate the machine's performance **(Figure 4).** A test batch of 200 grams of wet maggots was reduced to 114 grams of dry maggots within seven minutes. Throughout one month of operations, the Krida Manik team processed approximately 6 kilograms of wet maggots daily. The drying process yielded 2.7 kilograms of dry maggots per day, accumulating a total of 81 kilograms per month.

Operational efficiency was demonstrated by the minimal fuel requirement. Only four 3-kg LPG cylinders were consumed monthly, at a cost of IDR 20.000 per unit. Thus, the total monthly drying cost was IDR 80.000. At a local market rate of IDR 50.000 per kilogram, the sale of 81 kilograms of dry maggots generated monthly revenue of approximately IDR 4.050.000.

Several indicators of success were used to evaluate the intervention:

1) Waste conversion efficiency, the ratio of wet to dry maggot weight demonstrated a drying efficiency of 57%, indicating a substantial reduction in moisture while preserving biomass quality.
2) Cost-effectiveness, energy costs remained below 2% of monthly revenue, indicating economic sustainability.
3) Income generation, the Waste Bank achieved a measurable increase in income, strengthening its operational independence and reducing reliance on external funding.
4) Community engagement, active participation from MSME members in both cultivation and drying activities reflected successful capacity-building outcomes.
5) Environmental impact, a reduction in visible sludge accumulation and improved water flow in adjacent rivers were reported by local residents, suggesting environmental recovery.

While the program achieved most of its intended outcomes, some limitations were observed. The drying machine required a sunny environment to maintain solar power input, making continuous operation vulnerable during prolonged rainy periods. Although the LPG burner provided heat continuity, complete reliance on gas would increase operational costs. In addition, maggot storage required sealed containers with desiccants to prevent reabsorption of humidity during distribution.

Feedback from Waste Bank personnel indicated that the machine was easy to operate and maintain. However, some challenges occurred during the initial adjustment phase, particularly regarding the timing of larval harvesting and synchronization with drying schedules. Occasional bottlenecks occurred when maggot volumes exceeded drying capacity. Therefore, future modifications to expand drum size or improve airflow may be considered to accommodate increased production.

Another area for future improvement involves the market diversification of dried maggots. Currently, sales are directed toward poultry farmers within the Grobogan district. Broader marketing strategies, including e-commerce platforms or supply contracts with animal feed companies, may enhance revenue stability. Additionally, further research into maggot nutritional profiling could support organic feed certification and allow premium pricing.

From a socio-cultural perspective, the program aligns well with local values emphasizing community-based economic activities. Residents showed interest in replicating the technology, especially in households already managing livestock or agricultural waste. This indicates strong potential for horizontal expansion within the village and neighboring areas. The community's prior experience in cooperative work through the Waste Bank model facilitated rapid knowledge transfer and minimized resistance to innovation.

In terms of environmental impact, the introduction of maggot cultivation reduced the volume of sludge requiring disposal, alleviated pressure on the wastewater treatment facility, and contributed to a cleaner riverine landscape. The visual and olfactory improvement in the area also fostered greater community appreciation of proper waste management practices.

In conclusion, the hybrid solar and gas-powered drying machine successfully bridged the technological gap in maggot post-processing. The integration of renewable energy contributed to sustainable operations, while gas heating ensured process stability. The approach demonstrated strong alignment with the goals of circular economy, waste valorization, and community empowerment.

The advantages of the intervention included low-cost operation, use of locally available materials, and scalability. The challenges involved seasonal limitations, the need for technical calibration, and capacity constraints. The potential for future development includes the addition of multi-tier drying units, automated temperature sensors, and modular training packages for broader community dissemination.

The program in Sugihmanik Village offers a practical model for similar tofu-producing areas across Indonesia. With adequate institutional support and technical refinement, maggot-based bioconversion systems can become a cornerstone of rural circular economies. The fusion of environmental stewardship, local entrepreneurship, and technological innovation presents a replicable pathway for waste-to-wealth transformation.

CONCLUSION

The community service program in Sugihmanik Village achieved the intended objectives by transforming protein-rich tofu waste into a valuable input for maggot cultivation and subsequently into dry animal feed through a hybrid solar and gas-powered drying machine. The drying process demonstrated high energy efficiency, with only four LPG cylinders required monthly and a drying capacity reaching 81 kilograms of dry maggots. These outcomes contributed directly to improved environmental conditions, strengthened the operational capacity of the Krida Manik Waste Bank, and generated additional income for local stakeholders. The drying machine offered a practical technological solution that aligned with circular economic principles, combining renewable energy utilization with low-cost infrastructure. However, drying operations remained sensitive to weather fluctuations, and future enhancements are necessary to address limited capacity and seasonal constraints. The technological model developed in Sugihmanik holds strong potential for replication in other tofu-producing regions, with scalability for broader agricultural applications and rural economic empowerment.

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