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Sustainable Economy-Based Management of Tofu Industry Waste in Agrarian Areas

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Abstrak

Penelitian ini berfokus pada pengelolaan limbah industri tahu berbasis ekonomi berkelanjutan di Desa Teja Timur, Pamekasan, dengan menekankan pada penerapan prinsip ekonomi sirkular melalui pemberdayaan masyarakat. Metode yang digunakan adalah kualitatif deskriptif dengan teknik pengumpulan data berupa wawancara mendalam, observasi langsung, dan dokumentasi. Instrumen yang digunakan meliputi pedoman wawancara semi-terstruktur dan lembar observasi. Analisis data dilakukan secara tematik melalui tahapan reduksi data, penyajian data, dan penarikan kesimpulan. Untuk memperkuat validitas, penelitian ini melibatkan 7 informan yang dipilih berdasarkan kriteria tertentu, seperti pelaku industri tahu, pekerja, serta anggota masyarakat yang terlibat dalam pengelolaan limbah. Hasil penelitian menunjukkan bahwa masyarakat setempat secara aktif mengelola limbah padat menjadi produk bernilai ekonomi seperti tempe gembus dan pakan ternak, yang berdampak pada peningkatan pendapatan dan penguatan ekonomi lokal. Praktik ini mencerminkan penerapan prinsip reduce, reuse, dan recycle dalam konteks ekonomi sirkular. Penelitian ini merekomendasikan perlunya dukungan teknologi sederhana, pelatihan kewirausahaan, dan regulasi kelembagaan agar sistem pengelolaan limbah ini dapat lebih optimal dan berkelanjutan.

Kata Kunci: Ekonomi sirkular, limbah tahu, pemberdayaan masyarakat, pembangunan berkelanjutan

Abstract

This study focuses on the sustainable economy-based management of tofu industry waste in Teja Timur Village, Pamekasan, with an emphasis on applying circular economy principles through community empowerment. The study employed a descriptive qualitative method, with data collected through in-depth interviews, direct observation, and documentation. The research instruments consisted of semi-structured interview guidelines and observation sheets. Data were analyzed thematically through the stages of data reduction, data display, and conclusion drawing. To strengthen validity, the study involved seven informants selected based on specific criteria, including tofu industry owners, workers, and community members engaged in waste management. The findings indicate that local communities actively transform solid waste into economically valuable products such as tempe gembus *and animal feed, contributing to increased income and strengthened local economic resilience. These practices reflect the implementation of the reduce, reuse, and recycle (3R) principles within a circular economy framework. The study recommends enhancing support for appropriate technologies, entrepreneurship training, and institutional regulation to optimize and sustain this waste management system.*

***Keywords**: Circular economy, tofu waste, community empowerment, sustainable development*

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INTRODUCTION

In the current era, the issue of industrial waste management has become one of the primary focuses of sustainable development. Industrial waste, particularly from household-scale industries such as tofu production, has attracted attention due to its environmental and public health impacts (Nasir and Muqorobin 2011). Recent studies increasingly adopt the concept of a sustainable economy as an innovative approach to addressing industrial waste. This approach not only emphasizes waste reduction but also the utilization of waste as a new resource with economic value, in line with circular economy principles (3Rs: reduce, reuse, recycle) (Oktavilia et al. 2024).

The urgency to examine tofu industrial waste management within a sustainable economic framework is highly relevant, considering that most agrarian regions in Indonesia serve as hubs for small- and medium-scale tofu industries(Sari et al. 2024). Improperly managed waste—both solid and liquid—can pollute agricultural land and water sources and decrease the quality of life for local communities. Agrarian areas, on the other hand, are heavily dependent on environmental sustainability to support agricultural productivity. Therefore, the implementation of sustainable economy-based waste management systems is becoming increasingly critical (Alfakihuddin et al. 2023).

Realizing sustainable tofu waste management in agrarian areas requires collaboration between industry actors, local communities, and the support of governments and related institutions (Hayati 2021). Strategies that can be implemented include education on waste separation, the application of simple waste treatment technologies, and the development of derivative products from solid waste, such as tempe gembos or animal feed (Anggraeni 2023). Community involvement in the waste management chain is also a key factor in ensuring the sustainability of these programs (Emilia 2023).

Several regions in Indonesia and abroad have successfully implemented this concept. For instance, some tofu industries in Central Java process their solid waste into organic fertilizer, which is then sold back to farmers. In India, circular economy principles have been applied in soybean processing industries, where waste is converted into bioenergy to power the production process itself (Pranata 2010). These successes demonstrate that the application of a sustainable economic approach to waste management is not only possible but also impactful.

This topic is highly relevant to 21st-century needs, as the world faces pressing challenges such as climate change, environmental degradation, and limited natural resources (Hasid et al. 2022). Waste management innovations are crucial components of the Sustainable Development Goals (SDGs), particularly Goal 12 (responsible consumption and production) and Goal 13 (climate action)(Agustin et al., n.d.). Therefore, the development of sustainable economy-based waste management systems can directly contribute to addressing these global challenges.

A circular economy is defined as an economic system aimed at generating value by keeping products, components, and materials in use for as long as possible through strategies such as extending product life, repair, remanufacturing, and recycling, while avoiding waste and the excessive exploitation of natural resources. This model not only focuses on waste reduction but also on building inherently regenerative and restorative systems. In this context, the circular economy offers a structural solution to global environmental and economic crises by integrating economic growth with ecosystem preservation and resource efficiency.

Previous research, such as that by (Grameinie and Neolaka 2022) shows that converting tofu waste into biogas can reduce water pollution by up to 60% and significantly lower greenhouse gas emissions. Other studies by Sari et al. (2020) also

reveal that applying circular economy principles in tofu waste processing can increase the income of small-scale business actors by up to 20% (Nainggolan et al. 2023). These findings highlight the importance of developing waste management strategies that are both environmentally friendly and economically beneficial.

Tofu industrial waste is a significant source of environmental pollution if not managed properly—especially its liquid waste, which contains high levels of BOD, COD, and TSS that can contaminate water and produce foul odors (Damayanti, E., Widyastuti, N., & Handayani 2020). However, solid waste like tofu dregs still contains substantial protein and fiber, making it suitable for use as raw material for animal feed or tempe (Yuliani, A., & Nurhidayat 2019). Innovations in tofu waste management through circular economy approaches not only reduce pollution but also create new economic opportunities for surrounding communities (Suryani, D., Santosa, D. A., & Maulana 2021). Hence, adopting a sustainable tofu waste management approach is essential to support both environmental protection and the socio-economic development of local communities.

Tofu industry waste holds great potential to support the empowerment of agrarian communities if managed productively and sustainably. In rural agrarian contexts, tofu dregs can be used as an affordable, high-nutrition alternative for livestock feed, reducing farmers' dependency on commercial feed (Setiawan, B., Handayani, R., & Prabowo 2021), tofu wastewater can be processed into liquid organic fertilizer that improves soil fertility and crop yields in villages (Wijayanti, D., & Nurcahyo 2020). The application of simple technologies and community involvement in waste management not only promotes economic independence for farmers but also strengthens local institutions and enhances community capacity for sustainable resource management (Fauziah, S., & Susanto 2019). Thus, empowerment-based tofu waste management becomes a highly relevant strategy for enhancing agrarian community welfare while maintaining environmental sustainability.

Improper management of tofu industry waste can lead to environmental pollution. However, through a sustainable economic approach, that waste can be transformed into a valuable resource. According to Le(Lestari, P. D., Sari, I. A., & Utami 2021), the application of sustainable economy principles in tofu waste management involves reducing, reusing, and recycling waste into derivative products such as biogas, compost, and animal feed. Furthermore, this approach can empower local communities through environmentally friendly, waste-based economic activities (Amalia, D. R., & Hadi 2020). These findings are supported by (Rahayu, S., Prasetyo, B., & Wijayanti 2022) who observed that sustainable tofu waste management not only benefits the environment but also increases the income and well-being of micro-entrepreneurs and local residents near industrial sites. Hence, transforming waste into economic assets through sustainable approaches is a strategic step toward inclusive and environmentally conscious development.

However, despite the potential, most existing studies primarily highlight the technical aspects of waste utilization or the economic value of by-products, without sufficiently integrating community empowerment as a central driver in sustainable waste management. This study addresses that gap by combining the sustainable economy framework with the local potential of agrarian regions, positioning community empowerment as the primary agent of change. Therefore, the novelty of this research lies in its effort to develop a community-based model of sustainable tofu waste management that not only reduces environmental risks but also enhances rural livelihoods

Based on this background, the novelty of this study lies in integrating a sustainable economic approach with the local potential of agrarian regions in tofu industry waste

management while emphasizing community empowerment as the primary actor. This research aims to analyze models of sustainable tofu waste management, identify barriers and opportunities in implementation, and formulate development strategies tailored to the local conditions of agrarian regions

RESEARCH METHODOLOGY

This study employs a qualitative method with a descriptive approach, chosen to capture the complexity of social, economic, and environmental interactions in the community. This approach allows the researcher to explore in depth how the sustainable economy-based management of tofu industry waste in agrarian areas can contribute to improving the welfare of the local community. Data collection techniques include in-depth interviews, observation, and documentation. Interviews were conducted with the tofu factory owner initials Mrs. T and two of her employees initials O and Y; the waste managers initials Mr. N and Mrs. R; as well as local community members initials Mr. A and Mrs. M. Additional interviews were carried out with local residents who are involved in producing tempe gembos and raising livestock, including Mrs. Raudah, Mrs. Masrurah, and Mr. Nawwar. In terms of observation, the researcher visited the tofu factory to directly observe the waste management process, starting from the soaking phase to the final pressing stage that produces solid tofu waste.

The data sources in this study consist of both primary and secondary data. Primary data were obtained through direct interviews with the tofu factory owner, her employees, and surrounding community members, as well as through observation of the tofu waste management process. Secondary data were collected from various references such as academic journals relevant to the research topic. To ensure data accuracy, this study used data collection instruments such as semi-structured interview guides and observation sheets, designed to ensure that the information gathered aligns with the research objectives. Data analysis in this study was conducted using thematic analysis, which consists of three main stages: data reduction, data display, and conclusion drawing.

RESULTS AND DISCUSSION

A. Waste Management Framework of the Tofu Industry

In the tofu production process, one of the most prominent by-products is solid waste in the form of tofu pulp (ampas tahu). “This waste is generated from the filtration of soybean extract after the grinding and boiling process” (Tin, Ombri 2025). Although often regarded as waste, tofu pulp still contains nutrients and has economic potential for various uses, such as an alternative food ingredient or animal feed—if managed and utilized properly.

Research shows that the solid waste produced during tofu manufacturing, namely tofu pulp, still contains significant nutritional value, including protein, fiber, and plant-based fats. This makes it potentially useful as livestock feed or as an alternative food source. The utilization of tofu pulp exemplifies the application of circular economy principles, where what was once considered waste is repurposed into valuable and economically useful products. This indicates that with proper management, tofu pulp waste not only helps reduce environmental pollution but also enhances the well-being of communities surrounding tofu production industries (Sari, D. P., & Yuliani 2020).

At the tofu factory UD. Sainuri in Teja Timur, Pamekasan, solid waste is not simply discarded. “This solid waste (tofu pulp) is sold to the local community at an affordable price, around Rp15,000” (Nawwar 2025). Selling the tofu pulp marks an initial step in implementing circular economy principles, transforming what was

previously a useless by-product into a new economic resource. It also demonstrates the producer's awareness of the importance of sustainable waste management while simultaneously providing additional economic opportunities for nearby residents.
This initiative reflects a conscious effort by producers to manage waste sustainably while creating economic benefits for the surrounding community. It aligns with the concept of a circular economy, which encourages the reuse of waste as a productive resource. Additionally, this system helps reduce environmental burdens by preventing waste accumulation and pollution around the factory (Kehutanan 2020).
Once purchased by community members, the tofu pulp is processed into various products, one of which is tempe gembos. “The production process of tempe gembos begins with pressing the tofu pulp to remove excess water, letting it rest, then steaming it. After that, it is mixed with tempeh yeast and wrapped in small plastic packages. After three days, it is ready to be sold to consumers” (Raudah 2025).

Figure 1. The Pressing Process of Tofu Pulp to Remove Excess Water

In addition, the solid waste is also used as animal feed for livestock such as cows and goats. "Yes, that's right. I buy it for 15,000 rupiah and use it as animal feed," (Raudah 2025). This creative use of waste reflects the community's ability to respond to limited resources with practical and effective solutions.
The process of making tempe gembus involves pressing the tofu pulp to reduce its moisture content, steaming, cooling, mixing with Rhizopus spp. starter culture, and fermenting it for three days before it is ready to be consumed or sold (Sari, D. P., & Yuliani 2020). Moreover, tofu pulp is also used as livestock feed due to its relatively high nutritional content, including approximately 21.29% crude protein. This utilization reflects the community's creativity and local wisdom in transforming waste into economically valuable products, while also supporting the principles of circular economy and environmental sustainability (Zain 2013).
These processed products are then resold by the community. "Tempe gembus is sold at 300 rupiah per piece to mobile vendors and 500 rupiah to individuals for personal consumption," (Raudah 2025). The use of tofu pulp as animal feed also contributes to the productivity of local livestock farms. This cycle creates added economic value from waste and provides entrepreneurial opportunities for the communities surrounding the tofu factory. In addition to serving as an alternative source of income, these activities also foster an entrepreneurial spirit, especially among housewives and small-scale farmers.

Figure 2. Tempe Gembus Produced by the Local Community

In addition to serving as an alternative source of income, this activity has also fostered an entrepreneurial spirit among village residents, particularly housewives and small-scale livestock farmers. Through this kind of economic circulation, the community is not only positioned as consumers but also becomes active participants in the local economic chain. With adequate entrepreneurship training, rural communities can diversify their sources of income by developing new ventures based on local potential—such as processing agricultural waste into value-added products. This approach not only improves the local economy but also enhances the village's appeal as a livable and sustainable place (Damarsiwi, E., & Putri 2023).

Thus, the management of solid waste at the tofu factory has directly involved the local community—from purchasing to processing and resale. This initiative not only supports waste reduction but also increases residents' incomes and creates a sustainable local economic cycle. It stands as concrete evidence that sustainable economic approaches can be effectively implemented in small-scale agrarian-based industries. This strategy can also serve as a model for similar industries in other regions, demonstrating that wise waste management can simultaneously yield social, economic, and environmental benefits.

B. Implementasi Pengelolaan Limbah Industri Tahu

The solid waste from tofu production, in the form of soybean pulp (ampas tahu), is optimally utilized by the surrounding community after being purchased from the factory at an affordable price. This utilization not only serves as a form of waste reduction but also represents a clear example of resource recovery within the circular economy framework—reintegrating waste into the economic cycle as a new input to produce valuable products. "Yes, I buy it directly from the factory at an affordable price and then process it into a new product called tempe gembus. I have been producing tempe gembus for about 15 years now," (Raudah 2025). The tempe gembus is then resold at an accessible price, reflecting the principles of sustainable economy in practice.

What was once considered waste-soybean pulp-is purchased affordably by the community and transformed into tempe gembus, a food product with economic value. The production process involves pressing to remove moisture, steaming, cooling, inoculating with tempeh yeast, and fermenting for two days. The final product is then sold at reasonable prices, creating a sustainable economic cycle that empowers the local community. In this way, the community not only acts as consumers but also becomes active participants in the local economic chain, aligned with the circular economy principles that promote sustainability and rural empowerment (Putri, K. A., Sari, H. P. E., Persada, A. Y., Febri, S. P., Juliati, J., & Syahriandi 2023.

These processed products are then sold back into the local market, generating a microeconomic circulation that strengthens local economic resilience. This process demonstrates how applying the principles of reduce, reuse, and recycle (3R) can yield positive impacts not only for the environment but also for improving income and community welfare. Thus, this practice not only reflects the circular economy conceptually but also shows the direct connection between waste management, community empowerment, and sustainable development based on local potential (Patria, A. 2020). For a clearer picture, see the illustration of tofu industry waste management implementation below:

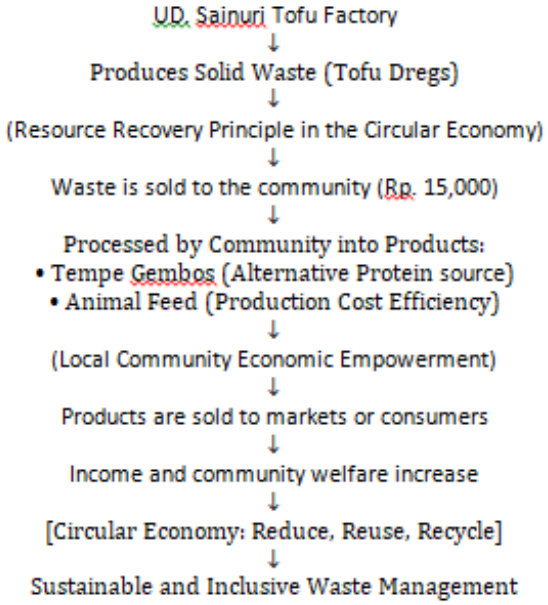

Figure 3. Concept Map of Tofu Industry Waste Management Implementation

C. Impact of Tofu Industry Waste Management on the Agrarian Environment

Based on research conducted in Teja Timur Village, the management of tofu industry waste has various impacts on the agrarian environment. The waste produced from the tofu production process consists mainly of two types: solid waste in the form of tofu pulp (okara) and liquid waste in the form of leftover production water. “With sustainable management, there is no negative impact because the tofu pulp is processed into a new product” (Aziz 2025). In daily practice, the utilization of solid waste has been carried out on a limited scale by the community. This condition reflects that the implementation of sustainability principles in managing small-scale industrial waste still faces several challenges, including technical, social, and institutional aspects.

The solid waste, namely tofu pulp, has been used by some community members as raw material for making tempe gembos and as livestock feed, especially for cattle and goats. This utilization indirectly has a positive impact on the agrarian environment. “Tofu pulp as livestock feed helps local farmers meet their feed needs at a lower cost, thereby supporting the sustainability of the local small-scale livestock sector, which is an important part of the village’s agrarian system” (Masrurah 2025). On the other hand, the home-based production of tempe gembos also encourages the emergence of productive economic activities at the local level, especially among women. This activity shows that the circular economy approach

can be applied simply at the village level by turning waste into a new, economically valuable resource. Moreover, the direct utilization of tofu pulp also contributes to reducing the amount of solid waste disposed of in the open environment, although its effect on improving soil quality is still minimal because it has not been processed into compost or organic fertilizer.

This practice not only conceptually reflects the principles of the circular economy but also demonstrates the interconnectedness of waste management, community empowerment, and sustainable development based on local potential. However, the direct use of tofu pulp also contributes to reducing solid waste dumped into the open environment, even though its influence on soil quality improvement remains insignificant since it has yet to be processed into compost or organic fertilizer (Yulistika, E. 2023).

D. Waste Management in the Industry from a Theoretical Perspective

According to the Ellen MacArthur Foundation, the concept of the circular economy is an economic approach aimed at maintaining the value of products, materials, and resources for as long as possible within the economic cycle, while minimizing waste and the use of new resources. This model emerged as a response to the shortcomings of the linear economic system characterized by "take–make–dispose," which in the long run proves unsustainable due to generating large amounts of waste and depleting natural resources (Foundation 2015).

The circular economy is based on three main principles: (1) designing out waste and pollution, (2) keeping products and materials in use, and (3) regenerating natural systems. These principles aim to create an economic system that is more efficient and sustainable environmentally, economically, and socially. In the context of managing waste from the tofu industry, these principles are reflected in the utilization of solid waste (tofu pulp) into new products with market value, such as tempe gembos and animal feed (Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink 2017).

Furthermore, the implementation of the circular economy in small-scale household industries like tofu production can be carried out through the 3R approach: Reduce, Reuse, and Recycle. The principle of reduce is realized by minimizing the amount of waste produced through production efficiency. Reuse is evident in the community practice of purchasing tofu pulp waste and using it again without destructive processing. Meanwhile, the recycle principle is applied when the waste is processed back into new products, such as tempe gembos sold as food or tofu pulp used as feed for cattle and goats.

CONCLUSION

The sustainable economy-based management of tofu industry waste in agrarian areas has shown positive results, particularly in the utilization of solid waste into products such as tempe gembos and animal feed. This activity not only reduces waste but also creates new economic opportunities for the community, especially for housewives and small-scale farmers. The implementation of circular economy principles occurs naturally through active community participation, although challenges remain in managing liquid waste and improving the quality of processed products. Therefore, support from various stakeholders, including the government and educational institutions, is needed to strengthen technology, training, and regulations to ensure the sustainability of this system.

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