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EVALUATION OF PRODUCTION EFFICIENCY AND WASTE MANAGEMENT IN THE PAK IMAM TOFU AND TEMPEH INDUSTRY USING CLEANER PRODUCTION METHODS

Evaluasi Efisiensi Produksi dan Pengelolaan Limbah di Industri Tahu dan Tempe Pak Imam Menggunakan Metode Produksi Yang Lebih Bersih

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ABSTRACT

The Imam's tofu and tempeh industry in Central Lampung Regency produces two main types of products: tofu and tempeh. Additionally, the industry processes tofu dregs into a third product, gembus tempeh. This study aimed to identify the production performance and waste management of Imam's tofu and tempeh industry using the quick scan method. The data used are in the form of primary data and secondary data. The data obtained are presented in the form of mass balances and graphs. The research results show that improvements need to be made in the aspects of technology, management, production processes, and waste management. Water consumption in the Pak Imam industry is still relatively high, that is, 2,251.68 liters per day. This has an impact on the high volume of waste produced, which is 2,119.98 liters per day. Potential waste that has not been optimally utilized is found in the crushing stage (tempeh production) and extraction stage (tofu production). It is necessary to carry out maintenance on waste storage ponds due to silting. In addition, there are problems with the cleanliness of the place and equipment, so that the resulting product is less hygienic.

Keywords: Quick scan method, tofu, tempeh, tempeh gembus

ABSTRAK

Industri tahu dan tempe Imam di Kabupaten Lampung Tengah, menghasilkan 2 jenis produk utama, yaitu tahu dan tempe. Selain itu, industri mengolah ampas tahu menjadi produk ketiga yang disebut gembus tempe. Tujuan dari penelitian ini adalah untuk mengidentifikasi kinerja produksi dan pengelolaan limbah industri tahu dan tempe Imam dengan menggunakan metode quick scan*. Data yang digunakan berupa data primer dan data sekunder. Data yang diperoleh disajikan dalam bentuk timbangan massa dan grafik. Hasil penelitian menunjukkan bahwa perlu dilakukan perbaikan dalam aspek teknologi, manajemen, proses produksi, dan pengelolaan sampah. Konsumsi air di industri Imam masih tergolong tinggi, yaitu 2.251,68 liter per hari. Hal ini berdampak pada tingginya volume sampah yang dihasilkan, yaitu 2.119,98 liter per hari. Potensi limbah yang belum dimanfaatkan secara optimal ditemukan pada tahap penghancuran (produksi tempe) dan tahap ekstraksi (produksi tahu). Penting untuk melakukan pemeliharaan pada kolam penyimpanan limbah karena pendangkalan. Selain itu, ada masalah dengan kebersihan tempat dan peralatan, sehingga produk yang dihasilkan kurang higienis.*

Kata kunci: Metode quick scan*, tahu, tempe, tempe gembus*

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INTRODUCTION

Global warming is an environmental issue whose negative impacts have increased in recent years (IPCC, 2023). In developing countries such as Indonesia, environmental problems caused by waste have not been fully resolved. Industrial activity is one of the sources of these emissions. This phenomenon arises from various human activities, including vehicle exhaust fumes, household chores, agriculture, industrial activities, and other activities with similar impacts (Kurniawan et al., 2024). Waste produced by industrial activities affects water, land, and air (Ditia, 2024). Indonesia has various types of industrial activities, one of which is much sought after and pursued by the community, namely, the tofu and tempeh industry.

In 2020, the number of tofu industries in Indonesia reached 160,000, and the number of tempeh industries reached 115,000 (Central Statistics Agency, 2020). The Central Statistics Agency (2024) stated that the average per capita consumption of tofu and tempeh from 2021 to 2024 was 4.18 and 3.91 kg, respectively. The high number of tofu and tempeh industries in Indonesia due to increasing consumer interest has the potential to cause industrial problems such as waste management. Environmental problems resulting from tofu and tempeh production in Indonesia are partly due to the industry players' low understanding of the importance of waste management, resulting in various environmental problems (Karimuna et al., 2025). Efforts are needed to improve industrial performance related to the production process and handling of environmental pollution that may arise in the future.

One effort that can be made to address the impact of pollution resulting from industrial activities is to implement cleaner production. Cleaner production is a preventive and integrated environmental management strategy that is implemented continuously throughout the production process and product life cycle to reduce risks to humans and the environment (UNIDO-UNEP, 2008; Morssy, 2007). Cleaner production methods have been proven to reduce resource use during the process and save costs, thereby increasing the profits. Khuriyati et al. (2015) reported that implementing clean production in food industry "Cracker" can save water usage by 22.4%, namely from 515 L to 401.5 L. Another application is in the cassava chips industry as reported by Rahmadyanti and Andre (2016), who showed that reusing cooking oil can save IDR 27,657,600 per year. In addition to process modifications, proper industrial waste management can transform waste into high-value products and reduce energy costs. Furthermore, Wattansilp et al. (2021) reported that processing cassava industrial wastewater into biogas can reduce costs by as much as 50% of the total energy requirement.

The aforementioned examples of cleaner production implementation demonstrate that clean production methods can help address environmental problems caused by industrial activities. Therefore, this study was conducted to evaluate the production process and waste management at the Imam tofu and tempeh industry located in Bumi Nabung Baru Village, Bumi Nabung District, Central Lampung Regency, Indonesia.

MATERIALS AND METHODS

Location and Time of Research

This research was conducted at Pak Imam tempeh and tofu production, located in Bumi Nabung Baru Village, Bumi Nabung Subdistrict, Lampung Tengah Regency, Lampung Province, from August to October 2022. Analysis was carried out in the ANALYSIS Laboratory, Lampung State Polytechnic, and Agricultural Technology Laboratory, Lampung University.

Data Collection

The types of data used in this study include primary and secondary data. Primary data were obtained through direct interviews with tofu and tempeh industry owners and through on-site observations. The primary data in this study consisted of the production process, amount of raw materials, energy used to produce tofu and tempeh per day, and the sources, water usage, and characteristics of liquid waste. The environmental conditions of production and industrial wastewater management served as the primary data. Secondary data were obtained from scientific

journals, documents, and direct reports from authorized agencies/institutions related to the commodities being studied.

Data Analysis

The data obtained were processed using descriptive methods, namely, in the form of mass balances and diagrams. Data calculations were performed using Microsoft Excel.

Research Stages

Problem Identification

A quick scan was used to identify problems in the industry. The stages of the quick scan method start from preparation, which includes collecting information and data, followed by carrying out a quick scan (interviews and tours of industrial facilities using a checklist), conducting data evaluation (flow diagrams, summary of production processes, materials, and energy), and finally, preparing a summary report.

Source Problem Identification

Identification of the source of problems in the tofu and tempeh industry was carried out by examining five production factors: materials or raw materials, technology, management, products, and waste. The causes of waste generation are shown in Figure 1.

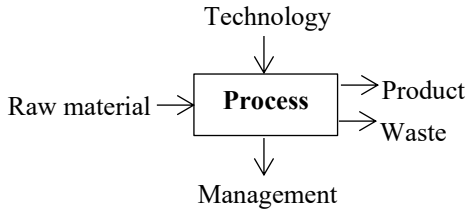

Figure 1. Identification of causes: Five things that cause waste to arise (Bantacut and Zulaikha, 2019).

RESULTS AND DISCUSSION

Industry Overview

Production capacity Imam tofu and tempeh industry ranges from 35 kg to 50 kg per day. The main products are tofu and tempeh. Approximately 32.40 kg, or approximately 33% of the total tofu dregs produced, are processed into gembus tempeh. The brand of the raw material is BOLA, which was obtained from the sales agent. The water resources used for production come from dug wells. The cooking process was carried out using a traditional wood-fired stove.

The industrial site is located near a residential area. To the south are residents, to the north is land owned by residents for cultivation, and to the east is a main road. All production and distribution activities were performed by three workers. The industry owner manages the entire production process personally, except for the fermentation and packaging of both tempeh and tempeh gembus, which are handled by one dedicated worker. Product distribution is performed by one worker, who is the owner's wife. Products are sold through registered stores, and the industry also handles special orders.

Imam's tofu and tempeh industry operates under three production capacities: low, normal, and high. Each type is determined daily based on the estimated supply needs for tofu, tempeh, and tempeh gembus at each store. The low production capacity is 35 kg per day, split into 19 kg of tempeh and 16 kg of tofu. The normal production capacity is 43 kg per day, with 24 kg of tempeh and 19 kg of tofu. The high production capacity is 50 kg per day, consisting of 30 kg of tempeh and 20 kg of tofu.

Tempeh produces only one type of waste because solid waste is included in tempeh products, including the rinds of soybeans. Tofu production generates liquid and solid waste in the form of soybean dregs. The last byproduct of tempeh Gembus is liquid waste. All liquid waste produced by tofu, tempeh, and tempeh gembus flows into a single waste storage pit. Half of the solid waste is used to produce tempeh gembus and animal feeds. The conditions of tofu and tempeh production by Pak Imam's industry are presented in Figure 2.

Tofu Production

Input material as soybean to produce tofu that is as much as 19 kg (normal production). The addition of water at this stage facilitated the machine's grinding of the soybeans. The resulting soybean porridge was divided into 12 cooking stages. The tofu production process can be seen in Figure 3.

Extraction was performed by flowing water through a sprinkler on the soybean

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porridge placed on a filter cloth. The water needed for 1 filtering process is 37.64 L, so the total water needed for 12 filtering processes is 451.68 L.

Figure 2. Tofu and tempeh production by Pak Imam's Tofu-Tempeh Industry production

The process of cooking soybean porridge and final boiling is carried out in a stove made by hand from red bricks with a single hole type with a diameter of 58 cm and a height of 40 cm, while the frying process is carried out in a stove with the same raw materials and size but has 2 holes. This is because the frying process was carried out twice, starting from the rear stove and the final frying on the front stove. The fuel used is firewood and the resulting boiling temperature is ± 100°C.

Tempeh Production

The rolling process is still performed manually using the feet, which produces solid waste in the form of soybean skin. The owner has used machines in the rolling process, but consumers prefer the taste of tempeh made using manual techniques (using their feet). Soybean skin from the rolling process is included in the tempeh product; therefore, this stage does not produce solid waste. The mass balance of tempeh production is shown in Figure 4.

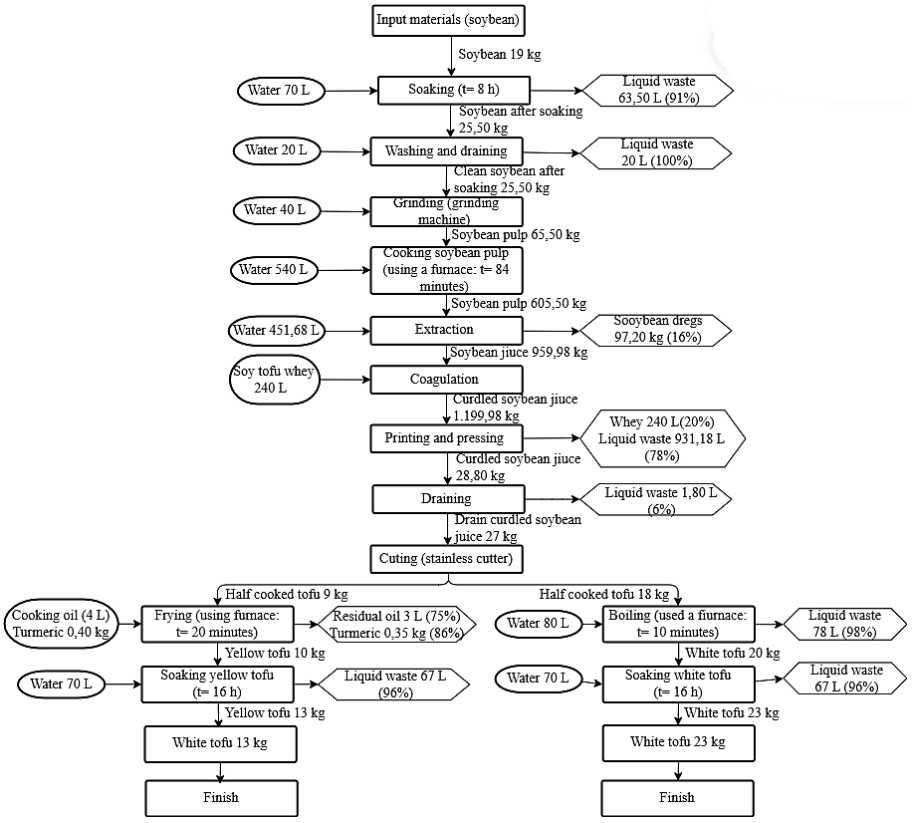

Figure 3. Mass balance of the tofu production process

In addition to tempeh and tofu, the industry also processes tofu byproducts, that is, dregs, into tempeh gembus. The gembus processing capacity is 32.40 kg of tofu dregs per day. Tempeh gembus production is different from tofu and tempeh production, with only three to four batches per week.

The raw material for tempeh gembus is the residue left over from soybean pulp extraction, consisting of soybean skins and seeds. The pressing process is still done manually start from soaking, washing, pressing 1 and 2, cooking, cooling, packing, and fermentation.

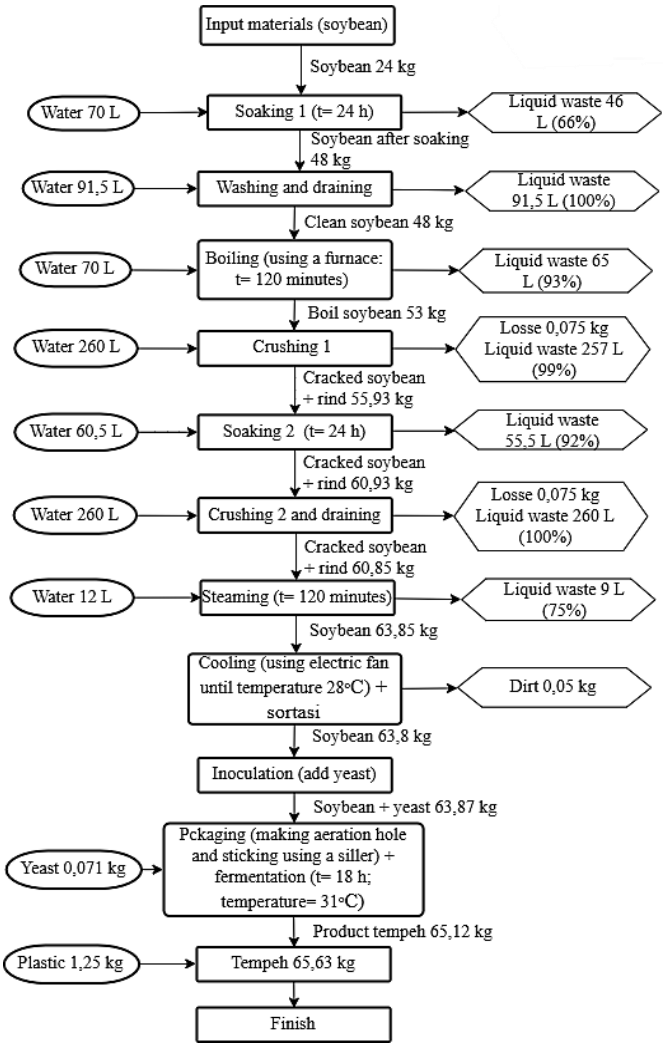

Figure 4. Mass balance of the tempeh production process

Identification of Water Use Efficiency

In general, the most commonly used auxiliary material in tofu and tempeh production is water. The water source for the tofu and tempeh production processes was dug wells. The overall water usage in the production processes of tofu, tempeh, and gembus tempeh is shown in Figure 5a.

The water usage per kg of raw material in tofu production was 69.68 L, tempeh 34.33 L, and gembus tempeh 2.65 L. Overall, the total water usage for these three products was 2,251.68 L/day at normal production capacity.

Waste Identification

Two types of waste are generally generated during the production process: solid and liquid waste. According to Sari and Rahmawati (2020) and Pambudi et al. (2021), liquid waste generated from the tempeh and tofu production process has the potential to cause pollution because of parameters such as COD, BOD, TSS, and pH that do not meet

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quality standards. Waste production during tempeh production is shown in Figure 5b.

Overall, the total waste produced in the production of 24 kg capacity tempeh was 784 kg. The second soaking process used a more concentrated waste than the first one. This is because the soybeans in the second soaking process were boiled first, making the soybean structure softer. According to Sari and Rahmawati (2020), the liquid waste produced from the soaking process after boiling and breaking down the soybeans contains 0.20 g protein, 1.47 g carbohydrate, and 0.02 g fat. In general, waste generated from food production contains several organic substances, such as proteins, fats, and carbohydrates (Khedkar and Singh, 2015).

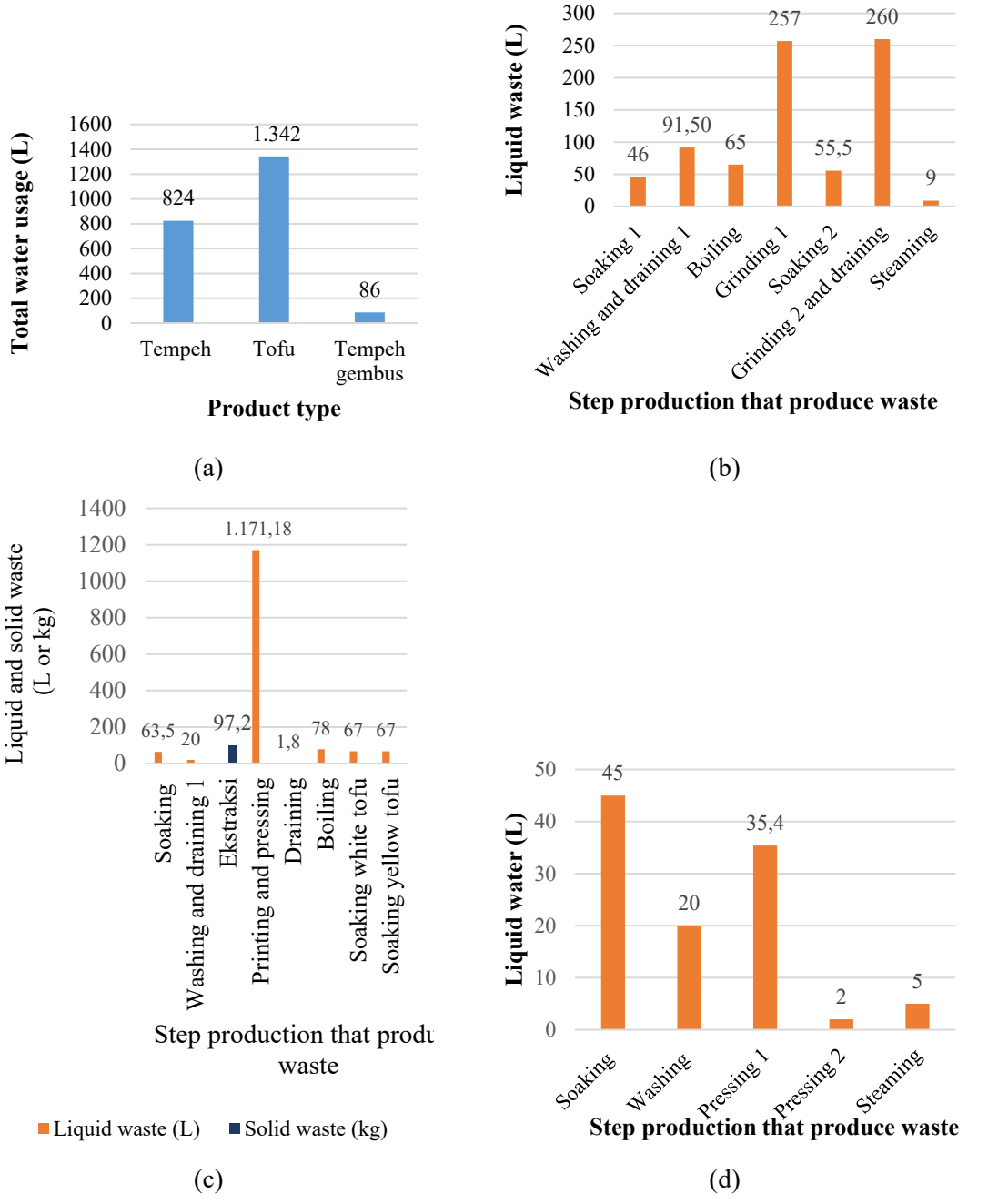

Figure 5. Water requirements for the production of tofu, tempeh, and tempeh gembus (a), Graph of liquid waste from tempeh production (b), Graph of liquid waste from tofu production (c), Liquid waste production from gembus tempeh production (d)

Next, we identified the waste generated during tofu production. Compared to tempeh production, the amount of waste generated during the production process is greater. Tofu production generates two types of waste: liquid and solid waste in the form of soybean pulp. The details of the liquid waste generated during the production process are shown in Figure 5c. Overall, the total liquid waste produced during the tofu production process was 1,4628.48 L. A total of 240 L of whey produced from the molding and pressing process was used for the soybean porridge coagulation process, so that the liquid waste discharged into the holding pond was reduced to 1,228.48 L.

Next, the waste generated from the tempeh gembus production process was identified. The details of the waste produced during tempeh gembus production are shown in Figure 5d. The total waste produced during tempe gembus production was 107.5 L. The total amount of waste produced was higher than the amount of water input because the initial raw material used was in the form of soybean dregs left over from making tofu, which contains ± 66% water from the total raw material used. The total liquid waste produced from the production process of tofu, tempeh, and tempe gembus, excluding the use of whey as a coagulant for making tofu, was 2,119.98 L. The liquid waste produced from the entire production process, starting from the production of tempeh, tofu, and tempe gembus, flows into the same holding pond.

Energy consumption identification

The energy sources used in the production process include human energy, firewood, and gasoline. Several pieces of equipment supporting the production process, such as water pumps and sillers, use electricity from PLN (the State Electricity Company) as the energy source.

Firewood is the most commonly used energy source. The average firewood consumption is 7 tons, which is consumed within 20 d of production. The following is a calculation of the energy consumption at the normal production capacity.

The increasingly difficult supply of wood fuel necessitates a solution to prevent the hampering of industrial operations. Wood burning was the source of the highest amount of energy. Other energy sources are considered unproblematic because of their relatively low demand (Table 1).

Table 1. Identification of energy types and consumption

Machines/Tools	Amount (Unit)	Usage Time (Hours/Days)	Energy (MJ/day)	Energy Sources
Water pump	1	4.50	8.10	Electricity
Fan	1	3.00	0.59	Electricity
Siller	1	3.00	3.24	Electricity
Light	2	9.00	1.49	Electricity
Grinding machine	1	1.96	3.88	Gas
Furnace	4	10.00	6,510.00	Firewood

Identification of Industrial Problems

Based on the on-site identification of the industry, several issues were identified that could impact product quality and negatively affect the environment. The following issues were identified in the Imam tofu and tempeh industry. The results of the identified problems are shown in Figure 6.

In general, water efficiency is a major challenge faced by every tofu and tempeh industry, including Imam. Previous research on cleaner production in the tofu industry, namely the study by Darmajana et al. (2013), stated that after improvements were made from the soaking stage to the molding stage, water efficiency was obtained by 21.12%, namely from the initial total water use of 239.07 L or 47.81 L per kg of raw material to 190.07 L or 38.01 L per kg of raw material. Compared with the results of this study, water use in Imam's industrial tofu production was 34% higher (Figure 5a). Inefficiency in water use in the Imam tofu and tempeh industry was found in several production stages, including

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the washing and draining stages as well as rolling 1 and rolling 2.

During the tempeh rolling process, there were losses, but only in small amounts, namely 0.075 kg (Figure 4), but this amount is considered not to affect production quality.

In terms of waste management, solid waste has been fully utilized for tempeh gembus and as livestock feed. All of the liquid waste from tofu and tempeh production is discarded into wastewater holding ponds, except for 240 L of liquid waste from soy whey tofu production and liquid waste from the boiling and steaming stages of tempeh production. Liquid waste from the boiling and steaming stages in tempeh production is also given to goats, but not all potential liquid waste has been optimally utilized, that is, waste from the crushing stage (tempeh production) and the extraction stage (tofu production). According to Yang et. al (2016), tofu whey contains several chemical contents, including total solids of 3.19%, protein 0.47%, crude fat 0.49%, total ash 0.54%, Ca 0.048%, Mg 0.042%, SO_4^{2-} 0.032%, Cl- 0.060%. This potential waste can be further utilized using different techniques. Waste management can be optimized by implementing the strategy 1E4R (elimination, reduction, reuse, recycling, and recovery).

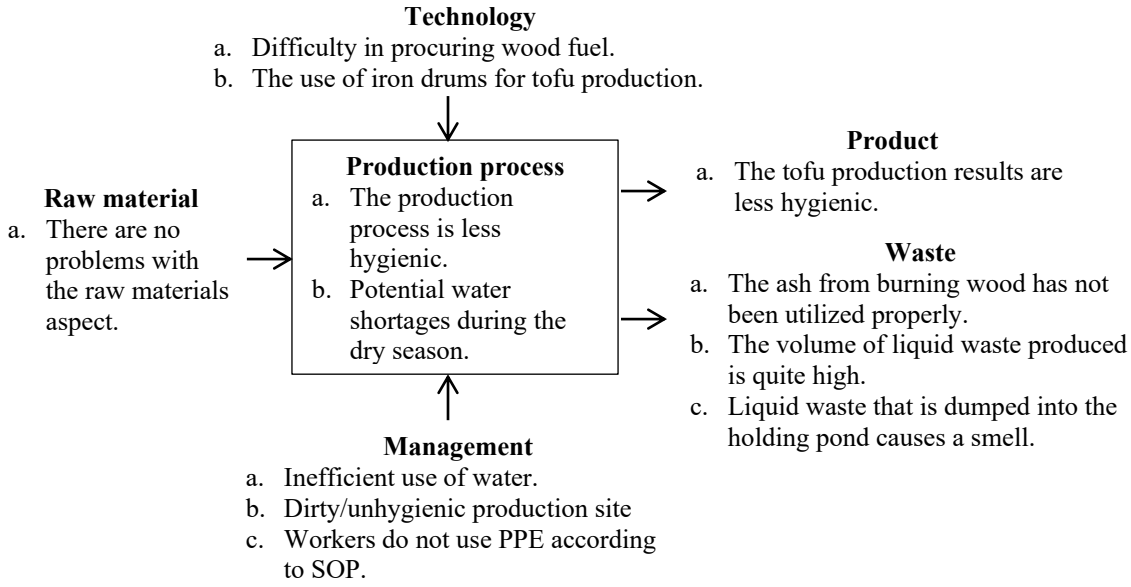

Figure 6. Results of problem identification in the Imam tofu and tempeh industry

Other handling problems related to waste are the ineffective performance of the holding ponds due to the silting of the wastewater holding ponds and the accumulation of solids carried along with the wastewater discharge. Simbolon et al. (2021) stated that the silting of holding ponds can reduce the effectiveness of bacteria in reducing organic matter. In addition, during heavy rain, water from the pool can rise to the surface of the production floor. This condition makes the production area unhygienic; therefore, periodic repair and maintenance efforts are required.

From a technological aspect, it was found that the equipment is dangerous and has the potential to cause cutlery toxicity during the tofu production process, that is, during the stages of cooking soybean porridge. The cooking stages in the tofu production process still use iron drums. The results of this evaluation indicate that it may be advisable to replace the equipment with a safer material.

From a production perspective, the water tank used in the tofu extraction process is not cleaned regularly, and the water supply is not hygienic. Furthermore, the industrial environment appears to be less clean. This is considered unhygienic and unsafe for the resulting products and consumers. It is necessary to provide directions to improve cleanliness, spatial planning, and housekeeping.

In terms of Occupational Health and Safety (OHS), the use of PPE has not been maximized. Workers only used PPE in the form of cloth masks during the cooking and extraction stages of tofu production. The use of PPE is considered important because many production stages use heat energy. Furthermore, burning wood as fuel produces smoke and fly ash, which can harm lung and eye health (Weyerheauser, 2022).

CONCLUSION

The evaluation results using Quick Scan Analysis indicate that the production process and waste management in the Imam Tofu and Tempeh industry have not yet been implemented properly. Improvements in technology and management are required to increase water efficiency and reduce the volume of wastewater produced. The identified problems are technological, including difficulties in procuring wood fuel and using equipment made from hazardous materials. Furthermore, from a management perspective, industrial hygiene levels and operational procedures do not meet the standards.

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