Technological Integration for the Growth of Small-Scale Tempeh Enterprises in Banguntapan, Bantul

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Abstract. The application of science and technology has an increasingly important role in the development of small industries, including the tempeh industry. The purpose of this study is to apply science and technology to establish a small tempeh industry in Banguntapan, Bantul, focusing on enhancing local production capabilities. The initiative aims to improve the quality and quantity of tempeh production while addressing local economic needs by creating sustainable business models. The method used in this study includes automated soybean grinders for improved processing, and fermentation control systems for product consistency. The study concludes that technological integration, combined with continuous training and support, can significantly improve the operational efficiency and market competitiveness of tempeh enterprises in rural areas. The soybean grinder test yielded an average of 78 grams of split soybeans when grinding 100 grams of soybeans at a spacing of 2.5 mm, using a variable grinder speed ranging from 300 to 700 rpm. The success achieved in Banguntapan demonstrates how small-scale enterprises can flourish when technology is effectively combined with entrepreneurial initiatives. Going forward, efforts should prioritize sustaining these advancements through continuous training and encouraging partnerships between local authorities and private stakeholders to further advance the tempeh industry in the region.

1 Introduction

Soybeans and their processed products such as tempeh, tofu, soy sauce, *tauco*, soybean juice and bean sprouts play an important role as a source of protein in the daily menu of Indonesian people [1]. More than 95% of Indonesian people's soy consumption is still dominated by tempeh and tofu, while the rest is in other processed forms such as soybean juice, soy sauce, bean sprouts, *tauco*, and flour, as well as fresh soybeans [2-4]. Tempeh is a native Indonesian food made through the fermentation process of soybean seeds with the fungus *Rhizopus spp*

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states that tempeh is a low-cost nutritious food which is consumed by all socio-economic groups in Indonesia and Malaysia [5, 6]. Data from the 2014 National Socio-Economic Survey (SUSENAS) shows that the average consumption of tempeh and tofu for Indonesians is 6.95 kg and 7.07 kg per person per year. Ironically, the fulfilment of soybeans as a raw material for tempeh and tofu until 2015 was 67.28% or 1.96 million tons still had to be met through imports because domestic soybean production has not been able to meet the demand for processed soybean producers, especially domestic tempeh, and tofu [7, 8].

Tempeh is generally made from soybean seeds and is produced in home industries or small industries. Making tempeh from soybeans in Indonesia, both on an industrial and traditional scale, is basically almost the same. The difference lies in the way the epidermis is removed from the soybean seeds. Soybean seeds that will be made into tempeh must be removed from the epidermis that is still attached to the seeds. Traditionally, the epidermis of soybean seeds is removed by first soaking the seeds in a container [9]. By soaking, the soybeans will absorb a lot of water so that they become large. The soybeans (Figure 1) are then boiled and wait until they are warm. The soybean seeds are then put in a large plastic bucket and trampled using human feet, then washed several times with water until the epidermis is floating. wasted. Peeling the epidermis of soybeans traditionally has weaknesses, including in terms of the time this process takes, and in terms of cleanliness and health, this process is very unhygienic. It is necessary to develop technology and equipment for removing soybean epidermis that is fast, clean, and hygienic [10, 11].

Tempeh contains protein, carbohydrates, fat, fiber, sodium, calcium, vitamin B12, vitamin D, and iron [12]. Tempeh can be processed into various kinds of new processed foods that are easy to digest and can be used as a business opportunity even though the nutritional value of pure soybeans is lower [13].

Fig. 1. Soybeans for tempeh products.

The application of technology in soybean tempeh production has significantly improved the efficiency, quality, and scalability of this traditional food-making process. One of the key technologies used is automated fermentation control systems, which ensure optimal conditions for soybean fermentation by monitoring temperature and humidity [6, 7]. This helps produce a consistent and high-quality product. Modern machinery is also used in the grinding, dehulling, and soaking stages of soybean preparation, speeding up the production process and ensuring uniformity in the size and texture of the beans. Advanced steaming equipment allows for precise heat control, enhancing food safety and minimizing nutrient loss during the cooking process [10].

Packaging technologies, such as vacuum sealing, have been introduced to increase the shelf life of tempeh while maintaining its freshness and quality (Figure 2). In addition, automated cutting and packaging machines streamline the production process, making it possible to handle larger volumes while reducing manual labour. Overall, the integration of these technologies has allowed the tempeh industry to modernize while maintaining the traditional aspects of production, supporting both small-scale and large-scale producers in

meeting growing consumer demand. This shift toward technology adoption is essential for the sustainability and growth of tempeh production in today's competitive food industry [11].

Fig. 2. Tempeh product.

1.1 Background to the application of science and technology in the small tempeh industry

The significant growth of the small tempeh industry in Indonesia and the potential for improving productivity and product quality through the application of technology serve as the two main driving forces behind the application of science and technology in the small tempeh industry [14].

First, small-scale industry has become an integral part of the economy of society in Indonesia. Tempeh, as a traditional food rich in protein, has high demand in local and international markets. The small tempeh industry provides a livelihood for thousands of small entrepreneurs, especially in rural areas, who depend on the tempeh production process for their livelihoods.

Second, the application of science and technology in the small-scale industry has great potential to increase productivity, efficiency, and product quality. Fermentation technology, the use of modern equipment in the production process, and efficient production methods can help reduce production losses, increase product competitiveness, and expand the market for the small tempeh industry.

By utilizing advances in science and technology, such as the use of appropriate microorganisms, optimal control of temperature and humidity, and the use of modern equipment in the production process, small tempeh industries can produce tempeh that is higher quality, safer, and longer lasting. Therefore, the application of science and technology in the small tempeh industry is not only important to improve the welfare of small entrepreneurs but also to strengthen food security, advance the local food industry, and support sustainable economic growth [15].

1.2 Objectives and benefits

The aim of applying science and technology in the small tempeh industry is to increase productivity, efficiency, and quality of tempeh products and provide long-term benefits for business actors and consumers. Some of the main benefits of applying science and technology in the small tempeh industry are as follows:

- Increased Productivity: By utilizing the right technology, such as modern machines and efficient production methods, small tempeh industries can increase their production output. This will help meet growing market demand and reduce the risk of supply shortages.

- Improved Product Quality: The application of science and technology allows the use of better fermentation techniques and tighter control of the production process. This can produce a higher-quality, safer, and longer-lasting tempeh, increasing consumer satisfaction and brand image.
- Cost Efficiency: By using the right technology, small tempeh industries can reduce production costs, such as energy costs, raw materials, and labour. This will help increase business profitability and make tempeh products more affordable for consumers.

Tempeh is a healthy food because it contains vegetable protein, which is safe for the body. Tempeh is a traditional food that is famous nationally; almost all regions in Indonesia produce food made from tempeh. The tempeh production business unit at Banguntapan Bantul is generally managed in the form of a household business, so its development is always faced with problems related to soybean raw materials, namely the availability and quality of production factors, marketing, and capital. The problems faced by most residents are employment and poverty. Making tempeh products from local soybean raw materials is an effort to increase the willingness of residents to try entrepreneurship and create products that have selling value. It is hoped that the use of natural products, by improving their quality, will make village communities aware that natural products can increase their income [16].

Appropriate technology for tempeh production emphasizes simplicity, affordability, and sustainability, making it accessible to communities with limited resources. The basic process involves soaking soybeans, cooking, inoculating with a tempeh starter culture containing *Rhizopus mold* fermenting, and incubating the mixture until the beans are bound together by a white mycelium network [17]. This process transforms the soybeans into a protein-rich, probiotic-rich food with a nutty flavor and firm texture. The tempeh industry has the potential for growth because of significant market demand. The tempeh manufactured is distributed to both local and regional markets in and around Bantul City. Most of the tempeh business continues to operate using traditional methods in a regular work setting. Tempeh items made by industrial towns struggle to enter current markets. Furthermore, there is a lack of an effective marketing strategy to enhance market potential, as well as a deficiency in innovation to offer additional value and product competitiveness. Given the issues, one may contemplate methods for efficiently and hygienically producing tempeh [18]. This project aims to utilize science and technology to develop a small tempeh business in Banguntapan, Bantul, with an emphasis on improving local production capacities. The initiative seeks to enhance both the quality and quantity of tempeh production while also meeting local economic needs through the establishment of sustainable business models.

2 Research method

The knowledge and technology that will be transferred in these studies are knowledge, technology, and applied skills. This is related to partner industries (households), most of which have education up to high school, as well as capital that can be classified as micro-small; therefore, the transfer of applied technology that is applied is in the form of simple technology as a development of existing technology to lighten the workload.

2.1 Systematic architecture

The application of tool or machine design technology, apart from considering aspects of work comfort, also ease of operation and maintenance, as well as ease of duplication with local materials that are cheap and easily available on the market and can be carried out by local workshops, so that the application of this technology does not burden partners. Our method is illustrated in Figure 3, which is described the whole system architecture

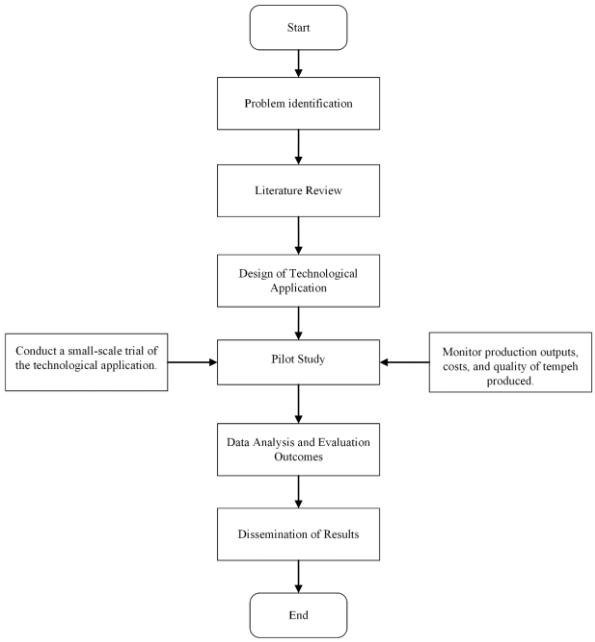

Fig. 3. Schematic architecture of making tempeh.

A soybean grinder for making tempeh is designed to break down whole soybeans into a fine, uniform mixture suitable for fermentation (Figure 4). The process starts by loading pre-soaked and cleaned soybeans into the grinder's hopper. Once the beans are inside, they move towards the grinding mechanism, typically consisting of rotating blades or grinding plates. As the soybeans pass through this system, the blades crush and grind them into a finer paste, which is necessary to achieve the right texture for tempeh production.

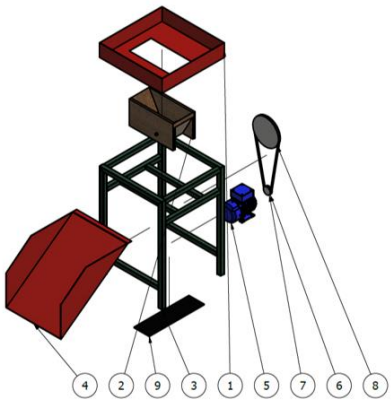

Fig. 4. Design of a soybean grinder for making tempeh.

In manual grinders, a hand crank powers the blades, requiring physical effort, while electric grinders use a motor for automated grinding. These grinders feature adjustable settings, allowing the user to control the level of coarseness or fineness based on specific requirements. The ground soybean mixture is then collected at the outlet, ready for the next steps in tempeh production, such as steaming and fermentation. This grinding process ensures that the soybeans are evenly broken down, which helps the fermentation culture (*Rhizopus mold*) spread uniformly, leading to high-quality tempeh. Overall, the soybean grinder simplifies and speeds up the labor-intensive process of preparing soybeans, making it more efficient for both small-scale and large-scale tempeh production.

The tool testing procedure has been divided into two steps. The initial stage involves preparing the machine to ensure its optimal functioning to support the investigation. In the second stage, data is gathered on the soybean grinding process using a set tool rotation speed [19, 20].

2.2 Feasibility Analysis

At this stage, an analysis of the feasibility of the process of making soybean tempeh using a soybean epidermis peeler is carried out. By using the data obtained, such as prices of materials, labor, income, production capacity, and so on, it is known whether the soybean tempeh production business can be developed or not [21]. The business eligibility criteria include the following:

1. Break Even Point (BEP) is used to determine the amount of sales volume without experiencing a loss or profit, which is formulated as follows:
$$BEP = \frac{Fixed\ cost}{(Selling\ price - Production\ price)} \quad (1)$$
2. Benefit Cost Ratio (B/C) is an indicator of business feasibility, which is seen from the comparison between the level of profit and the total costs incurred that seen in Equation 2.
$$B/C = \frac{PV\ Income}{PV\ Expenditure} \quad (2)$$
3. The payback period is the time required to pay back or return all the costs that have been incurred in investing in a project that seen in Equation 3.
$$Payback\ period = \frac{Total\ investment\ cost}{Total\ profit}\ x\ 1\ year \quad (3)$$
4. The return on investment is a comparison between the net profit obtained and the capital issued. ROI is calculated using the following Equation 4.
$$ROI = \frac{net\ profit}{Total\ Investment}\ x\ 100\% \quad (4)$$

3 Results and discussion

3.1 Appropriate technology for tempeh production

Appropriate technology for tempeh production refers to affordable, efficient, and sustainable tools tailored to small-scale producers. This technology considers local resources, skills, and conditions, ensuring accessibility and practicality for community-based tempeh production. Examples include simple fermentation systems that regulate temperature and humidity to optimize tempeh growth, ensuring consistent quality while minimizing spoilage. Small-scale

soybean dehulling and grinding machines can be powered manually or with minimal energy, reducing labour intensity and improving productivity [22].

Fig. 5. The process of making tempeh.

Additionally, solar dryers and efficient steamers help reduce energy costs in soybean preparation, making the production process more environmentally sustainable. Affordable packaging solutions, such as vacuum sealing, extend shelf life and preserving freshness without high costs. Overall, appropriate technology enhances production efficiency while remaining cost-effective and easy to maintain, enabling small-scale producers to compete in the market and sustain their businesses (Figure 5).

Generally, tempeh is used as a side dish, and tempeh is relatively cheap and can be purchased by all levels of society. The tempeh-making business has a very big role in efforts to equalize employment opportunities, business opportunities, and income [14].

Fig. 6. The result of soybean seeds being ground with a tool.

The result of the process of grinding soybeans for tempeh production using a grinder is 50 kg per hour and includes several important stages in preparing raw materials for fermentation into tempeh. In this process, soybean seeds are fed into a grinding machine that has a large capacity, making it possible to grind significant quantities of soybeans in a

relatively short time (Table 1). The grinding machine works by producing the texture of soybeans whose epidermis has been peeled off, which is the main basis for the subsequent fermentation process (Figure 6).

Table 1. Parts list

No.	Qty	Description
1	1	Upper cover
2	1	Grinder
3	1	Frame
4	1	Tilt plate
5	1	Electric motor
6	1	V-Belt
7	1	Grooved pulley 1
8	1	Grooved pulley 2
9	1	Machine plate

The next stage involves filtering and cleaning the soybeans to remove any dirt or epidermis fragments that are still attached that can be seen in Table 2. This process aims to ensure that the raw materials used in making tempeh are of good quality and free from contaminants. After going through these stages, the clean and smooth soybean seeds are ready to be prepared for the next fermentation process, which will produce high-quality tempeh (Figure 7). Thus, the results of the soybean grinding process with a grinding capacity of 50 kg per hour make it possible to produce tempeh in quite large quantities and efficiently, supporting a larger production scale to meet increasing market demand.

Table 2. The result of grinding machine.

Rotational speed (rpm) / Clearence space	Soybeans grinded in two (100gr)		
	2 mm	2.25 mm	2.5 mm
771.6	39.833	43.333	73
643	41.167	42.333	75.667
551	54	60.667	78.5
482.1	58.333	59.833	79.667
386	61.333	63.667	82.167

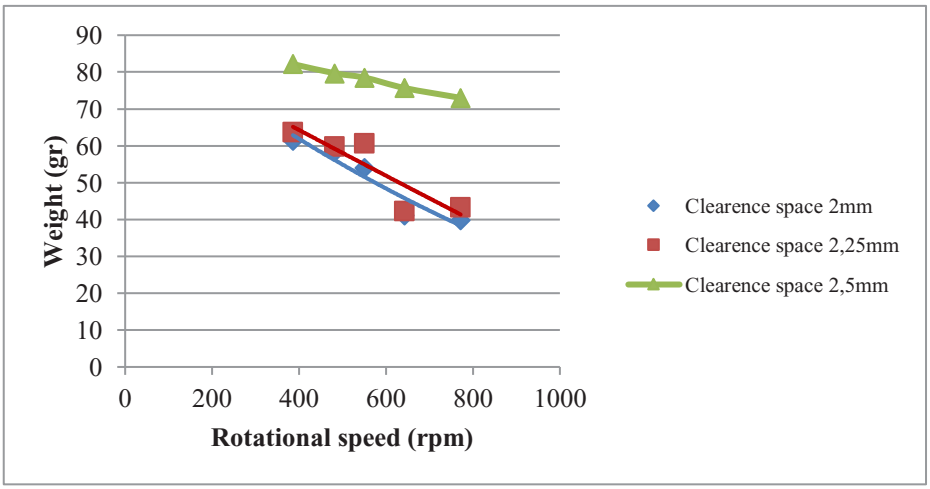

Fig. 7. The result of soybeans split into two.

Splitting the soybeans in half is a crucial step in preparing them for the subsequent fermentation stage in tempeh production that can see in Figure 7. Once the soybean seeds are halved, they are inoculated with *Rhizopus* culture to initiate the fermentation process for tempeh production. The soybean splitting process is a crucial step in tempeh production that readies the soybeans for fermentation, enhances tempeh quality, and minimizes contamination risks.

3.2 Economic analysis

Production investment costs refer to the various charges incurred in acquiring the items that are manufactured and seen in Table 3-5.

Table 3. Initial investment

No	Remarks	Unit	Cost per Unit (IDR)	Total (IDR)
1	Production house (m^2)	33	1,000,000	33,000,000
2	Grinded Soybeans tool	1	3,500,000	3,500,000
3	Gas stove	1	450,000	450,000
4	Gas canister	1	500,000	500,000
5	Production support equipment	1	1,000,000	1,000,000
Total Investment				**38,450,000**

Tempe production is planned to produce 6,000 pieces of tempeh per month with the initial investment costs mentioned above.

Table 4. Fixed cost (per month).

No.	Remarks	Unit	Cost (IDR)	Total (IDR)
1	Labor (person)	2	1,500,000	3,000,000
2	Maintenance (package)	1	30,000	90,000
3	Transport and distribution (days)	30	15,000	450,000
4	Depreciation of tool			60,083
5	Depreciation gas stove			7,500
6	Depreciation gas canister			8,333
7	Depreciation supporting equipment			15,833
Total Fixed Cost				**3,631,749**

Table 5. Variable cost (per month).

No	Remarks	Unit	Cost (IDR)	Total (IDR)
1	Soybeans seed (kg)	1,000	12,000	12,000,000
2	Tempeh yeast (package)	1	100,000	100,000
3	Plastic (pcs)	6,000	200	1,200,000
Total Fixed Cost				**13,300,000**

It is known that the price of soybean tempeh products is IDR 3,500 per piece, if the annual production capacity is 72,000 pieces, then the annual income is IDR. 252,000,000, as shown in Table 6.

Table 6. Investment and Sales Costs of Soybean Tempe.

No.	Remarks	Unit	Cost (IDR)	Total (IDR)
1	Total investment			55,381,749
2	Assumed product sales per month	6,000	3,500	21,000,000
3	Assumed product sales per year	72,000	3,500	252,000,000

The economic feasibility analysis used in this research is break-even point (BEP), benefit cost ratio (B/C ratio), and payback period (PBP), namely the rate of return on investment, which is used to measure the capital return period and return on investment (ROI). which can be seen in Table 7.

Table 7. Feasibility analysis.

No.	Feasibility analysis	Total	Remarks
1	Break-even point (BEP)-Product	24,973	Pcs
2	Break-even point (BEP)-Price	2,822	IDR
3	Benefit cost ratio (B/C ratio)	1.24	Point
4	Payback period (PBP)	1.13	Year
5	Return on investment (ROI)	88.3	Percent

The economic aspect involves evaluating the costs associated with setting up the tempeh production facility, including equipment, raw materials (soybeans), labour, and distribution. This part of the analysis helps determine the capital investment required and forecasts the potential profitability by assessing expected revenue from sales. From a technical perspective, the analysis considers the availability and appropriateness of the technology needed to streamline tempeh production. Key factors include the installation of automated fermentation equipment, modern packaging solutions, and quality control measures. Additionally, access to reliable suppliers of soybeans and the adequacy of local infrastructure (water, electricity) are considered to ensure uninterrupted production.

The feasibility study concludes that with sufficient technical support and marketing strategies, the creation of a small tempeh industry in Banguntapan is viable. The initiative can generate sustainable income for local producers while fulfilling market demand for this traditional yet nutritious food.

4 Conclusion and recommendation

The integration of technology, specifically the use of a soybean grinder machine, has proven to be a crucial factor in enhancing the productivity and efficiency of small-scale tempeh enterprises in Banguntapan, Bantul. The adoption of the grinder significantly reduced labour intensity increased the speed of soybean processing, and ensured a consistent texture of the soybeans, which is vital for producing high-quality tempeh. By streamlining the production process, the machine enabled producers to handle larger quantities of soybeans in a shorter time, thereby increasing overall output.

Additionally, the grinder machine allowed for better control over the quality of the processed soybeans, which directly impacts the fermentation process and the final product. This technological improvement not only optimized production but also made the business more competitive in local and broader markets. The soybean grinder test yielded an average of 78 grams of split soybeans when grinding 100 grams of soybeans at a spacing of 2.5 mm, using a variable grinder speed ranging from 300 to 700 rpm. The economic analysis results indicate that implementing soybean grinding technology in the small tempeh industry is possible, with a B/C ratio of 1.24 (>1), suggesting profitability in producing soybean tempeh using a peeler. Implementing small-scale soybean skin at home is possible, with a return on investment of 1.24.

This study has successfully demonstrated the critical role that modern techniques and digital tools can play in improving traditional food production. By introducing updated processing methods, and enhancing hygiene practices, the initiative has significantly increased production efficiency and market reach for local tempeh producers. This project highlights the importance of continuous technical support and education in sustaining the development of small industries. The success seen in Banguntapan can serve as a model for

similar communities, illustrating how small-scale industries can thrive with the right combination of technology and entrepreneurship. Future efforts should focus on maintaining these advancements, providing ongoing training, and fostering collaboration with both local government and private sectors to further develop the tempeh industry in the region.

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