Automated Soybean Dehulling for Tempe Cap Melati SME Supporting the MBG Supply Chain

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Abstract

The productivity of the soybean dehulling process at Tempe Cap Melati SME was improved through training and the application of appropriate technology in the form of an electric motor-driven soybean dehulling machine. The main problem faced by the partner was low production efficiency due to the use of manual equipment that required longer processing time, had limited capacity, and depended heavily on operator power. The activity methods included socialization, machine operational training, hands-on practice, productivity measurement, and comparative evaluation between manual and machine-based equipment. Testing was carried out through three trials for each dehulling method. The measurement results showed that the average dehulling time using the manual equipment was 38 seconds per bucket, while the machine required an average of 23 seconds per bucket. In addition, the average productivity of the manual equipment was 2.7 kg/minute, while the soybean dehulling machine reached 5.2 kg/minute. Based on these results, the machine increased productivity by 92.59% and reduced dehulling time by 39.47%. These results indicate that the soybean dehulling machine accelerated the production process, reduced manual workload, and increased the production capacity of the SME. Thus, this appropriate technology is suitable for supporting business sustainability and fulfilling tempeh supply needs more efficiently.

Keywords: *productivity; soybean dehulling machine; appropriate technology; tempe SME; training*

Introduction

Small and Medium Enterprises (SMEs) play a crucial role in supplying raw materials for the implementation of the Free Nutritious Meal Program (Makan Bergizi Gratis/MBG), particularly in providing protein-rich food products such as tempeh. Tempeh is a traditional Indonesian fermented soybean product that contains a high level of plant-based protein, which is essential for human health, especially for school-aged children. According to the Indonesian Ministry of Health, adequate protein intake is fundamental for supporting children's growth, cognitive development, and overall nutritional status (Ministry of Health of the Republic of Indonesia, 2023).

Strengthening human resources through the implementation of Appropriate Technology (AT) is not merely a process of transferring conventional technology into automated systems. Rather, it represents a strategic effort to enhance production efficiency, improve product quality, and increase operational effectiveness. The adoption of appropriate technology offers advantages beyond ease of operation; it also has the potential to significantly increase production capacity and productivity, ultimately contributing to higher income and improved economic welfare for business operators (Rogers, 2003; Tambunan, 2019).

The SME Tempe Cap “MELATI”, located in Purwosari Village, currently operates a traditional tempeh production business. The production process relies heavily on manual labor and simple non-mechanical equipment, particularly for removing soybean hulls after the cooking process. This conventional method requires considerable time and labor, which may limit production efficiency and output capacity. The existing soybean dehulling process can be seen in the following figure.

Figure 1.
Traditional soybean dehulling equipment used by Tempe Cap Melati SME.

The priority problems addressed through this community service program were identified and agreed upon with the primary partner, Tempe Cap Melati SME in Wonogiri. Considering that the partner is an economically productive business entity and part of the supply chain supporting the Government's Free Nutritious Meal Program (Makan Bergizi Gratis/MBG), the identified challenges included production efficiency, business sustainability, and the capacity to meet increasing tempeh demand (Tambunan, 2019).

To address these priority issues, the intervention adopted an integrated approach that combined the implementation of Appropriate Technology (AT) with practical capacity building for the partner. This approach was designed to strengthen the production process, improve operational performance, and support the sustainability of the enterprise (Rogers, 2003).

Production Sector Solution (Upstream Business Activities)

The primary challenge in the production sector was the low capacity and efficiency of soybean dehulling caused by the continued use of manual equipment. This condition limited production output, increased labor intensity, and reduced operational efficiency. Therefore, the program implemented a technological intervention through the provision and use of an automatic soybean dehulling machine.

Implemented Technology Solution

The project team introduced an appropriate technology innovation in the form of an electric motor-driven soybean dehulling machine to the partner SME. The machine was selected because its technical design and operational performance were more suitable for improving soybean dehulling capacity than the conventional manual equipment previously used by the partner.

The implementation of this solution consisted of the following activities:

1. Equipment Provision
   One unit of an automatic soybean dehulling machine was provided to support the partner's tempeh production process.
2. Installation and Operational Testing
   The machine was installed at the SME production facility, followed by operational testing to ensure that the equipment functioned properly and met the partner's production requirements.

3. Technical Training
   Technical training was provided for the SME owner, machine operators, and supporting volunteers on proper machine operation, cleaning procedures, safe use, and routine maintenance. The training also introduced roller adjustment procedures to accommodate different soybean conditions and achieve more consistent dehulling results.

Materials and Method

This study employed a quantitative descriptive approach within a community service framework based on the implementation of Appropriate Technology (AT). The descriptive approach was used to explain the training process, technology implementation, and changes in soybean dehulling productivity before and after the introduction of the machine. Meanwhile, the quantitative approach was used to measure and compare the working time and productivity levels between manual soybean dehulling equipment and an electric motor-driven soybean dehulling machine (Creswell & Creswell, 2018). The field activity was implemented during the 2026 community service program period and included socialization, operational training, hands-on machine practice, and performance testing at the partner's production site.

The community service activity was conducted at Tempe Cap Melati SME, located in Purwosari Village, Wonogiri District, Wonogiri Regency, Central Java Province, Indonesia. This SME is a community-based productive enterprise engaged in tempeh production. The participants involved in the activity consisted of the SME owner and production operators who were directly responsible for the soybean dehulling process. They participated in machine introduction, operation practice, cleaning and maintenance guidance, and comparative productivity testing.

The partner was selected using a purposive sampling technique because Tempe Cap Melati SME still relied on manual soybean dehulling equipment and required increased production capacity to meet growing market demand. Furthermore, the SME plays a strategic role in supplying tempeh as a plant-based protein source within the supply chain of the Government's Free Nutritious Meal Program (MBG) (Tambunan, 2019).

Data collection was carried out through direct observation, interviews with SME operators, time measurements during the soybean dehulling process, and documentation of production activities. Observations were conducted before and after the implementation of the automatic soybean dehulling machine to evaluate changes in operational performance (Sugiyono, 2022). The performance test consisted of three observation cycles using the manual method and three observation cycles using the machine-based method, with each cycle measuring processing time per bucket and resulting productivity.

The collected data were analyzed using quantitative descriptive analysis. The analysis focused on calculating the average dehulling time, productivity improvement, and time efficiency achieved through the use of the machine compared with the manual method. The results were then presented in tables and descriptive narratives to facilitate interpretation and evaluation of the technology implementation outcomes (Miles et al., 2018).

The average dehulling time was calculated using the following formula:

$$\left[\bar{T} = \frac{\sum T}{n}\right]$$

Where:

$(\bar{T})$ = Average dehulling time (minutes)

$(\sum T)$ = Total dehulling time from all observations

(n) = Number of observations

Productivity was calculated using the following formula:

$$\left[P = \frac{Q}{T}\right]$$

Where:

(P) = Productivity (kg/minute)

(Q) = Quantity of soybeans processed (kg)

(T) = Processing time (minutes)

The percentage increase in productivity resulting from the implementation of the soybean dehulling machine was calculated using the following formula:

$$\text{Productivity Increase } (\%) = \frac{P_2 - P_1}{P_1} \times 100$$

Where:

(P_1) = Productivity before machine implementation

(P_2) = Productivity after machine implementation

Meanwhile, time efficiency was determined using the following equation:

$$\text{Time Efficiency } (\%) = \frac{T_1 - T_2}{T_1} \times 100$$

Where:

(T_1) = Processing time using manual equipment

(T_2) = Processing time using the soybean dehulling machine

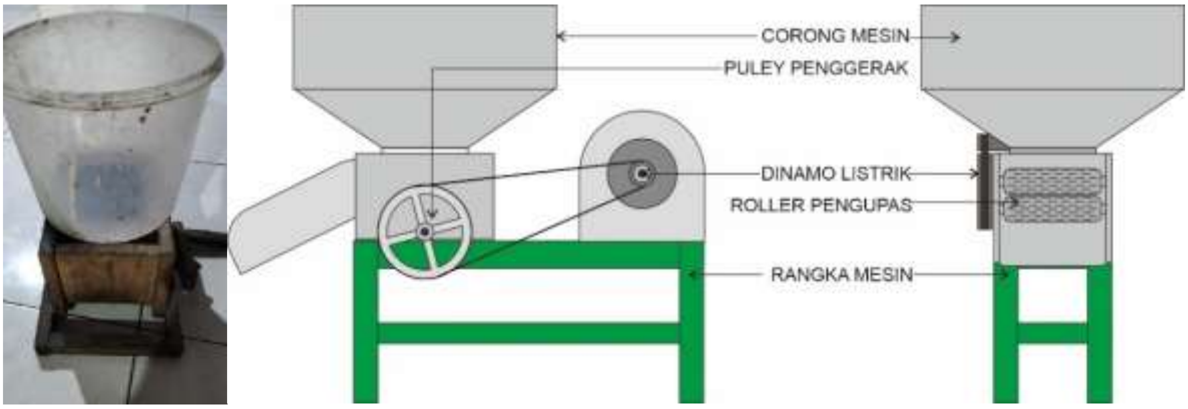
These indicators were used to evaluate the effectiveness of the appropriate technology intervention in improving operational efficiency and production performance at Tempe Cap Melati SME. All productivity results in the main tables are reported in kg/minute, while hourly capacity estimates were calculated by multiplying kg/minute values by 60.

Implementation and Results

The productivity performance of the soybean dehulling machine at Tempe Cap Melati SME represents an important outcome of this community empowerment program based on the implementation of appropriate technology. This initiative was motivated by a major challenge in the tempeh production process, particularly during the soybean dehulling stage, which had previously been performed using manual equipment.

Based on the partner's initial conditions, soybean dehulling was identified as one of the weakest points in the production chain because it required a relatively long processing time, greater labor input, and offered limited production capacity. This issue became increasingly important to address because Tempe Cap Melati SME serves as a supplier of tempeh products to support the nutritional needs of the Free Nutritious Meal Program (MBG) in the PPIT Al Huda Wonogiri area, where large quantities of tempeh are required each week.

Figure 2.
Design of traditional non-mechanical equipment and automated soybean dehulling system for soybean hull removal.



Tempe Cap Melati SME was identified as a productive partner facing constraints related to low soybean dehulling capacity. The previously used manual equipment was capable of processing only approximately 5–10 kg of soybeans per grinding cycle. In contrast, the implemented machine-based technology was designed to improve both production capacity and operational efficiency.

The performance evaluation was conducted by comparing the processing time and productivity levels of the manual dehulling equipment and the electric motor-driven soybean dehulling machine. The test results showed that the manual equipment required an average dehulling time of 38 seconds per bucket, whereas the machine required only 23 seconds per bucket. These findings indicate a substantial reduction in processing time following the implementation of the machine.

In terms of productivity, the manual equipment achieved an average processing capacity of 2.7 kg per minute, while the soybean dehulling machine reached 5.2 kg per minute. This result demonstrates that the machine was capable of processing nearly twice the amount of soybeans within the same period compared to the traditional manual method.

The findings confirm that the implementation of appropriate technology improved production efficiency at Tempe Cap Melati SME. The reduction in processing time and increase in productivity not only enhanced operational performance but also strengthened the SME's capacity to meet growing market demand, particularly in supporting the supply chain of the Free Nutritious Meal Program. Therefore, the adoption of the soybean dehulling machine can be considered a practical technological intervention for improving the productivity and competitiveness of small-scale tempeh producers.

Table 1.
Comparison of Average Productivity Between Manual and Machine-Based Soybean Dehulling Equipment

Type of Soybean Dehulling Equipment	**Average Productivity (kg/min)**
Manual Dehulling Equipment	2.7
Machine-Based Dehulling Equipment	5.2

Productivity Improvement : $\frac{5{,}2-2{,}7}{2{,}7} \times 100\% = 92{,}59\%$

The soybean dehulling machine implemented for the partner enabled independent operation, ensured compliance with safe operating procedures, and facilitated a direct comparison of productivity between manual and machine-based processing methods.

The measurement results showed that, in the manual process, the dehulling time for the first bucket was 36 seconds, the second bucket was 40 seconds, and the third bucket was 38 seconds. In contrast, when using the soybean dehulling machine, the processing time was significantly reduced, with 23 seconds for the first bucket, 22 seconds for the second bucket, and 24 seconds for the third bucket.

Based on these measurements, the average dehulling time using the manual method was 38 seconds per bucket, while the average time using the machine was 23 seconds per bucket. This indicates a substantial reduction in processing time following the implementation of appropriate technology.

The efficiency improvement was calculated based on the reduction in processing time, resulting in a time efficiency gain of **39.47%**, demonstrating that the machine significantly enhances operational performance and reduces labor time requirements. This improvement confirms that the adoption of appropriate technology effectively increases productivity and supports the operational sustainability of Tempe Cap "MELATI" SME.

Figure 3.
Manual and automated soybean dehulling machine.

Table 2.
Soybean Dehulling Time Using Manual and Machine Methods per Bucket

Type of Dehulling Method	Bucket 1 (seconds)	Bucket 2 (seconds)	Bucket 3 (seconds)	Average (seconds/bucket)
Manual	36	40	38	38
Machine	23	22	24	23

Table 3.
Time Efficiency per Kilogram

Type of Dehulling Method	Productivity (kg/min)	Estimated Time per kg
Manual	2.7 kg/min	± 22.2 seconds/kg
Machine	5.2 kg/min	± 11.5 seconds/kg

Based on the results of the soybean dehulling productivity test, the manual method achieved an average productivity of 2.7 kg/min, while the electric motor-based dehulling machine reached an average productivity of 5.2 kg/min. These results indicate an increase in productivity of 92.6% compared to the manual method.

In addition, the estimated dehulling time per kilogram decreased from approximately 22.2 seconds/kg using the manual method to approximately 11.5 seconds/kg using the machine. This represents a time efficiency improvement of 48.2%. Therefore, the implementation of appropriate technology in the form of a machine-based soybean dehulling device has proven to significantly enhance production capacity and accelerate the soybean processing workflow at Tempe Cap "Melati" SME.

Table 4.
Productivity Parameters of Soybean Dehulling Automation Technology

Parameter	Manual	Machine	Change
Average dehulling time	38 seconds/bucket	23 seconds/bucket	Time reduced by 39.47%
Productivity	2.7 kg/min	5.2 kg/min	Increased by 92.59%
Estimated hourly capacity	162 kg/hour	312 kg/hour	Increased by 150 kg/hour

Discussion

There is a clear practical difference in processing time between the use of manual equipment and machine-based equipment. When compared directly, the machine completed the dehulling process faster than the manual method. The average time difference between the two methods was 15 seconds per container. When converted into time efficiency percentage, the use of the machine reduced processing time by approximately 39.47% compared to the manual method. This value was obtained from the comparison of the time difference between the manual and machine methods relative to the manual processing time, namely $[(38 - 23) / 38] \times 100\%$. Thus, in terms of processing time, the soybean dehulling machine accelerated the production stage.

In addition to measuring processing time per container, productivity was also analyzed based on processing capacity per unit of time. Based on training observation results, the average productivity of the manual method is 2.7 kg/min, while the average productivity of the machine-based method is 5.2 kg/min. These data indicate that the use of the machine can achieve nearly twice the dehulling capacity compared to the manual method. The increase in productivity can be calculated using the formula $[(5.2 - 2.7) / 2.7] \times 100\%$, resulting in an improvement of 92.59%. In other words, the soybean dehulling machine is able to increase dehulling productivity by approximately 92.6% compared to the manual method. This increase serves as an important indicator that the implementation of appropriate technology has a direct impact on production efficiency at Tempe SME Cap Melati.

These findings strengthen the initial assumption of the program that the use of manual equipment is one of the factors contributing to low production capacity. In small-scale tempeh production enterprises or SMEs, production processes are often still reliant on human labor and simple equipment. While this approach offers advantages in terms of low initial cost and ease of use, it has limitations in capacity, speed, consistency, and labor dependency. When market demand increases, as in the case of Cap Melati SME which is linked to tempeh supply requirements for the MBG program, the limitations of manual equipment become a real bottleneck. Therefore, increasing productivity through simple mechanization represents a relevant and applicable strategy for the partner.

The average productivity of 5.2 kg/min achieved by the machine demonstrates that the applied technology has strong potential to support an increase in daily production capacity. The automation of the soybean dehulling machine not only accelerates the processing time per unit of raw material but also expands the SME's production capability on both a daily and weekly scale. This improvement is particularly relevant for small producers that need to maintain regular supply while reducing dependence on physically demanding manual work.

Contribution to Community

This community service program provides significant contributions to the partner SME, Tempe Cap "Melati", particularly in improving production efficiency, business sustainability, and workforce capacity. The introduction of appropriate technology in the form of an automatic soybean dehulling machine directly enhances the productivity of the production process by reducing manual labor intensity, shortening processing time, and increasing output capacity. As a result, the SME is expected to achieve higher operational efficiency and improved product consistency, which are essential for meeting increasing market demand, especially within the Free Nutritious Meal (MBG) supply chain.

In addition to technological intervention, the program strengthens the managerial and technical competencies of SME actors through structured training and mentoring. This capacity-building process equips business owners and workers with practical skills in machine operation, maintenance, and production management, thereby fostering independence and long-term sustainability of the enterprise. Furthermore, the program encourages a shift from traditional production practices toward a more efficient and technology-based production system, without eliminating local knowledge and craftsmanship.

At the community level, the program contributes to local economic empowerment by increasing the competitiveness of small-scale tempeh producers and supporting job sustainability in rural areas. By improving productivity and business performance, the SME is better positioned to expand its market reach and strengthen its role in local food supply chains. Ultimately, this initiative supports broader development goals, including food security, rural economic resilience, and community-based industrial development in Wonogiri Regency.

Conclusion

Based on the productivity analysis of soybean dehulling equipment used by Tempe Cap "Melati" SME, it can be concluded that the implementation of an electric motor-driven soybean dehulling machine significantly improves production efficiency and productivity. Prior to the adoption of this technology, the dehulling process was carried out manually, with an average processing time of 38 seconds per bucket and an average productivity of 2.7 kg/minute.

After the introduction of the soybean dehulling machine, the average processing time decreased to 23 seconds per bucket, while the average productivity increased to 5.2 kg/minute. This indicates a 39.47% reduction in processing time and a 92.59% increase in productivity compared to the manual method.

These improvements demonstrate that the applied appropriate technology is well-aligned with the partner's needs, particularly in addressing the limitation of low production capacity during the soybean dehulling stage.

Acknowledgements

The authors would like to express their sincere gratitude to all parties who have supported the implementation of this community service program. Special appreciation is extended to the management and members of Tempe Cap "Melati" SME, Wonogiri, for their active participation, collaboration, and willingness to adopt appropriate technology innovations during the implementation of the program.

The authors also acknowledge the support of the local community and relevant stakeholders who contributed to the smooth execution of program activities, particularly in facilitating field implementation and technical assistance.

Furthermore, gratitude is extended to all individuals and institutions who have provided moral, technical, and logistical support, directly or indirectly, in the success of this program.

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