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Green Manufacturing for Rural Tofu SMEs to Increase Global Competitiveness: Case Study in Tofu Industry Center, Banyumas Regency, Central Java

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Abstract. *Green manufacturing is an integrated sustainable activity that is expected to provide benefits for small industries, especially tofu industries that have obstacles such as pollution, simple technology, suboptimal processes, inefficiency of water and energy materials and limited financial capabilities. These obstacles cause the productivity process to be suboptimal and pollution around MSMEs due to waste that is disposed of without being processed. This research was conducted at the MSMEs center in Kalisari village, Banyumas, Central Java, which aims to obtain strategies in increasing tofu production efficiency through efforts to save the use of materials, water, energy and improve environmental quality through efforts to minimize and utilize waste with clean production options. The research method is green manufacturing audit method by identifying problems to analyzing feasibility opportunities from several aspects, namely technical, economic, and environmental. The results showed several counterfeits and alternatives recommendation to MSMEs in Kalisari Village, namely: gradual washing of soybeans, re-filtration of washing residues and soaking of water, use of boilers for cooking steam systems, application of Good Manufacturing Practices (GMP), use of automatic filtration tools for extraction, utilization of solid waste, and liquids. If green manufacturing is implemented, the total energy consumption per kg of soybeans from MSMEs in Kalisari Village can be reduced to 15.94 MJ/kg of soybeans. The percentage of liquid waste that can be lowered ranges from 59.64-71.07%. Tofu production can increase by 5.19%, the use of firewood can be reduced by 64.42% and the savings to be obtained range from 3.7-26.8 million rupiah/month.*

Keywords: *Audit, Green Manufacturing, Rural, SMEs, Tofu.*

1. Introduction

The tofu industry is one of the small business units that processes soybeans into white tofu or the like. Per capita tofu consumption in households in Indonesia in 2021 reached 8.23 kg and is predicted to increase to 8.67 kg in 2022 (BPS, 2021). In addition to producing tofu as the main product, the tofu industry also produces by-products in the form of solid, liquid and gas waste formed during the production process (Gaonkar, and Rosentrater, 2019).

The large amount of water used can cause problems with environmental pollution. In addition to waste, what has been an obstacle so far in various industries knows, especially the household-scale tofu industry, namely the technology used is still simple, relies a lot on human labor, low level of awareness of industry players, low knowledge about environmental management, suboptimal processes, inefficiency in the use of materials and energy and constrained financial capabilities.These obstacles cause suboptimal production processes which lead to insufficient productivity and encourage pollution around factories and water bodies due to waste that is directly disposed of without being treated. Therefore, a way is needed to be able to overcome existing problems, one of which is by applying the concept of a green manufacturing strategy in the tofu industry.

Green manufacturing is an environmental processing strategy that is preventive and integrated so that it can be applied to the entire production cycle (Shukla and Adil, 2021). Green manufacturing aims to increase productivity by providing a better level of efficiency in the use of raw materials, energy and water, encouraging better environmental performance through sources of waste generation and emissions and reducing the impact of products on the environment through environmentally friendly, yet cost-effective designs (Kholif and Asmoro, 2016).

The MSMEs production process knows the opportunity to apply green manufacturing as an alternative to process improvement (Nandy *et al*., 2022). The application of green manufacturing is carried out to increase efficiency, reduce pollutants and wasted energy to get better profits (Oliveira *et al.*, 2017). This can be done by eliminating waste, recycling waste, or utilizing waste for process improvement (Mishra and Dyadav, 2021). The resulting design will be carried out a feasibility analysis, especially from a financial point of view to determine the new design is feasible to be implemented (Hens *et al*., 2017).

The center of MSMEs knows Kalisari Village, Banyumas Regency, Central Java Province, which is a tofu industry center in the Banyumas area that produces liquid and solid waste. The waste can be minimized to reduce handling costs (Khalili, 2015). Seeing the existing problems such as inefficiency in the production process, less optimal production process conditions and the management of workers is still not correct, can be overcome by the application of green manufacturing (Zhang *et al*., 2018). Therefore, by implementing green manufacturing in tofu MSMEs, it is hoped that it can provide improvements in reducing industrial waste, increasing productivity and final quality of tofu produced, saving energy, and increasing profits for tofu MSMEs, especially the center of MSMEs in Kalisari Village, Banyumas Regency, Central Java Province.

The research of "green manufacturing" in MSMEs knows to increase global competitiveness is important to develop. Thus, strengthening food MSMEs based on green manufacturing will strengthen the nation's economy against current global competitiveness.

2. Materials and Methods

The materials used in this research were soybeans, tofu porridge, water, and firewood. The equipment used is a large bucket, cooking stove, cooking pan, filter cloth, grinding machine. The research variables in this research include: Mass, namely the mass of materials and the mass of water and energy.

Research Procedures are: (1) Quick Scan: In the quick scan analysis, environmental risk identification and waste formation analysis were carried out quickly to provide a basis for determining the activities obtained to be applied as green manufacturing activities for tofu MSMEs in Banyumas Regency, Central Java. (2) Determination of Alternative Green manufacturing Opportunities. The determination of green manufacturing opportunities is carried out based on waste and losses formed during tofu processing at the level of farmers, collectors, and industries. Green manufacturing activities are activities carried out to minimize waste and loss. Determination of green manufacturing alternatives based on literature search. (3) Feasibility Analysis: Feasibility analysis consists of technical, environmental, and economic. Technical analysis can be carried out based on the literature of reviews and interviews of related parties. Environmental analysis to determine green manufacturing opportunities can reduce the impact of pollution, minimize waste, and be able to support the concept of environmental maintenance. Financial analysis aims to estimate the costs and possible savings and benefits that can be obtained by applying green manufacturing. (4) Priority Selection Analysis with MPE Method: Priority selection uses the Exponential Comparison Method (MPE), which is a method for determining the order of priority of alternative decisions with plural criteria.

The data analyzed using the AHP method consists of several steps (Ma *et al*., 2020): (1) Structuring the hierarchy of problems faced in MSMEs, (2) Determining the priority of elements with the steps of making pairwise comparisons, filling in matrices, and synthesis. The result data is analyzed descriptively and mathematically based on measurements and field data. The formulation of the opportunity strategy for implementing green manufacturing is made by analyzing 5M elements (man, materials, methods, money, machines) in each MSME. The strategy formulation is formulated with the aim of providing convenience for MSME owners if these options/alternatives are implemented.

3. Results and Discussion

3.1. Material and Energi Identification in Process Staged

The process of processing soybeans into tofu consists of seven main stages, namely washing, immersion, grinding, cooking, separation of soybean juice from the pulp (extraction of soybean juice), clumping, molding, and pressing. Figure 1 shows the stages of the tofu production process in MSMEs in Kalisari Village, Banyumas Regency, Central Java Province which are analyzed.

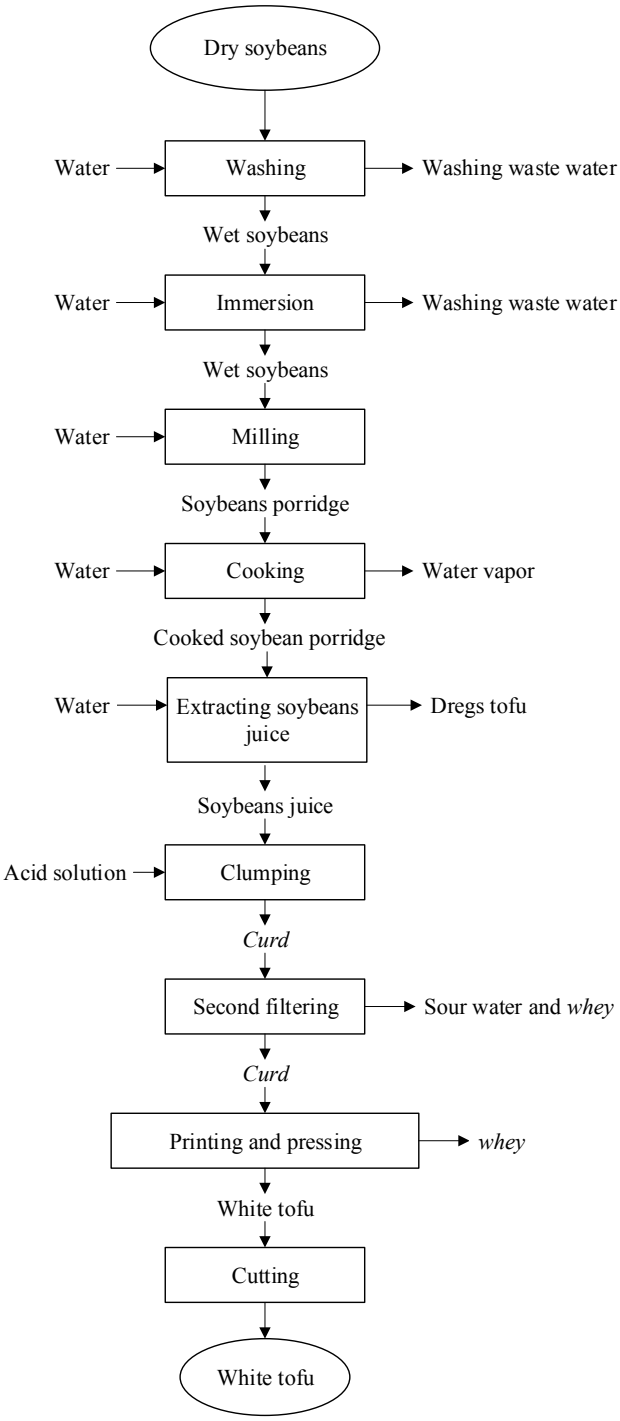

Figure 1. Stages of the tofu production process in MSMEs in Kalisari Village

3.1.1. Washing

Soybean washing is done by putting a few kilograms of soybeans into a large bucket container that is watered. Then stirring is carried out to clean the adhering dirt. After that, rinsing is carried out. The rinsing process at the Kalisari Village Tofu MSMEs on the washing resistance is carried out 3 times with flow.

The problem at this stage is the inefficiency of water use. In the washing process that uses 3 rinses on MSMEs, the village knows that every 80 kg of soybeans requires 680L/day with an average of 8.5L perkilogram. Another problem that occurs is the scattering of soybeans during the disposal of washing waste water which is also wasted around 0.2 kg. Wasted soybeans cannot be

reused because it is quite difficult to recover soybeans from liquid waste, the percentage of material loss at this stage is about 0.2%.

3.1.2. Immersion

Soybean immersion aims to soften the soybeans making it easier for the grinding process. The large amount of water absorption causes the weight of water to increase, the weight gain in MSMEs Tofu in Kalisari Village reaches 87% to 125% of the weight of all. Water temperature and immersion time affect the quality of wet soybeans . The water used uses ordinary water with normal temperature, immersion time for 3-5 hours. The problem that occurs at this stage is the inefficiency of water use and the scattering of soybeans on the floor, with the use of water for immersion quite a lot, which is about 2.7 L / kg of soybeans and the amount of wet soybeans that are scattered is about 0.3 kg. The average percentage of material loss at this stage is below 0.37%.

3.1.3. Milling

The grinding process is carried out per batch by entering 8.5 kg of wet soybeans per 1 bacth by draining water as much as 1 /kg to facilitate and speed up the grinding process. Grinding is carried out bacth to avoid deterioration in the quality and precision of the dosing of tofu. The explanation from the MSME election is that the waiting time from the grinding process to the cooking process is too long, resulting in a decrease in the quality of the soybean porridge that will be used. The problem at this stage is the scattering of wet soybeans and soybean slurry on the grinding device. The amount of wet soybeans and soybean porridge on the floor is about 0.4% wet soybeans and 0.6% soybean porridge. Wasted material cannot be reused because it has been mixed with dirt from the floor and liquid waste.

3.1.4. Cooking

The cooking process is done manually by heating soybeans on a wood-burning stove. The slurry cooking process is carried out by adding about 15 liters of water per batch of soybean slurry from the milling batch and cooked for 20-25 minutes. The problem at this stage is the formation of soot which causes the production roof to turn black and dirty, besides that cooking also requires a sufficient amount of time without efficiency.

3.1.5. Separation of soybean juice from pulp (extraction of soybean juice)

The filtering process is carried out manually by inserting cooked soybean porridge into a special tofu filter cloth hanging above the clumping tub by adding water which aims to facilitate the extraction process of soybean juice from the pulp and lower the temperature of the soybean pulp so that it is easy to squeeze or press. The amount of water used for the process is about 90 L/batch or about 1800 L/day. The results of the filtering and pressing process are directly accommodated in the clumping bath which will be further processed (Subramanian and Gunasekaran, 2015).

The problem at this stage is the use of a lot of water and less efficient than soy juice that is not optimal. The efficiency of the extraction process can be seen from the amount of curd produced from the extraction process to the second filtration. The churd produced is only about 16% of the total soybean juice produced from the extraction process, indicating that the soybean juice contained in the extracted liquid is still very low and dominated by water.

This process produces tofu dregs that can be directly sold as animal feed. The tofu dregs produced around 186 kg/day are divided into 2 sacks which are sold for around Rp20,000.00 - Rp25,000.00 per sack. Another problem is the tearing of the fabric used for the screening process which will endanger the workers.

3.1.6. Clumping

The clumping process is carried out by adding a solution of vinegar acid or acidic water (culprit). This process results in the protein contained in the soy juice coagulating due to acidification which will subsequently form curd. The clumping process is carried out approximately about 5-15 minutes with occasional stirring to form curd faster. The clumping process produces about 2505 kg of curd where the resulting curd is still mixed with whey. The acidic or 'culprit' water used at this stage can affect the quality of the tofu produced. The problem at this stage is the failure of the clumping process due to the coagulating solution (culprit) used has been stored for too long so that the quality is not good.

3.1.7. Printing and Pressing

This process is carried out by inserting curd into a square-shaped tofu mold made of bamboo covered with a special tofu filter cloth on the inside, pressing manually for further cutting. The problem at this stage is the scattering of curd on the floor so that the curd cannot be reused because it has been mixed with dirt from the floor.

3.2. Mass Balance and Energy Use

The results of the mass balance calculation show that from raw materials of 80 kg/day at the Kalisari Village Tofu MSMEs can produce about 231.2 kg/day of tofu with tofu pulp produced, which is around 186 kg/day and whey produced around 2144.8 L/day. The energy used is that of electrical energy and thermal energy. The process that requires thermal energy is the boiling/cooking process, which is around 38.59 MJ/kg of soybeans. While the process that requires electrical energy is the milling process to drive the grinding machine, production and non-production lighting lamps and water pumps with a total energy use of around 0.51 MJ/kg of soybeans. The total input energy required to process 1 kilogram of soybeans into tofu is about 39,097 MJ.

3.3. Identify Waste Minimization Opportunities

Identification of waste minimization opportunities begins with determining the source of waste formation and the emergence of inefficiencies in the use of water and materials. Based on the analysis of production stages that have been carried out at MSMEs Tofu in Kalisari Village, the stages that produce a lot of liquid waste and inefficiency in water use occur at the extraction stage of soybean juice to the 2nd filtration process, the washing stage and the immersion stage. The amount of water used and liquid waste in the form of whey produced from a series of extraction processes is about 1800 L/day and whey produced is around 2144.8 L/day from the extraction process to the 2nd filtration. Inefficiency of water use occurs because the extraction process of soybean juice is carried out by rinsing soybean slurry repeatedly with the use of very much water without any special dose.

The soybean extraction process still uses a manual process that is less effective and requires a lot of water, allowing the extraction of soybean juice not to occur completely so that the resulting yield is less than optimal. The efficiency of the extraction process can be seen from the amount of curd produced from the extraction process to the 2nd filtration, which is only about 16% of the total soybean juice produced from the extraction process. The resulting percentage is relatively small and can still be optimized again. This can be overcome by replacing the manual filtering system with a more efficient and effective automatic filtering tool. In this process produces quite a lot of tofu dregs. But this is not a problem, because it can be sold to third parties to be used as animal feed.

The process of washing and soaking soybeans is a source of waste generation, because at

these two stages the water used is quite a lot so that it is directly proportional to the liquid waste used. The amount of water used in the washing and soaking process is around 897 L/day or about 11.2 L/kg of soybeans /day. Meanwhile, the amount of waste generated from this process is around 806.5 L/day.

The use of water occurs most in the washing process. Washing is carried out with running water and the washing waste water is directly discharged into the environment. The tofu production process requires 28.8 L/kg of soybeans, which means that the use of water in the Kalisari Village Tofu MSMEs can be reduced so that the amount of waste produced is reduced (Rahayu, *et al*., 2016). The use of water in the washing process can be reduced by washing gradually, where the water in the last rinse is reused as the first rinse for the next batch so that waste is reduced.

The residual water of washing and soaking is usually directly discharged into the sewer, thus causing less efficient use of water. In fact, the water from the washing and soaking process can be treated physically by filtration so that it can be reused for the sanitary needs of the production room. Inefficiency in the use of materials and water is caused by poor procedures for handling materials by workers and poorly maintained production space due to the lack of awareness of workers in maintaining a clean environment in the production room environment.

Table 1. The amount of waste and water use in MSMEs Tofu in Kalisari Village (per kilogram of dry soybean raw materials)

Parameters	per kilogram of dried soybean raw materials
Know (kg)	2.89
Tofu pulp (kg)	2.325
Liquid waste	
- Whey (L)	28.423
- Washing Residual Water (L)	8.41
- Immersion residual water (L)	1.675
Use of water for production (L)	43.59
- Washing process (L)	8.5
- Immersion process (L)	2.71
- Filtering and pressing (L)	22.5
Sanitation of production tools and rooms (L)	700

The process of cooking soybean porridge still uses a furnace and takes longer, causing problems such as the emergence of soot on the production roof. This can be avoided by changing the furnace cooking system to a steam system by using a boiler equipped with a high chimney.

The clumping process produces a large amount of whey, which is about 2144 L/day. The resulting whey is directly discharged into the environment mixed with liquid waste from other processes. Whey itself can be used as a material for making nata de soya or can be used as a material for making biogas because it contains organic matter that can be converted into methane gas.

The tofu cutting process leaves the rest of the tofu fringe often dropped and wasted. The remaining tofu fringe that was dropped caused the production floor to become dirty and invited poultry into the production room to eat the remaining tofu fringe that fell on the floor. The rest of the tofu fringe itself can be used for the manufacture of round tofu so that this waste is not wasted and pollutes the environment. Based on the description of the existing problems, it is known that

the production process at MSMEs Tofu in Kalisari Village is still not optimal, so it is necessary to compare it with literature as a reference to make improvements.

3.4. Recommended Green Manufacturing Options/Alternatives

Recommended Options/Alternatives for improvement in MSMEs know Kalisari Village as follows: (1) Apply Good Manufacturing Practice (GMP): GMP training for workers is intended to improve worker performance, reduce the risk of human error so as to optimize the efficiency of using materials, water and prevent losses throughout the production process such as the scattering of soybeans and soybean slurry on the floor, excessive water use, use and maintenance of poor equipment and so on. (2) Use of Boilers For Cooking Steam Systems: The use of boilers in cooking steam systems can reduce the use of wood fuel by 50-70%. The advantage of steam system cooking is that the cooking time is relatively fast compared to furnace cooking so that it can speed up the process and increase productivity. (3) Gradual Washing: The washing process at MSMEs Tofu in Kalisari Village still needs to be improved. Soybean washing is carried out four times in stages with the reuse of the fourth washing rinse water for the first washing rinse (Djayanti, 2015). This will not affect the quality of the tofu produced. (4) Re-Filtration of Residual Washing and Soaking Water: The residual water of washing and soaking in MSMEs Tofu in Kalisari Village has been thrown away immediately, even though the water can be re-filtered because it only contains impurities that can be physically separated through a layer of porous material that is carried out by gravity. The materials and equipment used for filtration are quite simple, using only 2 reservoirs consisting of settling and filtering tubs whose size is adjusted to the amount of waste present. (5) Making Nata de Soya from Whey: The recommended green manufacturing option/alternative for MSMEs in Kalisari Village is the use of whey for the production of nata de soya which is formed through a fermentation process using Acetobacter xylinum bacteria, so as to produce a nata layer on the media. In addition to reducing the volume of whey, this option can also provide additional benefits for MSMEs in Kalisari Village. (6) Conversion of Tofu Liquid Waste Into Biogas: Tofu liquid waste, especially from the clumping process and other processes, has the potential to be used as biogas, because it contains organic matter that can be converted into methane gas through an anaerobic process. The advantage of this process is that in addition to decomposing environmental pollution caused by tofu waste, it can also produce renewable fuels that can reduce the use of fossil fuels and wood that have been used in MSMEs Tofu in Kalisari Village. In addition, effluent from anerobic processes can be used as a liquid fertilizer for plants. (7) Use of Automatic Filtering Tools: The use of automatic filtering tools can maximize the extraction yield so as to increase the yield of soybean juice. The advantages that can be obtained from the automatic filtration process are that the extraction process is faster and more effective, does not require water as an extraction medium, reduces liquid waste, and saves operational costs.

3.5. Prioritization of Green Manufacturing Options/Alternatives

The green manufacturing options/alternatives recommended to MSMEs in Kalisari Village Tofu are determined by testing alternative green manufacturing using the Process Hierarchy Analysis (AHP) method to determine alternatives that are prioritized in improving MSMEs in several parts, both in the production process, technology, management and waste treatment.

The initial stage in using AHP is to determine the goal. The purpose of this research is to improve the performance of the tofu industry through the implementation of green manufacturing. The criteria/factors used are 3 criteria for green manufacturing eligibility opportunities, namely technical aspects, economic aspects and environmental aspects.

Furthermore, a pair comparison between criteria / factors is carried out. According to Saaty

(1980), comparative assessment is said to be consistent if the consistency ratio (CR) does not exceed 10% or < 0.10, if the consistency ratio value obtained is more than 10%, it means that the assessment is still random so it needs to be corrected again. Based on the results of the comparison of pairs between each attribute in the criteria and alternatives to green manufacturing in this researchy, the CR value obtained was <0.1. This means that the comparison of criteria and alternatives carried out has been consistent so that it does not require revision of the reassessment.

Table 2. Priority of green manufacturing criteria factors

No.	Criteria Factors	AHP Score
1	Environmental Aspect	0.1373
2	Economics Aspect	0.2394
3	Technical Aspect	0.6233

Table 2 shows the results of the comparison of pairs between the factors of green manufacturing criteria set out in the research. The results of the comparative analysis of green manufacturing criteria factors show that the top priority in choosing green manufacturing options/alternatives that can be applied is the feasibility of these options/alternatives technically with an AHP score of 0.6233.

The technical feasibility criteria that are balanced in MSMEs know Kalisari Village are processes (according to procedures and improving process efficiency), materials (maintaining the quality of materials, utilization, and efficiency of using materials), equipment (ease of operating and maintenance systems), and human resources or HR (HR who understand and understand and system security for workers.

Table 3. Priority of green manufacturing options/alternatives in MSMEs know Kalisari Village

No.	Green Manufacturing Alternatives	AHP Score
1	Pembuatan Nata de Soya	0.032
2	GMP	0.065
3	Pemasakan sistem uap	0.080
4	Biogas	0.130
5	Penyaring otomatis	0.168
6	Penyaringan kembali	0.230
7	Pencucian bertahap	0.295

Table 3 shows the results of a pairwise comparison analysis of green manufacturing options/alternatives in MSMEs Tofu in Kalisari Village. The first priority of green manufacturing options/alternatives based on AHP scores is the gradual leaching of soybeans with a value of 0.295. The second priority is to return the remaining washing and soaking water with an AHP score of 0.230. The third priority is the procurement of an automatic filter for the soybean juice extraction process with an AHP score of 0.168. These three priority options/alternatives can have a very large impact on reducing waste, which has an impact on production efficiency and the environment.

3.6.Evaluation of Feasibility Opportunities for Priority Green Manufacturing Options/Alternative in MSMEs in Kalisari Village

3.6.1. Evaluation of First Priority Eligibility Opportunities

The first priority opportunity is the gradual washing of soybeans to address the problem of overuse of water or inefficiency of water use. This is an important problem because each stage of

the production process uses large amounts of water. (1) Technical Aspects: Washing soybeans is technically fairly easy, because it only requires the addition of simple equipment such as several large buckets. Water in the first to third rinses can be discharged into a temporary reservoir, but for water in the fourth rinse it can be reused for the first rinse. (2) Economic Aspects: Gradual washing has the potential to reduce water use in MSMEs Tofu in Kalisari Village. The potential water savings that can be done if this green manufacturing option/alternative is implemented, which is Rp. 34,807 /month. (3) Environmental Aspects: Gradual washing has the potential to reduce water use so that the waste generated at this stage is also reduced. Gradual washing of soybeans has the potential to reduce water use by 170 L/80 kg of soybeans /day so that the water used when implementing this option / alternative is carried out to 510 L/80 kg of soybeans.

3.6.2. Evaluation of Second Priority Eligibility Opportunities

Re-screening is the second option to reduce water use and minimize waste caused by the washing and soaking stages of soybeans, and can be used as a sanitation of the production room. (1) Technical Aspects: The washing and soaking residual water filtration option requires equipment in the form of one filtering tub and settling tub, as well as requiring materials for filtration such as alum, sand chlorine, ijuk, charcoal and bricks. This option will provide additional tasks for workers to control the filtering trough. (2) Economic Aspects: The cost of water supply needs in the washing and soaking process before the formulation of the green manufacturing option of 806.5 L/80 kg of soybeans is Rp165,233 /month. This option can provide savings on the use of production space sanitation water, and has the potential to reduce waste by 806.5 L/day and the savings that can be obtained by Rp143,530 /month. (3) Environmental Aspects: The green manufacturing option uses materials that have the potential to reduce liquid waste by 701 L/day from the washing and soaking process and can replace the need for water for room sanitation of around 700 L/day. This process requires a simple water recycling installation, so that the water can be reused and minimize pollution to the environment.

3.6.3. Evaluation of Third Priority Eligibility Opportunities

The priority opportunity of the third option is the procurement of automatic filtering devices for the soybean juice extraction process. The application of this option can solve the problem of water use and the amount of waste caused. The extraction process is the stage that requires the most water compared to other processes because water is used as an extraction medium so that it is directly proportional to the waste produced. The extraction process with an automatic filter does not require water, because the soybean slurry from the cooking process can be directly filtered by centrifugation principle. (1) Technical Aspects: The application of theoption of procuring an automatic filter for the soybean juice extraction process is quite easy to do by purchasing an existing automatic filter device or can make your own filter device consisting of a rotating tube, stirrer, pully, motor, inverter and filter cloth holder. The dimensions of the tubular tool have a height of 42.5 cm and a diameter of 30 cm with a working volume of about 30 L. But technically, it requires experts to understand the procedure for using the tool so as not to pose a danger to workers and the MSME environment. (2) Economic Aspects: The use of water for manual extraction of soybean juice before the formulation of this option is around 1800 L/day with a water supply cost of Rp368,550 /month. If this option is carried out, then the extrasion process no longer requires water so that it can reduce production costs. In addition, the extraction process with automatic filtering devices takes time relatively fast compared to manual processes, so the production time will be faster and reduce the cost of wage expenditure for workers. The total profit or savings that can be obtained if this option is carried out is around Rp645,350 /month. (3) Environmental Aspects: The application of this option has the potential to reduce water use and

the amount of liquid waste produced around 1800 L/day so that it can help to overcome the problem of waste in MSMEs Tofu in Kalisari Village, especially liquid waste or whey generated from the clumping process.

4. Conclusions

Priority options/alternatives to green manufacturing in MSMEs Tofu in Kalisari include gradual washing of soybeans, re-filtration of residual washing and soaking water, and procurement of automatic filtering devices for soybean juice extraction. The implementation of recommended options/alternatives can increase tofu production by 5.19%, with the percentage of decrease in the amount of water and waste use produced respectively by 63.83% and 71.07%. The decrease in energy and firewood use by 59.25% and 64.42% as well as the total savings and benefits that can be obtained if the 7 recommended options/alternatives are implemented in MSMEs Tofu in Kalisari Village reach Rp. 3,763,800/month. The strategies recommended in the opportunity to implement green manufacturing options/alternatives in MSMEs Tofu in Kalisari Village are the transition of more efficient technology, the gradual replacement of the washing system to washing, the importance of understanding the treatment of liquid waste and the separation of waste by type, characteristics and levels of pollutants, the transition of the use of imported soybeans to local soybeans, the importance of implementing GMP, making clear SOPs, and encourage the implementation of an environmental management system that is integrated with green manufacturing, as well as alternative uses of whey to nata de soya.

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