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Journal Title

Sustainable Organic Fertilizer Production in Shallots Using Bio-Pulverizer Technology and Solid-State Fermentation for Cost Reduction and Soil Degradation Prevention

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ABSTRACT

Probolinggo Regency, a key producer of shallots in East Java, faces challenges such as soil degradation, high fertilizer costs, and a decline in harvested land. This community service program aims to address two major issues: inefficiencies in organic fertilizer production and unstable market prices. By introducing a Bio-Pulverizer machine and Solid-State Fermentation (SSF) methods, the program seeks to reduce fermentation time from 30 days to 9 days, improve production efficiency, and reduce pesticide use. The program includes stages of socialization, training, technology implementation, ongoing assistance, and sustainability measures. Key performance indicators include process time reduction, production volume increase, and digital adoption. The program's overall objective is to enhance the sustainability and independence of shallot farming through efficient organic fertilizer production and data-driven decision-making, ultimately contributing to improved soil fertility and farm profitability.

Keywords: ***Shallots, Organic Fertilizer, Bio-Pulverizer, Solid-State Fermentation***

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1. INTRODUCTION

Probolinggo Regency's shallot production is facing significant challenges due to a 2.47% decline in harvested areas between 2021 and 2022, largely attributed to soil degradation from intensive chemical usage and rising costs of fertilizers and pesticides. The traditional practices, which increasingly rely on synthetic inputs, exacerbate these issues by contributing to soil and ecosystem degradation, ultimately impacting productivity and farmers' incomes [1]. The economic value of shallots in Indonesia underlines the necessity for sustainable practices; however, conventional methods often hinder this potential [2]. Concurrently, the rise in goat and sheep populations presents an opportunity to utilize livestock manure as organic fertilizer, a strategy that has not been fully embraced due to risk perceptions associated with organic production [1]. Optimizing this resource could help mitigate some of the soil quality issues while promoting a shift towards sustainable agriculture in shallot farming practices.

Field practices from shallot farmers indicate that properly processed organic fertilizer derived from livestock manure (KOHE) can enhance productivity. For example, on a 1/3 hectares plot using 2 quintals of seeds, yields have reached 2–2.5 tons within 50–60 days, reflecting increased production efficiency of approximately 25% [1]. Additionally, this method shows a potential reduction in pesticide application, aligning with sustainable farming goals. However, challenges persist, including the 30-day decomposition time of KOHE, limited labor resources, small-scale production constraints, and price fluctuations (IDR 10,000–IDR 50,000/kg) that complicate financial decision-making [3]. Moreover, the adoption of sustainable practices can bolster shallot farmer resilience against economic instability. By focusing on efficient and creative farming techniques, farmers can improve their financial stability and output [4]. The integration of KOHE into shallot farming not only supports environmental sustainability but could also pave the way for improved economic conditions for farmers [5].

The proposed community service program aims to address inefficiencies in organic fertilizer production and stabilize prices through enhanced management practices. The introduction of the Bio-Pulverizer machine, which operates at 6.5 HP and processes approximately 30 kg/hour, along with Solid-State Fermentation (SSF) technology, is expected to significantly reduce fermentation time to less than nine days, potentially leading to improved production efficiency and quality of the organic fertilizer. However, specific claims about homogeneity and organoleptic quality should be directly supported by evidence from relevant studies, which is not provided in the references [6].

Hatta et al. emphasize the importance of environmentally friendly practices in fertilizer production, demonstrating that stakeholder education and empowerment are crucial for sustaining agribusiness within farming communities [7]. This emphasis aligns with the notion that

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effective farm management practices can enhance decision-making and forecast pricing trends, thus aiding farmers in making informed business decisions, although direct evidence specific to price fluctuations is not clearly linked to the provided reference [8].

Moreover, innovative technologies like SSF and improved machinery are indeed vital for promoting efficient organic fertilizer production and helping local farmers navigate market challenges; however, there may be nuances regarding the integration of such technologies and their effectiveness across different contexts, which the references do not fully clarify [9].

The community service program is structured in progressive stages, focusing on addressing inefficiencies in organic fertilizer production and enhancing business management practices. Initiating with socialization through surveys and focus group discussions (FGDs), stakeholders align on targets while increasing awareness of the program's benefits [6]. Training sessions will cover operational guidance for the Bio-Pulverizer, application of Solid-State Fermentation (SSF), and the preparation of organic fertilizer using a specific formulation involving coconut husk, rice husk charcoal, and cocopeat.

In the application phase, tasks include installation, trial runs, and routine production that incorporates SSF to reduce fermentation time to nine days, ultimately targeting a production volume of about 30 sacks per month. Continuous mentoring and evaluation through weekly meetings will facilitate on-site troubleshooting and log audits. Furthermore, adopting digital tools promises to enhance the accuracy and consistency of data inputs. The goal for digital adoption is set for improvement; however, specific accuracy benchmarks were not provided in the references. These interconnected efforts aim to foster sustainable agricultural practices and empower local farmers economically and environmentally.

The general objective of the program is to strengthen the independence and sustainability of shallot farming through efficient organic fertilizer production and data-driven decision-making. Specific objectives include: enhancing technical capacity in producing fertilizer from local materials, synchronizing fertilizer production cycles with planting calendars, organizing financial record-keeping into a digital system, and providing predictive price information for planting-harvesting-selling strategies. The expected benefits include cost efficiency, strengthened cash flow and access to financing (digital track record), improved soil fertility, and enhanced technology literacy at the farmer level.

2. METHOD

2.1 Socialization Stage

The first stage involves initial coordination among the team to analyze the partner's needs. The activities begin with identifying the requirements through surveys and discussions with the partner to understand their specific needs regarding organic waste processing, cost efficiency in fertilizer production, and the digitalization of financial record-keeping

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and shallot market price information. This is followed by an introductory meeting where the program is introduced, and information about the Bio-Pulverizer machine technology, Solid-State Fermentation methods, and digital financial record-keeping systems are shared. These steps are aimed at aligning the objectives and expectations of the partners with the program's goals. After this, the team proceeds with the technical implementation, which begins with the design and construction of the Bio-Pulverizer machine and the application of Solid-State Fermentation. This includes identifying the technical requirements, creating mechanical designs, building a prototype, conducting initial trials, and evaluating the machine's performance before finalizing the production of the machine for use by the partner.

2.2 Training Stage

The training stage is structured to provide comprehensive knowledge and practical skills. The first component of this stage focuses on training the partners in the use of the Bio-Pulverizer machine and the Solid-State Fermentation method. Experts in mechanical engineering and agriculture conduct the training, ensuring participants learn how to effectively operate the machinery and optimize the fermentation process. In addition, an evaluation session is included to measure the participants' improvement and ensure that they have mastered the operation of the machine. The second component of training focuses on the digital application usage, specifically the digital financial record-keeping system and the shallot price prediction application. This training aims to enhance the partners' ability to navigate the application interface, input financial data, and interpret and use price prediction information. To ensure the success of this phase, participants undergo an evaluation of their skills to confirm that they are ready to independently use the digital tools for managing financial records and predicting market trends.

2.3 Technology Implementation Stage

The technology implementation stage begins with addressing production issues. This is done by procuring and implementing the Bio-Pulverizer machine, which is gasoline-powered with a 6.5 HP engine and a 30 kg/hour capacity, and integrating Solid-State Fermentation (SSF) techniques. The implementation process starts with analyzing the partner's technical needs, followed by the delivery of the machine and the training of the partner's staff on its use. After the training, a trial run of processing organic waste using SSF is conducted on-site at the partner's location. The technical evaluation at this stage ensures that the technology is able to speed up the production process from 30 days to ≤9 days and increase production output from 10 sacks to 30 sacks per month. The successful implementation of the technology has resulted in the partner independently utilizing the equipment and methods to produce organic fertilizer more efficiently.

2.4 Assistance and Evaluation Stage

The assistance and evaluation stage focuses on providing ongoing support and assessing the effectiveness of the technology implemented. Intensive mentoring is provided to the partner,

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particularly in operating the Bio-Pulverizer machine, applying Solid-State Fermentation, and using the digital applications for financial record-keeping. Regular technical consultations are held in the form of weekly meetings to discuss and address both technical and non-technical challenges faced by the partner. This allows for real-time problem-solving and continuous improvement in the process. Additionally, the evaluation of the effectiveness and functionality of the technology is conducted. This assessment includes evaluating the partner's ability to operate the machine, understand the SSF process, and use the digital applications for tracking expenses and sales. The evaluation results indicate that the success rate of using the digital application reached 90%, as measured by the accuracy and consistency of the data entered by the partner.

2.5 Sustainability Stage

The final stage focuses on ensuring the long-term sustainability of the program. Continued consultation and support are aimed at enhancing the capacity for large-scale organic fertilizer production, ensuring that the fertilizer produced can be marketed and distributed effectively. Additionally, the digital application system will be updated with the latest data to improve the accuracy of shallot price predictions, supporting more informed decision-making for farmers. To maintain the effectiveness of the technology, a routine maintenance schedule for the machine and application has been created and communicated to the partner. Furthermore, the partner has been provided with self-maintenance modules, ensuring that they are able to independently maintain the technology and sustain its benefits over time.

3. RESULT

3.1 Results of The Socialization Stage

The socialization stage serves as the initial step to align the perceptions between the implementation team and the partners regarding the problems faced and the technological solutions to be applied. This activity began with a brief survey on-site to identify the actual conditions of the organic fertilizer production process. The survey reviewed the workflow used, average fermentation time, monthly production capacity, and technical barriers commonly faced by partners, such as labor shortages and uncertainty in livestock manure supply. Following this, a Focus Group Discussion (FGD) was conducted with the partners to explore their managerial needs in shallot farming. The discussion focused on business cash flow, input costs, including the purchase of livestock manure (KOHE), and harvest sales patterns. The FGD revealed that financial record-keeping was still manual, and business decisions were often based on personal experience rather than data-driven analysis. Additionally, the team provided an initial demonstration of the technology to be used. Participants were introduced to the functions and benefits of the Bio-Pulverizer machine for accelerating the breakdown of organic materials and the Solid-State Fermentation (SSF) method to expedite the fertilizer fermentation process. The team also explained the planned application of digital financial record-keeping systems.

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The socialization activities produced documented outcomes, including: meeting minutes, attendance lists, and technical needs documentation, such as machine power specifications, a target production capacity of ±30 kg/hour, and the requirement for a dry, ventilated workspace. The minutes also captured non-technical needs, such as a brief SOP for operations and a machine maintenance schedule. The results also included a list of functional application requirements, covering features for expense input, income tracking, profit/loss summaries, and a daily price prediction display for shallots. Additionally, target results were aligned, with goals to reduce the fertilizer fermentation time to ≤9 days per SSF batch and increase production capacity to 30 sacks per month as an initial implementation target. This stage led to initial impacts, including the agreement on program success indicators. The partners committed to preparing raw materials and workspace to support implementation, while the implementation team took responsibility for providing the machines, operational SOPs, and digital application training. This agreement laid the foundation for progressing to the training and technology application stages.

3.2 Results of The Training Stage

The training stage aimed to enhance the partners' capacity to process local raw materials into high-quality fertilizer ready for use on shallot fields. During this stage, participants were introduced to and directly engaged in the processing techniques of three main materials: goat manure, rice husk charcoal, and cocopeat from coconut husk waste, as seen in Figure 1. The first activity focused on processing goat manure. The partners were taught how to conduct dry fermentation through a drying process to reduce moisture content, ensuring the material remains stable and odor-free. The addition of lime at 2-3% of the total weight serves to neutralize acidity and inhibit the growth of harmful microorganisms, thereby promoting a safer and more effective fermentation environment [10]. Subsequently, the fermentation occurs by stacking the treated manure under dry conditions, covered with tarpaulin, and periodically turning the stack every 3–4 days to ensure aeration. The fermentation period lasts between 7 to 14 days, which aligns well with practices that optimize microbial activity, essential for nutrient availability in the soil for crop growth [11]. This approach not only enhances the properties of the manure but also contributes positively to the overall fertility of the soil, as demonstrated in studies showing that the application of organic matter can significantly improve plant nutrient uptake and growth performance [12] Moreover, combining lime with organic manure has been shown to increase the availability of essential nutrients, further validating this method's effectiveness in sustainable agricultural practices [13].

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Figure 1. Bio-Pulverizer Machine Technology with Solid State Fermentation Process Training Activity

The second part of the training introduced participants to the production of rice husk charcoal, produced through controlled combustion in a low-oxygen environment, resulting in a light, grayish-black product. The role of rice husk charcoal as an organic fertilizer ingredient was emphasized, particularly its contributions to improving soil properties. Research indicates that rice husk charcoal enhances soil porosity and air circulation around plant roots, which are vital for healthy plant growth [14]. Furthermore, its moisture retention capacity significantly benefits soils by preventing water loss, which is particularly useful in drought-prone areas [15]. The addition of rice husk charcoal not only boosts soil moisture retention but also contributes to improving the overall ecosystem of the soil by providing a structure that supports microbial activities essential for nutrient cycling. These characteristics make rice husk charcoal a valuable amendment for enhancing soil health and productivity, particularly in organic farming systems [16,17]. This training equips participants with essential skills for charcoal production and reinforces the importance of integrating such sustainable practices into agricultural settings.

The third part of the training focused on processing cocopeat derived from coconut husk waste, emphasizing its benefits as a

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planting medium. Participants learned to crush the husks into a fine powder and underwent a thorough washing process to remove tannins, which can inhibit plant growth. Washing the cocopeat is essential to enhance its suitability for use as it optimizes its water-holding capacity, allowing it to retain moisture more effectively than traditional soil media or rice husk charcoal [18]. After washing, the cocopeat was dried in the sun to reduce moisture content and prevent mold growth, which is integral for maintaining its quality and effectiveness in plant cultivation [19]. Once the cocopeat was prepared, training advanced to the processing of dried, fermented goat manure, which participants crushed using the Bio-Pulverizer machine. Achieving a fine and homogeneous texture during this grinding step is critical for accelerating nutrient availability and facilitating effective mixing with other fertilizer components [20]. The integration of these techniques ensures that the organic fertilizer produced is well-structured, enhancing both its performance in promoting plant growth and its overall utility in sustainable farming practices [21,22].

The final stage of the training was dedicated to formulating an organic fertilizer mixture comprising 60% dried, finely ground goat manure, 20% rice husk charcoal, and 20% dried cocopeat. This composition was strategically selected to capitalize on the unique benefits of each component: goat manure serves as the primary source of macronutrients, rice husk charcoal enhances soil structure, and cocopeat retains moisture effectively [23]. The training successfully enabled participants to comprehend and sequence the processing steps, ensuring a thorough understanding of fermentation, washing, burning rice husks, and ingredient mixing. The resulting organic fertilizer demonstrated a fine texture, dark color, neutral odor, and excellent water absorption capacity, confirming participants' proficiency in producing organic fertilizers using standardized methods. This aligns with findings that underscore the benefits of organic fertilizers in enhancing soil physicochemical properties and nutrient availability, ultimately promoting plant growth [24]. Furthermore, properly formulated organic fertilizers not only enhance soil fertility but also contribute to sustainable agricultural practices, thereby supporting local farmers in improving their crop yields through better nutrient management and soil health [25].

3.3 Results of The Technology Implementation Stage

The technology implementation stage in the production sector focused on the installation and utilization of the Bio-Pulverizer machine and the application of the Solid-State Fermentation (SSF) method to accelerate organic fertilizer processing, as seen in Figure 2. The machine used is a gasoline-powered model with a 6.5 HP engine and a production capacity of ±30 kg/hour. Before use, the machine was installed and tested at the partner's location to ensure optimal performance. A specific area for solid-state fermentation was prepared according to basic standards, including a dry, ventilated surface, and protection from direct rainfall.

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The results from implementing the technology showed a significant improvement compared to the partner's initial conditions. The organic fertilizer production time, which previously required approximately 30 days, was reduced to ≤9 days per cycle using the SSF method. Meanwhile, the monthly production volume, which was initially only about 10 sacks, increased to about 30 sacks after regular operation of the machine and SSF techniques. This achievement aligned with the initial target set during the socialization stage and was directly validated through field evaluations.

Operational impacts were also felt significantly by the partners. With the Bio-Pulverizer machine, the breakdown of raw materials became faster and more uniform, thereby increasing the grinding throughput, as seen in Figure 3. This directly reduced the partner's dependency on external livestock manure supplies, as available materials could now be processed more efficiently. Furthermore, the use of the machine reduced the manual labor required during the preparation phase, allowing the workforce to focus on other productive activities, such as stacking SSF piles and fertilizer packaging. However, there were some limitations to note. The fermentation process is highly dependent on the moisture content of the raw materials. If the manure is too wet, the initial SSF process becomes slower and may result in uneven fertilizer quality. To address this, training participants were advised to dry the materials beforehand or add structural materials such as rice husks or sawdust to balance moisture.

Figure 2. Application of the fertilizer manufacturing process and its use in shallot fields

Additionally, the machine's performance must be well-maintained through a regular maintenance schedule, including bearing lubrication, belt checks, and cleaning after use. These maintenance steps are crucial for ensuring that the production capacity remains stable in the long term. Overall, the application of the Bio-Pulverizer machine and SSF techniques proved effective in enhancing production efficiency, reducing dependency on external sources, and improving the management of time and labor. These results demonstrate that the

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technological innovation applied meets the partners' needs and is ready for scaling up in larger production stages.

Figure 3. The process of refining fermented goat manure using a bio-pulverizer machine

3.4 Results of The Assistance and Evaluation Stage

The assistance and evaluation stage was conducted intensively to ensure that the partners were able to operate the technology and business management systems independently and in accordance with the standards taught. Assistance was provided through weekly meetings between the implementation team and the partners, focusing on reviewing the Bio-Pulverizer machine's log, progress of each SSF batch, and the consistency of inputting transaction data into the digital application, as seen in Table 1 and Table 2. These meetings also served as a space for the partners to share technical or managerial challenges encountered during implementation. In addition to routine meetings, on-site troubleshooting was conducted whenever process anomalies were detected. One example was an SSF pile that was too compact, obstructing aeration. This issue was promptly addressed by adjusting the pile's density and increasing the frequency of turning. This type of support is crucial to ensure that the partners not only understand the theory but also gain practical experience in addressing real issues on the ground. The evaluation results indicated that the Bio-Pulverizer machine could be operated independently by the partners, with the cleaning SOPs being followed consistently. The machine demonstrated stable vibrations within the normal operating range, indicating that basic operational and maintenance procedures were being properly followed. In terms of SSF fermentation, all processed batches adhered to the correct procedure, and no signs of predominant decay were found. Field indicators such as color changes, a more neutral odor, and uniform texture showed that the process was carried out according to the standards.

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Table 1. Batch Processing and Fermentation Loss Data for Organic Fertilizer Production

Batch Number	Processing Time (Days)	Weight of Cocopeat (kg)	Rice Husk Charcoal (kg)	Unfermented Goat Manure (kg)	Weight After Fermentation (kg)	Fermentation Loss (%)
1	9	378.4	378.4	1,290	1,135	12%
2	9	379.9	379.9	1,310	1,140	13%
3	9	390.0	390.0	1,300	1,170	10%
4	9	368.3	368.3	1,300	1,105	15%
5	9	396.0	396.0	1,350	1,188	12%
6	9	361.2	361.2	1,260	1,084	14%

3.5 Results of The Program Sustainability Stage

The sustainability stage demonstrated that the partners were not only able to adopt the technology provided but were also ready to further develop it. From a production perspective, with the fermentation process time reduced to ≤9 days and the stable grinding capacity of the machine, the partners expressed their readiness to increase monthly output according to the availability of raw materials and fermentation space. This provides a solid foundation for expanding production capacity to a larger scale.

Table 2. Batch Production Output and Sacks Yield for Organic Fertilizer

Batch Number	Total Weight Processed (kg)	Average Production per Day (kg)	Total Sacks Produced (sacks)	Total Sacks per Day Produced (sacks/day)	Total Sacks per Month Produced (sacks/Month)
1	1,892	210.2	9.5	1.05	31.53
2	1,900	211.1	9.5	1.06	31.66
3	1,950	216.7	9.8	1.08	32.50
4	1,842	204.6	9.2	1.02	30.69
5	1,980	220.0	9.9	1.10	33.00
6	1,806	200.7	9.0	1.00	30.10

4. DISCUSSION

4.1 Fermentation Loss and Its Impact on Production Efficiency

Fermentation losses in organic fertilizer production can range between 10% to

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15%, as seen in Figure 4. This variation reflects weight lost during fermentation, primarily due to moisture evaporation, microbial activity, and the breakdown of organic matter. The lowest loss observed in Batch 3 at 10% suggests effective moisture management and optimal fermentation conditions. In contrast, Batch 4's higher loss at 15% indicates potential challenges related to moisture content. Higher initial moisture levels can prolong the breakdown process, leading to increased fermentation losses due to inhibited microbial activity. Effective management of moisture content is, therefore, critical for enhancing fermentation efficiency and reducing overall losses in fertilizer production.

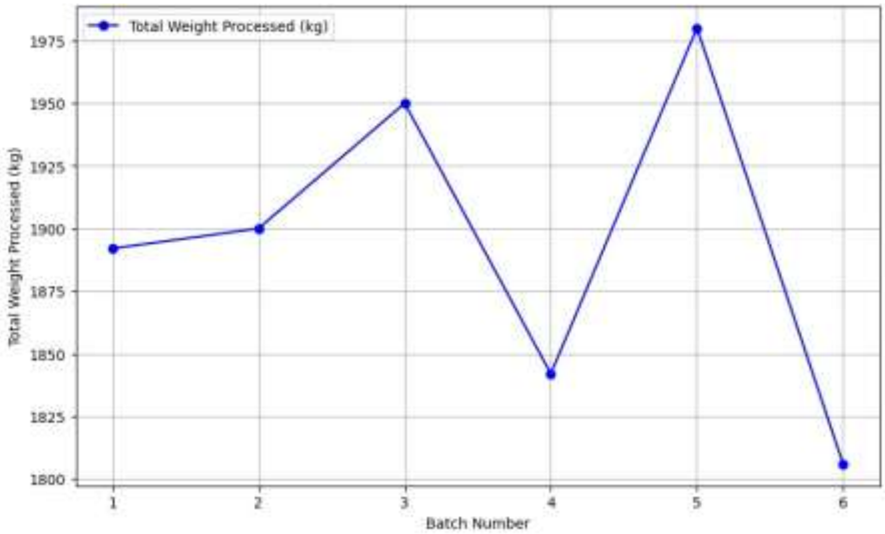

Figure 4. Fermentation Loss Percentage per Batch

Research indicates that controlling moisture levels during fermentation significantly impacts quality and efficiency. For instance, adjusting moisture content in total mixed rations (TMR) can affect fermentation quality and outcomes. However, it is noted that the effects may vary depending on the blending ratio of various materials and there is no universal causal relationship established between TMR fermentation patterns and moisture content [26]. Additionally, an understanding of the dynamics between moisture and microbial activity can guide improvements in fermentation practices, enhancing the formulation of organic fertilizers. Overall, these findings underscore the importance of moisture management in optimizing the organic fertilizer production process by minimizing losses and improving nutrient retention.

4.2 Variation in Input Material Quantities and Total Weight Processed

The production of organic fertilizer across various batches demonstrates considerable variability in the quantities of input materials such as cocopeat, rice husk charcoal, and livestock manure (KOHE), with amounts ranging from 361.2 kg to 396 kg per material. The total processed weight post-fermentation also showed discrepancies, with outputs from 1,806 kg in Batch 6 to 1,980 kg in Batch 5, as seen in Figure 5. Such fluctuations can be attributed largely to the quality of raw materials and the specific fermentation

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conditions experienced during each batch [27].

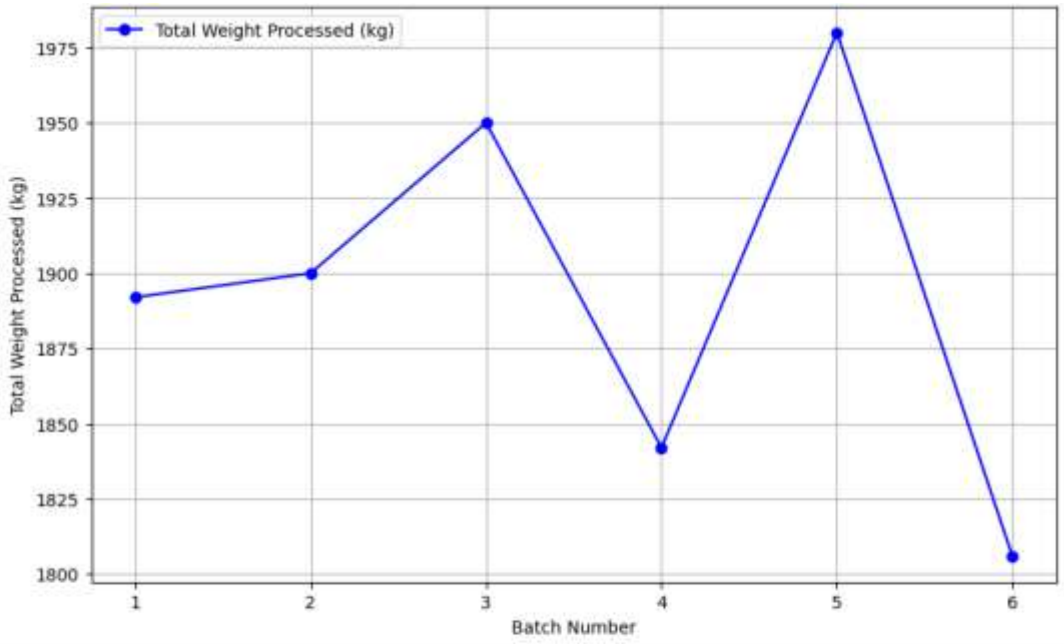

Figure 5. Variation in Total Weight Processed per Batch

The relationship between fermentation losses and processed weight is notably significant; higher fermentation losses due to moisture evaporation and microbial breakdown lead to reduced total processed weights. For instance, batches exhibiting lower loss percentages correlate with higher resultant weights, indicating that effective moisture management and optimal fermentation conditions enhance production outputs [19]. This finding aligns with research that emphasizes the importance of controlling the fermentation environment to minimize losses, as well as maximizing the nutrient retention of organic fertilizers produced from such materials [28].

4.3 Sacks Produced and Its Correlation to Batch Processing

The organic fertilizer production system demonstrates stable output, with the number of sacks produced per batch ranging from 9.0 sacks in Batch 6 to 9.9 sacks in Batch 5, as seen in Figure 6. This consistency indicates that the system effectively manages fluctuations in raw material quantity and fermentation efficiency. Despite variations in total weight processed and fermentation loss, the output remains largely unchanged, suggesting that the system operates at a level where minor changes do not significantly impact production.

These outcomes highlight the resilience of the system; however, variations in sack production can still be influenced by the quality of the input materials and specific fermentation conditions. Research confirms the importance of utilizing high-quality organic inputs, as this can enhance the production process and lead to improved fertilizer outcomes [29]. Furthermore, effective management of processing techniques is crucial for optimizing fertilizer quality and yield, ensuring that the benefits of organic inputs translate effectively into stable production

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levels [30]. Overall, while the system shows a commendable ability to produce consistent outputs, ongoing monitoring and management of input quality and fermentation conditions will be essential for sustaining these results.

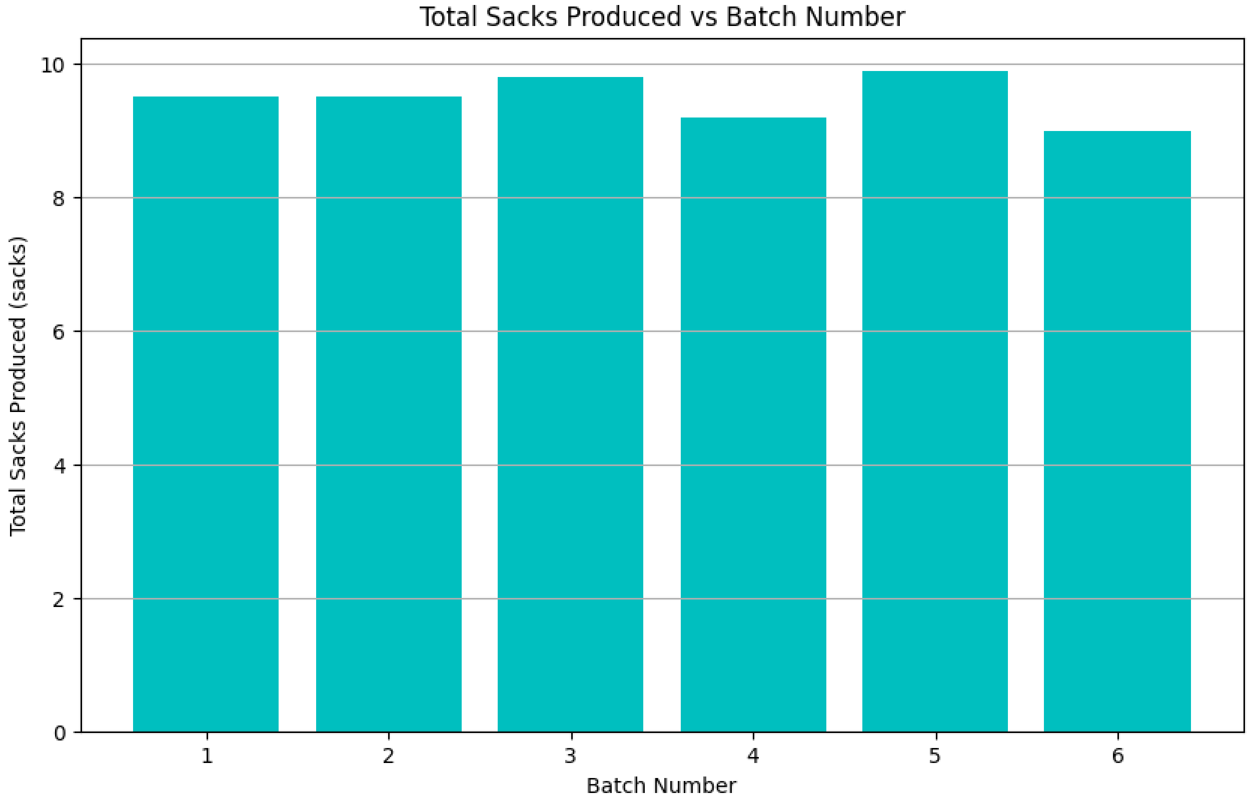

Figure 6. Total Sacks Produced per Batch

4.4 Average Production Per Day and Production Efficiency

The average daily production rates from the organic fertilizer production process show a range from 200.7 kg in Batch 6 to 220.0 kg in Batch 5, indicating that the production process operates with relatively minor fluctuations in output, as seen in Figure 7. These variations can be attributed to factors such as fermentation efficiency and raw material processing [31]. The consistency of the daily outputs suggests that the system is generally well-optimized; however, the slight differences signal potential areas for enhancement, such as refining raw material drying processes and improving machine operation consistency [32].

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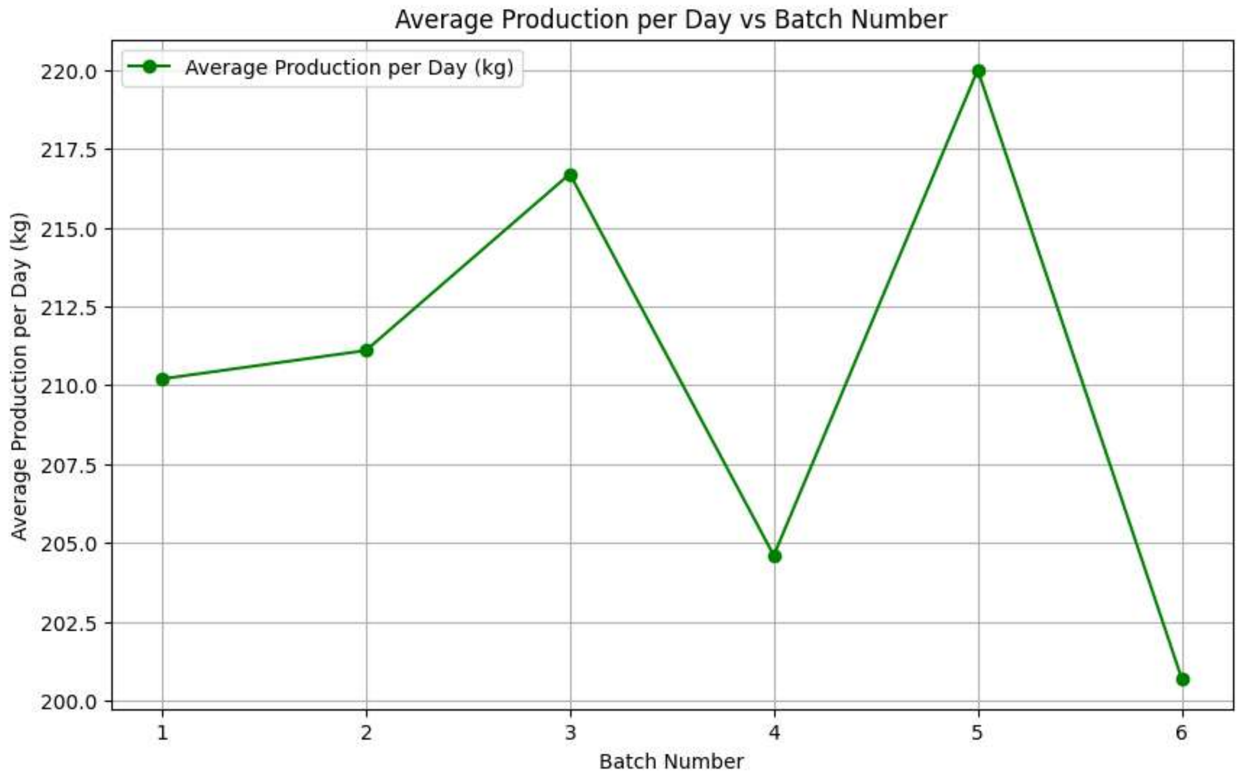

Figure 7. Average Production per Day per Batch

Research has demonstrated that effective management of inputs and operational efficiencies directly influences fertilizer production outcomes. For instance, the combined application of organic and chemical fertilizers has been shown to enhance soil nutrient availability while promoting crop growth and nutrient uptake [33]. This supports the notion that optimizing fertilizer production methods could improve daily yields and increase the overall effectiveness of nutrient application [34]. Overall, addressing the minor fluctuations in daily output through targeted improvements could further enhance the efficiency and productivity of organic fertilizer production.

4.5 Overall Production Performance and Machine Efficiency

The Bio-Pulverizer machine, characterized by its 6.5 HP engine and capability to process 30 kg/hour, significantly enhances the efficiency of organic fertilizer production. Its ability to break down raw materials quickly and uniformly facilitates faster processing times and consistent product quality. By reducing the labor required for material preparation, the machine allows producers to utilize their resources more effectively, conveying substantial operational advantages [35].

Furthermore, the stable performance of the Bio-Pulverizer is essential for the ongoing success of the production process. Regular maintenance practices, such as ensuring proper lubrication of bearings and comprehensive belt checks, help maintain peak operational efficiency and mitigate the risk of downtime. These enhancements in performance are vital for scaling production while sustaining high output levels, which aligns with industry standards for efficient fermentation

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processes [36]. Ultimately, the integration of such machinery not only contributes to higher productivity but also improves the sustainability of organic fertilizer production by optimizing resource use and minimizing potential waste during processing [37].

4.6 Challenges and Recommendations for Improvement

Effective moisture management is vital in organic fertilizer production, particularly during the fermentation process where moisture content directly influences fermentation efficiency and product quality. If organic materials, such as livestock manure, maintain excessive moisture levels, fermentation can slow, leading to increased fermentation losses and inconsistent product quality. Variations in moisture content can significantly impact fermentation quality, as noted in studies on various organic materials [38]. To address this issue, implementing pre-drying techniques or integrating drier materials like rice husks can help achieve optimal moisture levels, improving fermentation outcomes [26]. Furthermore, regular monitoring of fermentation conditions—including parameters like temperature, aeration, and moisture—is crucial for maintaining process efficiency. Adjustments in moisture content can influence fermentation quality, highlighting the need for precise control during production [39]. Although equipment like the Bio-Pulverizer effectively processes raw materials to ensure uniformity and speed, establishing a routine maintenance schedule is essential for operational efficiency, as it can prevent downtime and ensure optimal machine performance [40]. Managing variables such as moisture content in fermentation systems contributes to overall production efficiency [41].

5. CONCLUSION

The community service program implemented in Probolinggo Regency has demonstrated significant improvements in organic fertilizer production for shallot farming. By integrating the Bio-Pulverizer machine and Solid-State Fermentation (SSF) techniques, the production process time was reduced from approximately 30 days to ≤9 days, leading to a more efficient and consistent production process. The production capacity has also increased, with the number of sacks produced per batch reaching around 30 sacks per month. Despite some minor variations in fermentation loss and average production per day, the overall results indicate that the technology has successfully enhanced the efficiency and sustainability of organic fertilizer production. The program's success is also evident in the digital adoption for financial record-keeping and market price predictions, which will help farmers make informed business decisions. However, challenges such as moisture management in the raw materials and the need for regular machine maintenance remain. Moving forward, the program can scale up to improve production capacity further and support more farmers in the region.

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