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Technology Transfer-Based Capacity Building for Organic Fertilizer Production Using Non-Symbiotic Microbial Consortium

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Abstract: This community service program aims to enhance partners' skills in producing solid organic fertilizer using non-symbiotic microbial consortiums and shredding machines through a participatory-collaborative empowerment approach based on the ODSIMED stages. The program was implemented from August to December 2025 with KUB Surya Agrotani in Kediri Regency. Skill data were collected from 56 respondents using structured observation sheets administered at the beginning and end of the mentoring program, while service quality was evaluated through a Likert-scale questionnaire. Descriptive analysis revealed a significant improvement across 10 production skill indicators, with an average N-Gain in the high category (0.89). An important finding was that participants' compliance with occupational health and safety standards during the mentoring process also increased substantially, with a high N-Gain score (0.84). This result is consistent with the service quality assessment, which indicated that the team of lecturers and students paid strong attention to occupational health and safety standards throughout program implementation. These findings demonstrate that the integration of biotechnology and appropriate technology within the ODSIMED framework effectively strengthens partners' organic fertilizer production capacity in a measurable and sustainable manner, while maintaining strong attention to health and safety standards.

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Introduction

Empowering rural communities in the context of sustainable agro-industry requires a transformative approach that integrates knowledge systems, appropriate technology, and continuous mentoring within the framework of a circular economy and Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). Village empowerment is no longer limited to technical skill transfer but must be oriented toward creating closed-loop resource systems that convert local waste into value-added products while maintaining ecological balance. In this

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context, appropriate biotechnology emerges as a key driver of rural transformation, as it enables communities to efficiently process organic waste into environmentally friendly inputs, reduce dependency on external resources, and enhance soil ecosystem quality. Recent studies highlight that the success of such transformation depends on sustainable empowerment models, active community participation, and context-based technology transfer aligned with local potential (Holmén et al., 2025; Santoso et al., 2024). Cyclic empowerment frameworks such as ODSIMED (Observation, Development, Socialization, Implementation, Monitoring, Evaluation, Dissemination) provide a systematic pathway to integrate biotechnology innovation into rural practices in a measurable and sustainable manner (Santoso, et al., 2021; Santoso et al., 2023). However, existing community service practices in organic fertilizer processing remain predominantly procedural and have not yet fully integrated circular economy principles, biotechnology innovation, and mechanization as a unified strategy for rural development.

Contextually, Based on the results of observation analysis, the potential for organic raw materials in the Sumber Jembangan Tempurejo (Kediri, East Java) area was abundant but has not been optimally utilized. Leaf litter production reaches 25–50 kg per day, but is still collected and burned, contributing to carbon emissions and losing potential economically valuable organic material. On the other hand, goat manure production reaches approximately 100 kg wet weight per day and has not been processed productively.

Based on the results of the observation analysis, it was also revealed that goat breeders and farmers had never received special assistance in processing leaf litter and goat manure as ingredients for producing organic fertilizer. In fact, both of these materials have optimal potential to help improve the quality of environmentally friendly planting media. Farmers in Tempurejo Village, Kediri, East Java, still rely on commercial and subsidized chemical fertilizers. 61% of farmers' fertilizer needs are met through commercial and subsidized chemical fertilizers. This means the community remains highly dependent on chemical fertilizers. However, according to Johan et al. (2024), chemical fertilizers have a detrimental impact on the environment.

In addition, although conventional composting practices are generally recognized by rural communities, these practices are typically carried out in a non-standardized manner, relying on natural decomposition processes that are time-consuming and often result in inconsistent fertilizer quality. This condition indicates that the problem is not only the lack of skills but also the absence of a structured empowerment system that ensures effective technology adoption. Therefore, the ODSIMED model becomes a critical solution as it provides a systematic, iterative, and reflective framework that facilitates experiential learning and capacity building through continuous mentoring, aligning with adult learning (andragogical) principles. Furthermore, the application of a non-symbiotic microbial consortium represents a key biotechnological intervention that can significantly accelerate the biodegradation process, enhance nutrient availability, and produce more stable and mature organic fertilizer compared to conventional methods. The integration of ODSIMED and microbial consortium thus offers a dual advantage, namely strengthening both the process (empowerment system) and the product (fertilizer quality). This study highlights the novelty of combining a cyclic empowerment model with appropriate biotechnology as a unified strategy to transform traditional composting practices into a more efficient, standardized, and scalable rural production system.

In fact, the combination of leaf litter and goat manure has great potential as a raw material for organic fertilizer that can improve the physical, chemical, and biological

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properties of the soil (Hariadi et al., 2016). The addition of organic matter has been shown to increase soil aggregation, cation exchange capacity, soil microbial activity, and nutrient availability that support root growth and plant productivity (Abdillah et al., 2023; Ramlan & Purnaningsih, 2023). To date, the optimization of these two wastes within the framework of a rural circular economy has not been systematically implemented (Prihantini et al., 2024). Villages have significant circular economic potential due to their abundant local natural resources. This allows them to independently manage organic and inorganic waste and directly convert it into value-added products (compost, animal feed, crafts). This concept minimizes operational costs and waste, fosters village self-sufficiency, and extends the life cycle of raw materials (Sakiah et al., 2024; Sharma et al., 2019).

Scientifically, organic fertilizer production is an aerobic biodegradation process involving the activity of microorganisms in converting complex organic matter into stable, humus-rich compounds. The use of microbial consortia has been shown to accelerate lignocellulose degradation and increase compost maturity compared to natural processes without inoculum (Tyasmoro et al., 2024). Non-symbiotic microbes play a role through the production of cellulase, lignase, and protease enzymes that accelerate the mineralization of organic matter and enrich the nutrient content of fertilizer (Daunoras et al., 2024). The implementation of non-symbiotic microbial consortia at the village community scale is a simple form of biotechnology application that has the potential to significantly increase the efficiency of production time and the quality of organic fertilizer.

Optimizing leaf litter and goat manure through biotechnology interventions is also relevant within the framework of a circular economy and achieving the Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). A circular economy emphasizes the reuse of waste as a productive resource to minimize residues and carbon emissions (Kirchherr et al., 2017). Microbial-based composting has been shown to reduce greenhouse gas emissions from organic waste combustion and improve soil health and soil microbial biodiversity (Blanco-Canqui & Lal, 2009). The integration of appropriate technology and biotechnology at the village community scale can be positioned as a form of low-carbon rural innovation, a locally based innovation that converts waste into productive inputs with economic value while reducing the carbon footprint. Thus, this program not only improves partners' production skills but also contributes to environmental sustainability and the restoration of terrestrial ecosystem quality.

The observation results also revealed that partners do not yet have the skills to produce organic fertilizer by utilizing biotechnology interventions of non-symbiotic microbial consortia accompanied by shredding machines and mixing machines. Therefore, this community service program aims to improve partners' skills in producing fertilizer through the use of appropriate technology resulting from research that has been tested at KUB Surya Agrotani, Temprejo, Wates, Kediri Regency. This program is called the empowerment of assisted villages (PkM-PDB), where universities provide assistance to villages to empower community groups to become more independent and empowered.

Method

This program be implemented from August to December 2025 in Tempurejo Village, Wates District, Kediri, East Java. The program focuses on improving the skills of target partners in producing organic fertilizer by utilizing several appropriate technologies resulting from research by the program's implementing lecturer team. The appropriate technologies

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include: (1) a non-symbiotic microbial consortium, (2) a leaf litter and goat manure shredding machine, and (3) a mixing machine. The non-symbiotic microbial consortium is the result of research by the implementing team that has received a patent from the Directorate General of Intellectual Property, Ministry of Law of the Republic of Indonesia (IDS000006768). The two machines used in this program are also the result of research by lecturers and students whose copyrights have been registered.

The partner group involved in this program is the Surya Agrotani Community Business Group (KUB) located in Tempurejo Village, Wates District, Kediri Regency. This group consists of 56 active members who are predominantly smallholder farmers and goat livestock breeders, with several members also involved as local youth supporting community-based agro-industry activities. The group has been engaged in agricultural and livestock activities at a subsistence to semi-commercial scale, with limited prior exposure to biotechnology-based production systems and mechanized processing technologies. Therefore, this group represents a relevant target for capacity building in integrating appropriate technology and biotechnology for organic fertilizer production at the rural level.

This community service program was implemented using a participatory-collaborative empowerment approach, referring to Santoso et al. (2024). The participatory-collaborative empowerment approach prioritizes the impact on partners through intensive mentoring so that partners can overcome problems/obstacles during the implementation of appropriate technology that is downstreamed. This mentoring program is implemented by referring to the stages of community empowerment development, consisting of observation, development, socialization, implementation, monitoring, evaluation, and dissemination, or with the acronym ODSIMED (Santoso, et al., 2021).

Skills in producing fertilizer were collected using a developed performance observation sheet. The instrument used is a closed observation sheet for testing solid organic fertilizer production skills and consists of nine main skill points. The nine main skill points referred to include: (A) partners are able to prepare tools and materials according to the needs of the solid organic fertilizer production process; (B) partners are able to measure the required materials; (C) partners are able to operate shredding machines and mixers; (D) partners are able to control the size of goat manure powder and leaf litter as raw materials; (E) partners are able to activate non-symbiotic microbial consortiums as starters for the solid organic fertilizer fermentation process; (F) partners are able to stir the materials until a homogeneous mixture is obtained using a mixer; (G) partners are able to determine the water content and at the same time regulate the water content of the mixture so that the organic fertilizer fermentation process runs optimally; (H) partners are able to monitor the water content and temperature of the organic fertilizer during the duration of the fermentation process; and (I) partners are able to determine the time to harvest the organic fertilizer. Scoring of the skill test observations was carried out by three trained observers consisting of one resource person and two accompanying instructors, with a score of 1-4. The instrument has been assessed as feasible by waste management practitioners and lecturers in the field of process bioticenology with an instrument feasibility score of 94.24 (very feasible).

Result and Discussion

The results of each stage of ODSIMED are described as follows:

Observation

Program design begins with an observation phase conducted by a team of lecturers and students. This phase is implemented after the evaluation phase of the 2024 PkM-PDB

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implementation is completed. The 2025 PkM-PDB program is a continuation of the 2024 PkM-PDB program. This phase is carried out at the beginning of proposal development as a form of final verification of the continuity of the previous program. Semi-structured observations were conducted on the achievements of the 2024 PkM-PDB partners, including partner products and increased knowledge and skills. Interviews were also conducted with the Tempurejo Village Government, Wates District, Kediri Regency, regarding their commitment to joint program implementation.

Development

This stage aims to develop the program. After the implementation team received information on funding approval from the Ministry of Education, Culture, and Technology's DPPM (Regional Development Planning Agency), the implementation team held a limited Focus Group Discussion (FGD) with representatives from the Surya Arotani Tempurejo Community Empowerment Business Group (KUB) and representatives from village officials. This stage was held on June 29, 2025, at the Tempurejo Village Office. This stage validated the program plan previously formulated in the 2025 PkM-PDB proposal.

Socialization

This stage aimed to gain a mutual understanding between the program implementation team (lecturers and students from Nusantara PGRI University Kediri) and the partner team, the Surya Agrotani Tempurejo Community Empowerment Business Group (KUB). This stage involved disseminating information about the program name, objectives, various activities, schedule, and indicators of program success. This included the roles and contributions of each party. This stage was held at the Tempurejo Village Hall, Wates District, Kediri Regency, on July 5, 2025.

Implementation

At this stage, the activities of the program are implemented. The various PkM-PDB program activities include training on the use of goat litter and manure shredding machines, automatic mixers, and the production of solid organic fertilizer. The activity stages include: (a) brief presentation of the material by a team of lecturers as resource persons; (b) demonstrations followed by hands-on practice by the Surya Agrotani Tempurejo KUB partner team, accompanied by a team of students as accompanying instructors; (c) discussion and Q&A sessions; and (d) checking the results of the practice by the team of resource persons and instructors. This stage is held in four (4) meetings. The stage of checking the results of the Surya Agrotani KUB partner practice serves as learning material for the student team and lecturers. The student team explores and analyzes in depth based on existing theories and concepts of bioprocesses and biotechnology. At this stage, the student team begins active discussions with the Surya Agrotani KUB partner team regarding the products obtained from the practicum.

The use of direct demonstration methods in this program is considered more effective than lecture-based approaches because farmers as adult learners tend to learn better through experiential and problem-based activities that are directly relevant to their daily practices. This aligns with andragogical principles, which emphasize learning by doing, active participation, and contextual problem solving as key factors in enhancing adult learning outcomes. Empirical studies have shown that participatory and demonstration-based learning significantly improves farmers' understanding and skills compared to passive learning methods, as it allows immediate observation, practice, and feedback in real contexts (Aini et al., 2025; Marchand et al., 2021).

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Monitoring

This stage aims to uncover various obstacles faced by partners in implementing and implementing the appropriate technology transfer process, specifically during the production of solid organic fertilizer. This stage is implemented through direct mentoring. The students involved not only act as accompanying instructors but also act as monitors and evaluators, alongside a team of lecturers. The monitoring team is tasked with gathering information on the obstacles faced by KUB Surya Agrotani Tempurejo partners in producing solid organic fertilizer. The obstacles identified are recorded, the causes identified, and the monitoring and evaluation team then provides guidance on how to resolve them. Table 1 presents the various obstacles faced by partners in producing solid organic fertilizer.

According to Lamidi et al. (2024), in community service programs, monitoring aims to oversee the implementation of processes in the field, which involves daily supervision as a quality control measure. Based on Table 1, the daily technical challenges faced by partners lie in the use of appropriate machinery that does not comply with Standard Operating Procedures (SOP). The community is not yet disciplined in adhering to SOPs. An effective mentoring solution can overcome these obstacles. This problem solving solution is in accordance with the findings of (Indrashwara & Dirma, 2025) that with monitoring we can coordinate for program improvement.

Table 1. Various Constraints Faced by Surya Agrotani KUB Partners

Constraint	Causes and Solutions
The chopping machine is jammed	The raw materials, including litter and manure, still have a very high water content (over 80%). This results in suboptimal shredded output through the blade, clogging the outer cavity. The solution provided in the mentoring program is to improve understanding of the importance of material preparation. Specifically, partners must ensure the material's moisture content is below 30% for optimal shredding performance.
The mixer is jammed.	The partner loaded all the ingredients beyond the machine's capacity. This resulted in the machine's rotor working beyond its capacity. The solution provided in the mentoring was to provide a deeper understanding of the machine's capacity and the Standard Operating Procedures (SOP) for using the mixer.

Evaluation

This stage is conducted to determine the achievement of program objectives and key success indicators for the 2025 PkM-PDB program. The evaluation was conducted by the 2025 PkM-PDB program implementation team and the Institute for Research and Community Service (LPPM) of Nusantara PGRI University, Kediri. The evaluation was conducted through a site visit to the partner village's Compost and Silage House, specifically at the Surya Agrotani KUB in Tempurejo Village, Wates District, Kediri Regency. In addition to observing the appropriate technology being handed over, unstructured interviews and document review were also conducted as needed for the evaluation. Interviews were conducted with the production team and management of the Surya Agrotani KUB to verify the improvement of skills and the transfer of appropriate technology from the Nusantara PGRI University Kediri implementation team to the partners. In addition, the evaluation was also conducted by analyzing data from partner skill tests in producing solid organic fertilizer from Sumber Jembangan litter and goat manure using a non-symbiotic microbial consortium and two production machines: a shredder and a mixer. Partner skill data was collected at the beginning and end of the program. Initial data was collected before the program was implemented, and final data was collected through observations as partners produced organic

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fertilizer to fulfill incoming orders. The collaboration skill scores in producing solid organic fertilizer were analyzed descriptively, namely the scores were expressed in the form of an average accompanied by a standard deviation and analyzed using the N-Gain score. The partner's skill improvement scores are presented in Table 2.

Table 2. Skills Improvement Profile of Target Partners in PkM-PDB 2025

Code	Description of Observed Skills	Score		N-Gain
		Pre	Post	
A	Able to prepare the required tools and materials correctly	1,50 ± 0,51	3,95 ± 0,49	0,98
B	Able to measure organic fertilizer ingredients carefully according to the specified formula	1,30 ± 0,57	3,90 ± 0,31	0,96
C	Able to use a litter shredder (start the machine, adjust the speed, and turn off the machine)	1,35 ± 0,67	3,60 ± 0,68	0,85
D	Able to control the size of the chopped cohesion and litter consistently	1,05 ± 0,22	3,70 ± 0,57	0,90
E	Able to activate microbial consortium starter with molasses material	1,20 ± 0,52	3,75 ± 0,44	0,91
F	Able to stir the mixture of ingredients with the starter until homogeneous	1,45 ± 0,60	3,85 ± 0,37	0,94
G	Able to determine water content	1,05 ± 0,22	3,80 ±0,41	0,93
H	Able to monitor water content and temperature of organic fertilizer during fermentation period	1,45 ± 0,51	3,55 ± 0,60	0,82
I	Able to determine the harvest period for organic fertilizer from the initial incubation period	1,15 ± 0,37	3,40 ± 0,50	0,79
J	Able to comply with Occupational Safety and Health	1,25 ± 0,44	3,55 ± 0,51	0,84

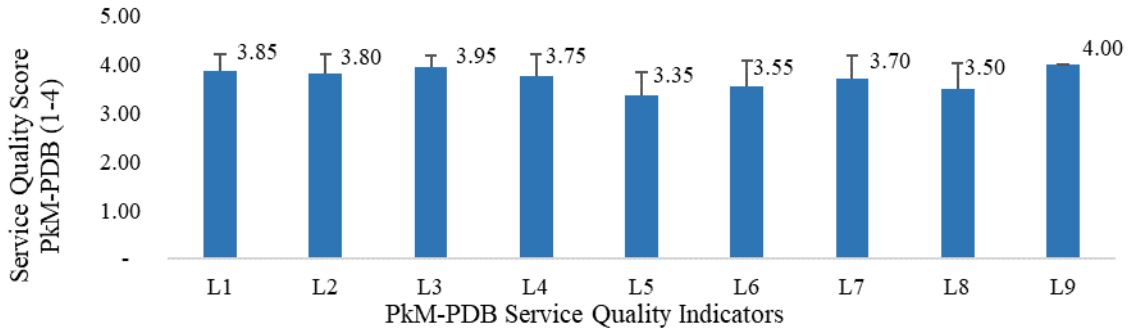

Figure 1. Service Quality Profile of the PkM-PDB Program in 2025

Based on Table 2, the partners' skill scores increased to the very good category. The N-Gain scores for all skill indicator codes (A to J) were high. Specifically, partners' skills in preparing raw materials and measuring organic fertilizer production materials reached 0.98 and 0.96, respectively. This can be explained by the demonstration followed by hands-on practice, which made it easier for the community to understand the material presented. Furthermore, this method allowed the community to receive feedback from the resource persons and instructors. Obstacles encountered during the training sessions were resolved, thus preventing misconceptions about organic fertilizer production.

In addition, the evaluation was also carried out by revealing the service quality of the 2025 PKM-PDB program. Service quality data was obtained by partners filling out a structured questionnaire containing nine (9) indicator items (L1 to L9) that reflect the quality

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of PkM-PDB services. The nine indicators are: program topics are in accordance with partner needs (L1), training materials delivered by resource persons are easy to understand (L2), instructors provide directions that are easy to understand and practice (L3), instructors provide empathy and motivation for people who experience obstacles (L4), demonstrations are conducted based on hands-on accompanied by positive feedback (L5), allocation of training time and representative mentoring (L6), appropriate technology is transformed according to needs (L7), guidelines are available that are easy to understand and practice (L8), and program implementation prioritizes occupational health and safety (L9). The instrument was developed and declared feasible by two lecturers who have a track record of twice obtaining village empowerment grants (an average score of 96.41). Respondents responded by giving a score of 1-4 for each service quality item. The collected data were tabulated and analyzed descriptively by presenting it in a table accompanied by the average score for each PkM-PDB service quality indicator item. The 2025 PkM-PDB service quality score is presented in Figure 1.

Based on Figure 1, the average program service quality score reached 3.72 (very good). The community gave the highest rating to empowerment practices that prioritize occupational health and safety (score 4.00). This reflects that the team of lecturers and students prioritizes not only improving the knowledge and skills of partners, but also how the work practices are carried out to pay attention to occupational health and safety. Another positive finding is that the student team involved as accompanying instructors was assessed by the community as being able to provide excellent direction and instruction that is easy to understand. This is indicated by the L3 indicator score reaching 3.95. The PkM-PDB program revealed that students do not play the role of enumerators on technical matters, but students are involved in activities that use critical thinking and problem-solving skills. The service quality of the PkM-PDB 2025 empowerment program received a high score. This indicates that the empowerment program is aligned with community needs and is able to make an impactful contribution (Widodo & Rachman, 2022), increasing community independence, increasing skills and knowledge that partner communities can use to increase productivity or address their problems/obstacles (Santoso, et al., 2021).

Dissemination

The dissemination of information in the form of good practices and program information to the wider public. This stage is implemented by publishing good practices and programs in:

a) National printed and electronic media, namely Radar Kediri and Jawa Pos, on September 23, 2025, with the title "Supporting Food Independence in Kediri, the UNP Kediri Community Service Lecturer Team Contributes Three Appropriate Technologies." (Figure 2).
b) The program video entitled "pkm PDB Desa Tempurejo, Wates, Kediri Regency-East Java" has been published and can be accessed on the institution's youtube channel link (UNP Kediri), namely https://www.youtube.com/watch?V=g9-sbsuv2l8. The video has been watched by more than 700 viewers (Figure 2).
c) In addition, printed and displayed program posters can be accessed at LPPM and the Biology Education Study Program, Nusantara PGRI University, Kediri.

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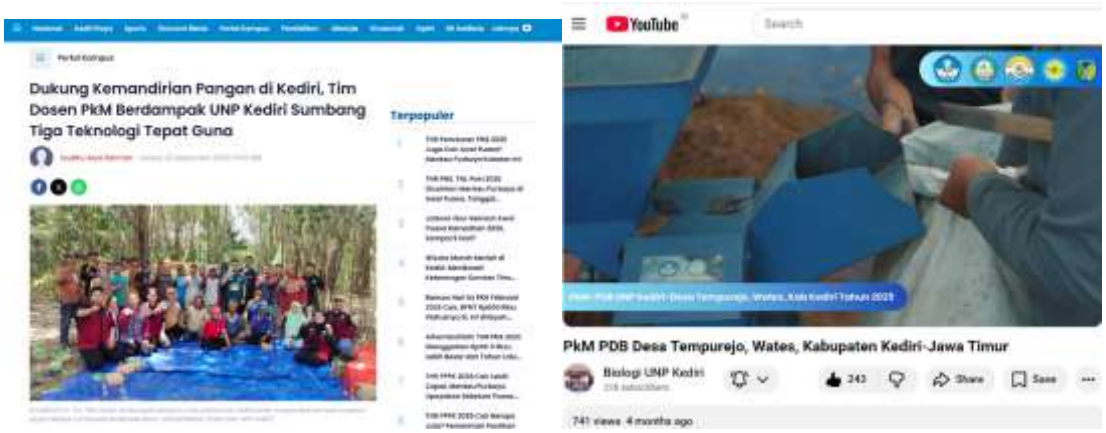

Figure 2. Publication of national newspaper (left) and video of the results of the program implementation which can be accessed on the institution's YouTube channel

The dissemination of program outcomes through mass media and digital platforms also contributes to strengthening the sustainability of the partner group. Media exposure, such as publications in national newspapers and institutional social media channels, increases the visibility of KUB Surya Agrotani and has the potential to expand market access beyond the village scale. This visibility not only enhances public trust in the quality of the products but also opens opportunities for external demand and collaboration with broader stakeholders. In this context, dissemination functions not merely as an information-sharing activity but as a strategic step to support the economic sustainability and independence of the partner group through increased product recognition and market linkage.

Dissemination of good practices resulting from community service is necessary. According to Kase et al. (2023), communities need good practices and scientific information to provide additional resources on alternatives to address the problems/obstacles they face. In this context in line with findings from (Santoso et al., 2024), good practices resulting from community service should be disseminated, particularly those containing practical information needed by communities or similar groups with similar contexts (resource potential and geography).

Conclusion

The intervention in the form of fermentation biotechnology utilizing a non-symbiotic microbial consortium, supported by shredding and mixing machines, implemented through a participatory-collaborative empowerment approach based on the ODSIMED stages, was proven to effectively improve the skills of KUB Surya Agrotani Tempurejo partners in producing organic fertilizer while adhering to occupational health and safety standards. This effectiveness is evidenced by the significant increase in partners' skills across all indicators, which falls into the high improvement category with an average N-Gain of 0.89, indicating that the intervention is statistically highly effective. Furthermore, this program not only strengthens partners' technical competencies but also contributes to the development of a more efficient, standardized, and sustainable organic fertilizer production system at the rural level, supporting environmental sustainability and fostering village economic independence.

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Recommendation

To ensure the sustainability and scalability of this program, several follow-up actions are recommended. For KUB Surya Agrotani members, it is essential to maintain consistent production practices based on standardized operating procedures and to further develop product diversification and marketing strategies to expand market reach. For the village government, stronger institutional support is needed through policy facilitation, allocation of village funds, and integration of organic fertilizer production into village economic programs such as BUMDes or local agro-industry initiatives. Meanwhile, related government agencies are expected to provide continuous technical assistance, certification support, and access to broader markets to enhance product competitiveness. In addition, designating Tempurejo Village as a living laboratory is recommended to support ongoing collaboration with universities in research, training, and community empowerment, thereby strengthening innovation-based rural development in a sustainable manner.

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