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JELANTUNG: Empowerment ALKAUSAR Jangek Cracker MSME through Bacillus subtilis Based Used Cooking Oil Processing

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Abstract

Purpose: This study aimed to empower the Alkausar Jangek Cracker MSME in Medan Denai, North Sumatra, to manage used cooking oil through Bacillus subtilis-based bioremediation while creating value-added products and reducing waste disposal

Research: This study addressed the management of 6–10 L of used cooking oil generated weekly, of which approximately 85% was previously discharged directly into drains and only 10% was sold to collectors at IDR 5,000–8,000/L.

Methodology: An eight-month participatory action research approach was implemented through problem identification, socialization, technical training, JELANTUNG technology implementation, mentoring and evaluation. The system integrates sedimentation, B. subtilis bioremediation, purification, and storage, with a processing capacity of 50–100 L per cycle.

Results: The intervention established an alternative utilization pathway for used cooking oil and strengthened the partners' technical capacity to perform bacterial culture preparation, inoculation, fermentation, purification, and filtration. The processed oil was successfully diversified into two value-added products: Getap Jelare liquid dishwashing soap and Lilin Jelare decorative/aromatherapy candles.

Conclusions: JELANTUNG provides a practical biotechnology-based approach for integrating waste treatment, product diversification, and micro, small, and MSME empowerment within a circular economy framework.

Limitations: The study involved one MSME and a limited intervention period; quantitative changes in oil quality, waste reduction, and economic returns require further longitudinal measurements.

Contributions: This study contributes an applied model for environmental biotechnology, sustainable waste management, and value-added development in food-based MSMEs.

Keywords: *Bacillus Subtilis, Bioremediation, Circular Economy, MSME Empowerment, Used Cooking Oil*

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1. Introduction

Deep-fried food-based MSMEs, specifically those producing kerupuk kulit (skin crackers) or kerupuk jangek, represent a rapidly growing household industry sector in Indonesia urban areas, driven by high market demand and relatively simple production processes. However, the practice of reusing cooking oil among many MSMEs remains inadequately addressed. Repeated use alters the physical and chemical properties of the oil, resulting in a dark color, rancid odor, increased Free Fatty Acid (FFA) levels, and the formation of thermal degradation compounds such as acrolein, peroxides, and free radicals, which pose health risks to consumers (Hala, 2026). Consumption of foods fried in repeatedly used oils has also been associated with an increased risk of cardiovascular disease, oxidative stress, and carcinogenic effects due to the presence of trans fatty acids and polymerized compounds. Beyond food safety concerns, the disposal of used cooking oil directly into waterways or onto the ground causes environmental pollution, clogs drainage systems, and degrades the quality of clean water sources in residential areas(Damayanti & Supriyatin, 2021). Used cooking oil can form a thin film on the water surface, reduce the dissolved oxygen, and harm aquatic ecosystems . Therefore, appropriate management of used cooking oil is essential not only for protecting public health but also for maintaining environmental sustainability and supporting the economic viability of food-based MSMEs

The "Alkausar" kerupuk jangek (skin cracker) MSME, located in Medan Denai District, Medan City, North Sumatra, is a micro-enterprise facing these challenges. Operating since 2014, the business is managed by a single owner and six employees, producing 150–300 kg of crackers daily with a turnover of IDR 1,500,000–IDR 3,000,000. Based on an initial field survey conducted by the research team, the partner generated approximately 6–10 liters of used cooking oil per week. The survey revealed that approximately 85% of this used oil was discharged directly into drains, while only 10% was sold to collectors at very low prices, ranging from IDR 5,000 to IDR 8,000 per liter. These figures represent the partner's baseline conditions rather than secondary data and were used to identify the priority problem addressed by the program. The remaining 5% should be described according to the original field-survey record before submission, so that the percentages account for the full volume. This situation is exacerbated by the partner's lack of knowledge regarding the hazards of used cooking oil, the absence of hygienic production Standard Operating Procedures (SOPs), and weaknesses in business management and marketing, all of which hinder the enterprise's competitiveness and sustainability(Alamsyah, Kalla, & Ifa, 2017).

Figure 1 shows the condition of used cooking oil generated from the kerupuk jangek production process (a) and the production kitchen of the "Alkausar" MSME (b), which illustrates the improper handling practices contributing to the food safety and environmental issues described above.

Figure 1. (a) Used cooking oil from Kerupuk Jangek production; (b) Kerupuk Jangek production kitchen Alkausar

Various studies have indicated that bioremediation using Bacillus subtilis is a potential solution for improving the quality of used cooking oil. Bacillus subtilis produces lipase enzymes that degrade triglycerides and oxidized fatty compounds, thereby reducing Free Fatty Acid (FFA) levels and improving the color and aroma of the oil (Aulia, Wulandari, Istiqomah, & Tita, 2022). The ability of bacteria to degrade organic pollutants has also proven effective in the bioremediation of crude oil spills (Kusrini, Pradina, Purbaningrum, Zahwa, & Safaanah, 2026) and the removal of heavy metals from water (Pika, Khairaputri, & Budiadnyani, 2025). Previous community service initiatives have demonstrated that utilizing used cooking oil can generate economic value for the community, for instance, by processing it into dishwashing soap (Adji et al., 2025) or eco-friendly biodiesel (Pramitasari et al., 2025). However, the application of Bacillus subtilis-based bioremediation technology, specifically within MSMEs producing fried snacks such as kerupuk jangek (fried cattle skin crackers), combined with business management and marketing enhancements, is rare. This represents a significant gap that this community service activity aims to fill.

Given these conditions, the *Jelantah Langsung Untung* (JELANTUNG) Turning Used Cooking Oil into Profit program was designed as a community partnership initiative aimed at empowering partners to process used cooking oil into safer, value-added, and eco-friendly products through the application of Bacillus subtilis-based bioremediation technology. The program also seeks to enhance partners' knowledge of food safety and production sanitation, strengthen business management capacity through simple financial record-keeping and raw material inventory management, and create new business opportunities derived from processed used cooking oil. These activities align with the Sustainable Development Goals (SDGs) specifically SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 8 (Decent Work and Economic Growth), and SDG 12 (Responsible Consumption and Production) while simultaneously supporting the strengthening of the grassroots economy and the development of green technology at the micro-enterprise level (Muhammad, Nikmah, Hidayah, & Haqiqi, 2020).

Through a simple, low-cost, and easily implementable biotechnology-based approach, the JELANTUNG Program is expected to serve as a sustainable empowerment model for MSMEs specializing in deep-fried foods. It aims not only to resolve the issue of used cooking oil waste but also to enhance product quality, ensure consumer food safety, and improve the overall economic well-being of the partners involved.

2. Research Methodology

This community service initiative was conducted with the "Alkausar" kerupuk jangek (cattle-skin cracker) MSME in Denai Urban Village, Medan Denai District, Medan City, North Sumatra, Indonesia. It employed a participatory action research approach, actively involving the partner from the problem identification stage to ensuring program sustainability. The activity spanned eight months and included at least eight field visits covering the preparation, implementation and reporting phases. The participants comprised the MSME owner and six employees (n = 7), who were directly involved in production and used cooking oil handling. Participants were purposively selected because of their direct involvement in the partner's production activities and their participation in the JELANTUNG training, implementation, mentoring, and evaluation stages. The process began with a needs analysis conducted via field observations and interviews to assess current cooking oil management practices and the partners' level of knowledge. The analysis revealed that the partner generated 6–10 liters of used cooking oil per week, with approximately 85% being discarded directly into drains, while only 10% was sold to collectors at a price of IDR 5,000–8,000 per liter. These operational figures were obtained from the partner's initial field assessment and were treated as baseline information for program planning. The remaining proportion should be verified against the original field records before submission so that the reported percentages account for the entire volume of the used cooking oil. Subsequently, the team raised awareness of the health and environmental risks associated with used cooking oil and introduced the concept of bioremediation using Bacillus subtilis bacteria through interactive lectures, educational video screenings, and group discussions.

The technical training phase involved demonstrating the preparation of *Bacillus subtilis* cultures, the procedure for inoculating the bacteria into used cooking oil, the controlled fermentation process, and the techniques for oil filtration and purification (Sari, 2019). The technology was then implemented directly at the partner's business site using the "JELANTUNG" used cooking oil processing unit, which is a system designed to be simple, portable, and energy-efficient (Figure 1). The unit comprises three integrated components: a primary settling tank, a biological reactor, and a final storage tank. The collected used cooking oil was first fed into a settling tank to separate the solid impurities via sedimentation. It is then pumped using a low-power electric pump into a biological reactor containing *Bacillus subtilis* media, where biodegradation and bioremediation processes break down free fatty acids, oxidation products, and compounds responsible for rancid odors (Bachtiar et al., 2022). The processed oil is subsequently transferred to a final storage tank as a ready-to-use product. Technically, the unit utilizes corrosion-resistant 304 stainless steel tanks with a capacity of 50–100 liters per cycle, a 150–250 Watt electric pump, and heat-resistant, food-grade flexible connecting hoses. It features overall dimensions of approximately 100 cm × 50 cm × 120 cm (length × width × height) and a portable hollow-steel frame for easy relocation, while the operation is semi-automated via electrical switches and flow-control valves.

Figure 2 show bioremediation was performed under controlled conditions according to the laboratory/operational SOP, using the bacterial concentration, treatment ratio, temperature, fermentation duration, and replication specified above.

Figure 2. "JELANTUNG" bioreactor for used cooking oil treatment based on Bacillus subtilis bioremediation

The effectiveness of the bioremediation process was evaluated by testing the oil's physical and chemical parameters specifically Free Fatty Acid (FFA) content, peroxide value, color, odor, and clarity before and after treatment; the targets were a minimum 30% reduction in FFA levels and a 1.5- to 2-fold extension of the oil's service life compared to pre-bioremediation levels (Bariyyah, Fairuz, & Roviati, 2025). In addition to technical production aspects, partners received training in basic business management, covering daily financial record-keeping (income and expenses), raw material inventory management, and the calculation of production costs to compare cost efficiency before and after using bioremediated oil. Marketing efforts were strengthened through training on basic branding (business naming, logos, and packaging) and digital marketing via WhatsApp Business and Instagram, alongside an introduction to the potential for diversifying into derivative products based on bioprocess residues such as solid soap and aromatherapy candles to reinforce the upstream-downstream integration of the partners' businesses(Septihanny & Moentamaria, 2020)

For safety control, the bioremediated oil was designated exclusively for non-food applications in this program, particularly as a raw material for downstream products, such as liquid dishwashing soap and decorative/aromatherapy candles. It was not intended to be returned to the human food chain or consumed as a cooking oil. This limitation is necessary because the present program did not establish the microbiological, toxicological, or regulatory requirements needed to demonstrate that bioremediated oil is safe for human consumption. Dedicated handling, personal protective equipment, hygienic procedures, and controlled storage were used to minimize contamination and occupational risks.

Periodic mentoring is conducted to ensure that partners can independently carry out the used cooking oil regeneration process in accordance with jointly established Standard Operating Procedures (SOPs). Program success was evaluated through process observation, comparisons of oil quality before and after bioremediation, and questionnaires assessing the partners' level of understanding and technology adoption. The results of the questionnaire evaluation and laboratory measurements were interpreted together with process observations to assess the technical adoption and changes in oil characteristics. Program sustainability is ensured by establishing a management group among the partners, providing operational guidelines and starter cultures, and creating networks with Bacillus subtilis culture suppliers and potential local government partners so that used cooking oil processing practices continue after the community service project is concluded (Hidayati & Kurniasari, 2026). Project implementation involved the team leader acting as the program coordinator and resource person for outreach and training; the first team member was responsible for preparing Bacillus subtilis cultures and demonstrating technical processing; the second team member handled used cooking oil sample analysis, administration, and report compilation; and four students were tasked with assisting in surveys and field outreach, laboratory bacterial culture preparation, oil sampling, and activity documentation to support the final report.

3. Results and Discussion

The implementation of the JELANTUNG Program has proceeded in accordance with its planned objectives, namely, to process used cooking oil from the “Alkausar” Jangek Crackers MSME into products that are safer, more beneficial, and of greater economic value. Partnership activities began in February 2026 through coordination between the Community Partnership Empowerment team at Medan State University and MSME owners and employees. This coordination aimed to align perspectives on the program's objectives, stages, mechanisms, and schedule while also identifying the partners' conditions and needs regarding used cooking oil management. These activities also served as the basis for the division of roles and responsibilities between the implementation team and the partners to ensure that all program stages were carried out effectively and in a participatory manner (Darojat, 2024). The documentation of the coordination activities is presented in Figure 3.

Figure 3. Coordination Between the Jelantung PKM Team and Alkausar Partners

Coordination was carried out to build a mutual understanding between the PkM team and the “Alkausar” Jangek Cracker MSME regarding the division of roles and responsibilities in implementing the program. At this stage, the PkM team presented the objectives, activity phases, implementation mechanisms, and expected outcomes, while the MSME provided information on field conditions, potential for development, and various obstacles that might arise during the program implementation. Based on the results of this coordination, a realistic schedule for implementing the

activities was drawn up, considering the availability of time and the operational activities of the "Alkausar" Jangek Crackers MSME. It is hoped that this structured planning will support the implementation of the program in an effective, efficient, and measurable manner, without disrupting the continuity of the partner's routine activities (Nais et al., 2026).

Coordination activities serve not only as a planning phase but also as a means to strengthen the partnership and communication between the Community Service (PkM) team at Medan State University and the "Alkausar" MSME. Through two-way communication, both parties can build trust, align their perspectives, and reinforce their commitment to achieving the goals of the JELANTUNG Program, specifically enhancing the partners' capacity to manage and utilize used cooking oil. The results of these coordination efforts form the basis for agreeing on strategies, task assignments, implementation mechanisms, and an activity schedule tailored to partners' conditions and operational activities. Structured planning is expected to ensure that the entire series of activities proceeds effectively, purposefully, and sustainably without disrupting MSMEs' production activities. The documentation of the coordination activities is presented in Figure 3.

The PkM team procured and prepared the necessary supporting equipment for the implementation of JELANTUNG technology at the "Alkausar" Jangek Crackers MSME. Procurement was carried out based on the needs of each stage of used cooking oil bioremediation, including a Bacillus subtilis biological reactor, primary settling and final storage tanks, a circulation pump, an oil spinner, food-grade hoses, Bacillus subtilis starter culture, nutrient broth, peptone, buffer solution, and oil quality testing materials. In addition to preparing the equipment, a Bacillus subtilis bacterial culture was established in July 2026 at the Microbiology Laboratory, Biology Program, Faculty of Mathematics and Natural Sciences, Medan State University, as part of the preparations for implementing bioremediation technology. This stage is crucial to ensure the availability of the bacterial culture required for the used cooking oil treatment. Figure 4 shows the preparation of the Bacillus subtilis bacterial culture and the JELANTUNG treatment equipment used in the used cooking oil bioremediation process

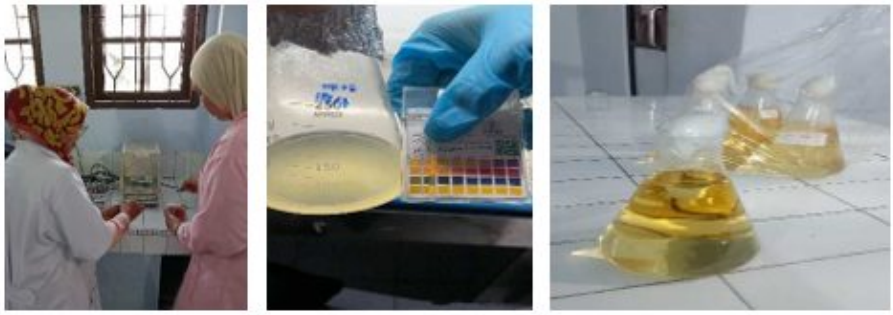

Figure 4. Preparation and cultivation of Bacillus subtilis cultures and the JELANTUNG apparatus

Each piece of equipment and material plays a complementary role in the used cooking oil treatment process. The biological reactor serves as the medium for the Bacillus subtilis-based bioremediation process, whereas the settling tank, circulation pump, spinner, and storage tank support the separation, purification, and storage stages of the treated oil. The use of Bacillus subtilis starter cultures and growth media is intended to support biological activity in improving oil quality, including reducing free fatty acid (FFA) content (Sari & Kembaren, 2019). With these facilities in place, the implementation of JELANTUNG technology is expected to enhance partners' skills in managing used cooking oil safely, efficiently, and in an environmentally friendly manner, as well as support its reuse as a value-added resource.

All necessary resources and supporting materials were prepared to facilitate the implementation of outreach, training, and application of JELANTUNG technology at the "Alkausar" Jangek Cracker MSME. The preparation phase included the procurement of materials and equipment, as well as the fabrication and assembly of a JELANTUNG prototype, an appropriate technology designed to support

the bioremediation of used cooking oil using Bacillus subtilis. The prototype was designed as an integrated system comprising a primary settling tank, biological reactor, pump system and connecting hoses, and a final storage tank, enabling the treatment process to proceed systematically from settling, bioremediation, and purification to storage of the treated oil. The documentation of equipment, materials, and the JELANTUNG technology prototype, as shown in Figure 5, demonstrates the readiness of supporting facilities for conducting training activities and implementing the technology in subsequent stages.

An outreach and training session on JELANTUNG technology was held on August 3, 2026, as part of the empowerment program for the "Alkausar" Jangek Cracker MSMEs. The session focused on enhancing the partners' understanding and skills in managing used cooking oil through the application of Bacillus subtilis-based, bioremediation technology. The material presented covered issues related to the repeated use of oil, its impact on food quality and the environment, the principles of bioremediation, and the operational stages of JELANTUNG technology. The event continued with demonstrations and hands-on practice, including culture preparation, inoculation, fermentation, purification, filtration, and observation of changes in oil characteristics (Yunira, Putra, Pratama, Witoyo, & Pangestuti, 2025). The event received positive responses from the partners, as evidenced by their active participation in discussions, practical exercises, and Q&A sessions. This participation indicates a growing interest and readiness among partners to adopt the JELANTUNG technology for safer, more effective, and more sustainable used cooking oil management. The documentation of outreach and training activities is presented in Figure 5.

Figure 5. Dissemination and innovation development activities for the JELANTUNG Program

Innovation development in the JELANTUNG Program is guided by the real needs and challenges faced by the "Alkausar" Jangek Cracker MSME, particularly regarding the management of used cooking oil generated from production activities. Innovation plays a crucial role in ensuring business sustainability, as changing needs, technological advancements, and demands for safer and more environmentally friendly production processes drive businesses to pursue continuous improvement (Hendrianie, Setyawan, Nanto, & Juliastusi, 2011). In this context, the JELANTUNG innovation is not solely focused on creating new products but emphasizes the development of processes and bioremediation technologies based on Bacillus subtilis to improve the quality of used cooking oil management while providing added value to its partners. The implementation of this innovation is expected to enhance waste management efficiency, support food safety, reduce environmental impact, and create opportunities for the reuse of oil produced through bioprocesses. The characteristics of the JELANTUNG innovation are reflected in its new ideas, planned application of technology, alignment with partner needs, and clear objective of enhancing the capacity and sustainability of the "Alkausar" MSME.

Innovation can be categorized into four main types: product, process, organizational, and marketing innovation. These four types of innovation play a strategic role in enhancing competitiveness and business performance (FATIMAH, 2020). In the context of the JELANTUNG Program, innovation is focused more on process and technological innovation through the application of Bacillus subtilis-based bioremediation to address the issue of used cooking oil management at the "Alkausar" Jangek Cracker MSME. The development of this innovation is based on the partners' actual needs and is

designed so that the technology can be implemented simply, efficiently, and in accordance with the characteristics of the microenterprises. JELANTUNG technology integrates sedimentation, bioremediation, purification, and oil storage processes through a comprehensively designed system (Mardiah, Fatimah, & Setiani, 2022).

The success of an innovation is determined not only by the novelty of the technology but also by its suitability to needs, ease of implementation, and the benefits it provides to partners. Therefore, the development of JELANTUNG technology aims to improve the quality of used cooking oil management while adding value to the production activities of MSMEs. Bacillus subtilis is used as a bioremediation agent because it has the potential to degrade fat components and reduce Free Fatty Acid (FFA) levels, thereby improving the characteristics of processed oil (Fitriyah & Pangesti, 2018). Consequently, the JELANTUNG innovation not only introduces a new approach to used cooking oil management but also strengthens the partners' capacity to implement safer, more efficient, and environmentally friendly production processes. This approach aligns with the importance of innovation in enhancing product value, user satisfaction and business sustainability (Anggraeni, 2021).

The key innovation of this community service initiative lies in the application of a used cooking oil treatment technology based on Bacillus subtilis bioremediation, which is directly integrated with the diversification of economically valuable derivative products of UCO. The “JELANTUNG” device used (Figure 6) is designed with three main components that operate sequentially: an initial settling tank to separate solid impurities; a biological reactor serving as a growth medium for Bacillus subtilis bacteria, where the biodegradation of free fatty acids and the oxidation of compounds occur; and a final storage tank for the regenerated oil. The portable, energy-efficient design, made of food-grade stainless steel, makes this technology easy for partners to operate directly at their business locations without requiring advanced technical expertise or costly equipment investments, making it well-suited to the characteristics of micro-scale SMEs such as “Alkausar” Jangek Crackers.

The second innovation lies in the downstream processing aspect, namely the utilization of regenerated used cooking oil not only for recycling into cooking oil but also for further processing into two market-ready derivative products: “Getap Jelare” liquid dish soap and “Lilin Jelare” decorative/aromatherapy candles. This approach differs from most similar community service initiatives, which generally focus on only one type of used cooking oil derivative, either soap or candles (Dewangga et al., 2025). By combining bioremediation technology as a purification step with the diversification of two products simultaneously as a downstream processing step, the JELANTUNG Program offers a more comprehensive empowerment model, ranging from improving oil quality and creating new products to strengthening branding and marketing, thereby potentially providing greater economic value to partners compared to a single-product approach.

Figure 6. JELANTUNG technology prototype device and handover of the device to the hospital

The partners' responses to the JELANTUNG technology outreach and training activities demonstrated positive enthusiasm. This is reflected in the participants' active engagement in discussions, Q&A sessions, and hands-on practice in processing used cooking oil using Bacillus subtilis-based

bioremediation technology, as well as in every stage of the activities, from explanations about the hazards of used cooking oil and demonstrations of the “JELANTUNG” device's operation to hands-on practice in making derivative products such as dish soap and candles. The activity not only enhanced the partners' understanding of the impact of used cooking oil use and management but also strengthened their skills in preparing cultures, inoculation, fermentation, purification, and oil filtration. The two-way interaction during the activity demonstrated a participatory process of knowledge and technology transfer while strengthening collaboration between the PkM team and the “Alkausar” Jangek Cracker SME. The documentation of the activity in Figure 7 illustrates the active involvement of the implementation team and partners during the outreach and training processes. Following the training, the activity continued with mentoring to ensure that the partners could independently apply the JELANTUNG technology in accordance with the procedures. Mentoring was provided through technical guidance on bacterial culture ratios, equipment hygiene, fermentation and purification processes, and monitoring the quality of bioremediated oil. Monitoring was conducted periodically through process observation and oil quality evaluation to identify challenges and enhance partners' skills. Through this approach, the JELANTUNG Program not only facilitated technology transfer but also fostered the partners' capacity to manage used cooking oil in a safer, more efficient, environmentally friendly, and sustainable manner. The success of this participatory aspect aligns with the principles of participatory action research, where partner involvement from the early stages has proven to increase the acceptance of new technologies and accelerate the knowledge transfer process at the microenterprise level.

Figure 7. Dissemination, training, and handover of products processed from used cooking oil to partners and students implementing the JELANTUNG Program

Mentoring is a follow-up phase aimed at ensuring that the knowledge and skills acquired by partners through outreach and training are applied appropriately, independently, and sustainably. At this stage, the PkM team provides technical guidance to the “Alkausar” Jangek Cracker MSME in applying JELANTUNG technology, ranging from the collection and settling of used cooking oil, preparation of Bacillus subtilis cultures, inoculation, fermentation, purification, to the filtration of the bioremediated oil.

Mentoring also focuses on utilizing processed oil as a raw material for value-added products, such as bar soap and aromatherapy candles, so that used cooking oil is not merely treated as waste but also has the potential to be developed into new economic products. The team provides guidance on equipment hygiene, processing steps, and analysis of the characteristics of the oil resulting from bioremediation. Monitoring and evaluation are conducted periodically to identify technical challenges and provide feedback on the processes carried out by partners. Through this technical assistance, the JELANTUNG Program is expected to improve partners' skills in managing used cooking oil, promote product diversification, increase economic value-added, reduce waste, and ensure business sustainability based on the principles of the circular economy (Riwanda, Mayasari, & Rasyidah, 2024).

One of the program's key achievements is the successful diversification of used cooking oil produced through Bacillus subtilis bioremediation into two economically valuable byproducts: “Getap Jelare” liquid dish soap and “Lilin Jelare” decorative/aromatherapy candles. This diversification is important

because not all of the regenerated oil is returned as cooking oil; thus, a portion of the bioprocess residue is redirected into non-food products that still provide added value to the partners. This downstream processing strategy strengthens the upstream-downstream aspects of the business as planned in the methodology phase and transforms used cooking oil from mere waste into a marketable raw material for household products.

The dishwashing soap was produced through the saponification of used cooking oil that had been purified with an alkaline solution, resulting in a liquid soap with good foaming properties and grease-cutting ability when tested directly by the partners and community members. These results reinforce the findings of similar community service activities, which show that used cooking oil from households and MSMEs can be processed into dishwashing soap that is safe to use and receives a positive response from the target community (Sari, 2019). Compared to commercial dishwashing soaps made entirely from pure vegetable oil, the “Getap Jelare” product offers a cost advantage in production because it utilizes waste that was previously simply discarded or sold at very low prices (IDR 5,000–IDR 8,000 per liter) to waste collectors, thereby increasing the economic margin earned by the partners involved.

The second product, "Lilin Jelare" candle, as shown in Figure 8, was made by mixing bioremediated used cooking oil with solidifying agents and fragrance, and then molded using decoratively patterned molds (Figure 8). The resulting candles exhibited a stable flame, solid texture, and distinctive natural green-yellow color gradation derived from the oil residue, without requiring additional artificial coloring. This characteristic is consistent with the results of another community service activity utilizing used cooking oil for aromatherapy candles, which reported that candles made from used cooking oil possess stable burning quality and long-lasting fragrance (Putri, Sulfiramita, & Erlinawati, 2024), and is also in line with findings that candle products made from used cooking oil are feasible as an additional source of income for micro-business actors (Insan, 2020). The success of students and partners in independently replicating the candle-making process across several trials further demonstrates that this technology can be easily adopted without requiring expensive equipment or specialized expertise.

Figure 8. "Lilin Jelantung" candle a product made from processed used cooking oil features a stable flame and a natural color

The success of product diversification is also supported by strengthening downstream aspects, such as branding and packaging. Both products are packaged with the “PKM JELANTUNG Products” label, which features the program's identity, logo, and a narrative on environmental sustainability, as shown in the promotional material “Jelare Candles: Natural Light, for a More Sustainable Earth.” This branding initiative complements the digital marketing training already provided to partners and sets these community service products apart from similar products on the market by linking their selling points to an eco-friendly narrative, namely, being environmentally friendly, providing a stable and clean flame, using natural and safe ingredients, and supporting MSMEs.

Overall, the successful processing of used cooking oil into dish soap and candles has three major impacts on the partners and the surrounding environment. First, the environmental impact is a reduction in the amount of used cooking oil disposed of directly into waterways, as most of the oil that was previously discarded is now utilized as a raw material for the production of derivative products. Second, the economic impact is the creation of an additional source of income beyond the jangek cracker business, given that used cooking oil, which was previously sold for only Rp5,000–Rp8,000 per liter to collectors, is now processed into products with a much higher unit selling price. Third, the social impact is the enhancement of knowledge and skills among partners, employees, and students in basic biotechnology and green entrepreneurship. These three achievements confirm that the JELANTUNG Program makes a tangible contribution to SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production), while also reinforcing SDG 6 through the reduction of water pollution caused by used cooking oil waste, as targeted in the program's preliminary phase. (Bachtiar et al., 2022).

The results of the observations show that the implementation of the JELANTUNG Program improved the partners' skills and readiness to adopt used cooking oil processing technology. An evaluation was conducted to assess the partners' ability to operate the JELANTUNG equipment, implement the bioremediation process using Bacillus subtilis, and utilize the processing outputs to produce value-added products, such as bar soap and aromatherapy candles (Azahra, Indirani, Kholis, Nurcahyanti, & Nurkartikasari, 2024).

Subsequently, the PkM team, together with the "Alkausar" Krupuk Jangek MSME, evaluated the entire series of activities, ranging from coordination, socialization, and training to technology implementation and mentoring. The evaluation was directed at identifying the partner's level of understanding and skills, the effectiveness of technology implementation, the quality of the bioremediation results, technical obstacles, and opportunities for the development and utilization of derivative products. The results of this evaluation formed the basis for developing a Follow-Up Plan *Rencana Tindak Lanjut* (RTL) that emphasizes independent technology implementation, oil quality monitoring, development of value-added products, and strengthening the sustainability of the partnership. Thus, the evaluation serves to measure the program's achievements and functions as an instrument to ensure that JELANTUNG technology can be consistently adopted and provide economic and environmental benefits for the partner.

Figure 9. Evaluation and development of a follow-up plan

Figure 9 show evaluation results indicate that the implementation of the JELANTUNG Program enhanced the technical capacity and readiness of the "Alkausar" Kerupuk Jangek MSME to apply Bacillus subtilis-based used cooking oil processing technology. The partner gained an understanding of the bioremediation stages, technology operation, purification, and quality monitoring of the processed oil. However, to optimize the sustainability of the program, further mentoring is needed, particularly in the development of derivative products, packaging, marketing, and business management. Based on these evaluation results, the PkM team, together with the partner, formulated a Follow-Up Plan (RTL) that included strengthening technology operation skills, monitoring oil quality, developing value-added products such as solid soap and aromatherapy candles, and reinforcing

marketing strategies. This product development is in line with the design of the JELANTUNG Program, which directs the processed oil toward utilization as an environmentally friendly product with an economic value. This RTL represents a shared commitment to ensuring that JELANTUNG technology can be applied independently, consistently, and sustainably, thereby providing economic benefits while supporting the reduction of used cooking oil waste.

The final stage of the PkM Program was carried out through the preparation of a scientific article and an activity report as a form of documentation and accountability for the entire series of programs implemented together with the "Alkausar" Kerupuk Jangek MSME. At this stage, the PkM team compiled and processed various data, observation results, documentation, and activity achievements, ranging from the coordination, socialization, and training stages to the implementation of JELANTUNG technology, mentoring, and evaluation of the program. All of these results were systematically compiled to describe the implementation process, the level of partner involvement, program achievements, and the impact of applying Bacillus subtilis-based bioremediation technology in used cooking oil management(Nasution, Lubis, Tumanggor, & Tanjung, 2024), on the use of Bacillus subtilis bacteria in handling crude oil spills). The preparation of the scientific article was aimed at disseminating the results and experience of program implementation to the academic community and serving as a form of the university's contribution to the development of appropriate technology(Viogenta, Sutomo, & Normaidah, 2023). Meanwhile, the PkM report was prepared as a form of technical and administrative accountability, encompassing the implementation process, achievement results, documentation, evaluation, and Follow-Up Plan (RTL). Through these outputs, the results of the JELANTUNG Program are expected to be well documented, serve as a reference for the development of similar PkM activities, and strengthen the sustainable application of technology in enhancing the capacity and independence of partners.

Several obstacles were encountered during the implementation of the PkM Program. First, limited training time, as the partner's production activities continued to run, thus requiring adjustments to the activity schedule to align with the MSME operational timetable. Second, the availability of certain supporting materials for processing and testing procedures remains a challenge, necessitating earlier procurement planning. Third, the process of adapting to new technology, particularly the application of bioremediation using Bacillus subtilis, required mentoring and repeated practice to enable the partners to apply each stage correctly. Fourth, limited digital marketing capability remained an aspect that needed to be strengthened to support the development and marketing of value-added products from the JELANTUNG Program. To address these obstacles, the PkM team implemented adaptive strategies by adjusting activity schedules, providing technical mentoring in stages, planning material procurement in advance, and offering further training related to product development and digital marketing. Through this approach, various obstacles are expected to be minimized so that the implementation of JELANTUNG technology can proceed effectively and sustainably.

4. Conclusions

4.1 Conclusion

The *Jelantah Langsung Untung* (JELANTUNG) program successfully strengthened the capacity of the “Alkausar” Jangek Cracker MSME in Medan Denai, North Sumatra, to manage used cooking oil through a simple, portable, and environmentally friendly bioremediation approach based on Bacillus subtilis. Through participatory activities involving problem identification, socialization, technical training, technology implementation, mentoring, and evaluation, the partners developed greater knowledge, technical skills, and readiness to independently operate JELANTUNG technology.

The program also demonstrated the potential for converting used cooking oil from production waste into value-added resources. The treated oil was further diversified into “Getap Jelare” liquid dishwashing soap and “Lilin Jelare” decorative/aromatherapy candles. This approach generated environmental, economic, and social benefits by reducing the disposal of used cooking oil into waterways, creating opportunities for additional economic value, and strengthening partners' knowledge and skills in biotechnology-based waste management and green entrepreneurship. These outcomes are consistent with the program's contributions to SDGs 3, 6, 8, and 12.

The contribution of this study is particularly relevant to MSME empowerment, environmental biotechnology, sustainable waste management and circular economy practices. For food-based MSMEs, particularly microenterprises involved in frying activities, the JELANTUNG model provides a practical approach for integrating waste treatment, product diversification, and basic business development processes. For community empowerment practitioners and researchers in biotechnology and environmental management, the program provides an applied model that demonstrates how low-cost bioremediation technology can be integrated with downstream product development and capacity building at the microenterprise level. Therefore, the JELANTUNG approach has the potential for adaptation to other food-processing MSMEs that generate used cooking oil, although further validation in different contexts is required. Thus, the program's contribution is best interpreted as an applied empowerment model that connects used cooking oil management, biotechnology-based processing, and non-food product diversification at the MSME level. The quantitative baseline and product outputs provide initial evidence of program implementation, while further measurement is required to establish the magnitude and sustainability of environmental, technical, and economic impacts

4.2 Limitations

Several limitations should be considered when interpreting the outcomes of the JELANTUNG Program. First, the intervention was implemented with only one MSME partner, namely the "Alkausar" Jangek Cracker MSME in Medan Denai, North Sumatra. Therefore, the findings cannot yet be generalized to other types of food-based MSMEs or to different geographical and socioeconomic contexts.

Second, the intervention and mentoring periods were limited, making it difficult to assess the long-term sustainability of technology adoption, business performance, and environmental benefits. Although the partner demonstrated improved technical capacity and readiness to operate the technology, continued mentoring was required, particularly in product development, packaging, marketing, and business management. Third, program evaluation primarily focused on partner participation, knowledge, technical skills, technology adoption, and the development of value-added products. Long-term quantitative measurements of economic returns, waste reduction, environmental impacts, and changes in the physicochemical quality of used cooking oil require extensive and systematic evaluation.

Finally, several operational constraints were encountered, including limited training time, availability of supporting materials, need for repeated practice to adapt to the new bioremediation technology, and limited digital marketing capabilities among partners. These constraints may influence the pace of technology adoption and the sustainability of the resulting business operations.

4.3 Suggestions and Future Studies

Future community empowerment programs should involve a larger number of MSMEs with different types of food-processing activities and from different geographical and socioeconomic settings to assess the transferability and scalability of the JELANTUNG Model. Comparative implementation across several MSMEs would also provide stronger evidence of the effectiveness and adaptability of Bacillus subtilis-based bioremediation technology.

Further studies should conduct longitudinal evaluations to examine the sustainability of technology adoption, changes in used cooking oil management practices, production costs, additional income generated from derivative products and the long-term environmental benefits of waste reduction. Quantitative measurements of physicochemical parameters, including Free Fatty Acid (FFA) levels, peroxide value, color, odor, and clarity, should also be systematically conducted before and after treatment to provide stronger evidence of the effectiveness of bioremediation. Future interventions should also strengthen the downstream aspects of the program, particularly product standardization, packaging, branding, digital marketing, market testing, and financial management. Collaboration among universities, MSMEs, local governments, biotechnology practitioners, and relevant business support institutions is recommended to support technology diffusion and long-term sustainability.

Finally, future research can develop the JELANTUNG model into a more comprehensive circular economy-based empowerment framework that integrates bioremediation, waste valorization, product diversification, digital marketing, and MSME business development. Such studies would strengthen the evidence base for replicating the model among food-based MSMEs and other small-scale enterprises generating used cooking oil waste

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