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Post-harvest seaweed quality support in Pagarbatu Village, Sumenep, using SWSolar Dryer technology to create competitive seaweed farmers

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ABSTRACT

Seaweed is a leading commodity in Sumenep Regency. However, post-harvest quality remains low due to traditional drying methods, which, in turn, affects selling prices and farmer welfare. This community service program aims to improve the quality and competitiveness of seaweed farmers in Pagarbatu Village by applying SW-Solar Dryer technology. Implementation methods include outreach, management and production training, SW-Solar Dryer application, mentoring, and ongoing evaluation with "Kelana" fishing group partners. The results showed that the SW-Solar Dryer can reduce drying time from 2–3 days to just 5–8 hours. It maintains product hygiene because the process is carried out in a closed room. Moisture content produced also meets industry standards. Furthermore, the mentoring program encouraged diversification of processed seaweed-based products. This increased farmers' income and reduced dependence on collectors. Thus, the application of SW-Solar Dryer technology has proven effective in improving post-harvest management, expanding business opportunities, and creating more competitive seaweed farmers.

Keyword: Seaweed, SW Solar Dryer, Competitive, Farmer, Sumenep

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INTRODUCTION

Seaweed is a leading commodity with high economic value in the fisheries sector, especially for farmers in Sumenep Regency. This regency offers several advantages for seaweed cultivation. Its clean, clear, and minimally polluted waters create an ideal environment for seaweed growth. Current stability and suitable water temperatures help photosynthesis and support cultivation productivity. Extensive land along Sumenep's coastline also allows for cultivation in bays and lagoons. Government support in the form of training and technology contributes to increased productivity. Sumenep also benefits from good market access and processing facilities. Cultivation practices here are effective, efficient, and environmentally friendly. Sumenep is now the largest seaweed producer in Madura (Ren & Adjie, 2024). The potential seaweed cultivation area is 243,254 hectares, with about 59,424 hectares used by 2023 (Pca & hjr, 2023).

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Table 1. Amount of Seaweed Production in Sumenep Regency

No.	Subdistrict	2021 (tons)	2022 (tons)	2023 (tons)
1	Gili Genting Subdistrict	56,683.38 tons	56,309.38 tons	57,441.38 tons
2	Talango Subdistrict	36,687.19 tons	38,412.19 tons	40,780.19 tons
3	Ra'as Subdistrict	145,517.04 tons	153,362.00 tons	160,762.04 tons
4	Sapeken Subdistrict	193,339.08 tons	219,245.18 tons	226,547.18 tons
5	Saronggi Subdistrict	147,736.50 tons	160,134.50 tons	182,064.50 tons

Sources: Kominfo.jatimprov.go.id (2025)

Overall, seaweed production in Sumenep reached 667,595.29 tons in 2023. The total potential cultivation area is 243,254 hectares, but only about 59,424 hectares have been used. Sumenep also has more than 4,093 seaweed farmers. This makes it one of the largest seaweed-producing regions in Indonesia after Maluku. Seaweed cultivation has contributed significantly to community income, especially in Tanjung, Pagar Batu, and Lobuk Villages. Total income in these villages reaches IDR 3,406.986 billion per year. The dominant type of seaweed cultivated is Eucheuma cottonii, which is in high demand domestically and internationally. Seaweed sells in different conditions: wet at IDR 2,000-3,000 per kg, dry-salted at IDR 15,000-17,000 per kg, and dry-fresh at IDR 20,000-23,000 per kg. Wet seaweed dominates production, reaching 200,411 tons per year (LPMUKP, 2022). With great potential but lacking proper management, Sumenep should be prosperous. However, production levels are still not enough to improve people's welfare. Sugi, a seaweed farmer from Pagarbatu Village, Sumenep, said his monthly income from seaweed farming averages Rp. 500,000 - Rp. 1,000,000. "Yes, the average seaweed farmer here earns between Rp. 500 thousand and 1 million, sir," he said on March 19, 2025, at his residence. If recalculated, the average income of seaweed farmers in Pagarbatu Village is only Rp. 30,000. Many young people prefer to maintain Madura stalls outside the city rather than become seaweed farmers. Traditional drying methods, still common among Sumenep's farmers, pose significant challenges that cannot be ignored. Sun-drying on plastic tarps or netting exposes valuable seaweed to dust, sand, and dirt, jeopardizing product quality and suppressing selling prices. When high water content persists, the risk of microorganism growth and quality loss increases. The lack of access to advanced drying technologies leaves harvests vulnerable and farmer incomes stagnant. These hurdles, while formidable, can be decisively overcome with appropriate, modern solutions that safeguard hygiene and boost profitability. Addressing them now will lay the foundation for a thriving future.

Figure 1. Drying Technique Using the Sun-Drying Method on A Tarpaulin or Netting Spread Out on the Ground, Used by Seaweed Cultivators.
Source: Primary Documentation

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To turn these challenges into opportunities, embracing appropriate technology is essential. Tailoring technology to community needs, leveraging simplicity, low maintenance, local culture, and available resources, can unleash profound benefits. Adopting solutions that are technically sound, economically viable, ergonomic, energy-efficient, socioculturally harmonious, and environmentally responsible will not only solve current problems but also position Sumenep as a beacon of innovation and prosperity in seaweed farming. The core of effective seaweed drying lies in achieving optimal moisture through process innovation (Rauf, 2021). The SW-Solar Dryer, inspired by the French method and refined for Sumenep's unique context, offers that innovative leap. By maximizing solar energy, automatically controlling temperature, and prioritizing efficiency and portability, this technology empowers farmers to produce world-class seaweed products. Seize this opportunity: with the SW-Dryer, Sumenep's farmers can enhance competitiveness and secure a sustainable, thriving seaweed industry.

Many researchers have conducted studies on drying systems, including environmentally friendly ones. Among them, the study "Drying kinetics and quality characteristics of Eucheuma cottonii seaweed in various drying methods" (Jamaluddin et al., 2021) showed that the solar dryer method produced the lowest final moisture content (≈ 12.07% db), and considered qualities such as carrageenan content, gel strength, and color compared to drying methods on tarpaulins and bamboo racks. (Amir et al., 2024) successfully designed a solar dryer tray that reduced moisture content from ~92% (wet basis) to 35-40% in 2 days, faster than open drying, while maintaining product quality, including minimal shrinkage and contamination. The "KELANA" Fishermen's Group, founded in 2013, is the oldest in Pagarbatu Village. Ms. Ida, a fisheries extension officer in Sumenep, said the group consistently farms seaweed, even when prices fluctuate. Members say they have no other jobs and view seaweed farming as a hereditary profession worth preserving. The following is evidence of the group's founding and its structure.

METHOD

Sicialization

The outreach program introduced the project to partners. It explained the benefits of the SW-Solar Dryer and taught dried seaweed quality standards. This was the first step in community service. "Kelana" group members and the village government were involved in building commitment for implementation.

Training

In this stage, partners are given two training sessions. First: SW-Solar Dryer technology utilization management training. Partners will be taught about the use and maintenance of the SW-Solar Dryer, including its practical operations. The SW-Solar Dryer, which is automatically portable, can be used by all partner members to maintain seaweed quality as requested by the company. Second: production training, which is carried out to reduce dependence on collectors and increase the income of seaweed farmers in Pagarbatu Village, Sumenep. In this training, partners will be informed about the potential of seaweed-based processed products and assisted in trials to develop them.

Application of SW-Solar Dryer Technology

The SW-Dryer was installed and tested directly at the partner's location. The team provided technical training on how to use and maintain the equipment to ensure optimal performance. The SW-Solar Dryer technology is a solar-powered drying device that accelerates seaweed drying while maintaining hygienic, efficient, and environmentally friendly conditions. Farmers in Pagarbatu Village have relied on traditional drying methods, such as drying seaweed on tarpaulins or mats in the open. These methods depend on the weather and are open to dust, dirt, and insects. Uneven drying often lowers harvest quality. As a result, selling prices drop. Using SW-Solar Dryer technology, the drying process can be faster and more even because the system uses solar heat

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stored in a closed space, maintaining a stable temperature. This technology also features a cross-ventilation system that optimizes air circulation, accelerating the evaporation of water from the seaweed. This results in cleaner, more evenly dried seaweed and a higher selling price. The implementation of this technology will be accompanied by training in equipment use, maintenance, and post-harvest management, enabling farmers to operate and maintain the technology independently. It is hoped that with the adoption of SW-Solar Dryer technology, seaweed farmers in Pagarbatu Village, particularly partners of the "Kelana" fishing group, will gradually and naturally transition from traditional methods to modern, automated methods. This will also improve productivity, work efficiency, and the economic well-being of their families.

Periodic Mentoring and Evaluation

After the implementation of technology and practices for making processed seaweed-based products, mentoring is then carried out to ensure that partners can operate the SW-Dryer properly in accordance with SOPs, consistently maintain its quality, and also make processed seaweed-based products such as seaweed chips, white seaweed used for cold drinks, seaweed jelly, and so on that are ready to be marketed. Intensive, continuous evaluation is conducted to ensure activities are implemented according to plan. The review includes a description of how the implementation is carried out in stages, along with indicators for achieving targets.

RESULTS AND DISCUSSION

The community service program began with a socialization event on September 8, 2025, at the "Kelana" fishermen's group base camp. This socialization aimed to convey the Community Service program and activity plan, and to introduce the objectives and benefits of implementing the SW Solar Dryer (Seaweed Solar Dryer System) technology to the local seaweed farmer group. During the event, the community service team explained the main post-harvest challenges of seaweed in coastal areas of Sumenep, particularly the highwater content and low quality resulting from traditional drying methods that rely on the weather. Through this socialization, participants understood the importance of innovative solar-powered drying methods to improve the quality and competitiveness of their products in the market. Community participation was high, with approximately 50 seaweed farmers and representatives from the Sumenep Regency Fisheries Office in attendance. Participants actively discussed challenges they frequently encounter, such as seaweed discoloration, sand contamination, and declining selling prices due to inconsistent quality. This socialization also served as a forum for participatory identification of field problems, allowing the community service team to formulate a training approach tailored to local conditions and farmers' capabilities.

Figure 2. Socialization of Community Service Implementation
Source: Primary Documentation

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Based on the initial evaluation results, most participants expressed interest in trying the new drying technology. They considered the SW Solar Dryer method a realistic solution to the challenges of extreme weather and the lack of clean drying space. Thus, the outreach phase successfully built farmer awareness and motivation to innovate in post-harvest processes.

Training

The training phase lasted four days, from September 8 to 11, 2025. The first and second days focused on production training and practical training in drying seaweed using the SW Solar Dryer. Participants were introduced to the working principles of this technology, including solar heat absorption, air circulation, and humidity regulation to maintain the seaweed's natural color. The training included a live demonstration on how to install, maintain, and operate the SW Solar Dryer. During the practical session, participants compared drying results using traditional methods and the SW Solar Dryer. Observations showed that drying time with the SW Solar Dryer was shorter (5-8 hours) than with conventional methods (2–3 days, depending on weather conditions). Furthermore, the resulting seaweed color was brighter and cleaner, free from dust or sand contamination. This indicates that this technology has the potential to significantly improve post-harvest seaweed quality.

Figure 3. SW Solar Dryer Training with the "Kelana" Fishermen Group
Source: Primary Documentation

The third and fourth days included training on post-drying seaweed processing, such as making seaweed chips, seaweed brownies, and seaweed jelly candy. This training aimed to enhance the added value of local products and diversify them. Participants learned the cleaning, soaking, further drying, and simple packaging processes to make the products more hygienic and commercially attractive.

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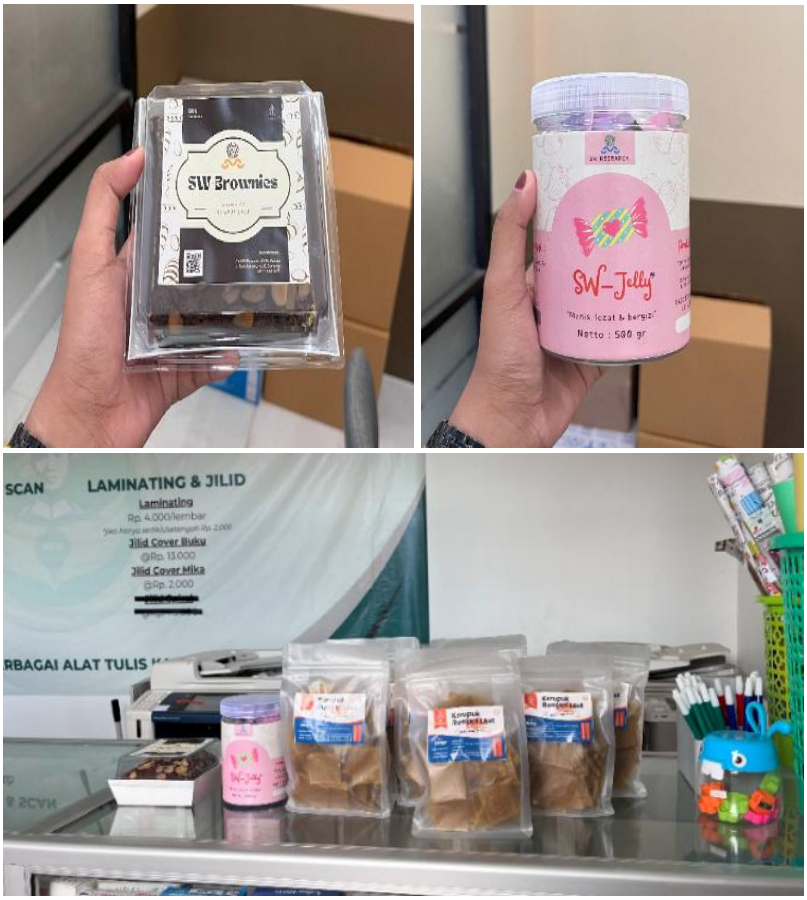

Figure 4. Training and Sales of Processed Seaweed Products
Source: Primary Documentation

Application of SW-Solar Dryer Technology

Following the training, the SW Solar Dryer technology was directly implemented on a pilot plot belonging to the "Kelana" fishermen's group. The dryer, with a capacity of 30–40 kg per cycle, features a natural ventilation system and a transparent coating for optimal heat absorption. Farmers were involved throughout the installation, operation, and recording of drying results to ensure they fully understood its operation. Field trials demonstrated a significant increase in efficiency. The average moisture content of dried seaweed decreased by 13–15%, meeting industry standards for agar and carrageenan processing. The first trial dried seaweed to a drying rate of 13.8%. Furthermore, using the SW Solar Dryer reduces the risk of mold and microbial contamination because the drying process is conducted in an enclosed space. Farmers reported a 20–25% increase in selling prices due to seaweed with a more uniform, cleaner quality.

This implementation also demonstrated positive social impacts, as farmers became more disciplined in managing harvest and post-harvest schedules. They began developing a group-work system to alternate the use of tools. This strengthened the spirit of collaboration and accelerated the adoption of new technologies at the community level. Furthermore, the implementation of seaweed production and sales has generated strong community enthusiasm among customers. This was evidenced by the Community Service team's one-month sales, along with Mrs. "Kelana," which generated a profit of Rp 4,674,000. The detailed calculations are as follows:

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Table 2. Sales Data

Product	Cost per Unit (IDR)	Selling Price (IDR)	Units/Day	Total Units (30 Days)	Revenue (IDR)
Jelly	1.300	1.690	100	2.400	4.056.000
Brownies	7.300	9.490	24	576	5.466.240
Kerupuk	15.600	18.180	40	960	17.452.800
Total	—	—	164	4.756	26.975.040

Source: Primary data processed by the authors.

Table 3. Production Cost Report (Capital / Initial Investment)

Product	Cost per Unit (IDR)	Total Units (30 Days)	Production Cost (IDR)
Jelly	1.300	2.400	3.120.000
Brownies	7.300	576	4.204.800
Kerupuk	15.600	960	14.976.000
Total	—	4.756	**22.300.800**

Source: Primary data processed by the authors.

Gross Profit:
Gross Profit = Total Revenue – Total Production Cost
= IDR 26,975,040 – IDR 22,300,800 = IDR 4,674,240
Gross profit during the production period is IDR 4,674,240.

Return on Investment (ROI):
This means that every Rp100,000 invested yields approximately Rp20,960 in profit.
An ROI above 20% indicates that this seaweed processing business is financially viable and has good capital efficiency.

Social Return on Investment (SROI):
In addition to financial profit, the production activities provide social benefits such as:
a. Empowering local labor, especially coastal women.
b. Utilizing local seaweed as a raw material.
c. Creating positive environmental impact through waste utilization.
If the social value is assumed to be 15% of the economic profit, then:
Additional Social Value = 15% × 4,674,240 = IDR 701,136
SROI = (Profit + Social Value) / Total Production Cost
= (4,674,240 + 701,136) / 22,300,800 = 0.241 = 24.1%

It can be said that every Rp1.00 invested produces Rp1.24 in economic and social value, indicating that this business is not only financially profitable but also has a positive social impact on the surrounding community. Thus, the Jelly, Brownies, and Seaweed Crackers processing business is declared financially and socially viable, and has the potential to support the achievement of SDGs 1, 8, and 12 through increasing welfare, employment, and environmentally friendly production.

Mentoring and Evaluation
The mentoring phase lasted two weeks after the technology was implemented, focusing on evaluating the equipment's performance, the quality of the drying results, and the sustainability of the new practices. The community service team conducted regular visits to ensure farmers could operate the SW Solar Dryer independently and perform simple maintenance, such as cleaning the panels and minor repairs to the covering structure. The evaluation found that most farmers were able to operate the equipment effectively and demonstrated an improved understanding of post-harvest management. They also began recording production results and comparing quality between

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https://ejournal.itbwigalumajang.ac.id/index.php/eps

the old and new methods. Challenges primarily relate to allocating equipment usage time and the need for additional drying units to accommodate increased harvest volumes.

Overall, the mentoring and evaluation activities demonstrated that the implementation of SW Solar Dryer technology has improved the quality and competitiveness of seaweed in Pagarbatu Village, Sumenep. In addition to producing products that meet export standards, this activity also raised farmers' awareness of the importance of post-harvest innovation and environmentally friendly energy efficiency. With continued support from the village and university, it is hoped that this technology can be replicated in other coastal villages in Sumenep.

The implementation of the SW-Solar Dryer has led to significant changes in the drying process. Drying time, which previously took 2–3 days with the open-air method, can now be reduced to 8–12 hours. This efficiency not only accelerates the production cycle but also allows farmers to increase drying volume more quickly. Furthermore, the resulting seaweed is much more hygienic because the drying process takes place in a closed space, preventing exposure to dust, sand, and other contaminants. This aligns with the findings of Jamaluddin et al. (2021), who reported that solar dryer technology can produce seaweed with a more stable moisture content and better physical quality than traditional drying methods. Another study by Amir et al. (2024) corroborates these findings by showing that solar dryer trays maintain the natural color of seaweed, reduce moisture content more quickly, and reduce shrinkage, resulting in a final product that better meets processing industry standards. This improvement in post-harvest quality is inseparable from the application of appropriate technology principles, which emphasize effectiveness, energy efficiency, and suitability to social conditions. Viles et al. (2022) emphasize that the success of sustainable technology lies in its ability to use environmentally friendly energy sources, have low operational costs, and be easily operated by local communities. The SW-Solar Dryer meets all these criteria and is well-received by farmers in Pagarbatu Village.

In addition to strengthening technical aspects, this program also significantly impacted the managerial capacity of the "Kelana" fishing group. Most farmer groups had not previously implemented systematic business governance, particularly in terms of production planning, financial transparency, and task allocation. After participating in management training, group members demonstrated improvements in business planning, transaction recording, and more organized production scheduling. Lubis et al. (2021) explain that poor managerial skills are a common problem in village-owned enterprises (BUMDes) and village business groups, underscoring the need for this training to improve organizational effectiveness. This change also strengthened group cohesion because each member understood their role and contribution to the production process. In addition to managerial improvements, this program also encourages diversification of seaweed products so that farmers do not rely solely on raw commodities. Through mentoring, groups have begun developing value-added products such as premium seaweed, seaweed-based processed foods, and various more modern packaging innovations. This diversification has been proven to open new markets and increase sales value. This aligns with research by Badri et al. (2022), which confirms that packaging innovation and product differentiation increase the attractiveness and affordability of MSME products. Valda et al. (2023) also show that packaging significantly influences purchasing decisions, especially for products aimed at retail consumers.

This community service program also integrates digital marketing strategies through social media platforms such as WhatsApp, Instagram, and Shopee. Digital marketing is highly relevant in increasing market reach and driving direct sales conversions. Marselina et al. (2024) demonstrated that the power of digital networks and business collaboration are crucial factors for MSMEs to survive and thrive in the era of the creative economy. In the context of Pagarbatu Village, collaboration with the Family Welfare Movement (PKK) group provides added value by improving distribution channels and strengthening the community-based marketing ecosystem.

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Economically, this community service program has had a tangible impact. The implementation of the SW-Solar Dryer has increased production capacity and yield quality, thereby increasing the selling price of seaweed. Furthermore, fishing groups can now process larger quantities of seaweed, accelerating capital turnover and reducing dependence on middlemen. Socially, this program strengthens community independence, increases farmer confidence, and provides empowerment opportunities for village women through the participation of women's business groups in Pagar Batu village in production and marketing.

CONCLUSION

Community service activities in Pagarbatu Village, Sumenep, have successfully improved seaweed farmers' understanding and skills in post-harvest management by implementing the SW Solar Dryer (Seaweed Solar Dryer System) technology. This technology has been proven to reduce water content by 12–15%, shorten drying time, and produce cleaner, brighter products that meet industry standards. This makes the drying process more efficient, hygienic, and less dependent on the weather. Financial analysis results show that the seaweed processing business in Pagarbatu Village generated revenue of Rp26,975,040 from September 12–October 11, 2025, with a gross profit of Rp4,674,240 and a return on investment (ROI) of 20.96%. The SROI value reached 24.1%, meaning that every Rp1.00 invested generates Rp1.24 in economic and social value. This business has proven efficient and profitable, while also providing a positive social impact through community empowerment and the use of local raw materials. Thus, this activity is worthy of development as a sustainable coastal business model that supports the achievement of the SDGs 1, 8, and 12.

In addition to economic benefits, this activity also raised farmers' awareness of the importance of energy efficiency and environmentally friendly technological innovation. The mentoring process demonstrated that farmers were able to operate the technology independently, establish a group work system, and begin simple production record keeping. This indicates that the program's sustainability can be achieved with the support of village institutions and cross-stakeholder collaboration. For further development, it is recommended that the seaweed farmer group in Pagarbatu Village expand its production capacity and add a SW Solar Dryer unit to meet increasing market demand. Further training in business management, financial recordkeeping, and digital marketing is needed to optimize product efficiency and added value. The village government and university partners are also expected to provide support through facilitating capital and standardizing the quality and packaging of processed seaweed products. With these steps, this business can develop sustainably, strengthen the coastal economy, and become a successful example of the application of appropriate technology in the marine sector. The authors express their deepest appreciation and gratitude to the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia for its financial support through the Community Service grant, which enabled the successful implementation of this program. The assistance and trust provided have played a significant role in supporting community empowerment efforts, particularly in improving the post-harvest quality of seaweed in Pagarbatu Village, Sumenep. We also extend our gratitude to the Rector of KH. Bahaudin Mudhary Madura University for the support, direction, and facilitation provided during the implementation of this community service activity. The institutional support provided has helped ensure the smooth running and completion of the program in accordance with the planned targets.

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