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FROM TRADITION TO INNOVATION: LITERATURE REVIEW ON SALT PROCESSING AND ITS REPLICATION POTENTIAL IN JEMBRANA

Dari Tradisi Menuju Inovasi: Literatur Review tentang Pengolahan Garam dan Potensi Replikasinya di Jembrana

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ABSTRACT

Salt is a strategic commodity that plays an important role in daily life, both as food, industrial raw materials, and in the health sector. Salt processing in Indonesia, especially in coastal areas, is generally carried out traditionally, which includes evaporation and boiling techniques. However, traditional salt processing in many areas, including Jembrana, Bali, still faces challenges related to product quality, production efficiency, and limited market access. Innovations in salt processing technology, such as the use of geomembranes and salt houses, have been shown to improve the quality and quantity of salt production. This article aims to review the literature related to traditional and innovative salt processing, and explore the potential for replicating these innovations in Jembrana. The results of the study indicate that Jembrana has great potential to develop an innovation-based salt industry, by adopting the latest technology and strengthening community-based business institutions. However, several gaps in technology, human resources, and institutions must be addressed to create a sustainable and competitive salt industry. With support from various parties, including the government, academics, and local communities, Jembrana has the opportunity to become a leading region in the production of high-quality local salt.

Keywords: Salt processing, technological innovation, traditional salt, local potential, business institutions

ABSTRAK

Garam merupakan komoditas strategis yang memiliki peran penting dalam kehidupan sehari-hari, baik sebagai bahan pangan, bahan baku industri, maupun dalam bidang kesehatan. Pengolahan garam di Indonesia, khususnya di daerah pesisir, umumnya dilakukan secara

tradisional, yang mencakup teknik penguapan dan perebusan. Meskipun begitu, pengolahan garam tradisional di banyak wilayah, termasuk Jembrana, Bali, masih menghadapi tantangan terkait kualitas produk, efisiensi produksi, serta akses pasar yang terbatas. Inovasi dalam teknologi pengolahan garam, seperti penggunaan geomembran dan rumah garam, telah terbukti meningkatkan kualitas dan kuantitas produksi garam. Artikel ini bertujuan untuk mengkaji literatur terkait pengolahan garam tradisional dan inovatif, serta mengeksplorasi potensi replikasi inovasi tersebut di Jembrana. Hasil kajian menunjukkan bahwa Jembrana memiliki potensi besar untuk mengembangkan industri garam berbasis inovasi, dengan mengadopsi teknologi terbaru dan memperkuat kelembagaan usaha berbasis komunitas. Namun, beberapa kesenjangan dalam aspek teknologi, sumber daya manusia, dan kelembagaan harus diatasi untuk menciptakan industri garam yang berkelanjutan dan berdaya saing. Dengan dukungan dari berbagai pihak, termasuk pemerintah, akademisi, dan masyarakat lokal, Jembrana berpeluang untuk menjadi daerah unggulan dalam produksi garam lokal berkualitas tinggi.

Kata Kunci: Pengolahan garam, inovasi teknologi, garam tradisional, potensi lokal, kelembagaan usaha.

INTRODUCTION

Salt is one of the most important staple foods worldwide, both for daily consumption, food preservation, and various industrial needs (Mujiburrahman *et al*., 2020; Rochwulaningsih *et al*., 2021; Rochwulaningsih *et al*., 2019; Utama *et al*., 2023). In Indonesia, traditional salt processing, which is often found in coastal areas, plays an important role in the lives of local communities (Amin *et al*., 2024; Aris *et al*., 2022; Syakur *et al*., 2024; Zevalukito *et al*., 2024). Traditional salt processing methods, which mostly still rely on weather and natural conditions, generally involve manual and time-consuming seawater evaporation techniques. Although this process has been around for centuries, the quality of the salt produced is often inconsistent, low productivity and dependence on natural factors are the main challenges faced by traditional salt farmers (Amin, 2023; Mahasin *et al*., 2020; Mardoni, 2022; Sudaryana & Pramesti, 2018).

In Jembrana Regency, Bali, salt processing is still carried out traditionally by a small number of farmers, even though this area has great potential for salt production. However, the process carried out is still very dependent on the weather and limited ability to access modern processing technology. The quality and quantity of salt produced are still far from their maximum potential. Therefore, research on the potential for replication of innovations in salt processing in Jembrana is very relevant, especially to increase the competitiveness of the local salt industry and open up wider market opportunities (Billy, 2015; Safitri & Marzaman, 2023).

Several previous studies have shown that salt processing in Indonesia is mostly carried out using traditional methods that use sunlight to evaporate seawater (Deswati *et al*., 2024; Fauziyah *et al*., 2023; Kunaifi *et al*., 2021; Suwasono *et al*., 2022). This method often cannot produce good quality salt due to the large amount of dirt and low NaCl content in the salt. In several areas, such as Madura and East Nusa Tenggara, technological innovations such as the use of geomembranes and salt houses have been implemented to improve the quality and efficiency of production (Bramawanto & Suaydhi, 2023; Efendy *et al*., 2023; Fauziyah *et al*., 2023; Nugroho *et al*., 2020; Syakur *et al*., 2024; Utomo, 2022; Wanta *et al*., 2023; Wantara *et al*., 2021). Research conducted shows that the application of modern technology in salt production not only improves quality but also reduces dependence on weather, which is a major problem in traditional salt processing (Listanti & Musthafa, 2020; Utomo, 2022; Utomo & Anggara, 2020).

However, although this innovative technology has been implemented in several areas, there are still many areas that have not utilized it, including Jembrana. Therefore, it is important to examine whether innovations implemented in other areas can be implemented and adapted

to local conditions in Jembrana (Abdullah & Susandini, 2018; Efnita et al., 2022; Fathony & Mahyah, 2023; Hidayah *et al*., 2023; Palin *et al*., 2022; Rochwulaningsih, Utama, *et al*., 2019; Safrida, 2021; Setiawan, 2019; Syakatera & Purnomo, 2023; Umam, 2019; Utomo & Anggara, 2020).

Previous studies have focused on salt processing in areas such as Madura, East Nusa Tenggara, and Sulawesi (Daris *et al*., 2023; Leo *et al*., 2021; Wanta *et al*., 2023). However, there has been no in-depth study discussing the potential for replication of salt processing technology innovation in Bali, especially in Jembrana Regency. However, the natural and cultural potential in Jembrana is quite large, but the lack of studies that connect local aspects with innovative technology is a knowledge gap that needs to be filled. In addition, the limited research that examines the challenges and opportunities for developing a community-based salt industry in Bali is also a gap that has not been widely discussed.

This study aims to explore the potential for replication of technological innovation in traditional salt processing in Jembrana Regency, Bali. Specifically, this study seeks to answer several key questions: (1) how can traditional salt processing in Jembrana be developed through the application of innovative technology to improve the quality and quantity of production, (2) what are the challenges and opportunities in adopting salt processing technology that has been applied in other areas, and (3) what is the impact of the application of this technology on the local economy and the sustainability of the salt industry in Jembrana.

By identifying existing obstacles and potentials, this study is expected to provide practical solutions for the development of a technology-based salt industry in the area (Budiharjo *et al*., 2017; Jamil *et al*., 2017; Kurniawan *et al*., 2019; Manek *et al*., 2022; Noviasari *et al*., 2023; Syarif & Pabiban, 2017). The results of this study will provide strategic recommendations to stakeholders, both at the community level, local government, and the industrial sector, in order to optimize the potential of local salt. In addition to increasing the competitiveness of Jembrana salt products in the domestic and international markets, the application of appropriate technology also has the potential to strengthen the local economy, encourage the sustainability of the salt industry, and open up new jobs for coastal communities. Therefore, this study has strategic value in supporting the transformation of the traditional salt sector towards a more efficient, adaptive, and sustainable production system.

LITERATURE REVIEW METHODOLOGY

This literature review was conducted by systematically searching the literature to obtain a comprehensive picture of traditional and innovative salt processing practices, as well as their potential for replication in coastal areas, especially Jembrana. This research was conducted from June 2024-April 2025, and was sourced from observations and 66 literature sources. These literature sources consisted of 54 scientific journals, 8 proceedings, 3 government and policy documents, and 1 from newspaper media. Literature sources were obtained from various scientific databases such as Google Scholar, ScienceDirect, ResearchGate, and national journal portals (Garuda and Sinta). Keywords used in the search include: "traditional salt processing", "people's salt innovation", "Indonesian local salt industry", "Bali salt", "salt business development", and "Jembrana salt potential". The inclusion criteria in the selection of literature were articles published in the last 15 years, either in the form of scientific journals, proceedings, research reports, or relevant government policy documents. Literature that specifically discusses the coastal areas of Indonesia and people's salt processing is prioritized, especially those related to technological, socio-economic, and environmental aspects. While the exclusion criteria include articles that cannot be accessed completely or are not relevant to the focus of the study.

In addition to the literature review, field observations were also conducted at several salt production locations in Bali, namely Tejakula, Amed, Kusamba, and Gumbrih. This

observation aims to determine the actual practice of salt production in various regions. Furthermore, interviews were conducted with 21 salt farmers at the location to obtain direct information regarding production methods, challenges, and local innovations that they carry out. To support this activity, documentation in the form of photos and videos was also carried out to provide a clear visual picture of the salt production process in Bali.

The analysis was carried out thematically by grouping library data and field data into several main themes, namely: (1) traditional salt processing in Indonesia; (2) technological and institutional innovation in the salt industry; (3) supporting and inhibiting factors for replication; and (4) potential for salt development in Jembrana. This approach allows for the preparation of a comprehensive synthesis and becomes the initial basis for developing a strategy for replicating salt processing innovations in Jembrana.

RESULTS AND DISCUSSION

Traditional Salt Processing in Indonesia

Indonesia has a long history of traditional salt production spread across coastal areas such as Madura, Bali, East Nusa Tenggara, and Sulawesi (Daris *et al*., 2023; Efnita *et al*., 2022; Leo *et al*., 2021; Nugroho *et al*., 2020; Rochwulaningsih, Utama, *et al*., 2019; Susandini & Islam, 2022; Utomo & Anggara, 2020; Wanta *et al*., 2023; Wantara *et al*., 2021). Salt is produced through two main methods, namely evaporation of seawater using sunlight and seawater boiling techniques. The evaporation method is more widely used because it suits Indonesia's tropical climate which is rich in sunlight. However, both of these methods are highly dependent on the weather and a fairly long dry season in order to produce salt crystals optimally. Salt production is also an important part of the cultural heritage of coastal communities that has been passed down from generation to generation (Artawan & Wenagama, 2020; Efnita *et al*., 2022; Yogana *et al*., 2016).

In Bali, people's salt production is not only a source of livelihood, but also reflects unique local values (Artawan & Wenagama, 2020; Efnita *et al*., 2022; Yana *et al*., 2022; Yogana *et al*., 2016). Several areas known as traditional salt centers include Tejakula in Buleleng Regency, Amed in Karangasem Regency, Kusamba in Klungkung Regency, and part of Jembrana in western Bali. Each of these areas has unique techniques and characteristics in salt processing (Figure 1). In Kusamba, for example, salt farmers use coconut trunk as a base to dry seawater until it becomes salt crystals, a traditional technique that is still preserved and produces salt with a distinctive taste (Mujiburrahman *et al*., 2020). Tejakula and Amed also use natural evaporation methods with the help of traditional tools such as drying tables made from coconut trunks or compacted sand.

(a) (b)

Figure 1. Salt production in Bali
(a) Coconut trunk; (b) Salt production house

However, not all coastal areas in Bali have ideal conditions for salt production. The success of this activity is highly dependent on four main factors: climate suitability, land contour, access to seawater, and soil texture. Suitable areas generally have annual rainfall below 1200 mm, air temperature of 31–33°C, air humidity below 70%, and a dry season that lasts at least 4.5 to 5 months. Seawater salinity also plays an important role, with ideal levels between 34.6–35.6 ppt (Hoiriyah, 2019; Rozalina *et al*., 2022). The Tejakula and Amed areas have these conditions, so they greatly support the efficiency of the salt evaporation and crystallization process (Maharani A.P. *et al*., 2022; Mangku *et al*., 2022; Pratiwi *et al*., 2022; Raningsih *et al*., 2023; Utama *et al*., 2023).

In addition to climate factors, land contours or topography are also important to ensure that seawater can flow by gravity without the need for additional pumps. Flat land with a maximum slope of 2–3% is ideal for developing salt ponds. However, because many areas in Bali do not have soil structures like those on Madura Island, people have developed adaptive methods by utilizing bamboo tables, stone bases, or coconut fibers as crystallization media. Stable access to seawater that is not mixed with fresh water from rivers or estuaries is also an important consideration because this mixing can reduce the salinity and quality of the salt (Hoiriyah, 2019; Rozalina *et al*., 2022).

On the other hand, areas such as Jembrana face their own challenges in developing the community salt industry. Although not included in the main centers of salt production in Bali, several coastal areas in Jembrana such as Gumbrih Village still maintain the tradition of salt production using the evaporation method. However, higher rainfall, less stable climate, and limited technology and market access are the main obstacles in increasing salt production capacity and quality. The Bali Provincial Government has taken steps through a technical guidance program for salt farmers in Jembrana, in line with the Circular of the Governor of Bali Number 17 of 2021 concerning the utilization of local salt products.

To increase salt production in areas such as Jembrana that have climate challenges, it is necessary to implement appropriate technologies such as prism houses (salt greenhouses), the use of geomembranes, and modular crystallization systems. This technology can reduce dependence on weather and increase the efficiency of the production process. In addition, it is necessary to strengthen the institutions of salt farmers, open market access, and promote the cultural value of traditional salt as a local superior product. With an integrated approach, salt production in Bali will not only be more competitive and sustainable, but also become a symbol of preserving coastal culture that has high economic and social value.

Innovation In Salt Processing Technology

The increasing demand for high-quality salt in Indonesia has driven innovations in salt processing technology, both technically and institutionally. These innovations are very important in overcoming the main challenges faced by traditional salt farmers, such as dependence on weather, limited land, low salt quality, and weak market access. This new approach is not only aimed at increasing production efficiency and quality, but also at strengthening the competitiveness of the national salt industry and improving farmer welfare through a more adaptive and sustainable production model. One of the most significant innovations is the greenhouse salt tunnel technology, a structure resembling a mini greenhouse that covers the salt crystallization plot. The transparent roof made of UV plastic allows for increased indoor temperatures and accelerates the evaporation process, while protecting the brine from rain and dust contamination. This technology is very relevant to be applied in tropical areas with high rainfall such as Jembrana, Bali, where the prolonged rainy season is a major challenge in traditional salt production. Studies show that prism houses can increase productivity up to two to three times compared to open methods (Amin, 2023; Kurniawan *et al*., 2021; Radityo & Pratomo, 2024). These technologies can be seen in Figure 2.

As a more flexible alternative, salt tunnels come in the form of smaller plastic tunnels that can be dismantled and reassembled. Suitable for small to medium-scale farmers, salt tunnels allow for faster adaptation to seasonal changes and light rainfall. This technology has been used effectively in several regions in Indonesia, providing a practical, cost-effective solution.

Another innovation is the use of geomembranes—black plastic sheets made of HDPE or LDPE—which are used as a base for salt plots. The dark color of the geomembrane absorbs heat well, accelerates evaporation, and prevents water from seeping into the soil. In addition, geomembranes make cleaning easier and extend the life of the production plots. The combination of geomembrane with prism house or salt tunnel has been proven to improve salt quality (with higher NaCl content and lower impurities) according to industry standards (Helena *et al*., 2022; Sharma *et al*., 2023).

For household scale, modular crystallization rack or table system is an innovative option. Using local materials such as bamboo or lightweight metal coated with waterproof plastic, this table can be moved as needed. When placed under a plastic canopy or in a semi-permanent building, this system provides high flexibility and is suitable for novice salt farmers or small business groups. In the future, the potential for integrating renewable energy such as solar panels is also starting to be eyed to automatically flow seawater and provide additional heating in the prism house, increasing the efficiency of the overall system (Kunaifi *et al*., 2021).

The use of renewable energy such as solar panels in the fisheries sector has been widely used (Demeianto *et al*., 2022; Nugraha, 2020; Sardi *et al*., 2020). In salt production, the use of solar panels is an innovation that has the potential to increase production efficiency and sustainability, especially in coastal areas with high sunlight intensity. Solar panels can be used to drive seawater pumps that fill salt ponds, replacing diesel engines that waste fuel and pollute the environment. In addition, solar energy can be utilized in seawater evaporation systems through a combination of greenhouse technology or plastic tunnels (solar tunnels), which accelerate the crystallization process and allow salt production to continue even when the weather is not favorable. Pond lighting at night can also use solar-powered lamps, which increases safety and supports post-harvest activities. To improve production accuracy and efficiency, IoT-based salinity and water level sensor systems can also be run on solar power. Overall, the use of solar panels in the salt industry not only reduces long-term operational costs, but also encourages the creation of an environmentally friendly, energy-independent, and climate-adaptive salt production system (Thalib *et al*., 2021; Wantira *et al*., 2023).

(a) (b)

Figure 2. Innovation in Salt Processing Technology
(a) Green House Salt Tunnel; (b) Geomembranes in Salt Ponds

In addition to physical innovation, institutional strengthening is also an important element in increasing the competitiveness of the salt industry. In several regions such as Madura and East Nusa Tenggara, the formation of salt farmer cooperatives, partnerships with the food industry, and digitalization of marketing have had a significant impact on increasing farmers' income and welfare. Programs such as PUGAR (Pemberdayaan Usaha Garam Rakyat) from the Ministry of Maritime Affairs and Fisheries, also provide support in the form of harvesting tools, business management training, and access to wider markets (Direktorat Jenderal Pengelolaan Kelautan dan Ruang Laut, 2023; Menteri Kelautan dan Perikanan Republik Indonesia, 2023). Experience in these areas shows that the combination of technological innovation and institutional strengthening can create a more resilient, efficient, and inclusive salt production system. However, the adoption of this technology and institutional model is not evenly distributed throughout Indonesia.

Potential For Replication in Jembrana

Jembrana Regency, located in the western part of Bali Island, has a fairly long coastline and geographical conditions that support salt production. Several coastal villages such as Gumbrih Village have a tradition of salt processing that has been passed down from generation to generation, although it is still small-scale and uses traditional methods. This shows that ecologically and culturally, Jembrana has a strong initial foundation for the development of a community-based salt industry.

However, this potential has not been optimally utilized due to a number of obstacles, such as limited technology, minimal policy support, and weak market access. Therefore, replication of various salt processing innovations that have been successfully implemented in areas such as Madura and East Nusa Tenggara is very relevant to be applied in Jembrana. Technologies such as geomembranes, prism houses (greenhouse salt tunnels), and efficient seawater distribution systems can significantly increase the productivity and quality of local salt.

Initial efforts have been made through a salt processing training program facilitated by the Bali Provincial Industry and Trade Office, which shows a commitment to transferring knowledge and skills to local communities. This program can be expanded by integrating small business management training, product packaging, and digital-based marketing strategies to create greater added value for salt farmers.

From a social and institutional perspective, the Jembrana community has strong potential to build a community-based production system through the formation of salt farmer cooperatives or joint business groups. The involvement of local governments, NGOs, and universities can be important catalysts in connecting technological innovation with local wisdom. However, this replication process cannot be done instantly, but must consider local characteristics, such as work culture, technology adoption capacity, and community socio-economic dynamics.

A collaborative approach involving various stakeholders is needed to design a sustainable, adaptive, and inclusive salt development model. With the right strategy, Jembrana has the potential to become a national pilot model for how salt industry innovation can be replicated and adapted contextually, while empowering coastal communities and strengthening the regional economy.

Gap Analysis and Development Opportunities

The development of the salt industry in Jembrana Regency has great potential that comes from the richness of local geography and culture. In terms of strengths, this area has a long coastline and is relatively clean from industrial pollution, as well as a tradition of salt processing that has been carried out by communities in coastal villages such as Gumbrih

(Artawan & Wenagama, 2020; KKP, 2025). Social capital in the form of local wisdom and a spirit of mutual cooperation is still strong, allowing the formation of a community-based production system. Initial support from the government, for example salt processing training from the Bali Provincial Industry and Trade Office, indicates attention to the development of local products, as well as being a starting point for strengthening the capacity of salt farmers.

However, various weaknesses are still the main obstacles in the development of this industry. Very traditional production methods, without the use of modern technology such as geomembranes or salt houses, cause the processing process to be inefficient and highly dependent on weather conditions. This has an impact on the low quality and quantity of salt products, which are less able to compete in the industrial market. In addition, limited human resource capacity and minimal technical and managerial training make it difficult for farmers to innovate or diversify their businesses. The absence of institutional institutions such as cooperatives or village business units also limits access to production facilities, financing, and wider marketing.

The most striking gap is seen in the less than optimal utilization of resources. Although Jembrana ecologically supports salt development, production technology is still far behind other regions such as Madura or East Nusa Tenggara which are more advanced in utilizing technological innovation. Likewise in terms of institutions and marketing; salt farmers still rely on informal distribution systems, which results in low selling prices and a weak bargaining position in the market.

However, there are strategic opportunities that can be utilized to bridge this gap. First, the potential for developing high-quality salt products, such as organic salt or healthy consumption salt, can be a superior selling point considering the relatively natural conditions of Jembrana's coast. Second, the existence of policy support from the regional and provincial governments through regulations that encourage the use of local products is a great opportunity to build the image of Jembrana salt as a typical Balinese product. Third, the development of digital technology and e-commerce opens up wider market access, including tourism and export markets. The geographical identity of Jembrana salt can be a special attraction for niche markets such as hotels, restaurants, and foreign consumers who value natural and sustainable products. Partnerships with higher education or research institutions also offer a path to strengthening technological innovation that is in accordance with local characteristics.

On the other hand, there are several threats that need to be anticipated, such as competition with imported salt or large industries that offer cheaper prices and more stable quality. In addition, climate change and unpredictable seasons have the potential to disrupt salt production which still depends on the weather. Community resistance to the adoption of new technologies, which may be caused by limited understanding or concerns about the loss of traditional values, is also a challenge in the industrial transformation process. In addition, the absence of a national policy that explicitly supports people's salt businesses as a whole makes this sector still structurally vulnerable.

By considering the strengths, weaknesses, opportunities, and threats that exist, the approach to developing the salt industry in Jembrana should be carried out collaboratively and in an integrated manner (Figure 3). This effort is not only aimed at replicating technology from other regions, but also encouraging the creation of a unique salt industry model, based on local wisdom, socially inclusive, and market-oriented. If carried out with the right strategy, Jembrana can be an example of the success of developing innovative and sustainable people's salt at the national level.

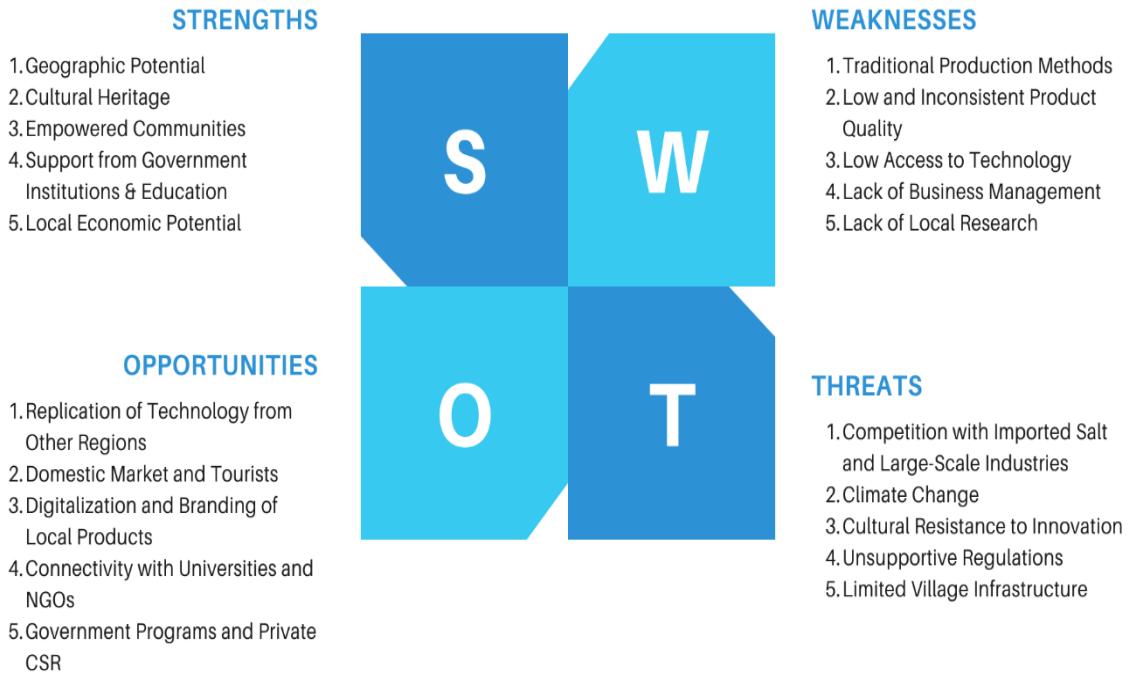

Figure 3. SWOT Analysis and Development Opportunities

CONCLUSION AND RECOMMENDATIONS

The development of a salt industry based on technological and institutional innovation is an important strategy in realizing food security and strengthening the local economy, especially in coastal areas such as Jembrana. Although traditional salt processing in Indonesia has high historical and cultural value, this method still faces serious challenges related to efficiency, quality, and sustainability. Innovations such as the use of geomembranes, prism houses, salt tunnels, and modular rack systems have been proven to increase productivity and added value of salt in areas such as Madura and East Nusa Tenggara. Unfortunately, the adoption of these innovations is not evenly distributed and has not yet fully reached potential areas such as Jembrana, Bali.

The results of the literature review and field observations show that Jembrana has strong ecological, social, and cultural potential to build a competitive people's salt industry. However, gaps in technology, human resource capacity, and market access are still major obstacles. To overcome this, the strategies needed include a participatory approach based on local needs, development of technology models that are appropriate to local conditions, ongoing training, strengthening salt farmer institutions through cooperatives or joint business groups, and policy support that supports the people's salt industry. Great opportunities can also be explored from the trend of market demand for quality local products, the potential of e-commerce, and the strengthening of the geographical identity of Jembrana salt as a typical Balinese product.

With a planned and collaborative approach between the government, local communities, academics, and the private sector, Jembrana has a great opportunity to become a pilot area for the development of an innovative, sustainable, and local wisdom-based people's salt industry in a tropical region facing high climate challenges.

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