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# STRENGTHENING THE QUALITY AND VALUE CHAIN OF COMMUNITY SALT THROUGH GREENHOUSE SOLAR DOME DRYER AND DIGITAL PACKAGING

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## Abstract

Traditional open-air salt drying in coastal areas is highly dependent on weather conditions and often produces salt with high moisture content, unstable NaCl purity, and contamination risks. This study aims to evaluate the effectiveness of a Greenhouse Solar Dome Dryer (GSDD) in improving the physicochemical quality of community-produced salt compared to conventional open drying and to assess its implications for downstream value addition through digital packaging.

Quality testing was conducted on two salt samples—without greenhouse drying and with greenhouse drying—using parameters of NaCl content, moisture content, color, odor, and water-insoluble matter. Quality interpretation referred to SNI 3556:2016 and Codex Alimentarius standards. The results show that greenhouse drying significantly reduced moisture content from 9.87% to 3.37%, increased NaCl content from 96.80% to 97.30%, and reduced insoluble matter from 0.11% to 0.06%. These findings indicate that greenhouse technology enhances salt quality, storage stability, and readiness for market integration. The study concludes that integrating greenhouse drying with digital packaging offers a viable pathway for strengthening the community salt value chain in coastal regions.

**Keywords:** community salt; greenhouse solar dryer; salt quality; NaCl purity; moisture reduction; digital packaging.

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## 1. Introduction

Salt is a strategic commodity for food security and industrial applications. In Indonesia, community-based salt production remains dominated by traditional open-air drying systems that are highly vulnerable to rainfall, humidity, and environmental contamination (Kurniawan et al., 2020; Hadi et al., 2021). These limitations frequently result in salt with excessive moisture content, inconsistent NaCl concentration, and reduced market competitiveness.

Previous studies have demonstrated that solar greenhouse dryers can improve drying efficiency and product quality in agricultural and marine commodities by providing a controlled microclimate with higher temperatures and lower relative humidity (Esper and Mühlbauer, 1998; Bala et al., 2017; Fernandes et al., 2024). However, empirical evidence on the application of greenhouse drying for community salt production, particularly in eastern Indonesia, remains limited.

This study aims to (i) compare the physicochemical quality of salt produced with and without greenhouse drying, (ii) interpret the results using national and international standards, and (iii) examine the implications of improved quality for downstream processing and digital-based market access.

## 2. Materials and Methods

### 2.1 Study Area and Period

The study was conducted in a coastal salt-producing area in Kupang Regency, Indonesia. Prototype drying trials were carried out in late November 2025. Laboratory quality testing was performed at Sucofindo Surabaya, an accredited testing facility.

### 2.2 Experimental Design

Two salt treatment groups were evaluated:

1. Open-air drying (without greenhouse)
2. Greenhouse Solar Dome Dryer (with greenhouse)

### 2.3 Quality Parameters

The analyzed parameters included:

- Sodium chloride (NaCl) content (%)
- Moisture content (%)
- Color
- Odor
- Water-insoluble matter (%)

Quality interpretation was based on SNI 3556:2016 for iodized consumption salt and Codex Alimentarius (2012) for food-grade salt.

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## 3. Results and Discussion

### 3.1 Comparison of Salt Quality

The quality test results are summarized in Table 1.

Table 1. Quality comparison of salt dried with and without greenhouse

| Parameter | Without greenhouse | With greenhouse | Quality reference |
|---|---|---|---|
| NaCl (%) | 96.80 | 97.30 | SNI ≥94.7%; Codex ≥97% |
| Odor | Normal | Normal | Normal |
| Color | White | White | White |
| Moisture (%) | 9.87 | 3.37 | ≤7% (SNI) |
| Insoluble matter (%) | 0.11 | 0.06 | ≤0.5% (SNI) |

### 3.2 Moisture Content Reduction

Moisture content decreased by 6.50 percentage points, equivalent to a 65.9% relative reduction, when greenhouse drying was applied. Salt dried without greenhouse exceeded the SNI maximum moisture limit (7%), whereas greenhouse-dried salt met the standard comfortably.

This substantial reduction can be attributed to the greenhouse effect, which increases internal air temperature and reduces relative humidity, accelerating water evaporation. Similar findings have been reported in greenhouse drying studies for fishery and agricultural products (Bala et al., 2017; Hossain et al., 2020). Low moisture content is critical for preventing caking, microbial growth, and quality deterioration during storage (Rahman, 2007).

### 3.3 Enhancement of NaCl Content

NaCl purity increased from 96.80% to 97.30% in greenhouse-dried salt. Although both samples met SNI requirements, only the greenhouse-treated salt reached the Codex threshold for food-grade salt. This increase is likely due to the combined effect of moisture reduction and reduced contamination during enclosed drying.

Previous studies have shown that controlled drying environments can indirectly improve mineral purity by minimizing exposure to windborne particles and rainwater dilution (Jayaraman and Das Gupta, 1995; Fernandes et al., 2024).

### 3.4 Reduction of Insoluble Matter

Water-insoluble matter decreased from 0.11% to 0.06% with greenhouse drying, indicating improved cleanliness. The greenhouse structure functions as a physical barrier against dust, sand, and other contaminants common in coastal environments (Hadi et al., 2021). Although both samples met SNI limits, the lower insoluble fraction enhances visual quality and consumer acceptance.

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### 3.5 Storage Stability and Shelf Life of Salt

The reduction in moisture content to 3.37% in salt dried using the Greenhouse Solar Dome Dryer (GSDD) has direct implications for product storage stability and shelf life. Low moisture content reduces water activity, thereby inhibiting caking and minimizing the potential for microbial growth. In the context of community-produced consumption salt, this physical stability is a critical factor, as it determines ease of distribution, medium-term storage performance, and consistency of quality at the consumer level.

In traditional practices, salt with moisture content above the permissible threshold often undergoes textural changes during storage, particularly in coastal environments characterized by high humidity. Therefore, the application of GSDD not only improves initial product quality but also generates downstream benefits in the form of reduced post-harvest losses, which have long been a persistent challenge in the community salt value chain.

### 3.6 Hygienic Aspects and Product Safety

Open-air drying in coastal areas poses a high risk of biological and physical contamination, including dust, sand, organic debris, and microorganisms from the surrounding environment. The dome-shaped structure of the GSDD serves as an effective physical barrier, enabling the drying process to occur in a more controlled and hygienic environment.

This improvement in hygienic conditions contributes to the reduction of water-insoluble matter and enhances visual quality perception. From a food safety perspective, such conditions constitute an essential prerequisite for the development of consumption salt targeting formal markets and small-scale food industries, which generally impose stricter hygiene standards than traditional markets.

### 3.7 Process Efficiency and Resilience to Climate Variability

One of the principal advantages of GSDD technology lies in its ability to reduce production dependence on weather conditions. During transitional and rainy seasons, traditional salt production is frequently halted or results in low-quality output due to exposure to rainfall and high ambient humidity.

The findings of this study demonstrate that the GSDD is capable of producing salt that meets quality standards even when trials are conducted during the onset of the rainy season. This indicates the potential of the technology as a climate adaptation instrument for community salt farmers, while simultaneously extending the effective production period within a calendar year.

### 3.8 Integration of Product Quality with Digital Value Addition

Improvements in the physical and chemical quality of salt constitute a fundamental foundation for digital-based value addition. Salt characterized by low moisture content and high purity is more suitable for modern packaging using airtight materials and digital labeling. The integration of QR codes on packaging enables the dissemination of information regarding product origin, production processes, and quality assurance to consumers.

From a value chain perspective, digital packaging functions not only as a marketing tool but also as a mechanism for strengthening the bargaining position of small-scale producers. The combination of technology-driven quality enhancement and digital innovation opens access to online markets, modern retail channels, and government procurement schemes that require product traceability.

**4. Implications for Downstream Value Addition**

Improved salt quality supports downstream processing and market access. In this study, quality enhancement was complemented by digital packaging, including QR-based product identification and linkage to digital payment and marketing platforms. Digital packaging strengthens traceability, transparency, and branding, which are increasingly important for small-scale producers entering formal and online markets (Kotler and Keller, 2016; Susanto et al., 2022).

**5. Limitations and Future Research**

The drying trials were conducted during the transition to the rainy season, limiting experimental replication and detailed thermal performance monitoring. Future research during the dry season (2026) should include continuous measurements of temperature, relative humidity, solar radiation, and drying duration to generate robust performance curves and enable techno-economic analysis.

**6. Conclusions**

The Greenhouse Solar Dome Dryer significantly improves the physicochemical quality of community-produced salt by reducing moisture content, increasing NaCl purity, and lowering insoluble matter. These improvements enhance compliance with national and international standards, improve storage stability, and support downstream value addition through digital packaging. Greenhouse drying thus represents a promising technological intervention for strengthening the community salt value chain in coastal regions.

**7. Recommendations**

1. Conduct multi-cycle drying experiments during the dry season.
2. Include additional quality parameters such as iodine content, heavy metals, and microbiological safety.
3. Integrate greenhouse drying with standardized digital packaging at the community level.
4. Perform cost–benefit and scalability analyses to support policy adoption.

5. Optimization of GSDD Design and Operation
   Further development of GSDD design tailored to the scale of community salt production is required, including ventilation configuration, loading capacity, and ease of maintenance.
6. Advanced and Continuous Quality Testing
   Future studies are recommended to incorporate additional quality parameters, such as

iodine content, heavy metal contamination, and microbiological analysis, to ensure comprehensive product safety.

7. Integration of Technology with Farmer Institutions
   The implementation of GSDD should be carried out through institutional approaches, such as cooperatives or joint business groups, to ensure equitable distribution of investment costs and technological benefits.
8. Strengthening Downstream Processing and Digitalization
   Local governments and relevant stakeholders should promote standardized digital packaging and provide training in online marketing to enhance the competitiveness of community-produced salt.
9. Economic and Policy Analysis
   Further studies on economic feasibility, cost–benefit analysis, and policy support are necessary to ensure the long-term sustainability of GSDD technology adoption.

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