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Optimization of Gracilaria sp. Seaweed Salt Purification Analysis through the Integration of Hydroextraction and Recrystallization Methods to Meet the Indonesian National Standard (SNI) for Edible Salt

Nurhikmah Wahab[1*], Rizka Octavia[2], Dwi Maryana[3], Ahmad Jusma Azhari[4], Erwin[5]

[1,2,4] Program Studi Kimia, Universitas Teknologi Sulawesi

[3,5] Program Teknologi Hasil Pertanian, Universitas Teknologi Sulawesi

e-mail: nurhikmahwahab05@gmail.com

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Abstract

This study was motivated by the high potential of *Gracilaria sp.* seaweed as a source of high-quality raw material for edible salt production. However, the purification process of seaweed-derived salt often faces challenges due to the high content of non-NaCl minerals, causing the final product to fall short of the requirements specified in SNI 4435:2017 for consumption salt. Therefore, further research is needed to improve the quality and purity of the salt produced. The objectives of this study were to: (1) optimize the salt purification process from *Gracilaria* sp. through the integration of hydroextraction and recrystallization methods to enhance NaCl purity;
(2) determine the effects of process parameter variations, including temperature, extraction time, and evaporation rate, on the quality of the resulting salt;and (3) develop technical recommendations for an efficient and environmentally friendly salt purification process. The study employed an experimental approach using a Completely Randomized Design (CRD) to evaluate variations in process temperature and duration. Salt obtained from the hydroextraction process was further purified through recrystallization to produce high-purity salt crystals. Quality analysis was conducted using gravimetric, titrimetric, and spectroscopic methods to determine NaCl content, mineral composition, and moisture content.The integration of hydroextraction and recrystallization methods effectively improved the purity of salt derived from *Gracilaria sp.* seaweed by increasing NaCl content and reducing impurities. The results demonstrated that the optimized purification process produced salt that met or closely approached the Indonesian National Standard (SNI) for edible salt.

Keywords: Salt Purification Optimization, Pure NaCl Salt, Hidroextraction, _Recrystallization, Consumption Salt SNI Standard.

1. Introduction

Salt is a strategic commodity that plays a vital role in both human life and the industrial sector. Besides its use as a food flavoring, salt is also utilized in the food, pharmaceutical, chemical, and preservation industries. Consumable salt used by the public must meet quality standards to ensure it is safe and suitable for consumption (Akbar et al.,2023). In Indonesia, the quality of table salt is regulated by the Indonesian National Standard (SNI) for iodized table salt, which stipulates requirements for sodium chloride (NaCl) content, water content, iodine content, and maximum limits for impurities such as magnesium, calcium, sulfate, and heavy metals. Table salt that meets the SNI generally has a high NaCl content, a pure white color, a low water content, and minimal impurities (Amah et al.,2022).

Salt quality is greatly influenced by the raw materials and processing methods. Traditionally produced salt often contains high levels of impurities, making it less than acceptable for consumption (Akbar et al.,2023). Impurities such as magnesium and calcium can cause a bitter taste, dull color, and reduce the purity of salt. Therefore, a purification process is necessary to improve the quality of salt to meet SNI standards. (Syah et al.,2022).

In Indonesia, the quality of table salt is regulated by SNI 4435:2017 concerning raw materials for iodized table salt. This standard establishes several important parameters that must be met, including physical condition, sodium chloride (NaCl) content, water content, water-insoluble components, and the presence of heavy metal contaminants such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) (Butarbutar et al.,2021). Based on SNI 4435:2017, Salt quality is classified into three categories, namely K1, K2, and K3, as shown in Table 1.

Table 1

Quality Requirements for Iodized Salt Raw Material According to SNI 4435:2017

No	Test Parameter	Unit	SNI Requirements		
			K1	K2	K3
1	Condition:				
	- Odor		Normal,odorless	Normal,odorless	Normal,odorless
	- Color		White	White to brownish-white	Other than K1 and K2 color
2	Moisture Content (H_2O)	% (w/w)	Maks.7	Maks.7	Maks.7
3	Sodium Chloride (NaCl), dry basis	% (w/w)	Min.94	Min.90	Min.85
	Sodium Chloride (NaCl), wet basis	% (w/w)	Min.87	Min.83	Min.78
4	Water Insoluble Matter, dry basis	% (w/w)	Maks. 0,5	Maks. 0,75	Maks. 1,00
5	Metal Contamination:				
	Lead (Pb)	mg/kg	Maks.10	Maks.10	Maks.10
	Cadmium (Cd)	mg/kg	Maks.0,5	Maks.0,5	Maks.0,5
	Mercury (Hg)	mg/kg	Maks.0,1	Maks.0,1	Maks.0,1
	Arsenic (As)	mg/kg	Maks.0,1	Maks.0,1	Maks.0,1

(Badan Standardisasi Nasional,2017).

One of the alternative raw material sources that has the potential to be used in salt production is the seaweed Gracilaria sp. This seaweed is a member of the red algae (Rhodophyta) group which is widely cultivated in Indonesia because it has high economic value (Rizkaprilisa.et al.,2023). So far, Gracilaria sp has been used more as a raw material for making agar, but the mineral content in it shows that this seaweed also has the potential to be used as a source of natural salt. Gracilaria sp contains minerals such as sodium, potassium, magnesium, and calcium which can be extracted to produce salt (Nurwulan.et al.,2025)

Morphologically, Gracilaria sp. has a branched thallus with a flexible, cartilaginous texture and a reddish-brown to greenish-brown coloration. This seaweed grows well in shallow waters with specific salinity and temperature conditions. As a maritime country, Indonesia has great potential for the development of Gracilaria sp. cultivation because its aquatic environments are highly favorable for the growth of this seaweed. The utilization of Gracilaria sp. as a raw material for salt production could serve as an innovation to support the diversification of national salt sources while simultaneously increasing the added value of seaweed cultivation products (Fadilah.et al.,2019) Although it has great potential, the salt produced from Gracilaria sp. seaweed still has several drawbacks, such as a high content of organic matter and mineral impurities (Swandari.et al, 2023). This condition results in a suboptimal NaCl content, and the salt quality has not yet met the Indonesian National Standard (SNI) for edible salt. Therefore, an effective purification method is needed to increase the NaCl content and reduce the level of impurities.

One of the methods that can be used in the salt purification process is hydroextraction. Hydroextraction is a separation method that uses water as a solvent based on differences in the solubility of components. In this process, salt is dissolved in a solvent, allowing impurity compounds to be separated from the NaCl solution (Wahab & Ramli,2020). The effectiveness of the hydroextraction process is influenced by several factors, including the salt-to-solvent ratio, extraction temperature, and extraction time. Higher temperatures generally increase the dissolution rate and accelerate impurity removal, while an optimal extraction time allows more effective contact between the solvent and the material, thereby enhancing the separation process (Martina et al.,2016)

In addition to hydroextraction, the recrystallization method is also widely used for salt purification. Recrystallization is carried out by dissolving the salt in hot water and then cooling the solution to allow purer NaCl crystals to form. During this process, most impurities remain in the solution, while NaCl recrystallizes with a higher degree of purity. Recrystallization has been shown to be effective in increasing NaCl content, improving crystal color, and reducing the magnesium and calcium content in salt (ZamZami et al.,2023)

The integration of hydroextraction and recrystallization methods is expected to produce salt of higher quality than the use of either method alone. Hydroextraction functions to reduce initial impurities, while recrystallization enhances the final purity of the salt crystals. The combination of these two methods is anticipated to yield salt with a high NaCl content, low moisture content, and minimal impurities, thereby meeting the Indonesian National Standard (SNI) requirements for edible salt (Kharismanto et al.,2020).

Salt quality analysis is conducted to evaluate the effectiveness of the purification process. Commonly analyzed parameters include NaCl content, moisture content, yield, crystal color, and the presence of impurity minerals. The determination of NaCl content is usually carried out using the argentometric titration method with $AgNO_3$ solution as the titrant. The higher the NaCl content obtained, the better the quality of the salt produced. In addition, moisture content analysis is also important because high moisture levels can affect the shelf life and quality of edible salt (Kurniawati,2023).

Through the optimization of the purification process by integrating hydroextraction and recrystallization methods, it is expected that the optimal conditions can be achieved to produce Gracilaria sp. seaweed salt with quality that meets the Indonesian National Standard (SNI). This research is expected to contribute scientifically to the development of salt purification technology based on local resources, while also supporting the improvement of quality and diversification of national salt products

2. Methods

2.1 Research Design

This study was conducted as a laboratory experiment using a factorial Completely Randomized Design (CRD) with three factors: salt-to-solvent ratio (1:3, 1:4, and 1:5), extraction temperature (60, 75, and 90°C), and extraction time (15, 30, and 45 minutes). Each treatment combination was performed in triplicate (three replications).

2.2 Time and Location of the Study

Seaweed samples were collected from Laikang Village, Takalar Regency, South Sulawesi, Indonesia. The laboratory analyses were performed at the Integrated Laboratory and the Instrumentation Laboratory of SMK-SMAK Makassar. The research was conducted over a period of approximately nine months, spanning April to December 2026

2.3 Materials and Equipment

Materials: Gracilaria sp. seaweed, seawater or freshwater, distilled water (aquadest), saturated NaCl solution, $AgNO_3$ solution, K_2CrO_4 indicator, and EDTA solution.

Equipment: blender, laboratory water bath, Soxhlet extraction apparatus, hot plate magnetic stirrer, measuring spoon, beakers, Erlenmeyer flasks, drying oven, analytical balance, Whatman filter paper, thermometer, Büchner funnel, Petri dishes, vacuum filtration unit, magnetic stirrer, desiccator, pH meter, wash bottle, titration burette, and an Atomic Absorption Spectrophotometer (AAS).

2.4 Research Procedure

2.4.1 Raw Material Preparation

Gracilaria sp. seaweed was washed with freshwater for **24 hours**, with the water replaced every **6 hours**, to remove natural salts, sand, and other impurities. The cleaned seaweed was then sun-dried until it reached a low moisture content. Subsequently, the dried seaweed was ground using a blender to obtain a homogeneous powder for further analysis.

2.4.2 Preparation of Crude Salt

The seaweed powder was processed by evaporation using a laboratory water bath until a saturated solution was obtained. The saturated solution was then dried in an oven at **105°C** until crude salt crystals were formed.

2.4.3 Hydroextraction Process

The crude salt crystals were cooled in a desiccator to room temperature. The crystals were then mixed with a saturated NaCl solution using different salt-to-solvent ratios of 1:3, 1:4, and 1:5 (w/v). The mixtures were heated at 60°C, 75°C, and 90°C for 15, 30, and 45 minutes, respectively, while being continuously stirred using a soxhlet extraction apparatus.

The Soxhlet extraction method was employed because it provides continuous contact between the saturated NaCl solution and the salt crystals through repeated solvent circulation. During the extraction process, the solvent continuously recirculates, thereby enhancing mass transfer between impurities present on the surface and within the pores of the salt crystals and the washing solution. This continuous extraction mechanism improves the efficiency of impurity removal compared with a single-stage washing process. (Rokhmah et al.,2026)

The use of a saturated NaCl solution was intended to take advantage of the common-ion effect, thereby suppressing the solubility of NaCl while promoting the dissolution of impurity ions such as Ca^{2+}, Mg^{2+}, and Fe^{3+} into the washing solution.

2.4.4 Recrystallization Process

The salt crystals obtained after the hydroextraction process were dissolved in hot distilled water at temperatures of 60°C, 75°C, and 90°C for 15, 30, and 45 minutes, respectively, until a saturated solution was formed.

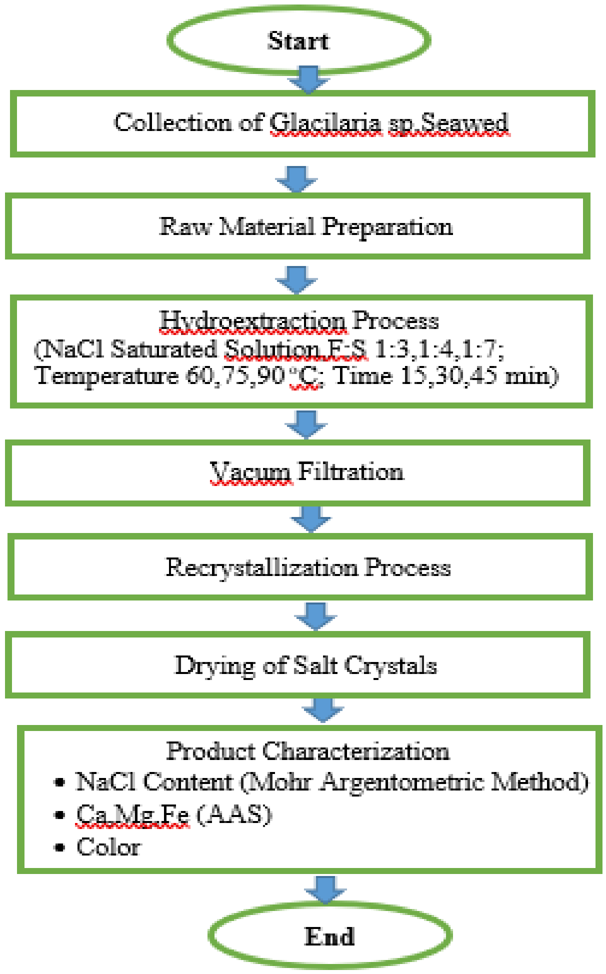
The resulting solution was filtered to remove insoluble impurities. It was then partially evaporated until it approached the saturation point and allowed to cool gradually to room temperature to promote the formation of purer NaCl crystals. The crystals were separated by vacuum filtration using a buchner funnel and dried in an oven at 105°C until a constant weight was achieved.

2.4.5 Product Analysis

The quality of the purified salt was evaluated using the following analytical methods:

- NaCl content was determined using the Mohr argentometric titration method.
- Calcium (Ca), magnesium (Mg), and iron (Fe) contents were determined using Atomic Absorption Spectrophotometry (AAS).
- Moisture content was determined using the gravimetric method.
- Visual characteristics such as color evaluated in accordance with the Indonesian National Standard (SNI).

Figure 1
Flowchart



3. Result and Discussion

3.1 Result

The data on salt quality obtained from laboratory experimental analysis through the hydroextraction and recrystallization processes are presented in the table below:

NaCl Concentration Quality Through the Hydroextraction Process Based on the F:S Ratio, Temperature, and Time Variables

Table 2.
Results of NaCl levels in the variables F:S, Temperature, and Time

No	F:S	Temperature	Time (Minute)	%NaCl
1		60	15	87,894
2			30	87,894
3			45	88,361
4		75	15	89,063
5	1:3		30	89,530
6			45	89,764
7		90	15	90,231
8			30	90,465
9			45	90,699
10		60	15	91,166
11			30	91,634
12			45	92,101
13		75	15	92,335
14	1:4		30	92,569
15			45	93,036
16		90	15	93,504
17			30	93,738
18			45	94,205
19		60	15	94,439
20			30	95,374
21			45	95,608
22	1:5	75	15	96,075
23			30	96,543
24			45	96,777
25		90	15	97,010
26			30	97.244
27			45	97.712

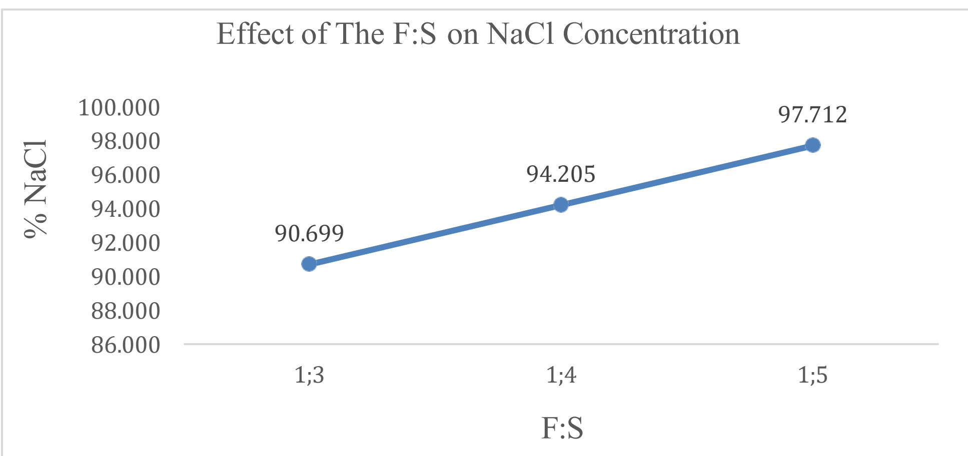
Table 3
NaCl Content Quality Through the Recrystallization Process

No	Temperature	Time (Minutes)	%NaCl
1	60	15	94.673
2		30	94.140
3		45	95.608
4	75	15	96.075
5		30	96.543
6		45	96.777
7	90	15	97.478
8		30	97.712
9		45	98.179

3.2 Discussion

3.2.1 The Effect of the Salt-to-Solvent Ratio on NaCl Content in the Hydroextraction

Process Figure 2
Effect of the F:S on NaCl Concentration



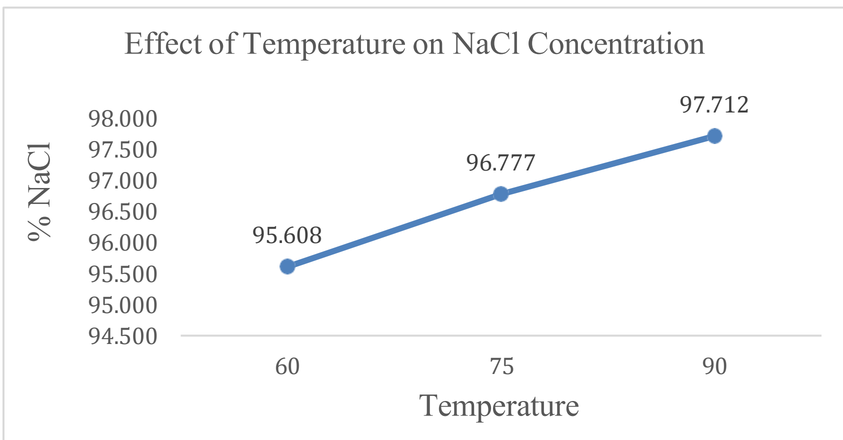
Based on Figure 1 in the graph above, it can be observed that increasing the salt-to-solvent ratio had a significant effect on enhancing the NaCl content during the salt purification process. The NaCl content increased from 90.699% to 94.205% at a ratio of 1:4, and reached its highest value of 97.712% at a ratio of 1:5

The increase in NaCl content indicates that the amount of solvent plays an important role in the hydroextraction process. A larger solvent volume enhances the solvent's ability to dissolve Na^+ and Cl^- ions. At a 1:3 ratio, the amount of solvent is relatively low, causing the solution to reach saturation more quickly. As a result, the solvent's capacity to extract NaCl is limited, and a portion of the NaCl remains in the raw material. In addition, the concentrations of impurities such as Mg and Ca remain relatively high. The best treatment was obtained at a 1:5 ratio, resulting in an NaCl content of 97.712%. The higher solvent volume prevented the solution from becoming saturated too rapidly, thereby allowing the NaCl extraction process to proceed more effectively. Consequently, a greater amount of NaCl was dissolved and separated from the impurities, leading to a significant improvement in the purity of the salt produced.

Based on Figure 1 in the graph above, it can be seen that increasing the salt: solvent ratio has a real effect on increasing the NaCl content in the salt purification process of 90.699%, then increasing to 94.205 at a ratio of 1:4 and reaching the highest value point of 97.712 at a ratio of 1:5.

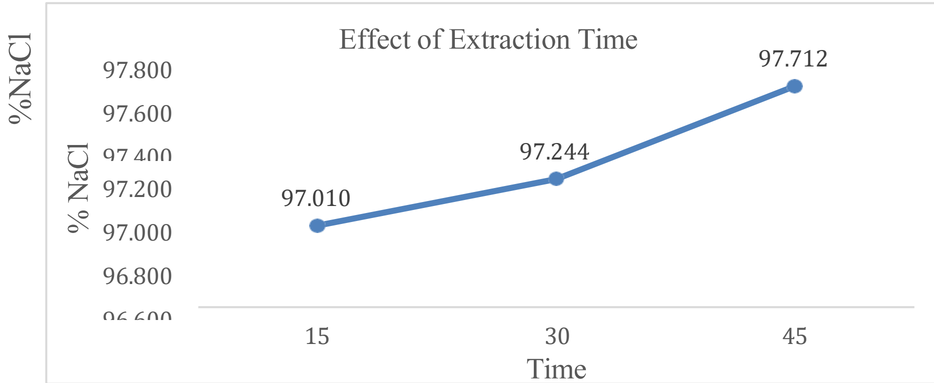
Figure 3

Effect of Temperature on NaCl Concentration



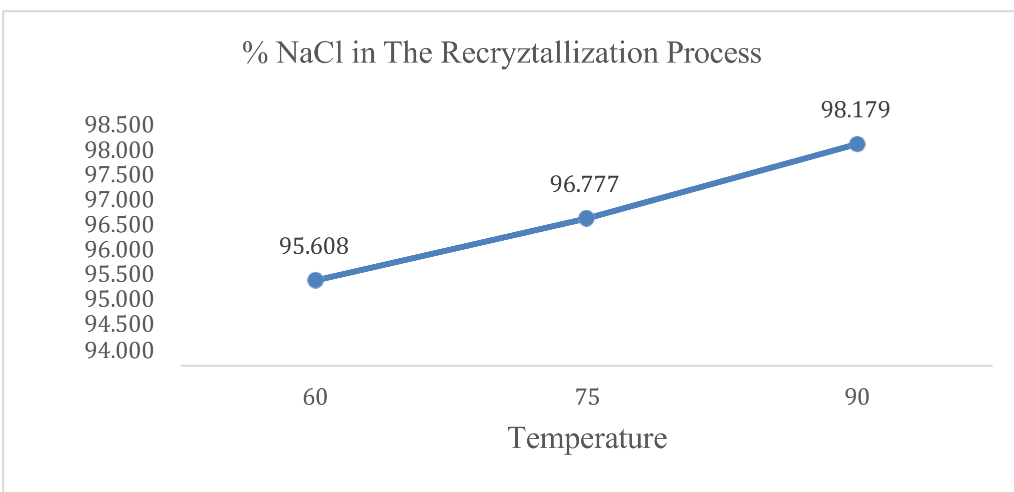
Based on the graph above, it can be observed that an increase in hydroextraction temperature significantly affects the NaCl content. At a temperature of 60°C, the NaCl content was 95.608%, which increased to 96.777% at 75°C and reached the highest value of 97.712% at 90°C. The increase in NaCl content can be attributed to the higher temperature, which enhances the solubility of NaCl and accelerates the diffusion of Na^+ and Cl^- ions into the solvent. Furthermore, elevated temperatures improve mass transfer efficiency, resulting in a more effective separation of NaCl from impurities such as Mg and Ca. These results indicate that 90°C is the optimum condition for the hydroextraction process, as it produced the highest NaCl content and met the Indonesian National Standard (SNI) requirements for edible salt.

Figure 4
Effect of Extraction Time



Based on Figure 3 in the graph above, it can be seen that increasing the extraction time had a positive effect on the NaCl content during the purification of Gracilaria sp. seaweed salt. At an extraction time of 15 minutes, the NaCl content was 97.010%, which increased to 97.244% at 30 minutes and reached the highest value of 97.712% at 45 minutes. Extraction time is therefore one of the key factors determining the quality of salt produced through the hydroextraction purification method. A longer extraction time provides a longer contact period between the salt crystals and the extracting solution, allowing more impurities present on the crystal surface and within the crystal lattice to be removed. As a result, the amounts of Fe, Ca^{2+}, and Mg^{2+} remaining in the salt crystals after the hydroextraction process are significantly reduced, leading to a higher degree of purity and a higher NaCl content.

Figure 5.
Graph of Salt Content from Recrystallization Results



Based on Figure 4 in the graph above, it can be observed that the NaCl content increased with the rise in recrystallization temperature from 60°C to 90°C. This increase indicates that higher temperatures enhance the dissolution of salt crystals more effectively, allowing impurities such as Mg^{2+}, Ca^{2+}, and Fe ions to be separated from the NaCl crystals during the recrystallization process. Consequently, the purity of NaCl improved as the recrystallization temperature increased.

At 60°C, the NaCl content was 95.608%, which increased to 96.777% at 75°C and reached the highest value of 98.179% at 90°C. These results indicate that increasing temperature is directly proportional to the increase in NaCl content. Therefore, the recrystallization process carried out at higher temperatures produces salt with a higher level of purity.

3.2.2 Atomic Absorption Spectroscopy (AAS) Results for Metal Content in Recrystallized Salt

Table 4

Table of AAS Test Results for Metal Content in Recrystallized Salt

Research Parameters	Concentration (mg/L)
Ca (Calcium)	520,00
Mg (Magnesium)	450,39
Fe (Iron)	4,32

The results of the analysis using the Atomic Absorption Spectrophotometry (AAS) method showed that the levels of calcium (Ca), magnesium (Mg), and iron (Fe) in the salt samples were 520 mg/L, 450.39 mg/L, and 4.32 mg/L, respectively. These three elements are natural minerals found in seawater and affect the level of salt purity.

The Ca and Mg levels obtained still indicate the presence of natural minerals in the sample, but the values are relatively low, indicating that the crystallization or salt purification process is proceeding smoothly. Meanwhile, the Fe content of only 4.32 mg/L indicates low levels of metal contamination, thus indicating good salt quality. According to SNI 4435:2017, the parameters Ca, Mg, and Fe are not included in the quality requirements with maximum limits, so these results cannot be used directly to determine compliance with SNI. However, in general, low Ca, Mg, and Fe contents can be used as an indicator that the sample has a good level of purity and contains relatively few mineral impurities.

Table 5
Table of Results of Observations of Salt Color Before and After Recrystallization

Sample	Salt Color
Before Recrystallization	Brownish White
After Recrystallization	White

Based on visual observations, the salt before recrystallization appeared off-white with a brownish or grayish tint. This coloration indicates that the salt still contained various impurities, including minerals such as magnesium (Mg), calcium (Ca), and iron (Fe), as well as organic compounds derived from the seaweed raw material, Gracilaria sp. After the recrystallization process, the salt became bright white in color. This change indicates that recrystallization successfully improved the purity of the salt through the dissolution of NaCl crystals and the removal of most impurities. The transformation from a brownish-white color to a bright white color serves as an indicator that the quality of the salt increased after recrystallization. The whiter the resulting salt, the lower the amount of impurities remaining within the salt crystals. Therefore, this color change can be used as an indicator of the effectiveness of the salt purification process.

3.2.3 Determination of Salt Water Content Table 6

Moisture Content Results at Different Temperature Treatments

Temperature	Time	Water Content
60 C	15 Minutes	13.488
	30 Minutes	13.033
	45 Minutes	12.192
75 C	15 Minutes	10.014
	30 Minutes	9.769
	45 Minutes	9.078
90 C	15 Minutes	8.870
	30 Minutes	7.745
	45 Minutes	6.046

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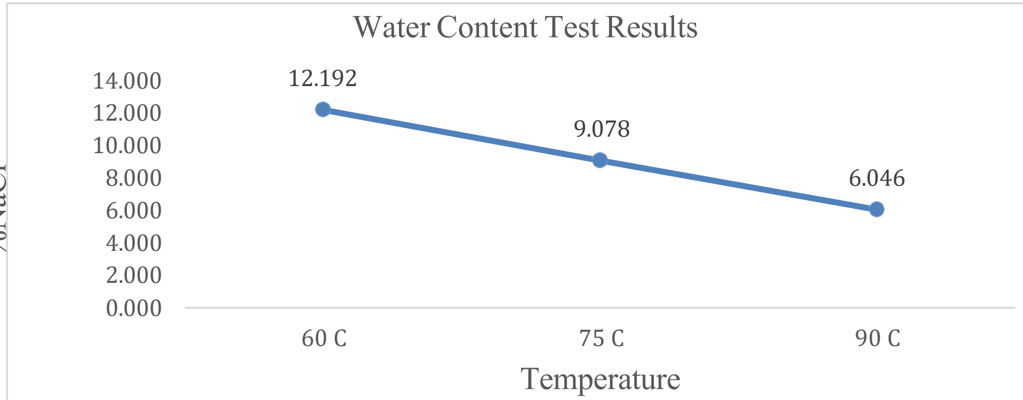
Figure 6
Graph of Water Content in Various Treatments



The analysis results showed that increasing the temperature and time of the purification process had an effect on reducing the water content of the salt extracted from Gracilaria sp. Treatment at a temperature of 90°C for 45 minutes with a solvent ratio of 1:5 resulted in the lowest water content of 6.04%, indicating that the purification and drying process was more optimal than other treatments. (Aisah et al.,2021)

4. Conclusion

The integration of hydroextraction and recrystallization methods successfully improved the quality of salt produced from Gracilaria sp. by increasing NaCl purity and reducing impurity levels. The color change from brownish-white to a whiter appearance after the recrystallization process indicated successful purification. The best treatment was obtained at a temperature of 90°C and a processing time of 45 minutes, resulting in a NaCl content of 98.179% after recrystallization.

Variations in process parameters significantly affect the quality of the purified salt. Increasing the extraction temperature and optimizing the extraction time can enhance NaCl dissolution efficiency and accelerate the removal of impurities. In addition, a controlled evaporation rate during the recrystallization process influences crystal formation, moisture content, color, and the overall purity of the resulting salt.

The hydroextraction and recrystallization methods can be recommended as efficient and environmentally friendly salt purification technologies because they use water as the primary

solvent, reduce the need for additional chemical agents, and have the potential to produce salt that meets the quality requirements of the Indonesian National Standard (SNI) for edible salt.

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