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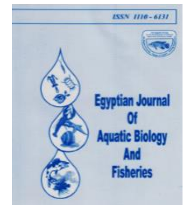

Physicochemical Analysis of Rich Minerals Sea Salt Produced in Salt House

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ABSTRACT

Salt is a chemical compound with the highest concentration of sodium chloride (NaCl). The salt house is a closed-design new technology by optimizing solar heat with HDPE geo-isolators to accelerate and produce high quality salt. The aim of this research was to determine the chemical and physical contents of rich minerals sea salt produced in the Salt House of Trunojoyo University. The treatment samples were analyzed, including the water, NaCl, sulfate, iodine and insoluble contents. The differences between the formulas were seawater volumes and the length of the Fleur De Sel harvesting process. The results of NaCl content were compared after harvesting and storing for 2 years at room temperature of 26°C. The control had higher value of NaCl and water content than the other formulas. The iodine content had more than 30ppm as Indonesian salt consumption standard, except for the 2nd formula. Based on the Tukey test, the water, NaCl, iodine and sulfate contents had significantly different results, except insoluble part contents. After being harvested and stored for 2 years, salt had differences in quality (chemical and physical content) because crystal salt grown from this process.

INTRODUCTION

Madura island is located in East Java Province, Indonesia. Madura possesses the largest salt productivity in Indonesia **(Rocha *et al.*, 2012; Samsiyah *et al.*, 2019; Fauziyah *et al.*, 2023)**. Via comparing between the salt's pond area on Java Island, Madura Island and salt ponds owned by the Indonesia Government, salt productivity has proven to be 10.231, 15.347, and 5.116 ha, respectively (**Efendy *et al.* 2011)**. Madura has a good environmental condition to support salt's production process, which are very suitable with an average temperature of 26,9 to 30,5°C. This heat and dry season are needed by salt farmers **(Sidik & Effendy, 2019; Bachri *et al.*, 2020)**. Salt production is dependent on the climate or weather **(Azizi *et al.*, 2011; Almasjah *et al.*, 2024)**.

The weather variability or meteorological approach adds several variables, such as temperature, solar radiation, humidity, rainfall and wind speed **(Tambunan *et al.*, 2012; Aris *et al.*, 2021)**. Generally, salt production in Indonesia uses a seawater solar evaporation system in the salt ponds. Salt pond's location is one of the main factors responsible for salt production. This indicates that the selected lands can support optimum, cost and resource efficient salt processes. Many researchers have found that land suitability for salt farms can be evaluated with several main hydrological and climatological parameters **(Latjoli & Auliyah, 2019; Cahyadi *et al.*, 2024)**. Although hydrogical and climatological elements are strong determinants of salt farming since these factors are difficult to manage and control **(Sudarto, 2011; Menendez, 2016; Cahyadi *et al*., 2024)**. There are many factors that influence salt production, such as weather, low productivity, local salt quality, inadequate technology, facilities and infrastructure, low marketing capabilities and distribution channels controlled by traders **(Syarif & Pabiban, 2017; Prabawa & Bramawanto, 2021).**

Salt's quality depends on the NaCl content in the product **(Inguglia *et al.*, 2017; Febriyanti *et al.*, 2024; Hurisyahrani *et al.*, 2024; Mutiara *et al.*, 2024)**. NaCl content is influenced by the location of sea water sources and the type of salt table layer. Sea water in each location has different salinity considering many factors influence, including differences in sunlight intensity, temperature, humidity, rainfall, fresh water contribution from land and others **(Andres *et al.*, 2005; Zanardi *et al.*, 2010; Zainuri *et al.*, 2016)**. In general, salt is produced using a crystallization table with an HDPE geomembrane base **(Wijayanti & Asiarini, 2017)**. Geo-isolator technology is an innovation to improve the quality of salt by covering the entire crystallization table using an HDPE geomembrane. These layers function as a base for the crystal table and accelerate the evaporation process. Besides, a combination of geo-isolator technique and salt house innovation is a closed design to optimize the solar heat. The quality of salt produced using a base in crystallization ponds is higher with less contaminant content **(Balde *et al.*, 2013; Sidik & Effendy, 2019; Ariyani *et al.*, 2020)**. Rich mineral sea salt is consuming salt product produced by salt house. Salt house is an innovation developed made of glass walls with small plots of land inside the greenhouse for the production process **(Kurniawan *et al.*, 2019; Nuzula *et al.*, 2023)**. Rich mineral sea salt produces inputs of free-contaminant sea water in a crystallization pond by separating the salt flower that appears at 25^{o}Be. Each treatment was added with a different volume of brine water to get the optimum product with sodium chloride below 50% **(Abdel, 2013; Afnani *et al.*, 2022)**.

Chemically, salt is greatly affected by the number of mineral compounds. Before the formation of salt crystals, old water that underwent evaporation process forms crystals floating on the surface of the salt table **(Ramos, 2022)**. These crystals are called salt flowers (*Fleur De Sel*). *Fleur De Sel* are crystals with a very high NaCl mineral content (NaCl content: 88.92% - 90.47%) **(Sainz *et al.*, 2019; Andini *et al.*, 2024)**. Its physical form is a hollow pyramid (hopper pyramids) with sodium chloride crystals that grow on the surface of sea water with a high concentration level (26^{o}Be) **(Zhang *et al.*, 2011;**

Fontana *et al.*, 2013; Fontana *et al.*, 2015). Based on the study of **Sun *et al.* (2022)**, the flotation of salts varies and is strongly affected by the brine ion composition and pH conditions.

In the flower of salt, 84 trace elements and micro-nutrients can be found, forming a natural source of potassium and magnesium **(Rocha *et al.*, 2012).** Salt flowers significantly influence the quality of mineral-KuKrich salt production.

Low sodium salt or rich mineral salt is a salt with rich content of minerals such as magnesium, potassium and calcium that humans need **(Miller, 2017)**. The NaCl content contained in rich mineral salt consists of 60% NaCl content and 40% other minerals **(Hernandez *et al.*, 2019)**. Sodium is a micronutrient that the body needs in small doses so it should not be consumed excessively **(Lim *et al.*, 2012)**. Salt products that are rich in minerals are a solution for people with hypertension (**Aburto *et al.*, 2013; Drewnoswki *et al.*, 2015**). Hypertension is a condition of increased blood pressure in the blood vessels caused by the heart working too hard to supply oxygen and nutrients and to pump blood throughout the body **(Liu *et al.*, 2025)**. One role of sodium, among many, is to maintain intravascular volume, as the main extracellular cation in the body. Infusion, or ingestion, of sodium chloride has a pressor effect on most people, which is the rationale for using sodium chloride infusions in acute shock and increasing daily sodium intake among those with symptomatic orthostatic hypotension **(Golovin & Duplyakov, 2018; O'Donnell *et al.*, 2020)**. This has led to recommendations by many health organizations for the Americans to significantly decrease sodium and salt intake. A reduction in dietary salt of less than 5-6 g/day will significantly benefit cardiovascular health **(Doyle & Glass, 2010)**. The WHO strongly recommended reducing dietary salt intake as one of the top priority actions to tackle the global non-communicable disease crisis and has urged member nations to reduce population-wide dietary salt intake to decrease the number of deaths from hypertension, cardiovascular disease, and stroke **(Frisoli *et al.*, 2012; Ha, 2014; Oku *et al.*, 2024; Stocker *et al.*, 2024)**.

The mineral content of rich mineral salt is very helpful for people with hypertension, especially in Indonesia. The low sodium content of rich mineral salt is possible with the increasing content of other mineral compounds. This research aimed to analyze the chemical and physical contents of rich minerals sea salt produced by Salt House at the University of Trunojoyo Madura. The products analyzed were salt stored for 2 years in a salt laboratory at a temperature of 26^{o}C.

MATERIALS AND METHODS

1. Sample collection

The experiment in this study contained 5 treatments with 3 repetitions for each sample. These samples include treatment 1 as a control, treatment 2 as a 1st formula, treatment 3 as a 2nd formula, treatment 4 as a 3rd formula, and treatment 5 as a 4th formula. The samples used were those stored 2 years ago in a salt laboratory at a room temperature of 26^{o}C. These samples were dried and then analyzed for the chemical and physical contents. The samples were dried for 3 days in the Salt House of Trunojoyo Madura University and in the oven at 105ºC until the salt had water content below 5% (ISO 2483-1973).

Fig. 1. Salt House

2. Water Content Analysis (American Public Health Association, American Water Works Association, Water Environment Federation-1999; The Salt Industry Center of Japan-2022)

The sample was put in porcelain cup, dried at 105ºC for 2 hours, cooled in the desiccator for 30 minutes, weighed with an analytical balance, then the results were recorded. To get a constant weight, the sample was re-put in the oven, and the water content was calculated using the following formula.

$$water\ content\ (\%) = \frac{(W1 - W2) \times 100\%}{W}$$

Information:
W1 = Weight of porcelain cup and sample (before)
W2 = Weight of the porcelain cup and sample (after)
W = Sample weight

3. NaCl Content Analysis (EUsalt/AS 016-2005; The United States Pharmacopeial Convention-2015)

The principle of sodium chloride analysis is the reaction of Cl^- ions contained in NaCl with Ag^+ ions from the $AgNO_3$ solution using potassium chromate solution. Salt sample of 0.1 gram was dissolved with distilled water, and measured up to 100ml. The sample solution was put into a 250ml Erlenmeyer flask, and 1ml of 5% K_2CrO_4 solution was added. The solution was titrated using standardized $AgNO_3$ at 0.1 N until a brick-red color was formed, and then the sodium chloride content was evaluated using the formula below:

$$NaCl\ Content\ (\%) = \frac{V \times N \times fp \times 58.5}{W} \times 100\%$$

Information:
V = Volume of $AgNO_3$ required for titration (mL)
N = Volume of $AgNO_3$ required for titration (N)
Fp = Dilution factor
Mr NaCl = 58,5
W = Sample weight (mg)

4. Iodine Content Analysis (American Public Health Association, American Water Works Association, Water Environment Federation-1999; The Salt Industry Center of Japan-2022)

Analysis of iodine content in salt using the UV-Vis spectrophotometry method requires a 1000ppm KIO_3 standard solution, which is used to calculate the calibration curve. The standard solutions used for the calibration curve were 10, 20, 40, 60 and 80 ppm. The standard solution was measured at an absorption wavelength of 352nm. Salt sample of 0.1g was put in test tube; distilled water of 10ml was added and the mixture was homogenized. The sample was measured for absorption at a wave length of 352nm, followed by recording the regression formula.

5. Sulfate Content Analysis (American Public Health Association, American Water Works Association, Water Environment Federation-1999; The Salt Industry Center of Japan-2022)

Sulfate analysis requires a standard SO_4 solution with concentrations of 0, 10, 20, and 30ppm. After that, 20ml of buffer and $BaCl_2$ were added to each concentration and homogenized. Calibration curves were made by measuring the absorption concentration of standard solutions at a wavelength of 420nm. The curve was made from the absorption results, and the regression equation was determined. A salt sample of 1g was put in beaker glass, dissolved with 10ml of distilled water then transferred into a volumetric flask and diluted to 100ml. The solution was put into an Erlenmeyer flask; 20ml of buffer solution was added and homogenized while adding 1 spoon of $BaCl_2$. Absorbance was measured by spectrophotometric UV-VIS at a wavelength of 420nm and the regression formula was calculated.

6. Insoluble Part Content Analysis (American Public Health Association, American Water Works Association, Water Environment Federation-1999; The Salt Industry Center of Japan-2022)

The analysis of insoluble part content is calculated based on the weight of the remaining material on the filter paper after being heated at 105^{o}C. Salt sample of 2g (W0) was put in a beaker glass; 200ml of hot water was added and homogenized. Filter paper was put in an oven at 105^{o}C for 2 hours, cooled in a desiccator for 30 minutes, and weighed (W_2). The cooled salt solution was filtered, and hot water was poured into the filter paper to get chlorine-free. The filter paper was dried in the oven at 105^{o}C for 2 hours and cooled in a desiccator and weighed (W_1). Calculation of insoluble part content results used the following formula:

$$insoluble\ part\ content = \frac{(W1 - W2)}{W0} X100\%$$

Information:
W0 = sample weight (g)
W1 = weight of filter paper and insoluble part (g)
W2 = filter paper weight (g)

7. Texture Analysis

A texture analysis on rich minerals salt used the tactile(touch). Tactile senses are important for identifying touch and texture. There are two scales in the interpretation of the analysis results, namely coarse and fine salt. Texture analysis is related to the size of salt. The small salt has fine salt texture, conversely **(Ramos, 2022)**.

8. Color Analysis

The eyes (vision) is one of the five senses used in color analysis of salt. Color measurements of rich minerals salt are performed by grouping types of salt into three categories, namely salt with very good quality clean white color tends to be clear, good quality salt white color, and medium quality salt dull white. This grouping refers to the quality of salt according to **Ramos (2022)**.

9. Size analysis

Size analysis for salt was achieved using a calliper instrument with an accuracy of 0.05mm and a repetition of 3 times in 1 experiment (10 times data collection on the same formula). Salt grouping is divided into three classes: salt measuring at least 0.5mm, including very good salt; salt measuring <4 mm, including good salt; and salt measuring <3 mm, including medium salt **(Ramos, 2022)**.

10. Shape analysis

Salt crystals depend on the production process. Generally, the shape of salt is cube shaped. The classification of salt shapes is cubes, pyramids, and flakes. The observations used in this analysis utilize the five senses, specifically the eyes (vision). Visual receptors are stimulated by light, color, and movement **(Ramos, 2022)**.

11. Statistical analysis

The data were processed using SPSS version 22. This processing was carried out to determine the normality test, analysis of variance (ANOVA) test and Tukey test. The purpose of this test is to determine the sample relationship between 1^{st}, 2^{nd}, 3^{rd}, 4^{th} formulas and control. In addition, there is data processing of the relationship between NaCl content and other mineral parameters using the Pearson correlation test

RESULTS AND DISCUSSION

1. RESULTS

1.1 Salt production at Salt House

Salt production using Salt House technology can increase the quality and quantity of salt. Salt House is the right choice as a new innovation in the salt industry in Indonesia. The advantage of salt house technology is that it can produce salt at any time without being influenced by the weather, so salt production can be carried out all year round **(Kurniawan *et al.*, 2019)**.

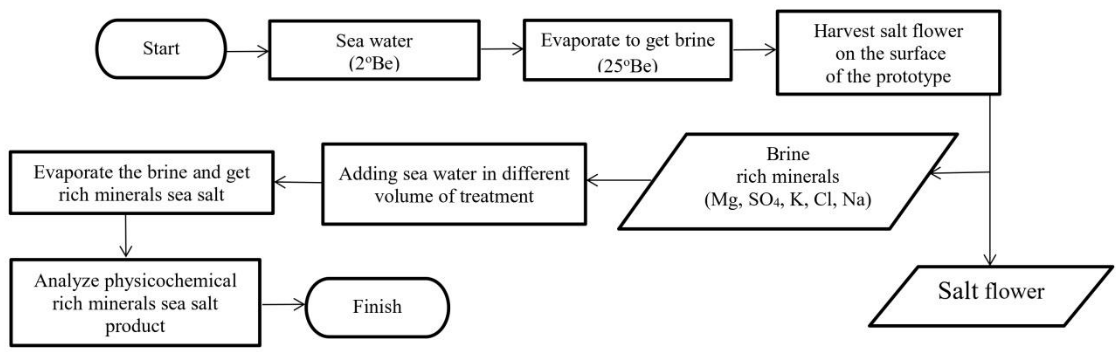

Fig. 2. Rich minerals salt production **(Kirchner *et al.*, 2009**, modified**)**

Apart from that, this technology does not require a large area of land and can be operated anywhere if sea water is available. Salt House technology is designed to meet the requirements of Indonesian National Standards by producing salt yields **(Wiraningtyas *et al.* 2019).**

Salt production using salt house innovation can produce salt products with low sodium or rich sea salt minerals. This salt production requires a different treatment than salt production in general. The scheme of salt production is presented in Fig. (2).

In this study, there were 4 treatments with 3 repetitions, namely treatment 1 (control), treatment 2 (1^{st} formula), treatment 3 (2^{nd} formula), treatment 4 (3^{rd} formula), and treatment 5 (4^{th} formula). The first process prepared brine water with a concentration level of 25ºBe from contaminant – free seawater. Each treatment added brine water with certain formulas, and salt flowers were harvested at 25–28ºC, except for the control treatment, without any addition of brine water and harvesting salt flowers (*Fleur de sel*). Second treatment (1^{st} formula) without adding brine water after the concentration level reached 25ºBe and harvesting *Fleur de Sel* directly. The third treatment (2^{nd} formula) added brine water once after the concentration level reached 25ºBe. The fourth treatment (3^{rd} formula) added brine water twice after the concentration level reached 25ºBe. Last formulation, the fifth treatment (4^{th} formula), added brine water three times after the concentration level reached 25ºBe. If brine water concentration level in treatments 2, 3, 4, and 5 reaches a concentration of 25ºBe, then *fleur de sel* is harvested upon appearing on the surface. *Fleur de Sel* is carried out every time when water concentration level increases (starting from 25º–28ºBe). If brine water was 25ºBe, then the treatment adds more brine water or *fleur de Sel* appears. These processes started until the water height in crystallization ponds reached 14cm with a water volume of 33.6L.

1.2 Water contents

Water content is one of the methods used for analyzing salt's quality. It is measured by calculating the weight loss of a sample when dried. The method is designed to reduce oxidation or substance loss while reducing humidity as much as possible **(Redjeki *et al.* 2020).** The results of analyzing are presented in the graph below (Fig. 3).

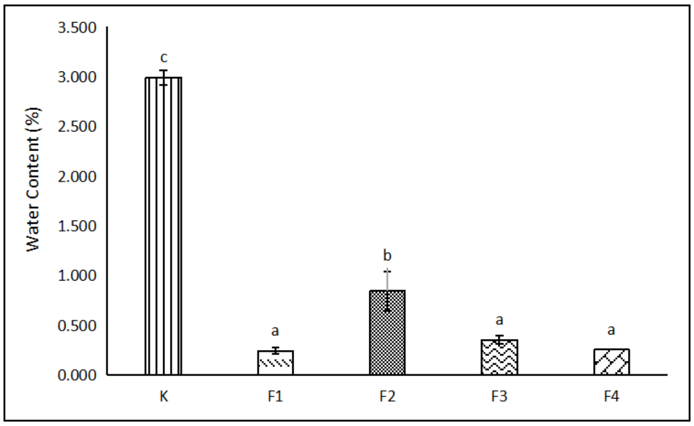

Fig. 3. water content

Water content analysis was carried out by calculating weight loss while heating sample in an oven at 105^{o}C for 3 hours until the sample weight was constant. The analysis showed that the highest value of water content was found in the control sample with a value of 2.99%, while the lowest value of water content analysis was found in the 1st formula (0.24%). Differences in the value of water content were detected in treatments during the production of rich minerals sea salt and storage factors.

Variance test (ANOVA) is used to determine differences between samples tested. The results of analyzing ANOVA test were interpreted with symbols "a," "b," and "c.". The 1st, 3rd, 4th formulas were not significantly different, while the control and 2nd formula both were significantly different. Salts are hygroscopic, so after storage, the water content of salt decreased. This decrease is caused by the drying process before analyzing.

1.3 NaCl content

Sodium chloride is an ionic compound with the formula NaCl. Generally, NaCl contains impurities such as magnesium chloride, magnesium sulfate, calcium chloride, calcium sulfate, and water. Salt quality can be known through sodium chloride. If salt contains a lot of magnesium, it will reduce the sodium content in salt products **(Pasaribu *et al.*, 2022). Deglas and Yosefa (2020)** explained that the main determinant of saltiness in salt is the concentration of NaCl in salt grains. NaCl is the main element in salt, with a composition of sodium (40%) and chloride (60%). Titration and Tukey tests are used to analyze NaCl content. The results of values in each formula are presented in the graph below (Fig. 4).

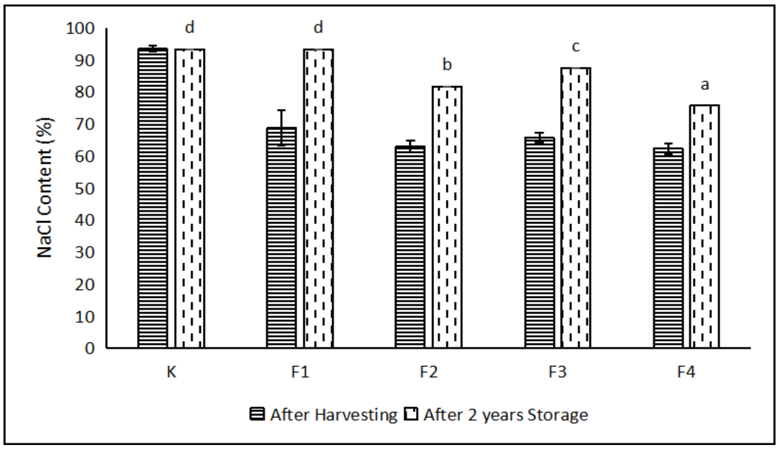

Fig. 4. NaCl content

The NaCl content after 2 years of storage was recorded with the highest value for the control sample at 93.32%, while in formula 4 it was determined with a low NaCl content value of 75.67%. These results are compared to the NaCl content value in salt after harvesting. Salt products after harvesting recorded the highest NaCl content in the control sample with a value of 93.38%, while the low NaCl content was that registered for the 4th formula, with a value of 62.24%. However, from both comparisons, there is an increase in NaCl levels in 4th formula and a decrease in the control. The results of the ANOVA test obtained a value that sig <0.05 which means that each sample tested is significantly different. This is in line with the test results by interpreting the graph with the symbols "a", "b", "c" and "d".

1.4 Sulfate content

Analysis of sulfate content in salt using a UV-vis spectrophotometric instrument with a wavelength of 420nm. Sulfate is a chemically stable compound because it has the highest sulfur's element. Sulfate can be detected by adding $BaCl_2$ which functions to bind Ba^+ ions and form a white precipitate. A white precipitate is present after adding BaSO4, which indicates that the solution has a sulfate ion **(Rocha *et al.* 2012)**. The results of the sulfate content analysis are presented in the graph below (Fig. 4).

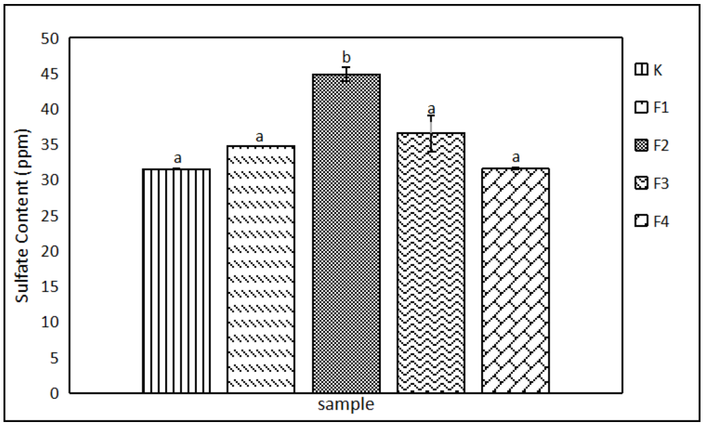

Fig. 5. Sulfate content

Based on the graph above, the highest sulfate content was detected in the 2nd formula with a value of 44.88ppm, whereas the lowest was observed in the 1st formula with a value of 31.52ppm. While the results of the ANOVA test showed that the control, F1, F3, and F4 were not significantly different, the 2nd formula was significantly different. The real difference can be seen in the symbol "b" which is not significantly different from the symbol "a".

1.5 Iodine content

Salt contains the compound potassium iodate (KIO_3), which is a nutrient that must be consumed regularly. The amount of salt that each person should consume per day is approximately 9 grams **(Lamusu *et al.*, 2022)**. The results of analysis of iodine content using UV-Vis spectrophotometry with a wavelength of 352nm are presented in Fig. (6).

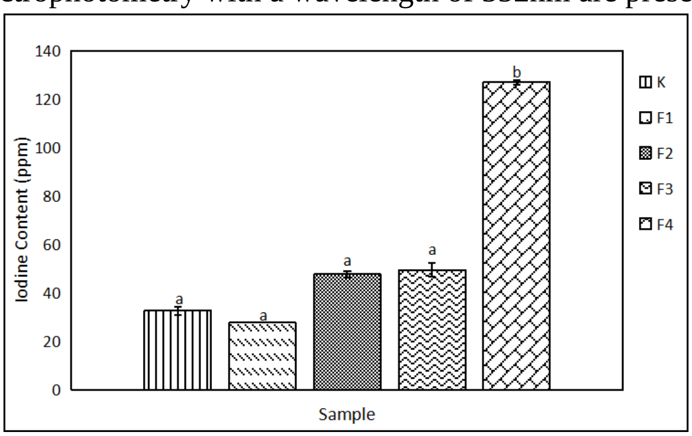

Fig. 6. Iodine content

The results of the iodine content analysis obtained the highest value in the 4th formula with a value of 126.85ppm while the lowest value was in the 2nd formula with a value of 27.6ppm. The results of the ANOVA test showed that the control sample, the 1st formula, 2nd formula, and 3rd formula were not significantly different, but the 4th formula was significantly different. In comparison with other formulas, 4th formula has extremely high iodine levels because it contains a huge amount of minerals from the repeated addition of brine water.

1.6 Insoluble part content

The level of the salt that is insoluble in water is used to determine the impurities or compounds that make up the salt that cannot dissolve in water so that they remain when filtered using filter paper. The results of this analysis are in Fig. (7).

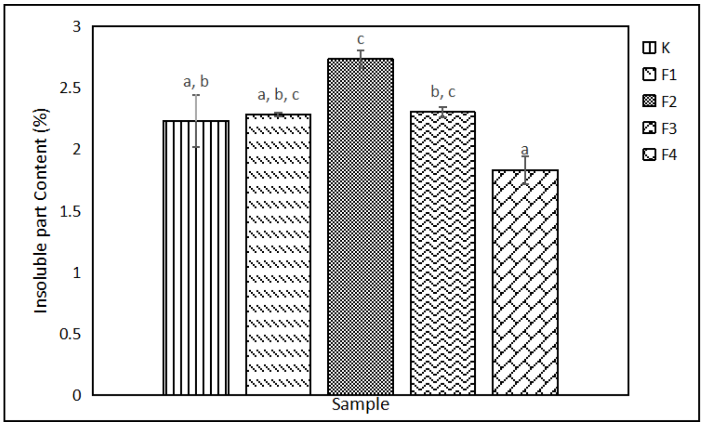

Fig. 7. Insoluble parts content

The graph above shows the same value in the test conducted, which is an average of 2%. The ANOVA test was conducted to determine the differences in the five samples which produced a sig value of 0,648. This proves that the value of sig> 0.05, which means that the five samples are not significantly different.

1.7 Physical analysis of salt

The physical characteristics of salt are characteristics of salt that can be measured and observed directly visually. The physical characteristics of salt can be seen based on color, size, texture, and taste. The physical characteristics of salt can be one of the determinants of the quality of the salt produced. Physical characteristics can be influenced by raw materials for production, the production process used and the harvesting process. The visual characteristics of salt are usually used by salt farmers to determine the quality of the salt before further testing the chemical content of the salt. The results of the analysis are presented in the Table (2).

Table 2. The result of physical analysis of salt

No.	Sample	Color	Shape	Texture	Size (mm)
1.	Control	White	Cube and flat	Coarse	4,17
2.	1st Formula	White	Cube and flat	Coarse	3,63
3.	2nd Formula	White	Cube and flat	Coarse	3,42
4.	3rd Formula	White	Cube and flat	Coarse	2,78
5.	4th Formula	White	Cube and flat	Coarse	2,3

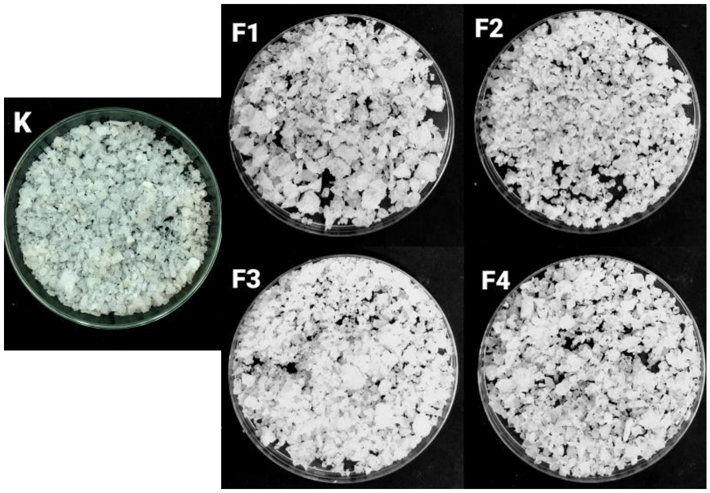

Fig. 8. Physical analysis salt

Rich mineral salt products that were stored for 2 years have a coarse texture. Texture is interrelated with salt size. Size analysis on salt products uses a caliper instrument with an accuracy of 0.05mm. The control sample has the largest size of 4.17mm, while the smallest size is found in 4th formula sample with a value of 2.3mm. Although the controls are larger, the shapes of these five formulas remain the same: they are cube-shaped and flat, with a white color.

2. DISCUSSION

Salt is an ionic compound composed of sodium chloride which is 40% sodium and 60% chloride. Salt crystals are translucent and cubic in shape, they normally appear white. Salt is readily soluble in water and dissolved in water it separates into Na^+ and Cl^- ions **(Ha, 2014)**. Due to some physiological process, humans need some sodium and this element can be extracted from salt **(Anderson *et al.*, 2010)**. In various industries and scientific discplines, selecting salts for specific applications present a significant challenge, as it necessitates a comprehensive assessment of factors such as mineral composition, crystallinity and dielectric properties **(Meng *et al.*, 2024).** According to this research, salt is produced through a multi-stage evaporation process, involving the harvesting of salt crystals, to obtain a mineral-rich salt product that meets established standards. The treatment of salt production varies due to several factors, primarily the addition of old water, the harvesting of salt flowers, and environmental conditions in the Salt House. The concentration of various parameters in brine for crystallization can vary, but calcium-rich brine is preferred for optimal crystallization. This is because the presence of calcium sulfate in brine enhances the solubility of sodium chloride. Additionally, temperature influences the presence of sulfate, which leads to the precipitation of calcium sulfate.

Conversely, the presence of magnesium chloride reduces the solubility of sodium chloride in brine, significantly impacting the reduction of the crystal growth rate due to this impurity. The samples used for analysis were samples from 2 years ago and were stored at room temperature of 26°C, so the NaCl content increased. These increases, marked by the salt melt and binding of other compounds, occur on each formula. Salt has hygroscopic ability, which makes it easy to become moist and watery due to humidity at room temperature **(Guozhao *et al.*, 2022)**.

When salt was melted, a new crystal nucleus was formed. This process is crystal growth related to the hopper theory. Salt was melted into a saturated solution, it causes an increase in ions and forms new surfaces. These chains of ions form cubic crystals which become the hopper morphology **(Desarnaud *et al.*, 2018)**. If super saturation is higher, then more cubic crystals will grow **(Wiraningtyas *et al.*, 2019)**. Compared to **Fontana *et al.* (2015)**, crystallization from aqueous sodium chloride solutions has different crystal morphologies. The morphologies are tabular hoppers, hopper cubes, circular oriented crystal and dendrites. Salts are hygroscopic, so after storage, the water content of salt decreased. It is caused by drying before analyzing.

Salt analysis using a dry method at 120°C is the optimal and ideal process for reducing water content **(Dawa *et al.*, 2022)**. According to **Pratiwi *et al.* (2021)**, if salt has a lot of magnesium compounds such as $MgCl_2$ and $MgSO_4$, there will be a large absorption of water vapor and air. Magnesium has very hygroscopic characteristics because magnesium compounds are commonly found in hydrates with a monoclinic crystal structure **(Saksono, 2002).** Water content is critical for determining the salt's quality. The higher the water content of salt, the faster damage will occur in salt's product. Salt is a hygroscopic crystal, so temperature and humidity affect the storage of salt's product **(Arwiyah *et al.*, 2015).** Sulphate is one of the minerals contained in bitterns. The concentration level in bittern >28°Be. The system for adding bittern water to sea water is called the injection system. The injection system can affect the quality of the salt because the dominant content in bittern is magnesium, so the crystallized salt will contain a high content of magnesium, and the salt will taste bitter **(Pasaribu *et al.*, 2022)**. According to **Sidik and Effendy (2019)**, the division of salt types is determined by the NaCl content and main impurities such as calcium, magnesium, sulfate, barium metal, and iron.

Pharmaceutical salt requirements generally refer to the Indonesian Pharmacopoeia, including NaCl content > 99.0%, Ca and Mg content < 50 ppm, sulfate < 150 ppm, and heavy metals < 2 ppm. Thus, the sulfate test results for salt production in the Salt House are included in the good category because they show a value of <150ppm. On the other hand, iodine is sensitive to light and heat, therefore salt storage has a major impact on the amount of iodine present. High iodine levels are obtained by using airtight containers that are protected from the heat of the sun, while low iodine levels are obtained by using open storage techniques and plastic bags placed in a place exposed to sunlight **(Susilowati *et al.*, 2023)**. Iodized salt should be stored in a colored plastic container that is tightly closed and protected from sunlight **(Sudrajat, 2019).** The high electrical interaction between the ions in salts makes them more difficult to dissolve than ions with a lower charge. Furthermore, because polar solvents like water may create hydrogen bonds and electrostatic interactions with salt ions, they are better at dissolving ionic salts.

Calculating the salt's chemical potential in both the solid and solution phases is necessary to assess how soluble NaCl is in water **(Aragones *et al.*, 2012)**.

The results of physical analysis samples include the characteristics of color analysis post-storage-rich minerals. Salt products have a white color in all samples. The color visualization of salt products is one of the indicators for determining salt quality. The white color of the salt indicates that the salt is not contaminated with soil during the crystallization process. This is supported by crystallization table at the time of production using HDPE geo-isolator. The cube shape in salt-rich minerals is formed due to the attractive force between positive and negative ions.

Ionic crystals have a high melting point and low electrical conductivity, and the morphology of the crystal form in NaCl and KCl compounds is a face-centered cube. While the fractional(flat) crystal form occurs due to the process of forming new crystals when the salt melts (hygroscopic). Salt’s size is influenced by the crystallization process, the longer the crystallization process, the larger the size of the salt. This is influenced by the win speed during the production process (crystallization).

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In this study, the highest NaCl content value was found in control with a NaCl content of 93.32% and the lowest NaCl content value was found in 4th formula with a value of 75.67%. Meanwhile, for the water content value, the lowest value is in F1 with a value of 0.24% and the highest value is 2.99% for the control. The sulfate content value ranges from 27 – 44 ppm with the highest value for the 2nd formula and the lowest value for the control. The highest iodine content was found in the 4th formula with an iodine content of 126.85 ppm and the lowest iodine content value was found in 1st formula with a value of 27.6 ppm. Insoluble content has the same average results, which is 2%. The salt produced by Salt House had NaCl content, water content and insoluble parts which are low compared with the SNI for dietary salt. However, the sulfate content produced is approved by the Ministry of Health's threshold and some formulas of iodine content (Control, 2nd and 4th formulas) were compared to SNI 2808:2016 diet salt. The increase and decrease in chemical parameters indicate that salt products are greatly influenced by treatment during production and storage. Good-quality salt is found in the 4th formula because it has a low NaCl content. Salt stored for 2 years at 26^{o}C can damage the product because of hygroscopic properties. Mineral content that grows from nuclei of salt crystals will increase the NaCl content because of the crystal growth process.

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