EFFECTIVENESS AND EFFICIENCY OF SEAWATER EVAPORATION USING TRADITIONAL METHODS AND THE INNOVATIVE FLOW DOWN SYSTEM IN SALT PRODUCTION

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Abstract. National salt demand increases every year along with the growth in demand and consumption. However, salt production decreased in 2019-2022. This encourages innovation in salt evaporation, namely the Flow Down System method, which is a seawater evaporation innovation that saves land. This research aims to analyse the process, effectiveness, and efficiency of evaporation with the Traditional method and the Flow Down System Innovation. The method used is Purposive Sampling to get statistical data processed in RStudio. The result of this research is that Flow Down System reduces land and production time compared to the traditional method. Flow Down System more effective in salt evaporation, with an average effectiveness of 98.69%-98.73% compared to the traditional 98.37%-98.69%. Flow Down's NaCl content is (44.25%) compared traditional (-24.02%) although the traditional moisture content was slightly better (46.5% vs. 44,29%). Flow Down System more efficient 100%-time efficiency compared to traditional 33.33%. Flow Down sales efficiency 100% (IDR 239,680/month) surpassed the traditional 33.18% (IDR 79,550/month). Flow Down's profit efficiency is 100% (IDR 105,710.32) compared to the traditional 75.25%. With 16,515 kWh of electrical energy, making it a superior method and SNI standard.

Keywords: Effectiveness, Efficiency, Seawater Evaporation, Flow Down System

1. Introduction

Madura is known as the Salt Island because it contributes to the national salt stock more than other islands [1]. Madura Island typically produces salt using the evaporation method, which involves flowing seawater into a reservoir and then moving it to the crystallization table under direct sunlight [2]. Water in the crystallization table evaporates and leaves salt

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crystals, but this method has limitations, especially in the quality of salt produced [3]. The condition of the national salt industry still faces challenges due to suboptimal salt production, both in terms of quantity and quality [4]. Traditional processes often produce salt that contains impurities and NaCl content, which may not always meet SNI quality standards [5].

The need for salt in the country keeps rising in tandem with the increase in demand and consumption, yet the limitations of production methods and technology result in a low production quantity [6]. Due to the inability of domestic salt production to meet demand, imports continue [7]. To lessen reliance on imported salt, For example the quality and quantity of salt production [8, 9].

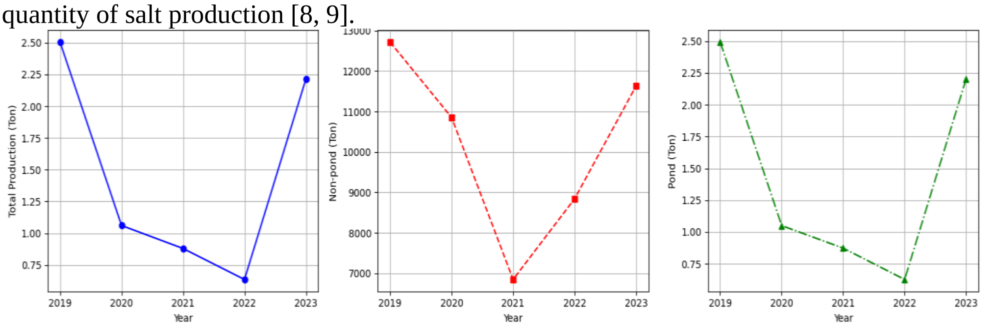

Fig. 1. Production Data from 2019 to 2023 (a) Total Production, (b) Non-Pond Production, (c) Pond Production

Source: Badan Pusat Statistik, 2024

A decrease in seawater evaporation intensity caused a significant decline in national salt production from 2019 to 2022 [10]. An alternative method to overcome this challenge is an innovation in the form of the Flow Down System [11]. The innovation incorporates a small bamboo frame for tying reed leaves [12]. The Flow Down System is a salt evaporation process that starts by pumping seawater into a flow down pond. The water is pumped upward into a trough, where it collects and flows through small holes, passing over reed leaves as the evaporation medium [13]. The water flowing upwards will fall over the reed leaves and into the storage pond [14]. An important aspect of the Flow Down System method is its level of effectiveness in accelerating the aging of raw material water [15]. The Flow Down System aims to accelerate groundwater aging more than the conventional method [16]. Statistical testing calculates effectiveness to address existing hypotheses [17].

The study focuses on the comparison between traditional groundwater evaporation methods and the innovative Flow Down System in salt production. Emphasis is placed on analysing the effectiveness and efficiency of each method in terms of the quality and quantity of salt produced. Insights gained aim to improve domestic salt production, reducing reliance on imports and supporting self-sufficiency in the salt industry. By enhancing production methods, the study intends to contribute to the acceleration of sustainable salt production. The research highlights the need for innovative techniques to address existing challenges and ensure the domestic salt industry's growth and stability.

2. Material and Methods

Conducted this research in Majungan Village, Pademawu Subdistrict, Pamekasan Regency, specifically at Kedai Reka Cipta Garam (figure 2). This study employed a quantitative approach, utilizing raw water sampling and salt products. Conducted sample analysis at the Marine Science Laboratory, Faculty of Agriculture, Trunojoyo University, Madura.

Fig. 2. Research location (red point)

Conducted primary data measurements at four points within one prototype, specifically at each corner of the prototype. Conducted observations and collected parameters six times a day, at 06:00, 12:00, 18:00, and 00:00 [19]. The parameters observed directly were Baumé degree and water level [20] [21]. collected samples from both the conventional pond and the flow-down system. The Marine Science Study Program at Trunojoyo University Madura developed this innovative flow-down system for the salt production process, as depicted in Figure 3. Reeds and a bamboo framework construct this building. The top of the flow-down system uses a gutter to drain the water pumped from below. The Flow Down system building utilizes reeds as a flow medium to expedite the rate of evaporation.

2.1 Salt Evaporation Effectiveness

The processing of salt evaporation effectiveness is calculated to determine how closely the actual results approach the maximum standard set. The smaller the difference between the actual output and the maximum output, the higher the effectiveness of the process. Effectiveness according to [22] can be calculated using the following equation:

$$Effectiveness\ (\%) = \frac{Maximum\ output - Actual\ output}{Maximum\ output}\ x\ 100 \quad (1)$$

The formula was then adopted to be used to calculate evaporation efficiency in salt production. The effectiveness calculation based on the quantity of salt produced uses the following equation:

$$Effectiveness\ (\%) = \frac{Initial\ Volume - Actual\ Result}{Initial\ Volume}\ x\ 100 \quad (2)$$

This equation calculates effectiveness based on the difference between the initial volume of salt before evaporation and the actual amount of salt after evaporation. A high effectiveness value indicates that the evaporation process is working well, producing salt close to the optimal amount. Effectiveness is also calculated for the moisture content, which is an important quality parameter in the salt processing. The equation used to calculate moisture content effectiveness is:

$$Effectiveness\ (\%) = \frac{Maximum\ SNI\ -\ Actual\ Result}{Maximum\ SNI}\ x\ 100 \tag{3}$$

SNI 4435-2017 sets the maximum moisture content at 7% to ensure the quality of the produced salt. Effectiveness is calculated based on the difference between the actual moisture content result and the maximum limit allowed by the SNI. The smaller the actual moisture content, the higher the effectiveness of the process in meeting the set standards. Another parameter evaluated in this process is the NaCl content, which is a key indicator of salt quality. The NaCl content effectiveness is calculated using the following equation:

$$Effectiveness\ (\%) = \frac{Actual\ Result\ -\ Minimum\ SNI}{Maximum\ SNI\ -\ Minimum\ SNI}\ x\ 100 \tag{4}$$

SNI 4435-2017 sets the NaCl content for Quality 1 salt in the range of 94% to 99.7%. This equation allows the effectiveness of NaCl content to be measured based on the difference between the actual result and the minimum standard set. The higher the NaCl content in the produced salt, approaching the upper limit of the SNI, the more optimal the effectiveness of the process being carried out.

2.2 Salt Evaporation Efficiency

The analysis of salt evaporation efficiency includes several components such as time efficiency, sales, energy, and profit-loss. The following methods are used to assess the efficiency:

2.2.1 Salt Evaporation Time Data Processing

The effectiveness of seawater aging in salt production using the Flow Down System method can be tested using a Two-Sample T-Test in R STUDIO. The °Be value is measured at the beginning and end of the aging process to calculate the effectiveness of seawater aging and the n-Gain value. Before proceeding with the Two-Sample T-Test, prerequisite tests are performed to ensure that the data meet the required assumptions, such as Normality and Homogeneity tests [23]. The Normality Test is used to check if the data from both samples follow a normal distribution. The hypotheses tested are:

- H0 : The sample is normally distributed.
- H1 : The sample is not normally distributed.

Normality testing can be done in R Studio using the Kolmogorov-Smirnov test. If the p-value > 0.05, H0 is accepted, and the data are considered normally distributed. The Homogeneity of Variance Test is used to ensure that the variances of the two samples are homogeneous [24]. The hypotheses tested are:

- H0 : The two samples have homogeneous variances.
- H1 : The two samples do not have homogeneous variances.

The Homogeneity of Variance test can be done in R Studio using the Levene test. If the p-value > 0.05, H0 is accepted, and the variances between the groups are considered homogeneous. After the prerequisite tests are met, the Two-Sample T-Test is performed to see if there is a significant difference between the means of the two sample groups [25]. The hypotheses are:

- H0: There is no significant difference between the two groups, indicating that the seawater aging efficiency of the two groups is similar.

- H1: There is a significant difference between the means of the two groups, indicating that one group has better seawater aging efficiency.

2.2.2 Salt Evaporation Efficiency Data Processing

Time efficiency is calculated by comparing the minimum time against the actual process time. The comparison result is then multiplied by 100% to get the efficiency percentage. Sales efficiency is calculated by comparing actual sales results with the maximum sales that can be achieved. This comparison is then multiplied by 100% to produce the efficiency value in percentage form. One aspect measured is the sales efficiency. Sales efficiency calculation is done by comparing actual sales with the maximum sales that can be achieved under ideal conditions. Efficiency according to [26] can be calculated using the following equation:

$$Efficiency\ (\%) = \frac{Output}{Input\ or\ Target}\ x\ 100\% \quad (5)$$

The formula was then adopted to be used to calculate evaporation efficiency in salt production. This sales efficiency is expressed as a percentage using the following formula:

$$Sales\ Efficiency\ = \left(\frac{Sales\ Results}{Maximum\ Result}\right) \times\ 100\% \quad (6)$$

This approach calculates how close actual sales are to the maximum potential available. The result serves as an indicator of market performance, or the marketing strategy applied. A high efficiency value indicates that sales are close to the maximum potential. A low efficiency value signals the need for improvement in the sales strategy or process. The Flow Down System method uses electricity as one of the main resources, while the traditional method in salt evaporation does not use electricity. Energy efficiency evaluation is not relevant for the traditional method. Energy efficiency is calculated by comparing the profit generated with the electricity used, expressed in kilowatt-hours (kWh). The formula used is:

$$Electricity\ Efficiency\ = \frac{Profit}{Energy\ Usage}\ \ (kWh) \quad (7)$$

This formula calculates how energy usage contributes to the profits gained. Higher efficiency indicates more productive use of energy. Low efficiency may indicate waste or inefficiency in energy use. Profit efficiency calculation is also conducted to evaluate the financial performance of the salt evaporation process. Profit efficiency is calculated by comparing actual profit with the maximum profit that could be achieved under ideal conditions. The result is then expressed as a percentage using the following formula:

$$Profit\ Efficiency\ = \left(\frac{Profit}{Maximum\ Profit}\right) \times\ 100\% \quad (8)$$

Profit is calculated to understand the maximum profit potential, serving as an indicator of cost management, pricing strategies, and operational efficiency. A high profit efficiency value indicates optimal management. A low efficiency value may signal the need for improvement in resource management and financial strategies. Time, sales, electricity, and profit efficiency calculations for the salt evaporation process provide an overview of the evaporation process performance.

3. Result and Discussion

3.1 Salt Production Process with Flow Down System

The Flow Down System method of salt making begins with the landscaping stage, followed by filling the pond with water of 3 - 3.5°Be concentration. The evaporation process takes place in the evaporation pond until the water reaches 25°Be, after which it flows to the crystallization table where salt crystals are formed at 29°Be. The salt crystals are harvested as a salt product, discarding any residual water or bittern containing more than 25°Be due to its bitter taste and magnesium (Mg) content. Traditional salt ponds have disadvantages mainly in water surface area and contact with air. If production is done on a large scale, it requires a large area of pond land and a long production time. This condition triggers the development of appropriate technology to accelerate the process of evaporation of seawater. The Flow Down System method, the technology developed, aims to increase the rate of seawater evaporation [27].

Fig. 3. Flow Down System

The Flow Down System method is an innovation in the seawater evaporation process that utilizes natural materials. This system uses reed leaves tied to bamboo as the main media. The basic principle of this system is to utilize the continuous movement of water. The system pumps the salt raw material water, which is then channelled through a series of reed leaves. Exposure to sunlight and wind flow accelerate this evaporation process. The design also aims to reduce the amount of land required for the traditional salt production process. A pumping system channels seawater upwards, allowing it to fall through the reeds installed vertically. The downward flow system method allows evaporation to take place faster due to the pushed water.

3.2 Effectiveness of Seawater Evaporation with Traditional Methods and Flow Down System Innovation in Salt Production

3.2.1 Quantity and Quality of Salt produced

The salt physics characteristics of the various samples will be described visually through images to provide a clearer picture of the color, shape and texture of each sample. The following images will be supplemented with tables below them to summarize the data:

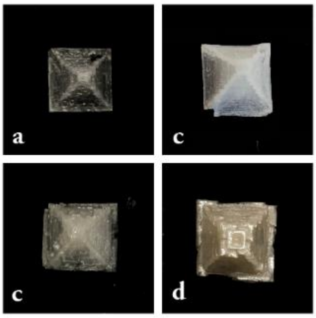

Fig. 4. (a) Traditional 1, (b) Traditional 2, (c) Flow Down System 1, (d) Flow Down System 2

The following table provides detailed information on the color, shape and texture of the analyzed salt samples:

Table 1. Physical Characteristics

Sample	Color	Shape	Texture
Traditional 1	Pure White	Small Crystalline	Coarse
Traditional 2	Pure White	Small Crystalline	Coarse
FDS 1	Yellowish White	Small Crystalline Flakes	Coarse
FDS 2	Yellowish White	Small Crystalline Flakes	Coarse

Source: Data Processed by Researchers, 2025

The Flow Down System method produces salt with a yellowish-white color, small crystals, and coarse texture, while the Traditional method produces pure white salt with similar crystal and texture characteristics. The smaller standard deviation of the Flow Down System indicates better production consistency [28]. The crystallization process in the Traditional method lasts longer and uses large ponds without optimal control, increasing the risk of environmental contamination. The Flow Down System uses a controlled process with shorter aging times, minimizing contamination. The Flow Down System is proven to be more effective in improving salt quality, especially NaCl content [29].

Volume is a measure of the space a substance occupies, measured in liters or cubic meters [30]. The volume of old water is used to measure evaporation efficiency in salt production [31]. In the Flow Down method, the initial volume of water was 33,325 liters, while the Traditional method was only 29,650 liters. After the process, the remaining volume of 20°Be old water in the Flow Down reached 6,300 liters, more than the Traditional with 4,600 liters. The difference in volume reduction of Flow Down is 27,025 liters, while Traditional is only 25,050 liters. In production, the Flow Down produces 239.68 kg of salt per month through six aging cycles, while the Traditional method only produces 79.55 kg with two cycles.

Water content and NaCl content are important parameters in determining the quality of salt produced. This research is a comparison between the Traditional method and the Flow Down System method to see the effectiveness of both methods in producing high-quality salt.

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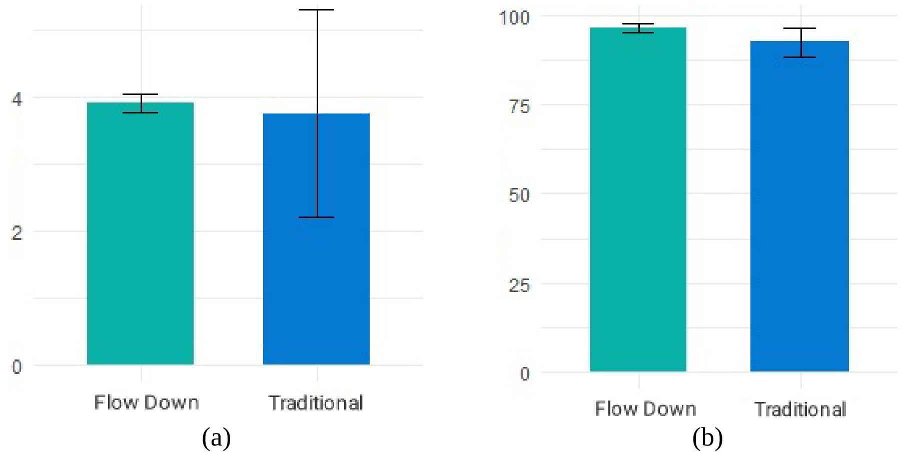

Fig. 5. Water content and NaCl Content test results
Source: Data Processed by Researchers, 2025

Figure 5 shows the results of the moisture content analysis of the salt produced by the Traditional method and the Flow Down System. In the Traditional method, the average moisture content was 3.745% with a standard deviation of 1.55%, while the Flow Down System had an average moisture content of 3.9% with a standard deviation of 0.14%. Although not significant, the Flow Down System showed a slightly lower moisture content. This difference is due to the aging duration, where the Traditional method requires 15 days, allowing moisture re-absorption. While the Flow Down System only requires 5 days, thus reducing the moisture content. Both methods meet the SNI 3556:2024 standard of <7% [32].

NaCl content is the main indicator of salt quality. In the Traditional method, the average NaCl content reached 92.625% (89.7% in the first repetition and 95.55% in the second repetition) with a standard deviation of 4.14%, still below SNI 3556:2024 which sets levels of 94-99.7%. The Flow Down System method showed superior results with an average NaCl content of 96.525% (95.55% in the first repetition and 97.5% in the second repetition) and a standard deviation of 1.38%. Salt produced through the Flow Down System method has a higher purity level, meets SNI standards, and shows better crystallization process optimization [33].

3.2.2 Effectiveness Calculation

The effectiveness of salt evaporation is an important parameter to assess the extent to which the process approaches the set standards. Effectiveness is calculated by comparing the actual results against the maximum standard. A smaller difference reflects higher effectiveness. Based on SNI 4435-2017, the maximum allowable moisture content is 7%, while the NaCl content must be in the range of 94%-99.7%. The effectiveness assessment was carried out using several equations as described in the research method. Based on the quantity of salt produced, it is calculated using Equation (2). Calculation of moisture content using Equation (3), and NaCl content using Equation (4). The equation used to determine the performance of the evaporation process of the Traditional method and the Flow Down System Innovation. The results of calculations using the above equations show varying numbers as explained below:

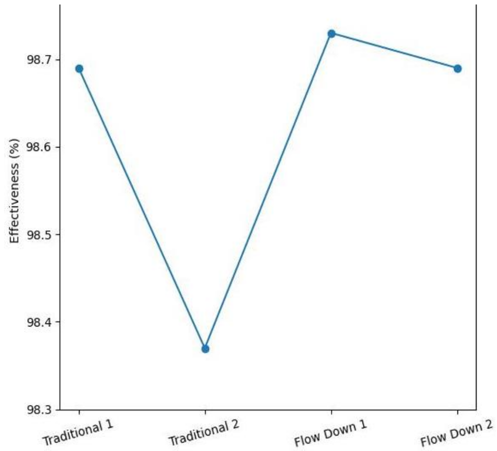

Fig. 6. Calculation of Effectiveness Based on Salt Quantity
Source: Data Processed by Researchers, 2025

Based on the Quantity calculation, the Effectiveness of the traditional method is in the range of 98.37% to 98.69%. The effectiveness of the Flow Down System shows a higher result, which is 98.69% to 98.73%. Flow Down System recorded the highest effectiveness of 98.73%, and the lowest effectiveness was traditional with a value of 98.37%. The average effectiveness of the Flow Down System remains better than the traditional method. The Flow Down System can maintain a more consistent and efficient yield quantity than the traditional method.

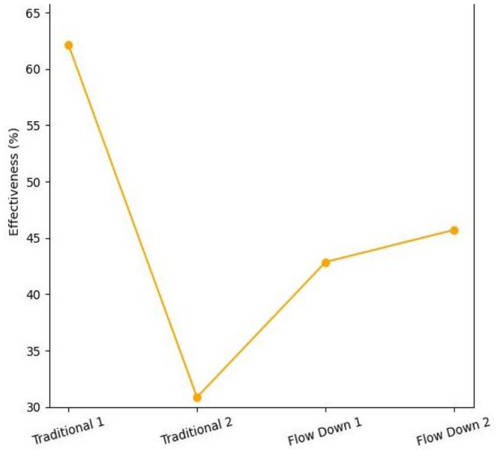

Fig. 7. Calculation of Effectiveness Based on Water Content
Source: Data Processed by Researchers, 2025

The average effectiveness of the traditional process based on moisture content is 46.5%. The 2.65% moisture content has an effectiveness of 62.14% and the 4.84% moisture content has effectiveness of 30.86%. The Flow Down System method has an average effectiveness based on moisture content of 44.29%. The 4.0% moisture content has an effectiveness of 42.86% and the 3.80% moisture content has effectiveness of 45.71%. The traditional method is slightly more effective in reducing moisture content than the Flow Down System although the difference is not significant. Both methods meet the maximum SNI standard for moisture content, both are feasible to use from this aspect.

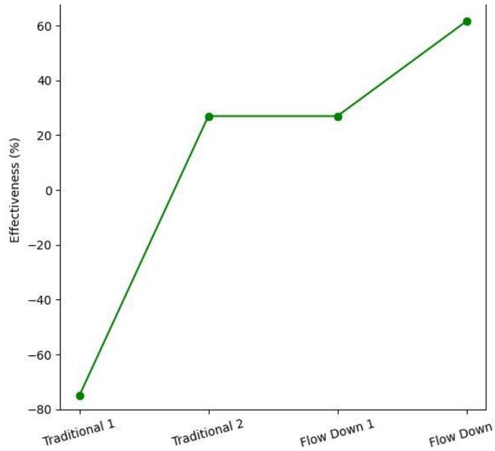

Fig. 8. Calculation of Effectiveness Based on NaCl Content
Source: Data Processed by Researchers, 2025

The effectiveness of NaCl levels in the traditional method shows an average of -24.02%. The 89.7% NaCl content has an effectiveness of -75% (below the SNI standard) and the 95.55% NaCl content has an effectiveness of 26.96%. One of the results in the traditional method failed to meet the minimum standard of NaCl content. The Flow Down System method has an average effectiveness of 44.25%. The 95.55% NaCl content has effectiveness of 26.96% and the 97.5% NaCl content has effectiveness of 61.54%. All results in this method meet the minimum SNI standards for NaCl levels.

Flow Down System innovation is more consistent in meeting SNI standards for NaCl levels than traditional methods. Effectiveness based on NaCl content on the Flow Down System shows a much better number. The Flow Down System innovation has an average of 44.25% compared to the traditional method which is only -24.02%. The traditional method for moisture content is slightly superior with an average of 46.5% compared to the Flow Down System with an average of 44.29%. The Flow Down System can be considered as a more effective method in producing quality salt according to SNI standards. The Flow Down System offers more stable results and meets the standard criteria more optimally than the traditional method [34].

3.3 Efficiency of Seawater Evaporation with Traditional Methods and Flow Down System Innovation in Salt Production

3.3.1 Time Efficiency

The density measurement is carried out to measure the increase in water °Be content from the beginning to the end of salt production [35]. Density is a measure that shows how much substance is present in a solution. The concentration level is calculated based on the amount of substance in a solution divided by the “total volume” of the solution. Higher concentration levels allow the salt crystallization process to begin immediately [36]. The following are data on the results of measuring the concentration level using two repetitions:

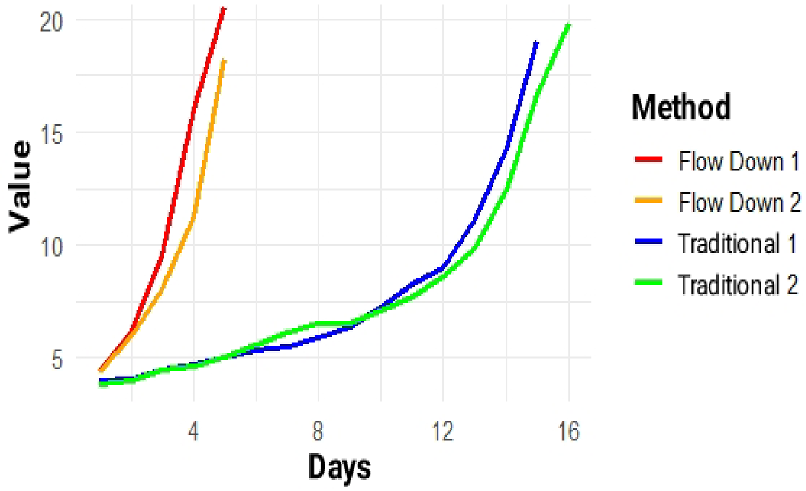

Fig. 9. Increase in salt density

Source: Data Processed by Researchers, 2025

Figure 9. Presents data on the improvement of Be, as measured by the Flow Down System method and the Traditional method. The data show that the Traditional system takes 15 to 16 days to complete a repetition. The Flow Down System innovation takes only 5 to 6 days. The Traditional system's first data recorded numbers ranging from 4 to 19 over a span of 15 days. The initial value of Traditional 1 was 4 on the first day and the final value was 19 on the 15th day. The second Traditional data of turnaround time ranged from 3,875 to 19,833 in 16 days.

The Flow Down System shows higher efficiency. The first data take 5 days, ranging from 4.5 on the first day to 20.5 on the fifth day. The second data took 6 days to complete, with an initial value of 4.375 to 18.25 on the sixth day. This significant difference shows the superiority of the Flow Down System in completing work faster than the Traditional method [37]. Hypothesis testing was conducted to evaluate normality, homogeneity, and mean differences in the Traditional and Flow Down System testing methods. In the Shapiro-Wilk normality test, data from the four tested groups, namely Traditional 1, Traditional 2, Flow Down 1, and Flow Down 2, showed W values of 0.79492, 0.80899, 0.93139, and 0.91407, respectively, with p values of 0.3167, 0.3594, 0.6059, and 0.4924. All p values are greater than 0.05, which indicates that the data come from a normal distribution.

The homogeneity test is conducted to ensure that the variance of each group being compared has the same value [38]. The basic assumption of the T-Test is the same variance between groups (homogeneous) [39]. The homogeneity test was performed using Levene's test for the BE variable [40]. Comparisons were made to compare the two variances in the data of the Traditional and Flow Down system variables from the Baumé data. The homogeneity test was conducted using the F-test of variance.

Traditional Method between repetition 1 and repetition 2, the F value is 0.84892 with a p value of 0.7643. The p value of 0.7643 indicates the variance of the two repetitions is not significantly different, so the data are considered homogeneous. The Flow Down System method between repetition 1 and repetition 2 shows an F value of 1.5239. The p value of 0.6931 confirms that the variance of the two repetitions is not significantly different. The variance between the Traditional method and the Flow Down System in repetition 1, the F value is 0.39326 with a p value of 0.1726. Repetition 2, the F value is 0.70596 with a p value of 0.5527. Both results indicate that there is no significant difference in variance between methods at the 0.05 significance levels [41]. So, it can be concluded that the two groups have homogeneous or similar variances [42].

One of the statistical methods for comparing two groups of paired data is the two-sample t-test. The purpose of this study was to determine whether there is a significant difference between the means of the two groups. The two-sample t-test results provide the following data:

Table 2. P-value Based on Two Sample T-Test

Statistical Test	Group Comparison	P-value	Conclusion
Normality Test (Shapiro-Wilk)	Traditional 1	p = 0.3167	Data is normal. (p > 0.05)
	Traditional 2	p = 0.3594	Data is normal. (p > 0.05)
	Flow Down 1	p = 0.6059	Data is normal. (p > 0.05)
	Flow Down 2	p = 0p.4924	Data is normal. (p > 0.05)
Homogeneity Test (F-Test)	Traditional 1 vs Traditional 2	p = 0.7643	Variances are homogeneous. (p > 0.05)
	Flow Down 1 vs Flow Down 2	p = 0.6931	Variances are homogeneous. (p > 0.05)
	Traditional 1 vs Flow Down 1	p = 0.173	Variances are homogeneous. (p > 0.05)
	Traditional 2 vs Flow Down 2	p = 0.553	Variances are homogeneous. (p > 0.05)
Two-Sample T-Test	Traditional 1 vs Traditional 2	p = 0.783	Not significant (p > 0.05)
	Flow Down 1 vs Flow Down 2	p = 0.665	Not significant (p > 0.05)
	Traditional 1 vs Flow Down 1	p = 0.016	Significant (p < 0.05)
	Traditional 2 vs Flow Down 2	p = 0.005	Significant (p < 0.05)

Source: Data Processed by Researchers, 2025

A statistical technique known as the two-sample t-test compares the means of two independent groups [43]. This test is performed to determine if there is a statistically significant difference between the two. The Baumé dataset contains two groups of data for comparison: "Traditional" and 'Flow System.' The null hypothesis states that there is no significant difference between the means of the two groups, while the alternative hypothesis states that there is a significant mean difference [44]. Tests of mean differences were conducted using a two-sample t-test. The results for Traditional 1 versus Traditional 2 showed a t value of -0.27758 with a p value of 0.7833. A p value greater than 0.05 means there is no significant difference between the means of the two groups of 7.625 and 8.067708. Flow Down System 1 versus Flow Down System 2 t value is 0.44902 with a p value of 0.6653. Flow Down System 1 versus Flow Down System 2 had no significant difference with averages of 11.325 and 9.575.

Comparing Traditional 1 with Flow Down System 1, the t value is -1.456 with a p value of 0.01626. The p value of 0.01626 means there is a significant difference between the two groups with a mean of 7.625 and 11.325. The comparison between Traditional 2 and Flow Down System 2 shows a t value of -0.61203. The p value of 0.005478 indicates a significant difference with averages of 8.067708 and 9.575. The results of this test show that the data in each group is normally distributed and homogeneous. There is a significant difference in the means between the Traditional and Flow Down System methods. The Flow Down System method has a different performance than the Traditional method. This difference needs to be further reviewed by considering other factors that may affect the results.

3.3.2 Energy Consumption for Flow Down System

Energy is the ability to produce change in the form of heat, motion, light, or otherwise [45]. Energy comes in many forms, including kinetic, potential, thermal, electrical, chemical, and nuclear energy [46]. The Flow Down System uses electrical energy in kilowatt-hour (kWh) units needed to drain water. Energy consumption is measured so that it can be seen how much electrical energy is needed to complete seawater aging [47]. The following are the results of the calculation of energy for the Flow Down System in the form of a table:

Table 3. Energy Consumption for Flow Down System

	kWh	Cost (IDR)
Repetition 1	16.00	21632
Repetition 2	17.03	23024.56
Average	16.515	22328.28

Source: Data Processed by Researchers, 2025

Table 3. Show the energy required for the Flow Down system measured in kilowatt hours (kWh). The energy is then converted into the cost of energy use in Rupiah (IDR). The Kedaireka Cipta Garam salt pond research site uses electricity with RI 900 VA power (RTM). The price per kWh of power RI 900 VA (RTM) set by PLN is 1,352 IDR [48]. The results based on the repetitions conducted show variations in energy consumption. The first iteration recorded an energy usage of 16.00 kWh at a cost of IDR 21632. The second repetition showed energy consumption increased to 17.03 kWh with a total cost of IDR 23024.56. The average energy usage after calculation in this study is 16.515 kWh. If calculated with prices from PLN, it is concluded that the cost of aging seawater Flow Down System Method is IDR 22328.28. This cost calculation is based on a one-time seawater aging process using the Flow Down System method [49]. The Flow Down System is much more expensive compared to the Traditional method which does not cost.

3.3.3 Calculation of Profit

Based on the test results, it is explained that the increase in BE in the Flow Down System is much faster than the Traditional. Calculation of Effectiveness based on Energy and Quantity needs to be done to determine the effectiveness of the Flow Down Method. The production method used in the salt industry can affect the final output as well as the profit earned [50]. Whether the method is more profitable than the Traditional Method. Table 4. Provide information on the comparison of the effectiveness of Salt Production using the Flow Down and Traditional Methods:

Table 4. Economic Value of Salt Production

Salt Production	Traditional Method	Flow Down System Method
Amount of Aged Water per Cycle	1 pond (500 cm x 400 cm x 20 cm) = 4,000 L of water/pan (15 days)	1 pond (500 cm x 400 cm x 20 cm) = 4,000 L of water/pan (4 days)
Monthly Production	39.775 kg x 2 aging cycles = 79.55 kg	39.946 kg x 6 aging cycles = 239.68 kg
Sales Revenue	79.55 kg x 1,000 IDR = 79,550 IDR/pond/month	239.68 kg x 1,000 IDR = 239,680 IDR/pond/month

Source: Data Processed by Researchers, 2025

Based on table 4. Above, the Flow Down System method offers significant advantages. The Flow Down System excels in the speed of the salt aging process as well as the total sales generated. Traditional salt production is done using a 400 cm x 500 cm pond, with a water level of up to 20 cm. In one harvest that takes up to 15 days, the volume of water used is 4,000 liters of water per harvest. The yield obtained is 79.55 kg of salt in one month from two aging times. The sales yield from this Traditional method is IDR 79,550 per pond per month. Given that the total expenditure is considered zero, the profit generated from this method is Rp. 79,550.

The Flow Down System method showed more promising results than Traditional [51]. The size of the pond used to collect the old water is much smaller at 400 cm x 500 cm. The water level is approximately 20 cm. The volume of water required in one harvest is only 4,000 liters and the time required for one aging is only 5 days. The yield per month using the Flow Down System Method reaches 239.68 kg of salt. The calculation is obtained from 7.5 times aging in one month.

Total sales proceeds from the Flow Down System method reached 105,710.32 IDR per pool per month. The financial benefits generated by the Flow Down method are also higher. Total expenditure comes from the cost of heating water during the production process (22328.28 per harvest). The net profit obtained for one month is Rp. 105,710.32. Even though there are expenses, the profits generated from the Flow Down method are still higher than the Traditional method. Even though the traditional method does not have expenses, the total recorded net profit is only Rp. 79,550.

3.3.4 Efficiency Calculation

Efficiency is an important factor that determines the success and sustainability of the production process. Efficiency can be seen from various aspects such as time, sales results, electrical energy and profits [52]. The two methods compared are the traditional method and the Flow Down System method. Traditional methods involve an evaporation process which takes longer. The Flow Down System innovation is an innovation that speeds up the process with the help of modern technology. Time efficiency is calculated by comparing the minimum time required to the actual processing time. The results obtained are then multiplied by 100% to get the efficiency percentage. Sales efficiency is calculated by comparing actual sales results with the maximum possible results achieved. Sales efficiency calculations use equation (5) and are expressed in percentages.

Electrical energy efficiency for the Flow Down System innovation is measured based on profit compared to electrical energy use in kilowatt-hours (kWh). Electrical energy efficiency is calculated using equation (6) contained in the research method. Profit efficiency is calculated by comparing actual profit with the maximum profit that can be achieved. Profit efficiency is expressed in percentage through equation (7). Based on the calculations following results were obtained:

Table 1. Perhitungan Efficiency

Components	Traditional	*Flow Down System*
Time Efficiency	33,33%	100%
Sales Efficiency	33,18%	100%
Energy Efficiency	Not Applicable	6,4 IDR/kWh
Profit Efficiency	75,25%	100%

Source: Data Processed by Researchers, 2025

Based on time efficiency calculations, the traditional method takes 15 days for the evaporation process. The Flow Down System innovation only takes 5 days which is much faster than traditional. Time efficiency is calculated by comparing the minimum time to the actual processing time. The traditional method achieves a time efficiency of 33.33%, while the Flow Down System achieves a maximum efficiency of 100%. The Flow Down System shows much better efficiency in terms of process duration. Efficiency based on sales results shows the comparison of actual sales results to maximum sales results. The traditional method recorded sales results of IDR 79,550 with a sales efficiency of 33.18%. The Flow Down System produces maximum sales of IDR 239,680 with efficiency reaching 100%. The Flow Down System innovation can optimize sales results compared to traditional methods. Sales results are still far from the maximum results that can be achieved.

Electrical energy efficiency is only relevant for Flow Down Systems because traditional methods do not use electricity. This efficiency is calculated based on a comparison of profit to the use of electrical energy expressed in kWh. The Flow Down System generated a profit of IDR 105,710.32 obtained by using 16,515 kWh of electrical energy. The electrical energy used reaches 6.4 IDR per kWh. Energy efficiency can still be considered feasible because it is supported by greater profits. Efficiency based on profit shows the comparison of actual profit to maximum profit. The traditional method produces a profit of IDR 79,550 resulting in a profit efficiency of 75.25%. Flow Down System achieved a maximum profit of IDR 105,710.32, with 100% efficiency. The Flow Down System is not only more efficient in terms of time and sales results but is also able to generate maximum profits compared to traditional methods.

The Flow Down System has significant advantages in almost all aspects over traditional methods. Flow Down System achieves significantly higher time, sales and profit efficiencies of 100% each. The electrical energy efficiency of the Flow Down System shows a value of 6.4 rupiah per kWh which is considered less efficient but is helped by the profits obtained. The Flow Down System is better than the traditional salt evaporation process because it minimizes time and maximizes sales and profits. This advantage makes the Flow Down System a more efficient and productive method in the salt processing process.

4. Conclusion

Based on the results explained above, the production of salt using seawater as raw material with the Flow Down System is an innovative approach aimed at accelerating the evaporation process by utilizing vertical bamboo media with alang-alang leaves. This system, which employs a downward water flow, significantly reduces the need for land and production time compared to traditional methods. The comparison between the effectiveness of salt evaporation using the traditional method and the Flow Down System, based on the SNI standards, reveals that the Flow Down System has a higher average effectiveness (98.69% - 98.73%) compared to the traditional method (98.37% - 98.69%). Although the moisture content in the traditional method is slightly better with an average effectiveness of 46.5%, the Flow Down System reaches 44.29%. Additionally, the Flow Down System surpasses the traditional method in meeting the NaCl content standards with an average of 44.25% compared to -24.02% in the traditional method. The Flow Down System offers more consistent, efficient results and better adheres to SNI standards, making it a superior innovation for salt production.

The Flow Down System proves to be more efficient than the traditional method in several aspects of salt processing. The system achieves 100%-time efficiency (5 days) compared to only 33.33% (15 days) for the traditional method. In terms of sales efficiency, the Flow Down System generates 100% more revenue (Rp 239,680/month) compared to the traditional method's 33.18% (Rp 79,550/month). Profit efficiency also favor's the Flow Down System, which delivers a profit of Rp 105,710.32, with a higher rate of 100% compared to the traditional method's 75.25%. Additionally, the energy consumption of 16.515 kWh for the

Flow Down System results in a profit of 6.4 IDR/kWh, further highlighting its superior performance in time, yield, and profitability when compared to traditional methods.

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