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Increasing NaCl Concentration by Using Precipitation and Filtration Process at Optimum Temperature

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Abstract

The sodium chloride salt or (food salt) is commonly used for consumption in our homes, as well as a raw material in industries and laboratories. The quality of this salt mainly depends on the sodium chloride concentration. The aim of this research is to obtain an optimum condition in production of NaCl industrial salt by using sedimentation and filtration process in order to achieve high concentration of industrial salt. The research has been conducted in two parts, mathematical calculations by mathematical models and experiment process by mixing the stearic acid with NaOH solution to produce the sodium stearic and the solution has been mixed with sea water, then the white solid was emerged, there are a calcium stearic and magnesium stearic. The final step is the filtration of evaporated mixture to obtain the intended salt concentration. Results obtained indicate that both result data are approximately identical with small deviation. The maximum concentration obtained of NaCl is 95% at optimum temperature of 83 ^{o}C.

***Keywords*: NaCl salt, precipitation, filtration, optimum temperature.**

زيادة تركيز كلوريد الصوديوم باستخدام عملية الترسيب والترشيح في درجة الحرارة المثلى

الخلاصة

يستخدم كلوريد الصوديوم (ملح الطعام) عادة في بيوتنا، وكمادة خام في المصانع والمختبرات. نوعية هذا الملح تعتمد بشكل رئيسي على نسبة تركيز كلوريد الصوديوم. الهدف من هذا البحث هو محاولة ايجاد ظروف التشغيل المثلى في درجات الحرارة المتغيرة للحصول على نسبة تراكيز عالية من ملح كلوريد الصوديوم الصناعي او (ملح الطعام). تم اجراء البحث بجزئيين، الحسابات الرياضية باستخدام نماذج رياضية (Mathematical models) والجزء العملي بإجراء التجربة. تم اجراء التجربة عن طريق خلط الحامض الدهني (Stearic acid) مع محلول هيدروكسيد الصوديوم (NaOH) لإنتاج الصوديوم. بعد ذلك تم خلط المحلول مع ماء البحر لتكوين كتل صلبة بيضاء من (Calcium stearic) و (Magnesium stearic). الخطوة النهائية هي عملية تبخير وترشيح الخليط للحصول على التركيز المطلوب للملح. وتشير النتائج أن كلا البيانات متطابقة تقريبا مع حيود بسيط. تم الحصول على الحد الأقصى لتركيز كلوريد الصوديوم بحدود 95% في درجة حرارة مثلى 83 درجة مئوية.

***الكلمات الدالة*: ملح كلوريد الصوديوم، الترسيب، الترشيح، درجة الحرارة المثلى.**

Introduction

One of the most kitchen cabinet items used for many purpose in our homes is the food salt. Common salt is a mineral that composed of sodium chloride (NaCl), a chemical compound belong to the class of salts. salt in its natural form as a crystalline mineral known as rock salt. Salt is present in seawater [1]. Salt is essential for human life, and saltiness is one of the basic human tastes. The tissues of animals contain large amounts of salt [2]. Salt is produced from salt mines or by the evaporation of seawater. Its main industrial products are caustic soda and chlorine and is used in many fabrication processes including the manufactures of

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some industrial products such as polyvinyl chloride , drugs and plastics [3].

The global need for NaCl salt in 2015 is about 3.6 million tons per year consisting of consumed salt of about 1.2 million tons and industrial salt of about 2,400,000 tons .Needs for NaCl salt is expected to increase in line with the huge development of population and industrial growth, so there is a need for increasing the concentration of NaCl in salt [4].

Some researches intended to reduce the impurities in the salt by combination laundering and rapid dissolution. This study was reacting NaCl salt with Na2 CO_3 and NaOH, so arising precipitate of $CaCO_3$ and Mg $(OH)_2$.

A study performed some experim-ents to determine the optimum ratio of Ca/Mg either with or without flocculants. The results obtained shows that the refining salt is very influenced by the ratio Ca/Mg, whereas if the ratio is too large or too small then the result with impurity is not good. Additions flocculent enough to affect a decrease in levels of Ca^{+2} and relatively little influence decreased levels of mg^{+2} [5].

Production the salt performed using solvent evaporation with NaOH and CO_2 gas, Solvent NaOH and CO_2 is a function used for precipitate of the Mg^{+2} and Ca^{+2} ions[6].

A study conducted on manufacturing industrial salt from seawater by three methods, namely the addition of stearic acid, addition of sodium carbonate and modifications process (modification of process is incorporation deposition method). Results obtained from this study show that the process modification method gives good results [7].

Methodology

Research has been conducted in the following steps:

- Mathematical calculations by two models for:

1. Reducing levels of Ca^{+2} and Mg^{+2}.
2. Increasing the NaCl salt.

- Experimental process had been conducted to product the:

1. Ca^{+2} and Mg^{+2} stearate.
2. NaCl salt.

- Comparison the calculation and experimental results to prove the validation of the models used.

-The experiment was conducted with a fixed variable in the processing time of 60 minutes; the volume of seawater is two liters and a mole ratio of stearic acid with sodium hydroxide 1:1. The experimental design used is the central composite design will be according to data results from Eqs.(1) and (2) as shown in Table (1).

Mathematical Calculations

We will use B_1 and B_2 as coding for the variables of temperature and concentration of sodium stearate. The B_1 and B_2 relationship with variable temperature and the concentration of sodium stearate as presented in Eqs. (1) and (2) [8].

$$B_1 = \frac{T - 83\ ℃}{5\ ℃} \tag{1}$$

$$B_2 = \frac{T - 7.3\ ℃}{2.4\ ℃} \tag{2}$$

where:
B_1: Temperature variable.
B_2: Concentration of sodium stearate.
T: Temperature.

Table 1. Experimental design data.

B 1	**B 2**	**Temp. (ºC)**	**Concentration Na Stearate (%)**
0.000	-1.414	83.00	5.000
1.000	-1.000	80.00	10.00
1.000	1.000	90.00	10.00
0.000	0.000	83.00	7.500
-1.000	1.000	80.00	10.00
0.000	0.000	85.00	7.500
-1.000	-1.000	85.00	3.960
-1.414	0.000	85.00	11.04
0.000	1.414	77.93	7.500
1.414	0.000	92.07	7.500

Experiment Process

The seawater is used as the main raw material for producing the salt, stearic acid and sodium hydroxide are obtained from the chemical store. The reactor used in the form of stirred tank equipped with a heater and a temperature controller. Process and apparatus are presented in Fig. (1).

Experiment was conducted on the following stages:

- The manufacture of sodium stearate,
- The reaction process, and
- The screening process and the formation of salt crystals.

Sodium stearate made by mixing stearic acid and water. The seawater is first filtered, heated, and vaporized water. The seawater is then treated with a solution of sodium stearate at predetermined operating variables. The reaction carried out in a stirred reactor equip-ed with temperature regulator. The solids that formed was filtered to separate the filtrate with sediment. The resulting filtrate was analyzed to determine the levels of Ca^{+2} and Mg^{+2}, and then the water is evaporated to obtain the salt deposits for its NaCl content was analyzed.

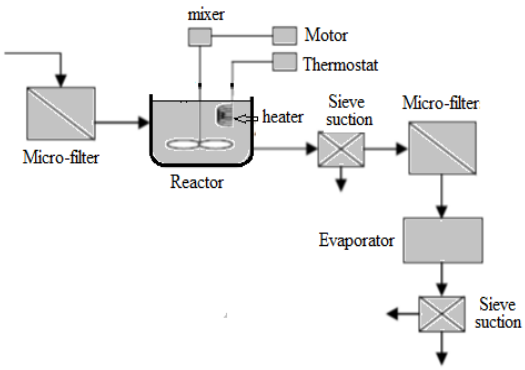

Fig. 1. The experimental setup.

Results and Discussion

- The maximum concentration obtained of NaCl is 95% at optimum temperature of 83°C.

- Fig. (4) shows that the point to point of the experiment is still out of the point of maximum reduction that can be achieved. From Fig. (4) we can be concluding that B_2 on the value of 2.663. The value lies outside of the operating variables to B_2 ($-1.42 \le B_2 \le 1.42$).

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Optimization Process in the Reduction Average of Ca^{+2} and Mg^{+2} Ions

Ca^{+2} and Mg^{+2} ions is the largest impurities contained in seawater. The existence of these two kinds of ions, causing salt products have low levels of NaCl. In present work, the Mg^{+2} and Ca^{+2} in seawater will be deposited into Mg-Ca-stearate and stearic using Na-stearate.

According to the model in Eq. (3) [8].

$$Y = 94.41 + 1.087B_1 + 0.2\,{B_1}^2 + 1.1\,B_2 - 0.24\,{B_2}^2 - 0.34\,B_1\,B_2 \qquad (3)$$

Results of reduced levels of Ca^{+2} and Mg^{+2} is shown in Table (2) where (Y*)* is the average of reduction Mg^{+2} and Ca^{+2} ions. The first column and the second is the operating conditions used in the experiment. The fifth column is the conversion average of Mg^{+2} and Ca^{+2}. The sixth column is the result of the calculation of the average conversion of Mg^{+2} and Ca^{+2}.

By sing the model of Eq. (3), the obtained reduction average of Ca^{+2} and Mg^{+2} is in range of about (89-91%). Results obtained in this experiment is less than the intended reduction average 94% because the lack of reactants sodium stearate reacting

Table 2: Results of reduced levels of Ca^{+2} and Mg^{+2} ions.

B_1	B_2	Conversion of Mg^{+2}	Conversion of Ca^{+2}	Conversion average (Ca^{+2} & Mg^{+2})	Calculated results%, (Y)
0.00	-1.50	97.89	83.45	90.12	92.22
1.00	-1.00	97.98	87.39	92.69	94.69
1.00	1.00	99.04	89.72	94.41	96.21
0.00	0.00	99.31	86.31	92.83	94.41
-1.00	1.00	99.75	84.64	92.20	94.72
0.00	0.00	99.00	88.76	93.85	94.41
-1.00	0.00	99.13	81.23	90.13	93.52
-1.41	0.00	99.18	87.34	93.29	93.27
0.00	1.41	99.30	91.86	95.58	95.48
1.41	0.00	99.06	91.82	95.44	96.34

with Ca^{+2} and Mg^{+2}. The value of critical variable B_1 is -0.517 at a temperature of 82°C and B_2 is about 2.663 for the concentration of sodium stearate of 13%. Comparison between calculated and experimental results on reduction of Mg^{+2} and Ca^{+2} is shown in Fig. (2) and reduction average of Mg^{+2} and Ca^{+2} is shown in Fig. (3).

Optimization Process in the NaCl Concentration

The optimization process is also observed in the NaCl concentration of the salt formed by using a mathematical model in Eq. (4) [8].

$$Y = 93.41 - 0.35B_1 - 0.34\,B_1{}^2 + 3\,B_2 - 0.94\,B_2{}^2 - 2\,B_1B_2 \qquad (4)$$

Results of Calculation results of NaCl salt concentration (%) or (*Y*) are shown in Table (3) where (*Y*) is the average concentration (%) of NaCl salt.

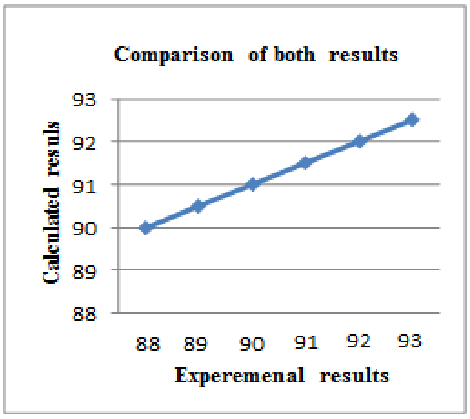

Fig. 2. Comparison between calculated and experimental results on reduction of Mg^{+2} and Ca^{+2}.

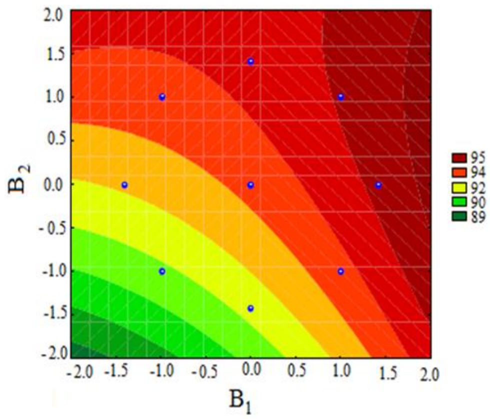

Fig. 3. Two-dimensional graph of the reduction average of Mg^{+2} and Ca^{+2}.

The third column is the result of analysis of NaCl concentration on salt products and the fourth column is the result calculation of concentration of NaCl. Comparison between calculated and experimental results on production of NaCl salt is shown in Fig. (4), while Fig. (5) represents the graph of production of NaCl salt.

From Fig. (4) it can be concluded that both data are approximately being identical with small deviation. Therefore, the model can be used in the process of increasing levels of NaCl.

Figure (5) indicates that for the value of variable B_1 = 0.0 and B_2 = 1.4, the concentration of NaCl salt is about 97%. This value is below standard 98.5% and this is may be due to the lack of Na stearate added.

Table 3: Results of calculation results of NaCl concentration (%) in salt products.

B_1	B_2	NaCl concentration results analysis (%)	Calculation results of NaCl concentration (%) (Y)
0.00	-1.42	84.58	87.25
1.00	-1.00	87.46	90.78
1.00	1.00	86.31	92.78
0.00	0.00	93.12	93.42
-1.00	1.00	92.96	97.48
0.00	0.00	92.38	93.41
-1.00	-1.00	86.37	87.48
-1.42	0.00	85.22	93.22
0.00	1.42	97.45	95.74
1.42	0.00	87.16	92.22

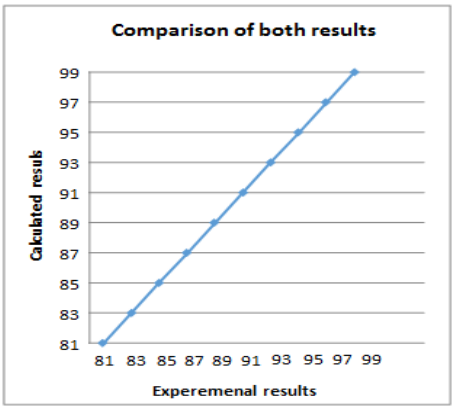

Fig. 4. Comparison between calculated and experimental results on production of NaCl.

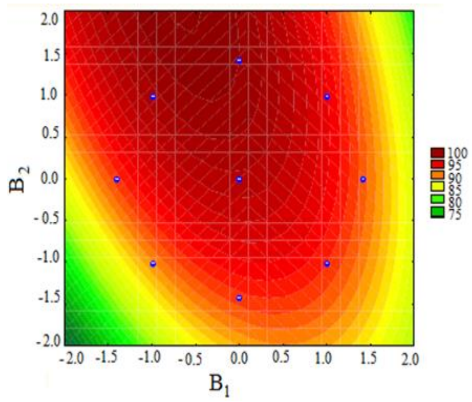

Fig. 5. Two-dimensional graph of production of NaCl salt.

Conclusions

From the results obtained, it can be concluded that according to the mathematical model Eq. (3) for the reduction average in Ca^{+2} and Mg^{+2}, the maximum value of conversion average is 95% on the value of B_1= - 0.71 at a temperature of 83°C and for variable B_2=2.7 the concentration of sodium stearate is about 15%.

According to the mathematical model Eq. (4), the concentration of NaCl is about 95% and for the variable B_1= - 0.7 or a temperature of 81 ^{o}C and variable B_2= 2.25 the concentration of sodium stearate is about 13.11%. both data are approximately identical with small deviation. Therefore, according to process used in this research, we can conclude that the mathematical models Equations. for mean reduction in Ca^{+2} and Mg^{+2} can be successfully used in the process of increasing levels of NaCl salt concentration.

References

[1] Golbas B. Role of salt in the formation of anatolian culture. Journal of Life Sciences 2012;1(1):45–54.

[2] Cunningham S. Wicca: a guide for solitary practitioner. Worldwide; 1989.

[3] Elvers B. Ullmann's Encyclopedia of Industrial Chemistry 1991;A24:319

[4] Pieters AJEB, et al. Experiment station work: Bread and the Principles of Bread Making. USA: 1899: 28–30.

[5] McNeil DG. In raising the world's I.Q. secret's in the salt. The New York Times: 2006.

[6] Discussions of the safety of sodium in table salt. Retrieved 7 July 2011.

[7] He, FJ, Li J. Effect of longer term modest salt reduction on blood pressure: Cochrane systematic review and meta-analysis of trials. BMJ (Clinical research ed.);2013:346

[8] Aburto NJ, Anna H. Effect of lower sodium intake on health: systematic review and meta-analyses. British Medical Journal 2013:346 (f1326).