Manufacture of flaky salt

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Equipment used for manufacturing flaky salt was investigated in an effort to improve the manufacturing efficiency and the characteristics of the flaky salt. The present study concerned, 1) the improvement in the performance of the crystallizing part of the evaporator and 2) the manufacture of salt flakes of larger particle size. A pan type evaporator has been developed which comprises both the heating part and the crystallizing part. These two parts are separated by a sluice. The sluice is open at both the upper and lower ends and incorporates heating pipes. Under the sluice, saturated brine can move from the crystallizing part to the heating part. Boiling brine in the heating part of the pan overflows from the top of sluice into the crystallizing part due to an air-lift effect, whereby evaporation and natural cooling from the surface of the brine induce the formation of flaked (tremie) crystals. The brine is then transferred under the sluice from the crystallizing part to the heating part. This structure enables us to separate boiling-induced disturbance from the crystallizing part, and as a result the temperature of the brine in the pan could be raised nearly to the boiling point. The operational performance of this equipment was about 8-10 $kg/m^2/h$ for flaky salt production at a brine temperature of 103-105 ^0C in the crystallizing part. The production rate was increased to about twice that for jacket heating type and other types of equipment.

1. INTRODUCTION

Flaky salt consists of tremie crystals and their fragments, which are developed at the surface of supersaturated brine when the brine is heated and evaporated in an open pan. Flaky salt has lower bulk density and better performance in mixing, sticks easily to other substances, and dissolves much faster than common cubic salt.

In Japan, various types of flaky salt are currently manufactured for use in dairy products, such as cheese and butter, marine paste products, such as *kamaboko* and *chikuwa*, and also for household use in pickles and seasonings.

We investigated a number of possibilities for realizing a production process for flaky salt in order to achieve the following:

1) Improved production capacity of flaky salt manufacturing equipment
2) Manufacture of flaky salt having a larger particle size.

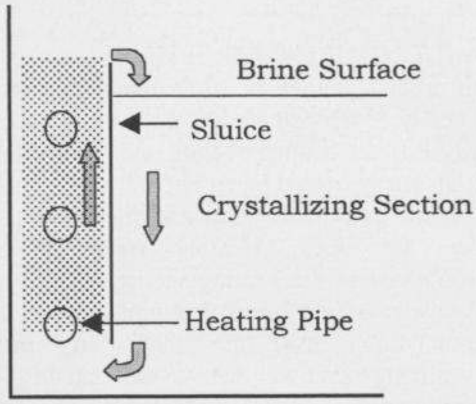

Figure 1. Cross-sectional view of flaky salt manufacturing equipment (Akoh Kaisui Plant)

2.BACKGROUND

Tremie salt crystals are grown at the brine surface due to the gentle evaporation of supersaturated brine.

In general, brine is evaporated in an open pan by heating from the bottom and/or the walls, or through other means, such as heating pipes (hereafter referred to as conventional methods). Since with such heating methods, the heating section and the crystallizing section are integrated into a single body, the boiling of the brine has a direct effect on the crystallization of tremie salt. When the brine starts to boil, the brine surface is

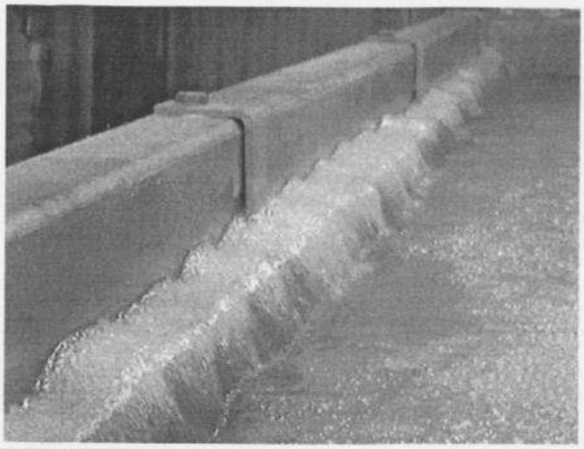

Figure 2. A photo of heating section (Akoh Kaisui Plant)

disturbed by the violent liquid convection and by steam bubbles, thus hindering the growth of tremie salt.

Slow evaporation, however, ensures that the brine surface is undisturbed. But it hampers the productivity of tremie salt.

3. RESULTS

3.1.DEVELOPMENT OF FLAKY SALT MANUFACTURING EQUIPMENT

In order to avoid the afore mentioned problem, the newly developed equipment is designed in such a way that the heating section and the crystallizing section are separated by an internal sluice, as shown in Figure 1. Both the top and the bottom of the sluice are open. Heating steam pipes are incorporated in the heating section. In this set-up, the supersaturated brine that boils in the heating section flows over the sluice and into the crystallizing section due to an air-lift effect. Consequently, crystals are grown due to evaporation from the quiet brine surface after natural cooling, and the saturated brine returns from the crystallizing section through the bottom of the sluice to the heating section.

Employment of such a set-up has made it possible to eliminate the disturbance on the brine surface in the crystallizing section.

Brine is boiled in the heating section, and the steam bubbles thus produced are mixed with the brine and travel upward. Due to air-liquid mixing, an air-lift effect is achieved in the heating section, and the liquid level in the heating section becomes higher than the liquid level in the crystallizing section by several centimeters. Figure 2 is a photo showing the heating section and its vicinity. In the heating section, the brine is in a state of complete boiling and is overflowing from the sluice into the crystallizing section.

The width of the heating section partitioned by the sluice varies depending on the heating conditions, and an air-lift effect can be produced when the width is several centimeters.

The brine, as shown in Figure 1, circulates in the following sequence: heating section overflowing the sluice crystallizing section passing the lower opening part of the sluice heating section. The temperature of the brine was 109 ^{0}C while boiling in the heating section, and 103-105 ^{0}C at the brine surface in the center of the crystallizing section.

Table 1. Specifications of Akoh Kaisui Plant

Item	Area (m^2)
Total surface Area	2.94
Surface Area of heating Section	0.14
Surface Area of the Crystallization Section	2.79
Surface Area of the Heating Pipes	1.20

The brine overflowing the sluice flows to the central part in the crystallizing section. The speed of the brine at the liquid surface is 5-10 cm/sec in the area at a distance of 10-20 cm from the sluice, and the velocity gets as low as 0.5-2 cm/sec further away from the sluice. The residence time of the brine in the central part of the open pan seems rather long. The flaky salt is produced in a series of processes, first, nuclei are formed in the flow near the sluice, and then start to grow at the brine surface at a distance of about 10-20 cm from the sluice. These nuclei continue to grow in a gentle stream and remain in the central part of the open pan, until the crystals precipitate in the mother liquor. Table 1 shows the specifications of our plant (Akoh Kaisui Plant) for manufacturing flaky salt. Table 2 shows the operation performance of our plant.

From the running performance of our plant, it can be deduced that the production capacity per unit brine surface area in the crystallizing section is

Table 2. Operation performance of Akoh Kaisui Plant compared to the conventional systems

Item	Akoh Kaisui System	Conventional Systems		
		JP No.1592992 Jacket Heating System	ST-type Open Pan	Alberger Process
Temperature in Crystallizing Section (^0C)	103-105	90-95		104
Temperature in Heating Section (^0C)	109			
Production Rate (kg/m^2h)	8-10	3-4	5-6	6.2 (Tremie) 13.1 (Total)
Crystal Form	Tremie	Tremie	Tremie+Cube	Tremie+Cube

improved by about a factor of two compared to conventional systems. As mentioned above, conventional systems are of three types: 1) a jacketed heating type open pan (JP No.1592992) [1], 2) an ST type open pan [2] and 3) Alberger Method [3].

System 1) has lower productivity, as shown in Table 2, because heating and crystallizing take place at a temperature below the boiling point in order to maintain a tranquil brine surface. Systems 2) and 3) produce a mixture of tremie crystals and cubic crystals.

The proposed system provides a solution for the effective production of tremie salt with larger particle size.

Our company employed this manufacturing method to build a production plant in 1994 and started manufacturing flaky salt at this facility. Though on a small scale, we continue to manufacture and market flaky salt.

3.2. COMPOSITION OF BRINE

It is described in [4] that the brine composition has an effect on crystallizing characteristics of sodium chloride.

Table 3. Analysis of variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F_0	Test	R^*-square (%)
Mg	584642	3	194881	19.608	Significant	70.3
Ca	100014	1	100014	10.063		8.9
Mg×Ca	49067	3	16356	1.646		2.4
K	18564	1	18564	1.868		-
Mg×K	6417	3	2139	0.215		-
Ca×K	1139	1	1139	0.115		-
Error	29817	3	9939			18.4
Total	789660	15				100

*R: Correlation coefficient

Such a phenomenon is expected also in flaky salt production / crystallization.

The major components of brine are sodium magnesium, potassium, calcium, chloride and, sulfate ions. Various tests were performed in order to determine how these components affect crystallization, particularly particle size of flaky salt.

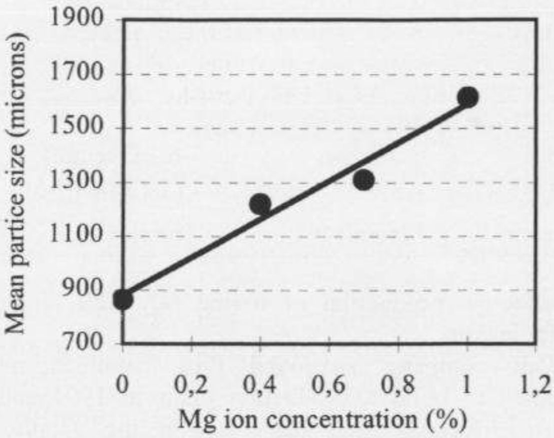

Figure 3: Relationship between the magnesium ion concentration in the brine and the mean particle size of the flaky salt

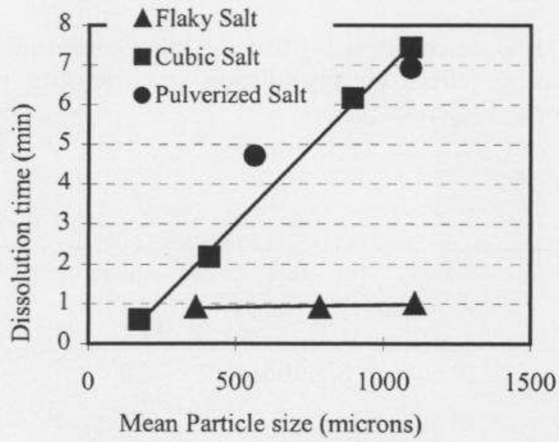

Figure 4. Dissolution time of flaky salt

In a flaky salt crystallization experiment, brine was first heated in a pan (size: 200 cm^2) and then evaporated to produce flaky salt. The collected flaky salt crystals were then washed using ethanol saturated with sodium chloride. After drying at 60^0C for 30 minutes, a sieve analysis was performed in order to determine the particle size distribution using the JIS standard sieves. The particle size at 50wt% on the cumulative under size distribution curve was regarded as the mean particle size.

The results of the test are shown in Table 3. The results show that magnesium ions have an effect on the mean particle size. In Figure 3, the effect of the concentration of magnesium ions on the mean particle size of the flaky salt is shown. The effects of potassium ions and calcium ions on the mean particle size are small.

A similar test was also carried out for sulfate, calcium and magnesium ions, revealing that sulfate ions contributed to the reduction of the mean particle size.

3.3. MEASUREMENT OF PHYSICAL PROPERTIES OF FLAKY SALT

3.3.1. DISSOLUTION TIME

The dissolving time for flaky salt, cubic salt and pulverized salt are shown in Figure 4. The flaky salt was collected from our plant. The cubic salt was obtained by vacuum crystallization, and the pulverized salt was made by crushing Australian solar salt.

A mixing method was employed for measuring the dissolving time. In this method, a 200g salt sample was mixed with 500 ml of water at 25 ^0C and stirred. The time required for the salt concentration to reach a value of 250 g/l in the solution was taken as the dissolving time.

In the cubic salt and the pulverized salt, a positive correlation was observed between the mean particle size and the dissolving time. The smaller the mean particle size, the greater the reduction in dissolving time and the higher the solubility. On the other hand, for the flaky salt, even though the mean particle size is larger, the dissolving time is shorter than those of the cubic salt and other salts.

3.3.2. Angle of repose

The angle of repose is an important index representing the flow characteristics of particles. It is related to the mixing and sticking performance of common salt. Figure 5 shows the measurement results for the angle of repose of the flaky salt and the cubic salt. Both salts were dried and then measured under conditions such that the effect of moisture on the measurement could be disregarded. The measurement was performed using a powder tester Model PTR of Hosokawa Micron Co. and the samples used in the measurement were the same as those used in the measurement of dissolving time.

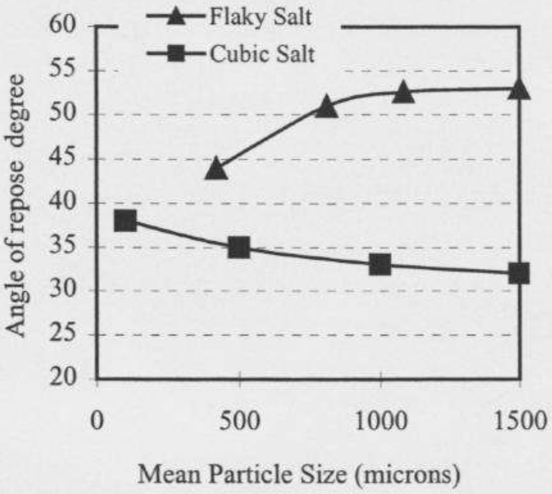

Figure 5. Angle of repose of flaky salt

4. CONCLUSIONS

The flaky salt, due to its characteristic crystal form, has properties that differ from those of cubic salt. Good application properties and a market preference for this salt have led to the manufacture and commercial availability of flaky salt in Japan. An effective production of flaky salt is difficult because this salt must grow on the brine surface. In Japan various systems have been examined in order to develop effective manufacturing methods for flaky salt. The method reported in the present paper was developed in the course of searching for more effective flaky salt manufacturing methods. The flaky salt particles manufactured by our method have larger diameter and distinctive properties.

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