DISCUSSION ON THE BEST CONTROLLING IN PROCESS OF PRODUCING SOLAR SALT

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Abstract: This paper introduced the experimental study of the production factors of influencing solar salt production. The aim is to find out the best controlling condition of production technology to supervise, control and guide the production in future.

Key words: production factors; factor level; output; quality

PREFACE

In recent years, domestic salt industry market is recession, so each salt enterprise has actively taken measures to develop new products and new markets. In order to open up the salt industry markets of Japan, Korea and other countries, Changlu Haijing Group Co., Ltd since 1998 has been researching and developing new products of solar salt production; after five years of production practice, the production and quality of solar salt have been greatly improved, but still not stable. There are many factors impacting the output and quality of solar salt in the production, and the influence degree of various factors is different. To increase the production and quality of solar salt more stably and carrying out the best controlling in the production process, the influence degree of all kinds of production factors production and quality of the solar salt should be mastered firstly, and then be controlled according to their influence status in actual production。

The purpose of this paper is to do the comparative production testing and data analysis about the crystallized area, the rate of sodium and magnesium of crystallized brine, the average temperature, the average temperature difference, the total consumption of evaporaten, crystallized brine depth and average relative humidity, which in the actual solar salt production may affect the yield and quality and also find the best controlling conditions to make the production in the optimal controlling state.

TEST DATA, CALCULATION AND ANALYSIS

The selection and level situation of production factors in the test, as is shown in table 1,

Table 1. The level of factors impacting production

production factors	Level one	Level two
A: crystallized area (h m^2)	0.144	0.036
B: crystallized brine sodium/magnesium	3.3	2.3
C: the average temperature (℃)	27.3	20.5
D: the average temperature difference (℃)	5.2	7.0
E: the total consumption of evaporaten (mm)	40.4	24.7
F: crystallized brine depth (cm)	4	5
G: average relative humidity (%)	75.3	62.8

TEST PLANS AND TEST RESULTS

In accordance with the selected number and level number of production factors, the orthogonal test plan with two -level and seven-factor (2^7) non-interaction was chosen to do the production tests, whose specific test results are shown in table 2:

Table 2 Test result data

Test number / production factors		1	2	3	4	5	6	7	8
A (h m^2)	1	(1)	(1)	(1)	(1)	(2)	(2)	(2)	(2)
crystallized area		0.144	0.144	0.144	0.144	0.036	0.036	0.036	0.036
B	2	(1)	(1)	(2)	(2)	(1)	(1)	(2)	(2)
Sodium/magnesium of brine		3.3	3.3	2.3	2.3	3.3	3.3	2.3	2.3
C (℃)	3	(1)	(1)	(2)	(2)	(2)	(2)	(1)	(1)
average temperature		27.3	27.3	20.5	20.5	20.5	20.5	27.3	27.3
D (℃)	4	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
average temperature difference		5.2	7.0	5.2	7.0	5.2	7.0	5.2	7.0
E (mm)	5	(1)	(2)	(1)	(2)	(2)	(1)	(2)	(1)
total consumption of evaporation		40.4	24.7	40.4	24.7	24.7	40.4	24.7	40.4
F (cm)	6	(1)	(2)	(2)	(1)	(1)	(2)	(2)	(1)
Crystallized brine depth		4.0	5.0	5.0	4.0	4.0	5.0	5.0	4.0
G (%)	7	(1)	(2)	(2)	(1)	(2)	(1)	(1)	(2)
average relative humidity		75.3	62.8	62.8	75.3	62.8	75.3	75.3	62.8
output value y	Yield (t)	46	45	56	33	50	35	58	52
	A-class rate (%)	68.5	51.3	81.3	65.4	76.3	70.6	84.7	65.4
	B-class rate (%)	16.3	36.5	12.5	29.1	12.6	21.8	14.2	14.3

Table 3 the analysis of test data											
Table head design	1		2	3	4	5	6	7	8	T_1	T_2	S
										180	195	28.125
A	1	1	1	1	1	2	2	2	2	266.5	297	116.28
										94.4	62.9	124.03
										176	199	66.125
B	2	1	1	2	2	1	1	2	2	266.7	296.8	113.25
										87.2	70.1	36.55
										201	174	91.125
C	3	1	1	2	2	2	2	1	1	269.9	293.6	70.21
										81.3	76	3.51
										210	165	253.125
D	4	1	2	1	2	1	2	1	2	310.8	252.7	422.0
										55.6	101.7	265.7
										189	186	1.1250
E	5	1	2	1	2	2	1	2	1	285.8	277.7	8.20
										64.9	92.4	94.53
										181	194	21.125
F	6	1	2	2	1	1	2	2	1	275.6	287.9	18.91
										72.3	85	20.16
										172	203	120.125
G	7	1	2	2	1	2	1	1	2	289.2	274.3	27.75
										81.4	75.9	3.78
Output value-- y										T=	$\sum y_i^2$=	S_T=
Output value	Yield (t)	46	45	56	33	50	35	58	52	375	18159	580.875
	A-class rate (%)	68.5	51.3	81.3	65.4	76.3	70.6	84.7	65.4	563.5	40468.1	776.56
	B-class rate (%)	16.3	36.5	12.5	29.1	12.6	21.8	14.2	14.3	157.3	3641.1	548.22

THE ANALYSIS OF TEST DATA

Analysis of factor superiority level

Comparing and calculating the total output value or the average value of the same factor in different levels, superiority level of factors can be got; when the required output value is big, the factor with big average value and total value has superiority level; on the contrary, when the required output value is small, the factor with small average value and total value has superiority level.

Taking the calculation of superiority level influencing production level as an example, first of all, looking at the first line, 1, 2 means the two levels of A, according to the level number, data is divided into two groups: "1" is corresponding output value {y1 (yield), y2 (yield), y3 (yield), y4 (yield)}, "2" is corresponding output value {y5 (yield), y6 (yield), y7 (yield), y8 (yield)}.

The four tests related to "1" are the same level of Factor A, but the two levels of Factor B participated in the two tests; at the same time, their two levels of Factor C, D, E, F and G also participated in two tests. The results of four tests and average value are respectively:

T1 (yield) = y1 (yield) + y2 (yield) + y3 (yield) + y4 (yield) = 46 +45 +56 +33 = 180
T1 (yield) = T1 (yield) / 4 = 180 / 4 = 45

The four tests related to "2" are the same level of Factor A, but the two levels of Factor B participated in the two tests; at the same time, their two levels of Factor C, D, E, F and G also participated in two tests. The results of four tests and average value are respectively:

T2 (yield) = y5 (yield) + y6 (yield) + y7 (yield) + y8 (yield)= 50 +35 +58 +52 = 195
T2 (y) = T2 (yield) / 4 = 195 / 4 = 48.75

From the above mentioned: the difference of - T1 (yield) and - T2 (yield) reflects only the difference between the two A-levels differences; among the test conditions of four groups, except factor A, Factor B, C, D, E, F and G are consistent as for the condition; therefore, comparing the two average value can confirm whether the level of factor A is good or not. Through calculation, as for factor A, - T1 (yield) is less than - T2 (yield); so as for output value production, Level 2 of Factor A is better than level 1.

Through the same calculation method, the output value of A-Class rate and B-Class rate and average value are:

T1 (A-class rate) = 68.5 +51.3 +81.3 +65.4 = 266.5
T1 (A-class rate) = T1 (A-class rate) / 4 = 266.5 / 4 = 66.6
T1 (B-class rate) = 94.4, - T1 (B-class rate) = 23.6,
T2 (A-class rate) = 76.3 +70.6 +84.7 +65.4 = 297
T2 (A-class rate) = T2 (A-class rate) / 4 = 297 / 4 = 74.3
T2 (B-class rate) = 62.9, - T2 (B-class rate) = 15.7

The following conclusions can be made:

(1) As for the output value of A-class rate, the level 2 of factor A is better than level 1;

(2) As for the output value of B-class rate, he level 1 of factor A is better than level 2. Numerical calculations above are all listed in Table 3 and Table 4.

Table 4 Superiority level of production factors

		T_1	T_2	$\bar{T}_1$	$\bar{T}_2$	The level of superiority
	yield （t/h m²）	180	195	45	48.75	2
A	A-class rate（%）	266.5	297	66.6	74.3	2
	B-class rate（%）	94.4	62.9	23.6	15.7	1
	yield （t/h m²）	176	199	44	49.75	2
B	A-class rate（%）	266.3	296.8	66.6	74.2	2
	B-class rate（%）	87.2	70.1	21.8	17.5	1
	yield （t/h m²）	201	174	50.25	43.5	1
C	A-class rate（%）	269.9	293.6	67.5	73.4	2
	B-class rate（%）	81.3	76	20.3	19.0	1
	yield （t/h m²）	210	165	52.5	41.25	1
D	A-class rate（%）	310.8	252.7	77.7	63.2	1
	B-class rate（%）	55.6	101.7	13.9	25.4	2
	yield （t/h m²）	189	186	47.25	46.5	1
E	A-class rate（%）	285.8	277.7	71.5	69.4	1
	B-class rate（%）	64.9	92.4	16.2	23.1	2
	yield （t/h m²）	181	194	45.25	48.5	2
F	A-class rate（%）	275.6	287.9	68.9	72.0	2
	B-class rate（%）	72.3	85	18.1	21.3	2
	yield （t/h m²）	172	203	43	50.75	2
G	A-class rate（%）	289.2	274.3	72.3	68.6	1
	B-class rate（%）	81.4	75.9	20.4	19.0	1

Similar approach can be used to calculate II, III, IV, V, VI, VII line, their data and average value are shown in Table 3 and Table 4. From the above mentioned the best factor combination which can make the output value index optimal is:

The superiority level of yield factor combination: $A_2B_2C_1D_1E_1F_2G_2$;
A-class rate superiority level factor combination: $A_2B_2C_2D_1E_1F_2G_1$;
B-class rate superiority level factor combination: $A_1B_1C_1D_2E_2F_2G_1$.

Analysis and calculation about the contribution rate of factors

The ratio of deviation sum of square and total deviation sum of square of total fluctuation is called contribution rate; the bigger the ratio is, the bigger the contribution rate is.

It is not adequate if only knowing what level of factor is good, and we should also distinguish the influence degree of various factors to output value. The following analysis is the influence degree of various factors to output value factors. Because of the different factor levels and the presence of the deviation, the data had some fluctuation; taking the calculation of yield and output value as an example, the total deviation sum of square of total fluctuation (S_T (yield)) was calculated:

$$S_T\,(\text{yield}) = \sum_{i=1}^{8}\left[y_i(\text{yield}) - \bar{y}(\text{yield}) \right]^2 = 580.875$$

Looking at the data fluctuations due to the difference of factor level, the deviation sum of square of A (S_A):

$$S_A\,(\text{yield}) = \sum_{i=1}^{4} 4\left[T_i(\text{yield}) - \bar{y}(\text{yield}) \right]^2 \div 8 = 28.125$$

Table 5 Analysis Table of the contributions of production factors

Source	factor deviation sum S			Contribution rate of deviation %			Contribution size		
	yield (t)	A-class rate (%)	B-class rate (%)	yield (t)	A-class rate (%)	B-class rate (%)	yield (t)	A-class rate (%)	B-class rate (%)
A	28.125	116.3	124.0	4.8	15.0	22.7	5	2	2
B	66.125	113.3	36.6	11.4	14.6	6.7	4	3	4
C	91.125	70.2	3.5	15.7	9.0	0.6	3	4	6
D	253.125	422.0	265.7	43.6	54.3	48.6	1	1	1
E	1.125	8.2	94.5	0.19	1.1	17.3	7	7	3
F	21.125	18.9	20.2	3.6	2.4	3.7	6	6	5
G	120.125	27.8	2.8	20.7	3.6	0.5	2	5	7
T	580.875	776.7	547.3	100	100	100			

In a similar way, the value of S_B, S_C, S_D, S_E, S_F and S_G can also be calculated, including the value of S_T by accumulated calculation:

$$S_T\,(\text{yield}) = S_A + S_B + S_C + S_D + S_E + S_F + S_G = 580.875$$

The contribution rate of A = S_A (yield) / S_T (yield) × 100% = 4.8%

In a similar way, the contribution rate of other factors which influence the output can be calculated shown in Table 3 and Table 5.

Similarly, from the calculation results shown in Table 3 and table 5, the contribution rate of each factor which influences A-Class rate and B-class rate. From the above mentioned, all the factors contribution rates are listed in sequence from big to small:

The sequence of factors which influence the output value production: D, G, C, B, A, F, E;

The sequence of factors which influence the output value A-class rate: D, A, B, C, G, F, E;

The sequence of factors which influence the output value B-class rate: D, A, E, B, F, G, C.

The analysis of key factor

According to the theory of "key factor is minority, the secondary factor is majority", in this test if the sum of contribution rates of 3～4 factors is 80%, then these factors are the key factors.

Knowing the superiority level of each factor and the influence degree of output value, and then making clear what is the key factor, which is a secondary factor, when guiding production, we will have a well-defined objective in mind. In order to find the key factor, the sum of contribution rate of B, C, D and G among the production factors:

The sum of contribution rate = 11.4% +15.7% +43.6% +20.7% = 91.4%

The contribution rate of these four factors is 91.4 percent, showing that the key factor affecting production is the average temperature difference, the average relative humidity, average temperature and sodium/magnesium in the crystallization brine; among them, the influence of average temperature difference is more significant; the contribution rate of the A , B and D among the factors influencing A-class rate is 83.9 percent, showing that key factor influencing A-class rate is the average temperature difference, crystallized area and sodium/magnesium in crystallization brine, of which the average temperature difference is the most prominent; the contribution rate of the A , D and E among the factors influencing B-class rate is 88.6 percent, showing that key factor influencing A-class rate is the average temperature difference, crystallized area and the total evaporation consumption, of which the average temperature difference is the most prominent.

How to control the production factors

From the above analysis, the influence degree to the output value of each factor, the superiority level in the same level and which is the key factor are made clear. In instruction production they should be adjusted in accordance with the different role of factors, so that production is in the best state. First of all, regulation of controllable factors should be strengthened, including crystallization area, crystallized brine depth, the rate of sodium and magnesium rate of crystalline brine and total evaporation consumption, etc; for example, reducing crystallization area is the best way to improve the quality; crystallized brine depth and the rate of sodium and magnesium rate of crystalline brine should be changed according to the response of weather conditions. As for increasing production and improving the quality, the smaller the average temperature difference, the better. But the weather conditions are not controllable, in actual production the only thing we can do is to adapt its change; in Table 6 below is the meteorological data of Tianjin Changlu Haijing Group CO. Ltd in nearly 40 years. From Table 6 it can be seen in June, July, August and September the weather conditions are beneficial to the solar salt production; from the point of the average temperature difference, the time when producing high-quality solar salt should in July and August.

Table 6 The meteorological data of Tang-Gu in the last 40 years (1957-1996)

Month	evaporation	temperature	relative humidity	the average wind power	Wind direction	precipitation	maximum temperature	minimum temperature	Temperature difference
	mm	℃	%	m/s		mm	℃	℃	℃
4	224.0	12.9	57.0	5.7	SE	21.4	17.8	8.8	9.0
5	302.4	19.4	58.8	5.5	SE	30.6	24.4	15.2	9.2
6	284.8	23.7	67.4	5.0	SSE	69.2	27.8	20.3	7.5
7	238.8	26.3	76.6	4.4	SE	197.8	29.5	23.4	6.1
8	224.7	26.2	74.4	4.0	SE	160.0	29.2	23.1	6.1
9	207.2	21.5	66.3	4.0	SW	49.7	25.4	17.9	7.5
10	153.5	14.5	64.1	4.2	SE	21.2	18.7	10.8	7.9

CONCLUSIONS

Through the comparative tests and the calculation analysis of test data, the status and effect of each factor in the actual production is made clear; as for the key factors such as the crystallization area, the average temperature difference, etc, the best level should be chosen, because the changes of levels will cause significant difference of index mark; while the level of indistinctive factors can be arbitrarily chosen, such as based on lower costs and easy operation in the actual production. In the production and controlling in the future such production factors as the average wind speed, whether it is salt boards, planeness of pool plate should be analyzed and researched further, as well as whether factors interact with each other, even what level of the factor is the best controlling point, and so on; In this way, production can be more fully controlled and guided.

References

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