

PHYSICOCHEMICAL PROPERTIES OF SOLAR SALTS IN JEOLLANAM-DO, SOUTH KOREA

Authors : Ho-Chul Yang

Sitology Doctor, Researcher, Officer,

co-authors : Gyung-Cheol Choi, Seon-Ho Jeong, Kyung-Sik Ham¹

Affiliations :

Food & Drug Analysis Division,

Jeollanam-do Institute of Health and Environment,

291-1 Nongseong-dong, Seo-gu, Gwangju, Republic of Korea, #502-810

Tel : 82-62-360-5343, Fax : 82-62-360-5347

Professor, Department of Food Engineering, Mokpo National University¹⁾

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Content:

Abstract : In order to estimate the physicochemical properties of the solar salt produced in Jeollanam-do, 60 Jeollanam-do solar salts(JSS) were analyzed with solar salts which were produced in France(GSS), China(CSS), Vietnam (VSS), and Australia and Mexico(AMSS). In sodium chloride contents, 83.20 % of JSS was lower than CSS(89.27 %), GSS(90.46 %), VSS(88.65 %) and AMSS(98.04 %). Whereas moisture(9.69 %) and sulfate ion(2.00 %) were higher than CSS(4.90 %, 0.96 %), GSS(4.42 %, 1.22 %), VSS(6.67 %, 0.90 %) and AMSS(0.58 %, 0.22 %). The mean value of major minerals(Mg, K, Ca except Na) in JSS was considerably higher than the others. In Mg, JSS 9,393 mg/kg, CSS 4,277 mg/kg, GSS 3,882 mg/kg, VSS 3,912 mg/kg and AMSS 282 mg/kg, in K, JSS 2,797 mg/kg, CSS 1,063 mg/kg, GSS 1,017 mg/kg, VSS 1,114 mg/kg and AMSS 178 mg/kg and in Ca, JSS 1,379 mg/kg, CSS 1,017 mg/kg, GSS 2,209 mg/kg, VSS 545 mg/kg and AMSS 514 mg/kg were detected respectively. Sr contents was prevalent in minor minerals(Sr, Fe, Mn, and Al) and order of amount was GSS(73.73 mg/kg), JSS(60.02 mg/kg), CSS(43.34 mg/kg), AMSS(21.99 mg/kg) and VSS(20.88 mg/kg). Although it was different from contents of each samples, sum of mean heavy minerals(Pb, Ni, Bi, Cd, Co, V, Hg and As) contained below 0.6 mg/kg in all origins.

1. Introduction :

Solar salt is produced through the natural evaporation of sea water. Salt water is captured in shallow ponds and allowed to evaporate by means of the sun and wind. During the process, a salt bed forms on the bottom of the pond and then the salt is harvested. The U.S. and China dominate in

world salt production, combining for 40 % of the world's quarter billion tons of salt produced each year. The Jeollanam-do, South Korea province has around 2,000 islands along the 6,100 kilometers long coastline. In Jeollanam-do, solar salts is produced 290 thousand tons (85 % in South Korea) annually is produced in shallow pond which a

stable salinity-gradient is artificially established in order to prevent thermal convection induced by the absorption of solar radiation.

The objective of this study is to investigate experimentally physicochemical properties of the solar salt produced in Jeollanam-do, South Korea.

Table 1. Clarification of solar salt samples used in this study

Abbreviation	No. of samples	Produced District
JSS	60	Jeollanam-do, South Korea
CSS	55	China
GSS	7	Guérando, France
VSS	4	Vietnam
AMSS	4	Mexico(2) and Australia(2)

2. Experimental method

All chemical reagents used were of analytical reagent grade, and triply distilled water was used throughout the experiments. Stock metal solutions was prepared by dissolving appropriate amounts of each 1000ppm solution (Merck) in 5% nitric acid or water. Working solution was prepared by appropriate dilution of its concentrated solution. All metals were analyzed with atomic adsorption spectrophotometer (Perkin-Elmer model 800, USA) after dilution

with water or 5% nitric acid. The operating parameters were set as recommended by the manufacturer. Atomic absorption measurements were carried out in an air-acetylene or nitrous oxide-acetylene flame, graphite furnace system and FIAS system (cold vapor generation system). All trace metals were measured by background correction mode. Sulfate ion was analyzed with ion chromatography (Dionex IC S-2000, USA)

Table 2. Condition of IC for analysis of anion in various solar salts

Instrument	IC S-2000 (Dionex)
Detection	Suppressed conductivity, ASRS Ultra 2 mm
Column	Ionpac AG16, AS16 2 mm (300×7.8 mm)
Column temperature	30 °C
Eluent source	EG40
Injection volume	10 µl
Flow rate	1.0 mL/min

3. Results and discussion

Compared with average sodium chloride contents, JSS 83.20%(75.46~93.54%) was lower than CSS(89.09%), GSS(90.46%), VSS(88.65%) and

AMSS(98.04%). whereas moisture(9.69±2.87%) and sulfate ion(2.00±0.76%) were higher than CSS(4.90, 0.96), GSS(4.42, 1.22), VSS(6.67, 0.90) and AMSS(0.58, 0.22).

Table 3. Contents of major ingredients of each solar salts (unit : mg/kg)

District	No. of samples	Ingredients	Minimum value	Maximum value	Mean value	SD ¹⁾
Jeollanam-do (JSS)	60	NaCl	75.46 ²⁾	93.54	83.20	4.19
		Total chlorides	44.89	57.88	50.83	3.06
		Moisture	3.44	15.72	9.69	2.87
		Sulfate ion	0.81	4.81	2.00	0.76
		Insoluble matters	0.00	0.20	0.07	0.03
		Sand matters	0.00	0.12	0.05	0.03
China (CSS)	55	NaCl	79.88	107.35	89.09	4.14
		Total chlorides	45.90	57.99	51.40	3.02
		Moisture	0.22	10.77	4.90	2.66
		Sulfate ion	0.13	2.08	0.96	0.41
		Insoluble matters	0.00	0.23	0.08	0.04
		Sand matters	0.01	0.20	0.06	0.04
France Guérando (GSS)	7	NaCl	88.10	92.76	90.46	1.77
		Total chlorides	53.06	55.86	53.83	1.36
		Moisture	2.28	6.97	4.42	1.86
		Sulfate ion	1.02	1.56	1.22	0.21
		Insoluble matters	0.27	0.67	0.47	0.21
		Sand matters	0.14	0.54	0.32	0.19
Vietnam (VSS)	4	NaCl	84.17	92.96	88.65	3.61
		Total chlorides	51.92	57.36	54.13	2.32
		Moisture	3.57	9.67	6.67	2.92
		Sulfate ion	0.54	1.62	0.90	0.50
		Insoluble matters	0.00	0.08	0.05	0.03
		Sand matters	0.01	0.08	0.05	0.03
Mexico & Australia (AMSS)	4	NaCl	95.17	99.24	98.04	1.94
		Total chlorides	57.72	58.56	58.25	0.46
		Moisture	0.35	1.15	0.58	0.39
		Sulfate ion	0.13	0.47	0.22	0.16
		Insoluble matters	0.00	0.02	0.01	0.01
		Sand matters	0.00	0.01	0.00	0.00

¹⁾SD : Standard deviation

²⁾Each values represented mean of triplicate determinations each samples

The amount of major minerals (Mg, K, Ca except Na) in JSS were considerably higher than the others. In Magnesium(Mg), JSS

9,393 mg/kg (3,639~17,963 mg/kg), CSS 4,277 mg/kg (274~11,475 mg/kg), GSS 3,882 mg/kg (3,256~4,526 mg/kg), VSS 3,912

mg/kg (2,521~7,654 mg/kg) and AMSS 282 mg/kg (106~565 mg/kg), in Potassium(K), 2,797 mg/kg (1,191~5,284 mg/kg), CSS 1,063 mg/kg (159~3,097 mg/kg), GSS 1,017 mg/kg (749~1,217 mg/kg), VSS 1,114mg/kg (601~2,331 mg/kg) and AMSS 178 mg/kg (133~219mg/kg) and in Calcium(Ca), JSS 1,379 mg/kg(413~4,392 mg/kg), CSS 1,017 mg/kg(376~2,486 mg/kg), GSS 2,209 mg/kg(1,256~3,430 mg/kg), VSS 545 mg/kg(438~745 mg/kg) and AMSS 514 mg/kg (296~1,109 mg/kg) were detected respectively.

District	No. of samples	Ingredients	Minimum value	Maximum value	Mean value	SD ¹⁾
Jeollanam-do (JSS)	60	Na	282,861 ²⁾	364,567	320,510	19,196
		Mg	3,639	17,963	9,393	3,378
		K	1,191	5,284	2,797	911
		Ca	413	4,392	1,379	723
China (CSS)	55	Na	304,900	393,400	354,436	21,610
		Mg	274	11,475	4,277	2,538
		K	159	3,097	1,063	618
		Ca	376	2,486	1,017	414
France (Guérando) (GSS)	7	Na	344,117	359,300	353,443	5,990
		Mg	3,256	4,526	3,882	560
		K	749	1,217	1,017	179
		Ca	1,256	3,430	2,209	969
Vietnam (VSS)	4	Na	315,300	362,100	349,600	22,908
		Mg	2,521	7,654	3,912	2,497
		K	601	2,331	1,114	818
		Ca	438	745	545	139
Mexico & Australia (AMSS)	4	Na	387,200	391,400	389,325	2,285
		Mg	106	565	282	213
		K	133	219	178	41
		Ca	296	1,109	514	397

Table 4. Contents of major elements of each solar salts (unit : mg/kg)

¹⁾SD : Standard deviation

²⁾Each values represented mean of triplicate determinations each samples

The amount of minor minerals (Sr, Fe, Mn and Al) in GSS were mainly higher than the others. In Strontium(Sr), JSS 60.02 mg/kg (20.25~180.25 mg/kg), CSS 43.34 mg/kg (14.28~181.55 mg/kg), GSS 73.73 mg/kg (63.64~80.80 mg/kg), VSS 20.88 mg/kg (17.92~22.35 mg/kg) and AMSS 21.99 mg/kg (20.83~24.73 mg/kg), in Iron(Fe), 5.17 mg/kg (2.11~12.17 mg/kg), CSS 4.84 mg/kg (1.72~16.03 mg/kg), GSS 20.31 mg/kg

(10.04~35.66 mg/kg), VSS 4.56 mg/kg (2.56~6.87 mg/kg) and AMSS 4.74 mg/kg (0.85~13.06 mg/kg) and in Aluminium(Al), JSS 2.41 mg/kg(1.03~7.67 mg/kg), CSS 3.14 mg/kg(0.48~8.72 mg/kg), GSS 18.32

mg/kg(15.70~23.03 mg/kg), VSS 2.36 mg/kg(1.76~2.77 mg/kg) and AMSS 1.29 mg/kg (0.27~4.27 mg/kg) were detected respectively.

Table 5. Contents of minor elements in each solar salts (unit : mg/kg)

District	No. of samples	Ingredients	Minimum value	Maximum value	Mean value	SD ¹⁾
Jeollanam-do (JSS)	60	Sr	20.25 ²⁾	180.25	60.02	27.96
		Fe	2.11	12.17	5.17	2.00
		Mn	1.25	11.57	5.19	2.00
		Al	1.03	7.67	2.41	1.17
China (CSS)	55	Sr	14.28	181.55	43.34	26.73
		Fe	1.72	16.03	4.84	2.51
		Mn	1.47	14.48	4.20	1.91
		Al	0.48	8.72	3.14	1.89
France (Guérando) (GSS)	7	Sr	63.64	80.80	73.73	7.34
		Fe	10.04	35.66	20.31	9.79
		Mn	4.53	11.90	7.19	3.05
		Al	15.70	23.03	18.32	3.01
Vietnam (VSS)	4	Sr	17.92	22.35	20.88	2.02
		Fe	2.56	6.87	4.56	1.77
		Mn	2.63	4.37	3.66	0.85
		Al	1.76	2.77	2.36	0.43
Mexico & Australia (AMSS)	4	Sr	20.83	24.73	21.99	1.83
		Fe	0.85	13.06	4.74	5.69
		Mn	0.66	5.62	1.98	2.43
		Al	0.27	4.27	1.29	1.98

¹⁾SD : Standard deviation

²⁾Each values represented mean of triplicate determinations each samples

Table 8. Contents of heavy metals in each solar salts (unit : mg/kg)

District	No. of samples	Ingredients	Minimum value	Maximum value	Mean value	SD ¹⁾
Jeollanam-do (JSS)	60	Pb	0.049 ²⁾	1.752	0.223	0.263
		Cd	0.000	0.054	0.010	0.013
		Hg	0.000	0.007	0.001	0.002
		As	0.000	0.006	0.002	0.002
		Ni	0.004	0.327	0.108	0.085
		Bi	0.012	0.275	0.107	0.069
		Co	0.000	0.038	0.005	0.009
		V	0.000	0.028	0.005	0.008
China (CSS)	55	Pb	0.058	0.894	0.214	0.143
		Cd	0.000	0.048	0.014	0.010
		Hg	0.000	0.020	0.001	0.003
		As	0.000	0.001	0.000	0.001
		Ni	0.063	0.657	0.255	0.097
		Bi	0.000	0.175	0.042	0.047
		Co	0.000	0.058	0.010	0.014
		V	0.000	0.067	0.005	0.014
France (Guérando) (GSS)	7	Pb	0.118	0.359	0.220	0.103
		Cd	0.000	0.000	0.000	0.000
		Hg	0.000	0.000	0.000	0.000
		As	0.000	0.006	0.002	0.003
		Ni	0.092	0.145	0.118	0.022
		Bi	0.082	0.109	0.094	0.011
		Co	0.000	0.001	0.001	0.000
		V	0.000	0.002	0.000	0.001
Vietnam (VSS)	4	Pb	0.047	0.370	0.231	0.167
		Cd	0.000	0.000	0.000	0.000
		Hg	0.000	0.000	0.000	0.000
		As	0.000	0.002	0.001	0.001
		Ni	0.042	0.096	0.069	0.024
		Bi	0.025	0.150	0.094	0.052
		Co	0.000	0.004	0.002	0.002
		V	0.000	0.000	0.000	0.000
Mexico & Australia (AMSS)	4	Pb	0.035	0.057	0.043	0.012
		Cd	0.000	0.000	0.000	0.000
		Hg	0.000	0.000	0.000	0.000
		As	0.002	0.002	0.002	0.000
		Ni	0.041	0.071	0.055	0.015
		Bi	0.022	0.096	0.055	0.038
		Co	0.001	0.002	0.002	0.000
		V	0.000	0.000	0.000	0.000

¹⁾SD : Standard deviation

²⁾Each values represented mean of triplicate determinations each samples

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