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Iodine Fortification from *Sargassum sp.* on the Quality of Iodized Consumption Salt

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ABSTRACT

Iodized consumption salt is salt intended for consumption purposes that has been enriched or fortified with Potassium Iodate (KIO_3) to meet iodine requirements. One type of seaweed known for its high iodine content is dried *Sargassum sp.*, which ranges from 0.2-0.5% in 2 grams. Samples of coarse salt, to be purified into pure salt, will be treated with 2N NaOH to increase NaCl content and fortified with *Sargassum sp.* iodine extract. This research method involves using iodine extract from *Sargassum sp.* as a compound to replace KIO_3 in the process of iodizing consumption salt. The study aims to determine the optimum concentration of *Sargassum sp.* iodine for fortification in consumption salt according to SNI 3556:2016. The quality of iodized consumption salt is analyzed using parameters such as moisture content, NaCl content, insoluble matter content, iodine content, heavy metal contamination, and sample surface analysis. The results indicate that the best treatment to increase iodine content in consumption salt is P3 with the addition of 80 ppm *Sargassum sp.* iodine concentration and to ensure sustainable fisheries that are environmentally friendly.

INTRODUCTION

Minerals are essential components required by all living organisms, known as inorganic substances or ash content. Minerals are divided into two groups based on quantity, namely macro minerals and trace minerals. Iodine is one of the trace minerals. Iodine is abundant in marine fish, shellfish, crabs, squid, and salt intentionally mixed with iodine compounds (Arifin, 2008).

Consumption salt has long been used as a medium for the eradication of Iodine Deficiency Disorders (IDD) (Sasmi, 2022). The iodine compound fortified in consumption salt is in the form of KIO_3 (Potassium Iodate), which easily dissolves in water and is susceptible to degradation when exposed to light and heat. KIO_3 is a strong oxidizing agent, hence prone to converting into volatile iodine (Subhan, 2014).

Seaweed is a local food source that can serve as an alternative for daily fiber intake and contains high levels of iodine (Anggraini, 2018). Seaweed with high iodine content, such as dried *Sargassum sp.*, ranges around 62.3 mg/100 g dry weight (Nunes *et al.*, 2019). Due to the high iodine content in *Sargassum sp.*, it has the potential to be used in iodine-fortified consumption salt. Therefore, research is needed to assess the impact of adding iodine from *Sargassum sp.* on the quality of iodine-fortified consumption salt.

LITERATURE REVIEW

Salt

Salt is a compound formed from the reaction of acids and bases. NaCl is the main element in salt with sodium (40%) and chloride (60%) (Dawa *et al.*, 2021). Salt is classified as consumption salt and industrial salt, this is based on the chemical content contained in the salt (Wibowo, 2020). Iodized consumption salt is salt for consumption purposes that has been enriched or has undergone fortification with 30-80 ppm of Potassium Iodate (KIO_3) (Hartati *et al.*, 2014).

Iodine

Iodine is a mineral that is needed by the body in relatively small amounts, but has a very important role in the formation of the hormone thyroxine (Sugiani *et al.*, 2015). It is necessary to add iodine to salt in the form of KIO_3 to meet the human body's need for iodine, disorders due to iodine deficiency can result in goiter (Sugiani *et al.*, 2015). Sources of food that contain a lot of iodine are all foods of marine origin such as seaweed, fish, shellfish and the like (Mutalazimah *et al.*, 2021). Seaweed is also a source of dietary fiber and a good source of iodine for the body with an iodine content of 54.59 ppm (Astawan *et al.*, 2005).

Seaweed *Sargassum sp.*

Sargassum sp. is a type of brown algae (Phaeophyta). *Sargassum sp.* has characteristics such as the shape of the thallus, generally cylindrical, lush branches resembling trees on land, the leaves are wide, oval or sword-like, have air bubbles (bladder) which are generally solitary, the length of the thallus can reach seven meters and is brown in color (Pamungkas *et al.*, 2013). This type of seaweed has high economic value because it contains alginate and iodine which are used in the food, pharmaceutical, cosmetic and textile industries (Fitriani *et al.*, 2023). Iodine content of *Sargassum sp.* dry during the process of making and serving tea amounting to 2,742.91 µg/g bw (Nurdayat, 2005). Addition of *Sargassum sp.* cakes can increase the iodine content by 0.16 mg/100 g (Darmawan *et al.*, 2004).

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Fortification

Fortification is the process of enriching a food ingredient with certain substances (Edam, 2016). The government's response to iodine deficiency is through iodine fortification of table salt in the form of KIO_3. Salt fortification with iodine is mandatory in Indonesia (Novitriani, 2015). Seaweed, which has a fairly high iodine content, can be used as a fortifying ingredient in food and has been proven to increase iodine levels (Zava and Zava, 2011). Iodide in seaweed functions as an antioxidant that protects the apoplast (cell wall space) in the cortex cell layer (Küpper, 2015). Banu's (2015) research shows that the addition of Sargassum cristaefolium to cereal flakes can increase the iodine content which ranges from 9.07 ppm to 16.42 ppm.

MATERIALS AND METHODS

Materials and Tools

The materials needed are *Sargassum sp.*, krosok salt, distilled water, chloroform, NaOH, NaCl, H_2SO_4, KI, $AgNO_3$, K_2CrO_4, $Na_2S_2O_3.5H_2O$, starch indicator. The tools used are digital balance, beaker glass, vacuum pump, Erlenmeyer, oven, rotary shaker food processor, hotplate, SEM EDX.

Seaweed Extraction

The seaweed is cleaned and sorted from sand and foreign objects by washing. The *Sargassum sp.* that has been washed is then soaked in lime water, followed by drying under sunlight at 45°C for 3 days. Once dried, the *Sargassum sp.* is cleaned from lime residue through washing and then dehydrated using a dehydrator at 50°C for 4-5 hours. Subsequently, it is ground finely with 150 grams using a grinder. Maceration is carried out using 300 ml of Chloroform at a ratio of 1:2 (w/v) in a rotary orbital shaker for 72 hours at 120 rpm. The filtered solution is then dried in an oven at 44°C for 48 hours, covered with aluminum foil (Arisandi *et al.*, 2023). The results of iodine extract from *Sargassum sp.* weighed according to the treatment, namely concentrations of 60 ppm (0.0189 g), 70 ppm (0.0220 g), and 80 ppm (0.0252 g).

Krosok Salt Purification

Krosok salt was weighed as much as 315 grams, dissolved in 1 liter of distilled water and then heated at 70^{o}C for 15 minutes. After a temperature of 25^{o}C-30^{o}C, 90 ml of 2N NaOH was added and allowed to settle for 45 minutes then filtered with a vacuum pump. Then the recrystallization stage was carried out using a hot plate at a temperature of 250^{o}C to form crystals (Rahem and Kartika, 2020). After that, the iodization process was carried out by dripping Sargassum sp iodine solution. with various treatments, namely 0 ppm, 60 ppm, 70 ppm, and 80 ppm then stirred with a food processor for 5 minutes (Manek *et al.*, 2022).

Water Content Measurement

Analyze the levels using a Moisture Analyzer by adding 2 grams to the aluminum base and then closing it, the tool will heat the product and the results will be printed on the tool (Kumalasari, 2012).

Sodium Chloride Measurement

Determination of NaCl levels in salt according to SNI 3556:2016 is carried out by weighing 10 grams of salt samples. Dissolve in 40 mL of distilled water, stir, and filter into a 100 mL measuring flask. Rinse with distilled water until it reaches the flask line (Solution A). Add 1 mL of 5% K_2CrO_4 solution to the sample solution and titrate with 0.1 N $AgNO_3$ solution until a brick red color forms.

Measurement of the Insoluble Part in Water

Testing for the water insoluble part according to SNI 3556:2016 is carried out by drying the filter paper and porcelain cup at a temperature of (105 ± 2)^{o}C for one hour, then weighing (W0). A 4 gram salt sample was dissolved in 100 ml of distilled water, heated for 30 minutes, then filtered. The filter paper and porcelain cup were dried again at the same temperature, cooled, and weighed to obtain a constant weight (W1).

Iodine Measurement

Determination of iodine levels according to SNI 3556:2016 is carried out by weighing 25 grams of salt sample and dissolving it with 75 mL of distilled water. Add 3 mL of 2N H_2SO_4 and 7.5 mL of 10% KI solution, then let the reaction take place in a dark place for 10 minutes. Next, titrate the salt solution with $Na_2S_2O_3$ until a straw yellow color appears, add 2 mL of starch indicator to change the color to blue, and continue the titration until the solution is clear again.

Metal Contamination Measurement

Test for heavy metal contamination using an Atomic Absorption Spectrophotometer (AAS). The standard sample solution is put into an AAS test tube. The system is regulated via computer, the flame and AAS cathode lamp are turned on to achieve maximum absorption. The standard solution was absorbed in an arsitelin air flame, and the atomic absorption results were recorded to determine the metal concentration in the sample based on the AAS calibration curve (Warni *et al.*, 2017).

Sample Surface Structure Testing

This test was carried out using a SEM tool, which is an electron microscope used to investigate the surface of solid objects directly, with a magnification of up to 3,000,000x, a depth of field of 0.4 - 4 mm, and a resolution of 1 - 10 nm (Walewangko *et al.*, 2021). Analysis of the synthesized solid ZSM-5 using SEM-EDX was carried out to evaluate its morphology and element content. The solid was placed on a carbon tape base and coated with Pd/Au for 15 minutes at a pressure of 6 x 10-2 mBar (Dismayanda and Prasetyoko, 2015).

RESULTS AND DISCUSSION

Water Content Test Results

The results of the one way ANOVA statistical test on salt consumption showed that there was a significant difference ($p<0.05$). Duncan's further test showed that the lowest water content value was the addition of 60 ppm iodine (P1) at 1.29% and the highest was the addition of 80 ppm iodine (P3) at 0.55%. According to SNI 3556:2016, the maximum allowable moisture content in consumption salt is 7%. The moisture content in purified salt meets the quality standards specified by the SNI.

Table 1: Water Content Test Results

Sample	Water Content (%)		Information
	Means ± SD	**SNI 3556:2016**	
P0	0,62^{ab} ± 0,06	Maximum 7%	Comply with SNI
P1	1,29^{c} ± 0,05		
P2	0,73^{b} ± 0,12		
P3	0,55^{a} ± 0,11		

The level of moisture in salt can be influenced by impurities such as Ca and Mg compounds, which are hygroscopic and readily absorb water molecules (Tobing and Dewajai, 2020). Increased moisture content also affects the sodium chloride (NaCl) content in salt, as higher moisture levels lead to lower NaCl content (Kurniawan *et al.*, 2019). *Sargassum sp.* seaweed contains alginates or hydrocolloid algin, which are colloid systems formed by organic polymers in water (Ode and Wasahua, 2014). Hydrocolloids can be used as additives to improve the quality of food products. This is due to their ability to easily absorb water and form gels (Herawati, 2018).

Sodium Chloride Level Test Results

The results of the one way ANOVA statistical test on salt consumption showed that there was no significant difference ($p<0.05$). NaCl levels based on the results of research conducted ranged from 94.36%-94.63%. According to SNI 3556:2016, the minimum sodium chloride (NaCl) content in consumption salt should be 94%. Purified salt meets the quality standards set by SNI.

Table 2: Sodium Chloride Level

Sample	Sodium Chloride Level (NaCl) (%)		Information
	Means ± SD	**SNI 3556:2016**	
P0	94,53^{a} ± 0,112	Minimum 94	Comply with SNI
P1	94,46^{a} ± 0,085		
P2	94,51^{a} ± 0,090		
P3	94,55^{a} ± 0,053		

The increase in NaCl content after purification with 2N NaOH is due to the precipitation and filtration of impurities during the filtration process (Ihsan and Jaeni, 2002). The addition of NaOH in the purification process is a method to bind impurities, thereby increasing the NaCl content. The use of sodium hydroxide (NaOH) 2N is particularly effective in enhancing the NaCl content (Pujiastuti *et al.*, 2018).

Water Insoluble Part Test Results

The results of the one way ANOVA statistical test on salt consumption showed that there was a significant difference ($p<0.05$). Duncan's further test showed that the lowest value of the insoluble part in water was the addition of 60 ppm iodine (P1) of 0.043% and the highest was the addition of 70 ppm iodine (P2) of 0.015%. According to SNI 3556:2016, the maximum

Table 3: Water Insoluble Part

Sample	Water Insoluble Part (%)		Information
	Means ± SD	**SNI 3556:2016**	
P0	0.034^{c} ± 0.0020	Maximum 0,5	Comply with SNI
P1	0.043^{d} ± 0.0020		
P2	0.015^{a} ± 0.0046		
P3	0.027^{b} ± 0.0020		

allowable insoluble residue in consumption salt is 0.5%. After purification, the insoluble residue content in salt shows that all samples meet the SNI standards.

After recrystallization with the addition of NaOH, there is a reduction in the insoluble residue content in salt due to the filtration process used to separate impurities. Iodine in seaweed exists in the form of inorganic iodine compounds such as I- ion and IO3-, which are fully soluble in water, and low-molecular-weight organic iodine molecules that remain in the insoluble residue (Hou *et al.*, 1997).

Iodine Level Test Results

The results of the one way ANOVA statistical test on salt consumption showed that there was a significant difference ($p<0.05$). Duncan's further test showed that the lowest iodine content value was the addition of 0 ppm iodine (P0) of 20.60 mg/kg and the highest was the addition of 80 ppm iodine (P3) of 39.18 mg/kg. Based on SNI 3556:2016, the minimum iodine content in consumption salt should be 30 mg/kg. After iodization with iodine from *Sargassum sp.*, the iodine content in salt meets the SNI standards.

Table 4: Iodine Level

Sample	Iodine Level (mg/kg)		Information
	Means ± SD	**SNI 3556:2016**	
P0	$20{,}60^{a} \pm 0{,}99$	Minimum 30	Does Not Comply with SNI
P1	$33{,}26^{b} \pm 0{,}66$		Comply with SNI
P2	$35{,}61^{c} \pm 0{,}31$		
P3	$39{,}18^{d} \pm 1.21$		

Research results have shown a decrease in iodine content in consumption salt compared to the intended formulation. Formulation P1, which aimed to add 0.0189 grams of iodine per 315 grams of salt to achieve a iodine content of 60 ppm, yielded an iodine content of only 33.54 ppm. The longer the iodization or mixing process, the lower the iodine content in the salt, although the resulting mixture becomes more homogeneous (Manek *et al.*, 2022). Storage conditions also affect iodine content in iodized salt. Iodine content in iodized salt stored in transparent plastic containers decreases more significantly compared to salt stored in glass containers (Aslinda and Astuti, 2019).

The iodine content from *Sargassum sp.* used in this study resulted in lower iodine content in iodized consumption salt compared to the intended formulation. This is because the *Sargassum sp.* underwent a soaking process using slaked lime or calcium hydroxide $Ca(OH)_2$. Iodine can react with alkali metals such as calcium. Soaking seaweed in a calcium hydroxide solution causes iodine content to decrease because $Ca(OH)_2$ is a basic solution that hydrolyzes iodine into hypoiodous acid and iodide, leading to higher pH levels which destabilize iodine (Monikasari *et al.*, 2021).

Metal Contamination Test Results

Based on the results of testing for metal contamination in consumption salt, it shows that all treatments do not contain metal contamination such as Cadmium (Cd), Lead (Pb), Mercury (Hg), and Arsenic (As). The testing results for heavy metal contaminants Cd, Pb, Hg, and As in this study indicate that all samples did not detect any traces of these metals, adhering to the maximum allowable limits according to SNI standards: Cd ≤ 0.5 mg/kg, Pb ≤ 10 mg/kg, Hg ≤ 0.1 mg/kg, and As ≤ 0.1 mg/kg.

Table 5: Metal Contamination

Metal Contamination	Test Results (mg/kg)					SNI 3556:2016
	Krosok Salt	**P0**	**P1**	**P2**	**P3**	
Cadmium (Cd)	0,13	0.00	0.00	0.00	0.00	Maximum 0,5
Lead (Pb)	2,16	0.00	0.00	0.00	0.00	Maximum 10,0
Mercury (Hg)	0,00012	0.00	0.00	0.00	0.00	Maximum 0,1
Arsenic (As)	0,025	0.00	0.00	0.00	0.00	Maximum 0,1

The low levels of heavy metal contamination in the salt from this study are attributed to the filtration treatment, which effectively separates heavy metals in the salt. This is supported by Said (2018), who noted that filtration treatments in saline water can reduce levels of heavy metal contaminants and other dissolved metals.

Sargassum sp. seaweed is rich in minerals such as Na, K, Ca, and Mg. The low levels of Cd, Pb, Hg, and As in iodized salt derived from *Sargassum sp.* indicate that the habitat of *Sargassum sp.* in the waters of Kepulauan Seribu is not contaminated with heavy metals, making it safe and suitable for use as raw material in consumption salt production. *Sargassum sp.* has the ability to absorb heavy metals and is known for its effectiveness in removing metal ions and polar organic compounds. Its extensive and shallow areas provide quick and reversible binding sites for ions (Dewinta *et al.*, 2022).

Sample Surface Structure Test Results

SEM is a type of magnification tool that uses a focused electron beam to obtain information. This test is basically used for morphological examination and analysis. SEM testing carried out at 2500X magnification and a scale bar of 50 µm, the appearance of the structure and particles in iodized consumable salt looks like solid granules and crystals with various spatial shapes, such as cubes and tubes with a slightly rough texture. Increasing magnification indicates that the texture of consumption salt becomes clearer with a surface that is undulating, resembling the crystalline form of salt. The crystal size or particle size significantly influences the crystallinity and dissolution rate of salt crystals. Regarding particle size, the size of particles

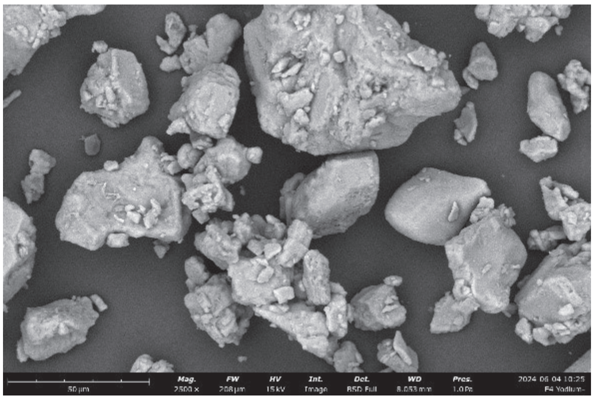

Figure 1: SEM Testing Results of Consumable Salt at 2500X Magnification

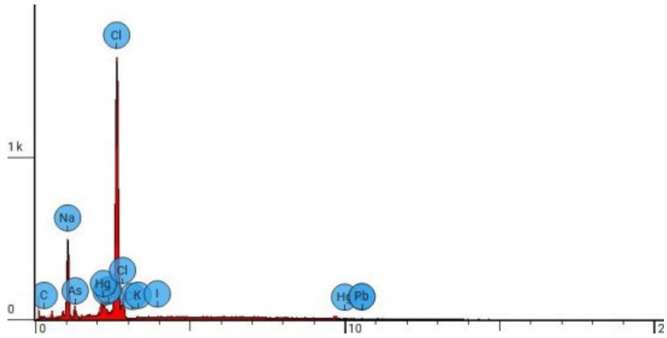

Figure 2: SEM-EDX Testing Graph

affects the surface area of a crystal (Sumarmi *et al.*, 2017). From this magnification, the EDX test is then continued to determine the chemical content. Some of the most abundant elements are Cl (Chlorine), Na (Sodium), Hg (Mercury), C (Carbon), As (Arsenic), Pb (Lead), I (Iodine), K (Potassium), Cd (Cadmium). The Na and Cl content dominates the consumption salt formulation. The chemical compounds contained in iodized table salt can be seen in Table 6.

Table 6: The Results of EDX Testing for Components in Consumable Salt

	Element Number	Element Symbol	Element Name	Atomic Conc. (at. 100%)	Weight Conc. (wt. 100%)
	6	C	Carbon	11.160	4.012
	11	Na	Sodium	19.231	13.240
	17	Cl	Chlorine	66.716	70.812
	19	K	Potassium	0.343	0.401
	33	As	Arsenic	0.805	1.805
	48	Cd	Cadmium	0.119	0.401
	53	I	Iodine	0.211	0.802
	80	Hg	Mercury	1.253	7.523
	82	Pb	Lead	0.162	1.003

CONCLUSION

This study concludes that adding iodine from *Sargassum sp.* impacts the quality of iodized table salt by increasing the iodine content. The optimal concentration for iodine fortification from *Sargassum sp.* regarding the quality of iodized table salt is found in treatments with the addition of 80 ppm iodine from *Sargassum sp.*

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