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Investigation of Iodine Stability and Uptake in Iodized Salt: Effects of Temperature, pH and Radiation

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ABSTRACT

Iodine is a trace element which needed in human being since it plays vital role for metabolism rate. The iodine will be adsorbed by thyroid gland to secrete hormone for controlling metabolism. Iodine is volatile as it readily sublimes at high temperatures. Thus, it is important to keep iodine at suitable temperature and important for the consumers to take enough iodine in our daily meals. Therefore, the objectives of this research are to verify the temperature and pH properties of iodine, to investigate the effect of radiation on iodized salt and to evaluate the suitability amount of iodine uptake by human thyroid. This research involved the titration method. The amount of thiosulfate used in the titration is proportional to the amount of iodine in the salt. The absorption peak and functional group present in salt solution is analysed using UV-Visible spectroscopy and FTIR spectroscopy. The iodized salt is radiate with Cs-137 to analyse its composition using FESEM-EDX. Concentration of iodine resulted from titration is converted into parts per million, ppm to determine the iodization level in the salt that approved by World Health Organization, WHO and the suitable amount of iodine uptake for healthy thyroid. From this study, the iodine content is low at high temperature and in acidic condition. The UV and infrared absorption in salt sample solution had shown its peak value and the functional group present in the sample. The non-irradiated and irradiated iodized salts had shown their elemental composition using FESEM with EDX. Also, the iodine concentration in iodized salt and its suitability of iodine consumption in human followed the iodization level by WHO.

1. Introduction

Iodine is one of the halogens in Group 17 of the periodic table. It has an atomic number of 53 with an atomic mass of 126.9045 amu. When comparing iodine with other halogens above it, it shows similar chemical properties but different physicalproperties. It appeared as a steel-grey solid that changed into purple vapour when heated. It is mainly found in seawater as solid states as the sea evaporates. It sublimes when heated and gives an iodine vapour of violet colour with a harsh odour.

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However, at cold temperatures, these vapours then change into iodine. Iodine is insoluble in water but dissolves in some liquids to give distinctive purple solutions.

Iodine can exist as a natural and unnatural isotope. The Iodine-127 is a natural isotope. Some of these isotopes are used in medical applications, such as being injected into the body or as medicine. For example, iodine-131 is used in thyroid disease. The isotopes that enter the body will travel through the bloodstream and emit radiation. The radiation emitted could be detected using X-ray film. The pattern formed by the isotope radiation could describe how the body functions. Iodine is also needed not only in humans but also in animals and plants as it maintains good health and average growth. In humans, iodine is used to make thyroid hormones. The thyroid gland will adsorb the iodine consumed. The thyroid cannot make hormones if the body has insufficient iodine. A lack and excess of iodine in the body will cause thyroid diseases such as hypothyroid and hyperthyroid. The thyroid is essential as it releases hormones that regulate and control the function of other organs.

Iodine is an essential trace element required for the biosynthesis of thyroid hormones: thyroxine (T4) or tetraiodothyronine and triiodothyronine (T_3). Both hormones are essential to regulate biochemical reactions such as enzymatic activity and protein synthesis [1]. Trace element means a chemical element is required in minute quantities or tiny amounts. These hormones are necessary for brain development and metabolism rate. It was known that iodine deficiency has become one of the world’s most frequent preventable causes of mental retardation [2]. In a day, about 150 mg of iodine is needed in humans [3]. Iodine is primarily found in seafood. The fish’s flesh of sea fish and shellfish may contain 300-3000 µg $1kg^{-1}$, compared with 20-40 $µgkg^{-1}$ offish from rivers or freshwater [4].

Iodine deficiency can cause many effects, such as abnormal growth and development, and most of it is mental retardation which faces worldwide. This deficiency is due to inadequate thyroid hormone production, which relates to the lack of iodine [2]. When the iodine intake is below 100 mcg daily, the TSH is excessively increasing secreted. The low iodine intake could reduce the thyroid hormone, although TSH is high.Critical iodine deficiency may cause thyroid cancer [5]. Several health risks arise from excessive iodine intake. The excess iodine will inhibit thyroid hormone synthesis and, therefore, increase the production of TSH, which causes goitre [6].

The thyroid is an endocrine gland with a butterfly shape that makes hormones which help regulate the body's metabolism. It is located in the lower part of the neck, below the Adam's apple, wrapped around the trachea. The thyroid uses iodine and changes it to thyroxine (T_4) and triiodothyronine (T_3). This thyroidgland is controlled and regulated by thyroid-stimulating hormone (TSH), secreted by the brain's pituitary gland. TSH controls the hormone productions, which are T_4 and T_3 [7]. The pituitary gland will reduce the release of TSH if there is too much T_4 and increase if there is too little iodine. The difference between T_4 andT_3 is the number of iodine atoms. T_3, derived from T4 by reducing one atom, is more active than T4 and produced in smaller amounts. T_3 has a concise life span in the body, while the life span of T_4 is much longer, ensuring a steady supply of T_3. As iodine plays a critical role in producing the thyroid hormone, any deviation of iodine will cause thyroid diseases such as hyperthyroidism and hypothyroidism.

In hyperthyroidism, a large amount of thyroid hormones are circulating in the bloodstream. So this will increase the rate of metabolism. This is an autoimmune condition in which the antibodies also behave like TSH and induce the thyroid out of control. This thyroid disorder can lead to heart failure and, finally, death. Grave’s disease is one of the examples. Meanwhile, hypothyroidism is a case where too little hormones are circulating in the bloodstream. This causes the rate of metabolism to slow down. This is an autoimmune condition in which the antibodies and white blood cells attack the thyroid gland and inhibit the production of hormones. It occurs when the iodine intake is below 10- 20 mcg daily [7]. This thyroid disorder could lead to mental retardation and death if untreated. Hashimoto's disease is one of its examples, and goitre is the earliest sign.

In some countries, there are cases where the soils are deficient in iodine content. So, this will cause an increase in iodine deficiency among the population who consume food such as crops from the areas. Thus, a salt iodisation program has been implemented worldwide to reduce iodine deficiency. In the United States, iodine has been added to table salts since the year 1920 [8]. The housekeepers will use this table salt containing iodine in their cooking. Iodine found in iodized salts could be sodium salt, potassium salt, inorganic iodine (I2), and iodate [9]. Since iodine is readily sublimed under high temperatures, thus potassium iodate is used due to its more excellent stability. A study shows almost 96.4% of potassium iodide is completely adsorb in humans. Also, there was a report on the approval of potassium iodide as thyroid-blocking agent in reducing the risk of thyroid cancer in radiation due to the releaseof radioactive iodine by nuclear plant [10].

From previous experiments, the iodometric titration method is used to find the iodine content in salt. The salt samples were collected from different production site and kept in different condition such as in refrigerator, in thecupboard and under the sun for days. The objective was to determine the iodine concentration in different storing condition and does iodine storage is varies with time [11]. Based on this objective, this research project is structured using the same iodometric titration method. The iodine content ofiodated salt samples is measured using an iodometric titration [12]. The difference in this research study is that the salt samples is collected from same brand and heated in several different temperatures in oven for 10 minutes before undergo titration. This will be as manipulated hypothesis in order to find out how the concentration of iodine in salt samples varies with temperatureand also to know the approximate temperature suitable for cooking. As the salt is in the form of iodate, thus to liberate iodine, the excess KI is added to help solubilize the free iodine before undergo titration. The outcome of the experiment should be that the iodine concentration decreases as temperature increases [13].

The stability of iodine is also determined by the alkalinity and acidity not only affect by temperature [14]. Thus, in this research study, in order to determine the concentration of iodine in solution of different pH values, thetitration method is used but slightly modified. The iodated salt will mixed with solution of different pH values. As the iodine from the iodated salt samples is liberated, the solution will then undergo titration. To differentiate each solution of different pH values, a buffer technique is used by alternate the volume of NaOH and H_2SO_4 in each acidic and alkaline buffer solution. Buffer is important as a strong acid or base is able to add into a solution without causing a large change in the pH value. In most research, the radioactive iodine is used to treat the thyroid disease and then examined the morphology of thyroid. But, in this study, the morphology of radiated iodized salt will be seen using FESEM coupled with Energy- Dispersive X-ray spectroscopy (EDS). EDS is use to analyse the elemental composition that exist and forming the iodized salt. UV-vis spectroscopy and FTIR will use to examine the absorption spectrum of iodine in different temperature and pH condition.

Iodine is available in the form of iodized salt. This form of salt is to prevent the loss of iodine. This table salt is the most efficient and reliable way for iodine consumption [15]. Iodine is volatile as it sublimes when heated. Thus, when using the table salt, the way of cooking is important in order prevent the lossof iodine. Thus, iodine adsorption gives effect in thyroid disease. Therefore, it is important to consume sufficient amount of iodine in daily meals.

2. Materials and Methods

2.1 Sample Preparations

The iodized salt as shown in Figure 3.1 is used as the salt sample. The salt sample was divided into 20 samples of equal amount. Label the test tubes with A to J. Then 10g of iodized salts was weighted into a 100 ml beaker. The salt sample A_1 was set as reference of the initial content of iodine at room temperature. This sample will be compare with the other test tube on the iodine content difference. The salt samples B to E were heated under different temperature on the heater machine. These salt samples were double to make for example A_1 and A_2 toE_1 and E_2. Meanwhile, different pH buffer solution was added into the salt sampleF to J. These salt sample also were doubled to make for example F_1 and F_2 to J_1 and J_2. Then, prepare iodized salt samples to undergo FESEM analysis.

2.2 Buffer Solution Preparation

An acidic buffer solution of a specific pH was prepared by a mixture of hydrochloric, HCl acid and sodium hydroxide, NaOH in solution. Since the acid and base are concentrated, thus it is needed to dilute them before making a buffer solution. Distilled water is used for dilution. For several different pH buffer solution, as example acidic buffer, the diluted hydrochloric acid was adjusted the pH up to the desire value by adding diluted NaOH. For alkaline buffer solution, pH value of the diluted NaOH was adjusted by adding diluted HCl up to desire pH value. The digital pH meter as shown in Figure 3.2 was used to measure the pH value for both acidic and alkalinebuffer solution. For this experiment, buffer solution of pH 2, pH 4, pH 6, pH 8and pH 10 were chosen.

2.3 Reagent Preparation

A 1.24 g of $Na_2S_20_35H20$ was dissolved in 1000 ml water. Then, the solution is stored in a cool and dark place. A 6 ml of concentrated H_2S0_4 was slowly added into 90 ml of water. The solution was diluted with water to make up to 100 ml. The solution is stable indefinitely. Acid was added to water, not water to acid to avoid excess heat formation and spitting of acid. The solution was stirred while adding acid. While a 100 g of KI was dissolved in 1000 ml water. Then, it was stored in a cool, dark place.

A saturated NaCl solution was prepared by adding NaCl to approximately 80 ml water in a beaker. The solution was stirred and heated until excess salt dissolves. This solution is stable for at least one year. Then, 1 g of soluble starch was weighted into 100 ml beaker and 10 ml of water was poured into it. The solution was heated until it completely dissolves. Then the saturated NaCl solution was poured into the hot starch solution to make up to 100 ml and it was stored in a cool, dark place. The starch solution was prepared every day since starch solution cannot be stored.

2.4 Temperature vs Volume

Salt samples that was placed in a 100 ml beaker are labelled with B_1 to E_1 was then heated on the heating machine at 30°C to 100°C respectively for 10 minutes. Then the salt samples were cool to room temperature in cupboard (dark place). After it cooled down, then the salt sample B_1 was put into a 250 ml Erlenmeyer flask with a stopper. Then approximately 30 ml of water was added and swirled to dissolve the salt sample. Further additional of water was added to make volume up to 50 ml. 1 ml 2N H_2SO_4 was added and after that 5 ml 10% of KI was added as well. The salt sample solution will turn yellow which indicate the presence of iodine in the salt sample. Next, the salt sample was put in the dark (cupboard or drawer) for 10 minutes.

A burette was prepared and rinsed. The burette was filled with 0.005M $Na_2S_20_3$ and adjusted the level to zero. The sample containing flask was then removed after 10 minutes from drawer and it was put under the burette stand. $Na_2S_20_3$ was added into salt sample drop by drop from the burette until the solution turns pale yellow.

Then approximately 2 ml of starch was indicator solution (the solution should turn dark purple) added and titrating was continued until the solution becomes pink and finally colourless. Finally, the level of thiosulphate in theburette was recorded. The value recorded was converted into parts per million according to the conversion table. Then, the steps were repeated using salt samples A_1, C_1, D_1, and E_1. Salt sample A_1 was not heated to maintain its original temperature whichis according to room temperature. The result was tabulated in the table.

2.5 pH Level vs Volume

Salt samples that were placed in a 100 ml beaker are labelled with F_1 until J_1 was then mixed with buffer solution of pH 2 to pH10 respectively. The salt sample F_1 was put into a 250 ml Erlenmeyer flask with a stopper. Then, approximately 30 mlof water was added and swirled to dissolve salt sample. Further additional of water was added to make volume up to 50 ml. 1ml 2N H_2SO_4 was added and after that 5 ml 10% KI was also added. The salt sample solution turned yellow which indicate the presence of iodine in the salt sample. Next, the salt sample was put in the dark (cupboard or drawer) for 10 minutes. A burette stand was prepared and rinsed. The burette was filled with 0.005M $Na_2S_20_3$, and adjusted the level to zero. The sample containing flask after 10 minutes was removed from drawer and it was put under burettestand. $Na_2S_20_3$ was added drop by drop from the titration burette until the solution turns pale yellow.

Then, approximately 2 ml of starch indicator solution (the solution should turn dark purple) was added and titrating was continued until the solution becomes pink and finally colourless. Finally, the level of thiosulphate in the burette was recorded and converted into parts per million according to the conversion table. Then, the steps were repeated using salt samples labelled with G_1, H_1, I_1 and J_1.

2.6 UV and Infrared Absorbance in Iodine

The salt samples labeled with A_2 to J_2 were prepared. Then, all the salt samples were undergoing the liberation iodine process. The salt sample solution of different temperature and pH value was then examined with UV-vis spectroscopy.Then, the most stable content of iodine in those salt samples was then examined with FTIR. The stable content was chosen based on the highest number of iodine content in the titration method. The iodine solution from irradiated salt sample of stable temperature and pH were also examined using FTIR.

2.7 Morphological Study of Radiated Iodized Salt

The iodized salt was prepared in a test tube to be radiated with Cs-137 with an activity of 30 mCi. The dose given was 374μRhr^{-1} and radiated for 24 hours. Both iodized salt samples of non-irradiated salt and irradiated salt were examined using FESEM coupled with Energy-Dispersive X-ray spectroscopy (EDS). Then, the morphology and elemental composition of the sample were analyzed.

2.8 Iodine Adsorption in Thyroid Disease

The quantity of iodine consumption that should be consumed was compared with the volume of iodine content in iodized salt result from titration. Then, the irradiated salt was then compared with the non-irradiated salt for the iodinecontent. The comparison was determines for their iodine stability and for the quantity of iodine consumption suitable for thyroid.

3. Results and Discussion

3.1 Titration of Iodine

The initial temperature of the iodized salt at room temperature is 20°C with pH value of pH 9.17. The iodized salt sample was titrated with the 0.005 M Sodium thiosulfate ($Na_2S_20_3$) in order to determine the iodine content in the salt. Iodine content is expected to be low at high temperature and medium in acidic. This is because iodine in nature sublimes under high temperature and it is unstable in acidic medium. Table 1 shows the result of 5 salt samples that heated with different temperatures. It showed that the iodine content decreases as the temperatureincrease. This is due to that iodine is unstable in high temperature. Hence, it is volatile exist in nature. Thus, the result tabulated seems aligns with the expected result from previous research study carried out by Prodhan, *et al.*, [13].

Table 1
Iodine content in salt sample of different temperature

Salt sample	Temperature (°C)	Volume of sodium thiosulfate used
A_1	20	3.7
B_1	40	3.4
C_1	60	3.3
D_1	80	3.1
E_1	100	2.8

Data from Table 1 was then plotted in the Figure 1. It is clearly seen that iodine content of salt decrease as the salt is heated with increasing temperature. The higher is the temperature, the lower the iodine content.

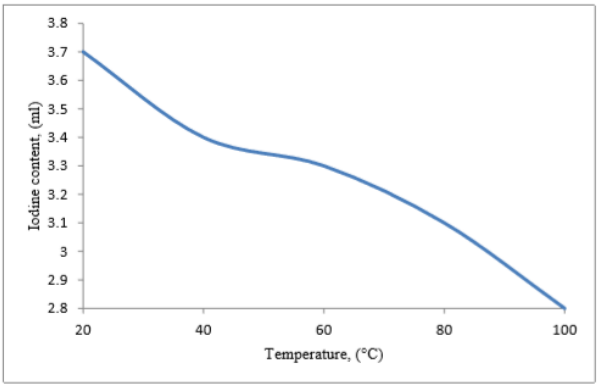

Fig. 1. Graph of iodine content at different temperatures

Meanwhile the iodine content of another 5 salt samples in which mix with pH buffer solution at different pH values showed that the iodine content in acidic medium is the least and in alkaline medium is the most stable. The Table 2 showed the iodine content at different pH condition. This result also aligns with the expected result from previous research study by Kelly [14].

Table 2
Iodine content in iodized salt samples at different pH condition

Salt sample	pH	Volume of sodium thio sulfate used
F_1	2	2.2
G_1	4	3.4
H_1	6	3.6
I_1	8	3.7
J_1	10	3.7

The data from Table 2 was then plotted in Figure 2 graph plotted ofiodine in salt samples at different pH condition. From the graph, it was clear that the iodine content in salt sample is proportional to pH value. The lower is the pH values the, the lower the iodine content in salt sample. At pH value up range from pH 9 to pH 10, the iodine content in salt is constant due to the pH value of the iodized salt sample is pH 9.17.

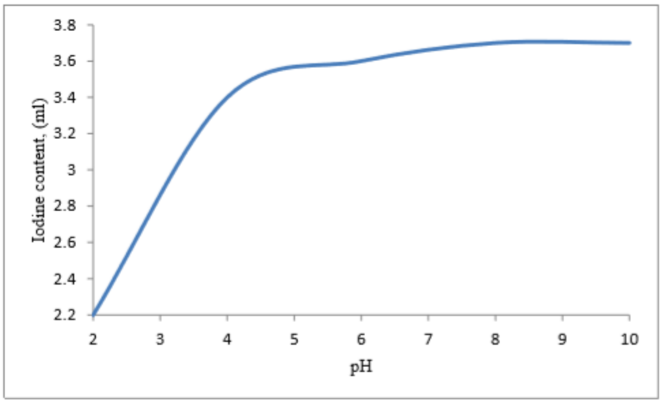

Fig. 2. Graph of iodine content in salt sample at different pH

3.2 UV Absorbance in Iodine

As for UV light absorbance in iodine, all the 10 salt samples solution from A_2 to $J_2$of which heated different temperature were tested with UV-visible spectroscopy. The results showed that the overall samples have 2 peaks in between the range of 280 nm to 310 nm and in between 340 nm to 360 nm. This follows the previous research carried by Wei *et al.*, [16] which stated that as iodine, I_2 aqueous solution in the presence of KI solution, two absorption peaks will appear at 288nm and 350 nm. This is because triiodide ion, I_3^- is forming at band 350 nm.

Thus, the salt sample solution results from UV- visible spectroscopy showed that it contains iodine with the existence of potassium iodide as well.Therefore, the sample has two peaks due to the potassium iodide present as reagent in which it is function to increase the solubility of iodine in water. However, due to the reaction, triiodide ion also formed which finally become thereactive species instead of iodine. Also, the salt sample solution may form the I_3^-as well through the reaction. The reaction was shifted to the right as it achieved equilibrium. The salt sample solution prepared for the UV-visible spectroscopy is undergoes the iodine liberation process without titrate with sodium thiosulfate. This is because to extract out iodine from its salt so that the UV absorbance in iodine can be known. Otherwise, the sample tested may not show the peak absorbance of iodine, instead it shows the peak absorbance of iodized salt only.

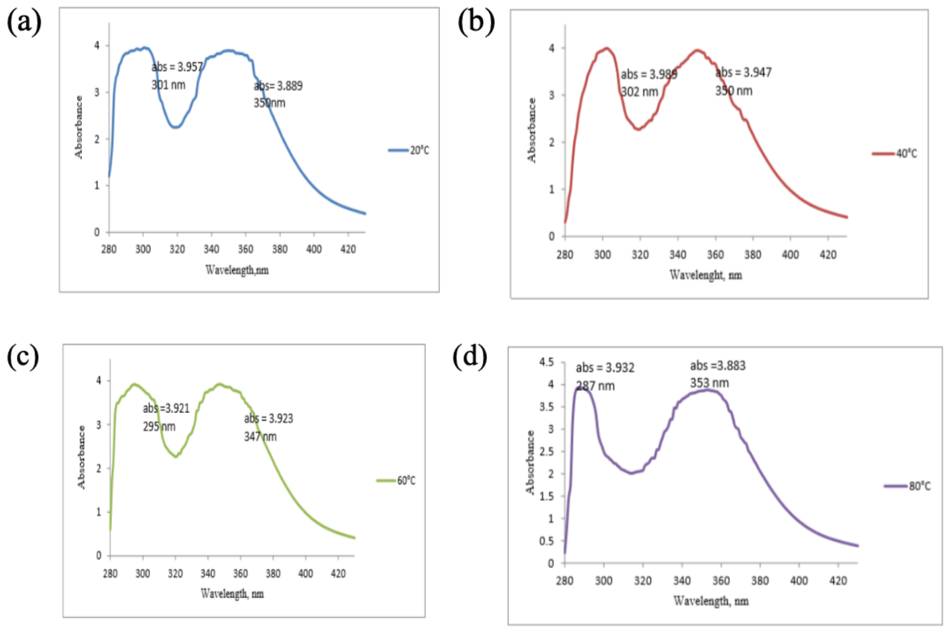

Fig. 3. UV absorbance of iodine in iodized salt sample heated at (a) 20°C (b) 40°C (c) 60°C (d) 80°C

When comparing the peak number of all samples at different temperature, they are not varied far from each other. The absorbance values approach to 4 for every sample. This is due to that the iodized salt that heated only reducing the content of iodine in the sample. The UV absorbance for NaOH shows no peak, however, it absorbance increase indefinitely at band lower than 240 nm. As for HCl, the peak is observed in between 220 nm to 240 nm and then the absorbance increases at band lower than 220 nm. These two solutions were actually mixed with the salt sample to see the absorbance in iodine at different pH condition. However, when comparing the samples at all five different pH condition, the peak values are not varied apart.

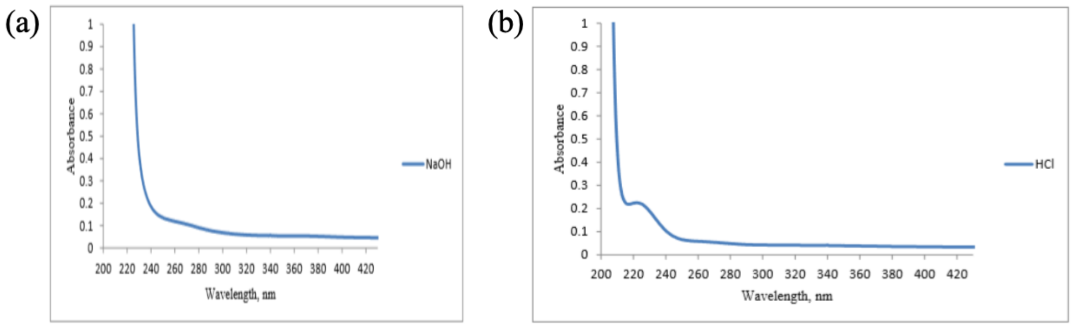

Fig. 4. UV absorbance in 3.0 M (a) NaOH (b) HCl

The result for sample F_2 to J_2 showed the same with the salt samples heated at different temperature. The absorbance values approach to 4 for every sample. This is due to that the iodized salt that mixed with acidic buffer solution only reducing the content of iodine in the sample, meanwhile the alkaline buffer solution maintains the content of iodine in salt.

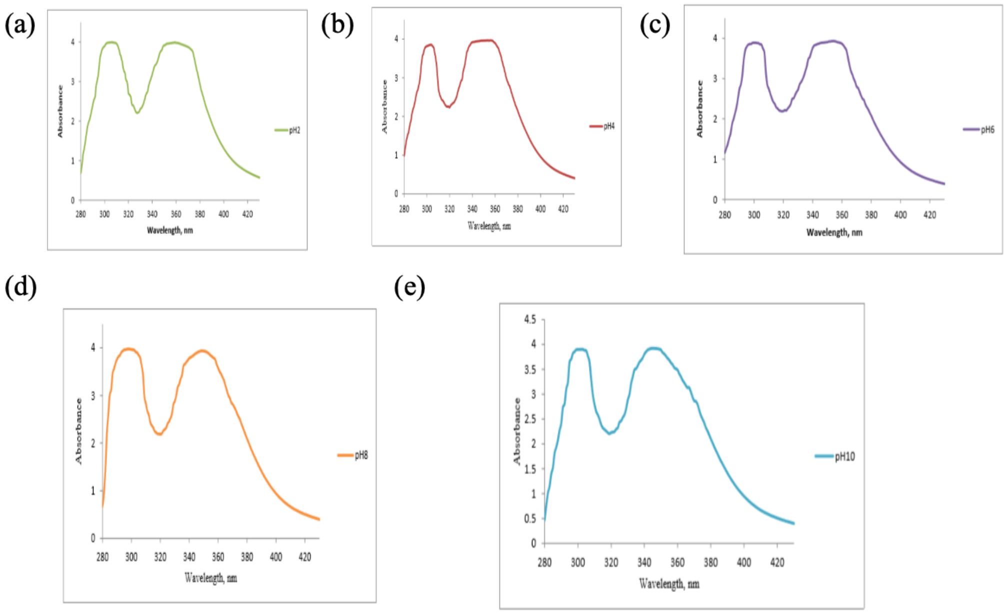

Fig. 5. UV absorbance of iodine in salt sample of (a) pH 2 (b) pH 4 (c) pH 6 (d) pH 8 (e) pH 10

3.3 Infrared Absorbance in Iodine

The Raman spectrum or FTIR spectrum for iodine showed that, the transmittance in irradiated salt sample much higher than in the non-irradiated salt sample. For salt sample at 20°C showed that there are 2 peaks present which is group alkane innon-irradiated salt sample. However, alkane group is absent in the rest of salt sample. For all salt sample, amine and amide group are present. All salt sample form the same group as the IR absorption peaks are of the same band. This is true as the composition of all salt sample are the same except for the matter which some are radiate and some are not. This difference are showed by the transmittance spectrum in Figure 6.

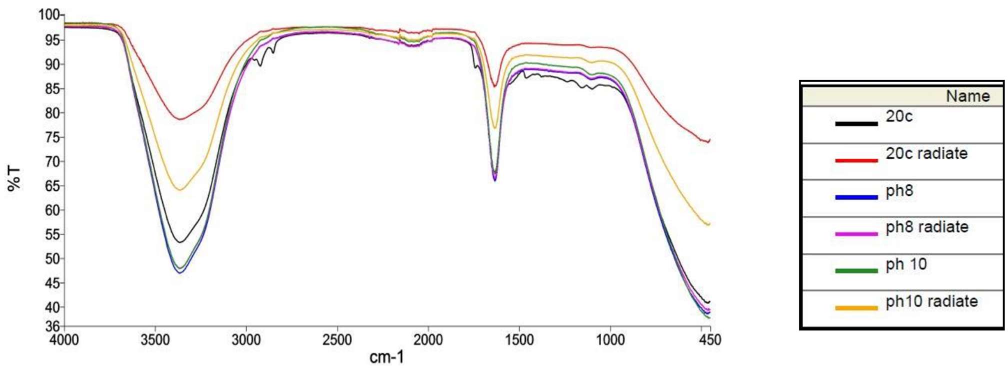

Fig. 6. Infrared transmittance in irradiated and non-irradiated iodine of different salt samples

Table 3
Type of functional group and bond in salt sample

Salt sample	Functional group name	IR absorption peak (cm^{-1})	Type of bond
20°C	Amine	3368	N-H
	Akane, alkyl group	2925.4 and 2885	C-H

	amide	1634.7	C=O
20°C (irradiated)	Amine	3369.4	N-H
	Amide	1637.7	C=O
pH8	Amine	3368.2	pH8
	Amide	1634.4	C=O
pH8 (irradiated)	Amine	3368.3	N-H
	Amide	1634.4	C=O
pH10	Amine	3371	N-H
	Amide	1634.4	C=O
pH10 (irradiated)	Amine	3373.6	N-H
	Amide	1635.5	C=O

3.4 Morphology and Elemental Analysis

The salt samples were coated with pure gold in coater sputtering with thickness of 5 nm. The current was set to 20 mA for 1 minute. Figure 7(a) and figure 7(b) shows the morphology of the non-irradiated and irradiated iodized salt respectively. The size and morphology of both sample shows no difference. The colour of salt sample when radiated with Cs-137 remains the same which is white in colour. The elemental analysis present which shown in Table 4.4.1 of the non- irradiated salt sample are oxygen, sodium and chlorine. Salt is in the form of sodium chloride, thus, it is true as the elements are present when analysed with EDS. The oxygen present indicates that the salt sample used was iodized with iodate. So, the iodized salt is in the form of sodium iodate, $NaIO_3$. However, the iodine, I which should be present as well was not identified may due to the heat from coating process.

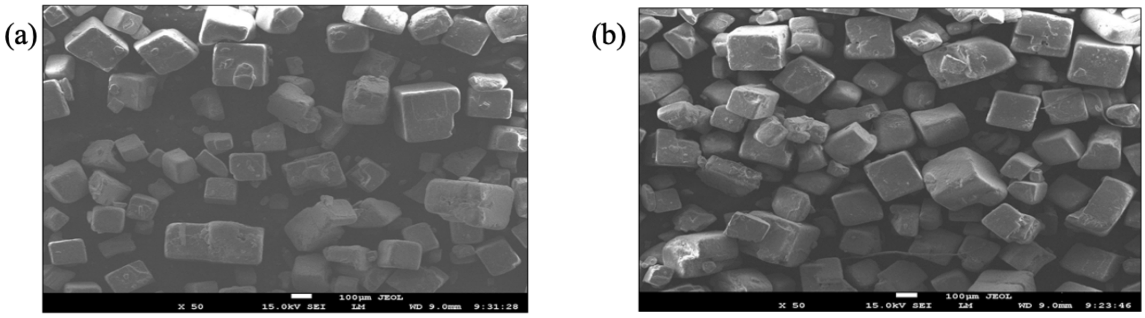

Fig. 7. Morphology of (a) non-radiated iodized salt (b)irradiated iodized salt

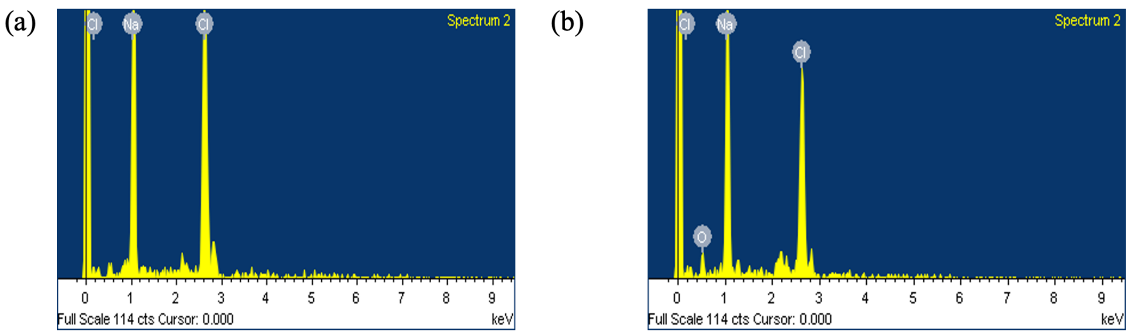

Fig. 8. Elemental analysis spectrum of (a) non-radiated iodized salt (b) irradiated iodized salt

The oxygen present is the lowest peak as the element weight was about 14.3% with atomic of 22.82% which is smaller compared to sodium and chlorine of in the non-irradiated salt sample as shown in Figure 8(a) and Table 4. The element present in the irradiated iodized salt identified no oxygen as shown in Figure 8(b) and Table 5. This can be concluded that the ionizing radiation had dissociate and eliminate oxygen from the salt sample. Therefore, iodate is absence in irradiated iodized salt, thus, it is not suitable for consumption as there is no iodine content in it. Human need iodine forabout 150µg per day.

Table 4
Weight and mass of the element present in non-radiated iodized salt

Element	Weight%	Atomic%
O	14.31	22.82
Na	39.67	44.04
Cl	46.03	33.14
Totals	100.00	100.00

Table 5
Weight and mass of the element present in irradiated iodized salt

Element	Weight%	Atomic%
Na	39.36	50.02
Cl	60.64	49.98
Totals	100.00	100.00

3.5 Iodine Absorption in Thyroid

The iodine concentration at the lowest temperature and the most stable is 39.1 ppm. This means that the iodine concentration for 10 g of iodized salt is 39.1 ppm.The values were compared with the recommended iodization levels by the [17] which is between 40-50 ppm. Therefore the iodized salt sample is safe to use as the iodization in the salt approach to the level given by the WHO. 1 ppm is equal to $0.001 mgg^{-1}$, so the iodine content for 1 gram of salt is equal to 0.0391mg. Since the recommendation of iodine consumption per day is about 150 µg per day, thus the salt sample should be taken about 3.836 mg per day. It is necessary for us to consume adequate amount of iodine for a healthy thyroid gland. Hence, if large amount of iodine is consume more than the requirement, this will then induced hyperthyroidism due to excess iodine.

Table 6
Parts per million of iodine in salt samples

Salt sample	(Volume of sodium thiosulfate used	Parts per million of iodine(ppm)
A_1	3.7	39.1
B_1	3.4	36.0
C_1	3.3	34.9
D_1	3.1	32.8
E_1	2.8	29.6
F_1	2.2	23.3
G_1	3.4	36.0
H_1	3.6	38.1
I_1	3.7	39.1
J_1	3.7	39.1

4. Conclusion

The iodized salt sample shows that the iodine content in it decreases as the temperature increases. The iodine content also decrease as the pH value of the salt solution decreases. The spectrum for UV-Visible shows that the graph of iodine samples has two peaks which at range of maximum wavelength of 288 nm and 350 nm. The peaks formed indicate the formation of tri-iodide, I_3^-. In FTIR spectrum, the salt samples showed several functional groups that exist at certain peak which are amine, alkane and amide. When the iodized salt is analysed using FESEM coupled with EDX, the element presents are oxygen, sodium and chlorine. Thus, the iodized salt is in the form of sodium iodate. However, oxygen had lost in irradiated salt. The iodine content in salt sample follows the given iodization level by WHO which is 39.1 ppm.

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