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Stability of Iodine in Differently iodized Salts

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ABSTRACT

Iodine deficiency is a public health problem worldwide. Iodization of salt is a valuable technique to overcome iodine insufficiency. There are, however, problems in uniform iodization of salt. The study was conducted to investigate comparative stability and uniformity of mixing of iodine in iodized salt fortified with aqueous solution of KIO_3(powder grade salt) or the same compound added additionally in dry form (granular grade salt). **Objective:** To assess the stability of iodine in differently iodized salts. **Methods:** The research study was conducted in the laboratory of Nutrition, Section of the Food science Division of Nuclear institute for Food and Agriculture (NIFA), Peshawar. Salt samples were prepared in a medium sized salt crushing facility at Lahore. These samples were transported in bulk packing to Nuclear Institute for Food and Agriculture (NIFA), Peshawar. Following 3 types of samples will be prepared; powder grade salt fortified with 50 ppm of iodine as KIO_3 solution using drip system, granular grade salt iodized with the same system without additional KIO_3 (this grade of iodized salt always lacks complete and homogeneous iodization and needs addition of more iodine to attain the 50 ppm level) and granular grade salt iodized with additional KIO_3 to make up the total to 50 ppm. The salt samples were packed in high density polyethylene (HDPE) and low density polyethylene (LDPE) packing separately. Analysis was carried out at the initial stage (0day) and subsequently at monthly interval up to fourth month. By standard iodometric titration all collected salt samples were tested for their iodine levels. Data were statistically analyzed using Statistic version 8.0. ANOVA were worked out by completely randomized design with factorial arrangement. **Results:** Means were separated using Tuckey HSD test. The mean moisture contents of salt packed in LDPE and HDPE varied significantly ($P < 0.05$), salt packed in LDPE showed higher average moisture contents than the salts packed in HDPE. Effect of iodization type was also significant ($P<0.05$) on the moisture contents of the salts. Granular salt iodized with drip and additional dry KIO_3 had the highest moisture contents followed by granular salt iodized with drip system and the lowest moisture content was exhibited by powdered salt iodized with drip system only. The mean moisture contents of salt during different storage intervals were significantly ($P < 0.05$) different from each other, except during third and four month, With the salt showing higher average moisture contents during the last month and lowest in the first month. Effect of iodization type was also significant ($P<0.05$) on the moisture contents of the salt. Granular salt iodized with drip and additional dry KIO_3 had the highest moisture contents followed by granular salt iodized with drip system and the lowest moisture content was exhibited by powdered salt iodized with drip system only. The mean moisture contents of salt during different storage periods were significantly ($P < 0.05$) different from each other, except during third and four month. The salt showed higher average moisture contents during the last month and lowest in the first month. Effect of packing material type was also significant ($P<0.05$) on the moisture contents of the salt. The mean moisture contents of salt packed in LDPE and HDPE varied significantly ($P < 0.05$). However, salt packed in LDPE showed higher average moisture contents than that of salts packed in HDPE. **Conclusions:** The powder salt retained iodine better than the other two salts types used. The iodine retention gradually decreased during storage periods. Among the

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packaging material used the salt in low density polyethylene showed higher moisture content. During storage intervals the average moisture content increased. The granular salt (grade II) showed maximum moisture content among the three salt types.

INTRODUCTION

Iodine is a trace element having atomic mass 126.9 atomic mass unit (amu), present in the outer layer of the earth . Iodine is usually but irregularly dispersed in the earth's surroundings as iodide . Iodide is mostly found in the oceans and iodide ions in salt water corrode to form basic iodine which is unstable and evaporates into the environment and proceeds to the earth by rainwater and finishing the cycle in this approach. In 1813, iodine was primary cut off from seaweed followed by thoughts for cure of goiter . Iodine is necessary constituent of the hormones formed by the thyroid gland. The body of healthy person includes 15-20 mg of iodine in which 70-80 percent is present in the thyroid gland.The need of iodine in the diet goes ahead to iodine shortage which consists of a wide spectrum of mental, goiter and rational deficiency including deaf-mutism, cretinism and paralysis . Iodine deficiency disorder can also lead to miscarriages, infant deaths, stunted growth, abortions, spastic diplegia, congenital anomalies and lesser degrees of neurological defects Iodine absence harmfully affects the physical condition of women, quality of life and as well as economic productivity. Youth and adults require iodine in quantity of 150 μg/day. Worldwide two billion individuals taking inadequate iodine ingestion, in which sub-Saharan Africa and south Asia mostly affected. Salt iodization is done for the control of iodine insufficiency in all the countries, which is gainful way to supply to economic and social improvement. In Europe and USA key dietetic sources of iodine are milk and bread. In constant iodine insufficiency, the iodine substance of the thyroid may fall to less than 20 μg. In iodine sufficient region, the adult thyroid catch about 60 μg of iodine per/day to equilibrium losses and keep amalgamation of thyroid hormone. Salt is a perfect transporter of micronutrients in sight of its almost uniform and universal regional utilization Iodized oil and iodized salt are appropriate for the alteration of iodine insufficiency on a mass weighing machine. For 3-5 years cruel iodine shortage can be corrected by a single dosage of iodized oil Iodized-oil injections are rapidly effective and are recommended as an emergency measure where there is severe deficiency Salt fortification with iodine is stable, inexpensive and effective way of guaranteed enough iodine ingestion. Iodization of salt is a valuable technique towards falling iodine lacking in populations. It is a widespread foodstuff, ingestion is seasonally constant and easily dispersed .

METHODS

Reaction 1: Free Iodine is liberated from salt iodate

Addition of H_2SO_4 in iodated salt sample releases of free iodine present in the salt sample.

KI is added in larger amount to solubilize the iodine that is set free, which isn't soluble in pure water under normal conditions.

Reaction 2: Free Iodine titrated with thiosulfate

In the titration phase sodium thiosulfate consumed the iodine that are freely available in salt sample. The amount of the iodine that is set free from the salt depends on the quantity of thiosulfate used.

Starch is added and it acts as indicator in this reaction, results in production of blue color after reaction with freely available iodine. When added near the end of the titration the disappearance of blue color with moreover titration shows that all of the iodine that has been set free and left been used by thiosulfate.

Reagent Preparation

0.005M Sodium thiosulfate (Na2S2O3), 2N Sulfuric acid (H2SO4), 10% Potassium iodide (KI), Starch indicator solution were Used.

Calculation: $\% \text{ Moisture} = \frac{\text{loss in weight of sample}}{\text{Weight of sample}} \times 100$

Statistical Analysis

Data were statistically analyzed using Statistic version 8.0. ANOVA were worked out by completely randomized design with three factorial arrangement. Means were separated using Tuckey HSD test.

RESULTS

Moisture contents of differently iodized salt packed in two types of packaging materials: The means concerning the moisture content of various salts stored in low density polyethylene (LDPE) and high density polyethylene HDPE are presented in Table 1.The mean moisture contents of salt packed in LDPE and HDPE varied significantly ($P < 0.05$), salt packed in LDPE showed higher average moisture contents than the salts packed in HDPE. Effect of iodization type was also significant ($P<0.05$) on the moisture contents of the salts. Granular salt iodized with drip and additional dry KIO_3 had the highest moisture contents followed by granular salt iodized with drip system and the lowest moisture content was exhibited by powdered salt iodized with drip system only.

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Packing	Salt types			Means
	Powdered	Granular (Grade I)	Granular (Grade II)	
LDPE	0.50 ± 0.14^{d}	1.14 ± 0.38^{a}	1.10 ± 0.16^{ab}	0.91^{a}
HDPE	0.65 ± 0.14^{c}	0.71 ± 0.25^{c}	0.98 ± 0.22^{b}	0.78^{b}
Means	0.58^{c}	0.93^{b}	1.04^{a}	

Table 1: Moisture contents (%) of differently iodized salt packed in two types of packaging
Means with different superscript are significantly different at p< 0.05.
LDPE= Low density polyethylene, HDPE= High density polyethylene

Moisture contents of differently iodized salt during different storage periods : The mean moisture content of differently iodized salt and at different storage intervals are presented in Table 2. The mean moisture contents of salt during different storage intervals were significantly (P < 0.05) different from each other, except during third and four month, With the salt showing higher average moisture contents during the last month and lowest in the first month. Effect of iodization type was also significant (P<0.05) on the moisture contents of the salt. Granular salt iodized with drip and additional dry KIO3 had the highest moisture contents followed by granular salt iodized with drip system and the lowest moisture content was exhibited by powdered salt iodized with drip system only.

Storage	Salt type			Means
	Powder	Granular(Grade I)	Granular(Grade II)	
0	0.16 ± 0.02^{g}	0.44 ± 0.08^{f}	0.85 ± 0.15^{cde}	0.48^{d}
1	0.23 ± 0.04^{g}	0.83 ± 0.35^{de}	0.95 ± 0.25^{cde}	0.67^{c}
2	0.52 ± 0.18^{f}	0.96 ± 0.37^{cd}	1.02 ± 0.12^{bc}	0.83^{b}
3	0.77 ± 0.32^{e}	1.18 ± 0.23^{ab}	1.15 ± 0.12^{ab}	1.03^{a}
4	0.81 ± 0.33^{de}	1.23 ± 0.25^{a}	1.22 ± 0.04^{a}	1.09^{a}
Mean	0.50^{c}	0.93^{b}	1.04^{a}	

Table 2: Moisture contents (%) of differently iodized salt during different storage periods

Moisture contents of salt packed in different packaging materials during different storage periods: The mean values of moisture content of various salt stored in low density polyethylene (LDPE) and high density polyethylene (HDPE) during different storage intervals are presented in Table 3.The mean moisture contents of salt during different storage periods were significantly (P < 0.05) different from each other, except during third and four month. The salt showed higher average moisture contents during the last month and lowest in the first month. Effect of packing material type was also significant (P<0.05) on the moisture contents of the salt. The mean moisture contents of salt packed in LDPE and HDPE varied significantly (P < 0.05). However, salt packed in LDPE showed higher average moisture contents than that of salts packed in HDPE.

Storage	Packing		Mean
	LDPE	HDPE	
0	0.53 ± 0.35^{d}	$0.44^{D}\pm0.26^{d}$	0.48^{d}
1	0.80 ± 0.47^{b}	$0.54^{CD}\pm0.28^{cd}$	0.67^{c}
2	0.93 ± 0.43^{b}	$0.74^{C}\pm0.14^{c}$	0.83^{b}
3	1.00 ± 0.42^{a}	$1.05^{A}\pm0.09^{a}$	1.03^{a}
4	1.05 ± 0.42^{a}	$1.12^{A}\pm0.11^{a}$	1.09^{a}
Mean	0.86^{a}	0.78^{b}	

Table 3: Moisture contents (%) of salt packed in different packaging materials during different storage periods
Means with different superscript are significantly different at p< 0.05.

Moisture contents of differently iodized salt packed in two types of packaging materials during different storage periods: The moisture content of granular salt grade I packed in LDPE during initial analysis was significantly different from first and second storage periods and non-significantly different from third and fourth month (Table 4).

Packaging type	Storage (Months)	Salt type			
		Powder s alt	Granular salt Grade I	Granular salt Grade II	Mean
LDPE	0	0.15 ± 0.01^{n}	0.44 ± 0.08^{jklmn}	0.74 ± 0.11^{ghij}	0.53^{d}
	1	0.26 ± 0.05^{lmn}	0.51 ± 0.05^{jkl}	0.85 ± 0.22^{fghi}	0.80^{b}
	2	0.68 ± 0.03^{hij}	0.63 ± 0.08^{ijk}	0.91 ± 0.03^{efghi}	0.93^{b}
	3	1.05 ± 0.12^{cdef}	0.98 ± 0.03^{defg}	1.13 ± 0.05^{bcdef}	1.00^{a}
	4	1.11 ± 0.02^{bcdef}	1.01 ± 0.08^{cdefg}	1.25 ± 0.01^{abcd}	1.05^{a}
HDPE	0	0.18 ± 0.02^{n}	0.44 ± 0.10^{jklmn}	0.96 ± 0.07^{defgh}	0.44^{d}
	1	0.21 ± 0.02^{mn}	1.14 ± 0.01^{bcdef}	1.05 ± 0.28^{cdef}	0.54^{cd}
	2	0.37 ± 0.04^{klmn}	1.29 ± 0.07^{abc}	1.12 ± 0.06^{bcdef}	0.74^{c}
	3	0.48 ± 0.05^{jklm}	1.37 ± 0.10^{ab}	1.16 ± 0.19^{abcde}	1.05^{a}
	4	0.51 ± 0.04^{jkl}	1.45 ± 0.02^{a}	1.19 ± 0.02^{abcde}	1.12^{a}
Mean		0.51^{c}	0.93^{b}	1.04^{a}	

Table 4: Moisture contents (%) of differently iodized salt packed in two types of packaging materials during different storage periods
Means with different superscript are significantly different at p< 0.05.
LDPE= Low density polyethylene, HDPE= High density polyethylene

Iodine contents of differently iodized salt packed in two types of packaging materials: The means concerning the iodine content of various salts stored in low density polyethylene (LDLE) and HDPE are presented in Table 5. The mean iodine contents of salt packed in LDPE and HDPE varied significantly (P < 0.05), salt packed in HDPE showed higher average iodine contents than the salts packed in LDPE. Effect of iodization type was also significant (P<0.05) on the iodine contents of the salts. Powdered salt iodized with drip system had the highest iodine contents followed by granular salt iodized with drip system only and the lowest iodine content was exhibited by the granular salt iodized with drip additional dry KIO3.

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Packing	Salt type			Means
	Powder	Granular(Grade I)	Granular(Grade II)	
LDPE	28.03± 1.15^{b}	27.22± 1.63^{c}	27.21± 1.41^{c}	27.48^{b}
HDPE	28.89± 0.75^{a}	28.19± 1.01^{b}	27.41± 1.18^{c}	28.16^{a}
Means	28.46^{a}	27.70^{b}	27.31^{c}	

Table 5: Iodine contents of differently iodized salt packed in two types of packaging

Means with different superscript are significantly different at p< 0.05. LDPE= Low density polyethylene, HDPE= High density polyethylene

Iodine contents of differently iodized salt during different storage periods : The mean concerning the iodine content of differently iodized salt and during different storage period are presented in Table 6. The mean iodine contents of salt during different storage periods were significantly (P <0.05) different from each other.

Storage	Salt type			Means
	Powder	Granular(Grade I)	Granular(Grade II)	
0	29.97±0.05^{a}	29.60±0.14^{a}	29.00±0.20^{b}	29.52^{a}
1	28.64±0.56^{bc}	28.45±0.50^{c}	28.10±0.25^{cd}	28.40^{b}
2	28.45±0.57^{c}	27.67±0.49^{def}	27.30±0.21^{f}	27.80^{c}
3	27.85±0.65^{de}	26.75±0.71^{g}	26.74±0.31^{g}	27.12^{d}
4	27.38±0.82^{ef}	26.03±1.11^{h}	25.40±0.56^{i}	26.27^{e}
Mean	28.46^{a}	27.70^{b}	27.31^{c}	

Table 6: Iodine contents of differently iodized salt during different storage periods

Iodine contents of salt packed in different packaging materials during different storage periods: The mean concerning the iodine content of various salt stored in low density polyethylene (LDPE) and HDPE and during different storage period are presented in Table 7. The mean iodine contents of salt during different storage intervals were significantly (P <0.05) different from each other.

Storage	Packing		Mean
	LDPE	HDPE	
0	29.52± 0.45^{a}	29.52± 0.44^{a}	29.52^{a}
1	28.00± 0.16^{c}	28.78± 0.44^{b}	28.40^{b}
2	27.54± 0.44^{d}	28.08± 0.73^{c}	27.80^{c}
3	26.77± 0.57^{e}	27.46± 0.80^{d}	27.11^{d}
4	25.58± 0.92^{f}	26.96± 1.00^{e}	26.27^{e}
Mean	27.48^{b}	28.16^{a}	

Table 7: Iodine contents of salt packed in different packaging materials during different storage periods

Means with different superscript are significantly different at p< 0.05.

LDPE= Low density polyethylene, HDPE= High density polyethylene

Retention contents of differently iodized salt packed in two types of packaging materials: The means concerning the retention content of various salts stored in low density polyethylene (LDPE) and HDPE are presented in Table 9. The mean retention contents of salt packed in LDPE and HDPE varied significantly (P<0.05), salt packed in HDPE showed higher average retention content than the salts packed in LDPE [7]. studied the effects of packaging materials on the stability of iodine in iodized salt. He stored the iodized salt in three types of packaging materials HDPE, LDPE and WHDPE. The obtained results showed HDPE retained iodine from iodized salt better than the two other packaging materials used. The percentage of iodine lost at the six month was 22.55 %, (stored in LDPE), 15.12 % (stored in HDPE) and 23.88 % (stored in WHDPE) [19].

Packing	Salt			Mean
	Powder	Granular (Grade I)	Granular (Grade II)	
LDP	91.99±2.21bc	89.96±4.12d	92.27±4.09c	91.41b
EHDPE	95.57±1.92a	94.03±2.65ab	93.14±3.25bc	94.25a
Mean	93.78a	92.00b	92.71b	

Table 9. Retention contents (%) of differently iodized salt packed in two types of packaging.

Means with different superscript are significantly different at p< 0.05.

LDPE= Low density polyethylene, HDPE= High density polyethylene

Retention content of salt packed in different packaging materials during different storage periods: The means concerning the retention content of salts stored in low density polyethylene (LDPE) and HDPE during different storage intervals are presented in Table 9. The mean retention contents of salt packed in LDPE and HDPE varied significantly (P<0.05), salt packed in HDPE showed higher average retention content than the salts packed in LDPE. The salt showing higher average retention level during the 1st month and lowest in the fourth month.

Storage	Packing		Mean
	LDPE	HDPE	
1	95.04± 1.20^{b}	97.50± 0.65^{a}	96.27^{a}
2	93.29± 1.34^{bc}	95.09± 1.26^{b}	94.19^{b}
3	90.69± 2.04^{e}	93.00± 1.56^{cd}	91.84^{c}
4	86.62± 2.31^{f}	91.31± 2.21^{de}	88.96^{d}
Mean	91.41^{b}	94.22^{a}	

Table 10: Retention content (%) of salt packed in different packaging materials during different storage periods

Means with different superscript are significantly different at p< 0.05.

LDPE= Low density polyethylene, HDPE= High density polyethylene

Retention contents of differently iodized salt during different storage periods: The means concerning the retention content of differently iodized salts during different storage intervals are presented in Table 11.The mean retention contents of salt during different storage periods were significantly (p<0.05) different from each other. The salt showing higher average retention level during the 1st month and lowest in the fourth month. There were non-significant difference in the retention content of granular salt iodized with drip system and granular salt iodized with drip and additional dry KIO3. The highest

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retention was exhibited by the powder salt followed by granular salt iodized with drip and additional dry KIO3 system which is then followed by granular salt iodized with drip system only.

Storage	Salt			Mean
	Powder	Granular (Grade I)	Granular (Grad e II)	
1	95.73± 1.88 ^{abc}	96.16± 1.79 ^{ab}	96.91± 0.92 ^{a}	96.27 ^{a}
2	94.94± 1.90 ^{abcd}	93.50± 1.84 ^{cde}	94.13± 0.32 ^{bcde}	94.19 ^{b}
3	92.94± 2.19 ^{de}	90.38± 2.27 ^{fg}	92.21± 1.10 ^{ef}	91.84 ^{c}
4	91.38± 2.77 ^{def}	87.94± 3.81 ^{gh}	87.57± 1.81 ^{h}	88.96 ^{d}
Mean	93.75 ^{a}	92.00 ^{b}	92.71 ^{b}	

Table 11: Retention contents (%) of differently iodized salt during different storage periods

Retention contents of differently iodized salt packed in two types of packaging materials during different storage periods: The retention content of granular salt grade II packed in HDPE during first storage period was significantly different from third and fourth storage period and non-significantly different from second storage period. The retention content of granular salt grade II was non-significantly different from powdered and granular salt grade I. He stored the iodized salt in three types of packaging materials HDPE, LDPE and WHDPE.

Packaging type	Storage (Months)	Salt type			Mean
		Powder salt	Granular salt Grade I	Granular salt Grade II	
LDPE	1	94.10±0.69 ^{abcde}	94.69±0.7 ^{abcd}	96.32±0.92 ^{abc}	95.04 ^{b}
	2	93.44±1.35 ^{bcde}	92.20±1.48 ^{efg}	94.22±0.25 ^{abcde}	93.29 ^{bc}
	3	91.10±1.34 ^{efg}	88.40±0.59 ^{ghi}	92.58±1.04 ^{cdef}	90.69 ^{e}
	4	89.32 ±0.98 ^{efg}	84.57±1.47 ^{i}	85.98 ^{HI}±0.55 ^{hi}	86.62 ^{f}
HDPE	1	97.35±0.66 ^{ab}	97.64±1.01 ^{a}	97.50 ^{A}±0.44 ^{a}	97.50 ^{a}
	2	96.44±0.69 ^{abc}	94.80±1.08 ^{abcde}	94.03±0.41 ^{abcde}	95.09 ^{b}
	3	94.77±0.38 ^{abcde}	92.36±0.88 ^{defg}	91.85±1.24 ^{efg}	93.00 ^{cd}
	4	93.44±2.34 ^{bcde}	91.31±0.35 ^{efg}	89.17±0.48 ^{fgh}	91.3 ^{de}
	Mean	93.75 ^{a}	92.00 ^{b}	92.71 ^{b}	

Table 12: Retention contents (%) of differently iodized salt packed in two types of packaging materials during different storage periods

Means with different superscript are significantly different at $p < 0.05$.

LDPE= Low density polyethylene, HDPE= High density polyethylene

DISCUSSION

Granular salt iodized with drip and additional dry KIO3 had the highest moisture contents followed by granular salt iodized with drip system and the lowest moisture content was exhibited by powdered salt iodized with drip system only. Diosady and Mannar examined the stability of iodine in typical salts available in 12 countries in a controlled laboratory setting, at high temperature (40°C) and controlled humidity (60 or 100%) for periods up to 12 months [15]. They stored the salt samples in three different types of packaging materials i.e woven high density polyethylene (HDPE) bags, low-density polyethylene (LDPE) film bags, and in open plastic containers. They found that the Packaging affected the levels of moisture present in salt samples. The LDPE film provided an excellent moisture barrier, and maintained the total moisture content in each bag approximately constant. In open containers the absorbed and condensed moisture was retained and contributed to the instability of iodine. Woven HDPE bags allow the flow of air and moisture, behaved similarly to the open containers. Another study assessed the effect of salt moisture content, relative humidity and packaging materials on the stability of iodine. In controlled laboratory setting he examined the typical salts collected from different salt industries for period of six months. The salts containing the higher moisture content lost iodine rapidly. The unrefined salt containing 14% moisture retained only 17.85% iodine of its original after six months of storage. Higher the percentage of iodine retention in salt if lower the moisture content. Salt containing higher moisture content lost iodine at higher rate than the salt contained less moisture content [9]. Haque (2009) assessed the effect of salt moisture content, relative humidity and packaging materials on the stability of iodine. In controlled laboratory setting he examined the typical salts collected from different salt industries for period of six months. The salts containing the higher moisture content lost iodine rapidly. The unrefined salt containing 14% moisture retained only 17.85% iodine of its original after six months of storage. Higher the percentage of iodine retention in salt if lower the moisture content. Salt containing higher moisture content lost iodine at higher rate than the salt contained less moisture content. The packaging materials affect the level of moisture present in salt. The absorbed and condensed moisture was retained in the open container and resulted in instability of iodine, woven high density polyethylene also allowed the flow of air and moisture resulted in loss of iodine. The low density polyethylene provided an excellent moisture barrier [21]. The moisture content of granular salt grade I was significantly different from powdered salt and non-significantly different granular salt grade II in our study. While the moisture content of granular salt grade I packed in LDPE during fourth month was significantly different from the other storage periods and non-significantly different from the third month [10]. The moisture content of granular salt grade I was non-significantly different from powdered and granular salt grade II [11]. The moisture content of granular salt grade II was significantly different from powdered salt and non-significantly different from granular salt grade I. The moisture content of granular salt grade II packed in HDPE during fourth month was non-significantly different from

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other storage periods. The moisture content of granular salt grade II was significantly different from powdered salt and non-significantly different from granular salt grade I [12]. examined the stability of iodine in typical salts available in 12 countries in a controlled laboratory setting, at high temperature (40°C) and controlled humidity (60 or 100%) for periods up to 12 months [13]. They stored the salt samples in three different types of packaging materials i.e woven high density polyethylene (HDPE) bags, low-density polyethylene (LDPE) film bags, and in open plastic containers [14]. They found that the Packaging affected the levels of moisture present in salt samples. The LDPE film provided an excellent moisture barrier, and maintained the total moisture content in each bag approximately constant. In open containers the absorbed and condensed moisture was retained and contributed to the instability of iodine. Woven HDPE bags allow the flow of air and moisture, behaved similarly to the open containers. A study assessed the effect of salt moisture content, relative humidity and packaging materials on the stability of iodine. The low density polyethylene provided an excellent moisture barrier [15]. Effect of iodization type was also significant ($P<0.05$) on the iodine contents of the salts. Powdered salt iodized with drip system had the highest iodine contents followed by granular salt iodized with drip system only and the lowest iodine content was exhibited by the granular salt iodized with drip additional dry KIO_3 while a research studied the effects of packaging materials on the stability of iodine in iodized salt. He stored the iodized salt in three types of packaging materials HDPE, LDPE and WHDPE [16]. The mean iodine contents of salt during different storage periods were significantly ($P <0.05$) different from each other. Ranganathan and Narasinga [16] observed iodine losses of about 20% in iodized salt after the period of 12 months. Similarly another analysis performed by them on five types of Indian salt (including powder and crystal) they found iodine losses after 3 months 28-51 %, after 6 months 35-52 %, and up to 66 % after 12 months of period showing losses of iodine over the period of time. Losses from powder salt appeared lower. Similar results were also obtained in our study. A study observed the effect of storage and exposure of salt in Ghana. They observed 10% to 100% losses in iodine levels depending upon storage conditions indicating that losses of iodine occur during storage [17]. The mean iodine contents of salt during different storage intervals were significantly ($P <0.05$) different from each other. The salt showing highest average iodine content during the initial analysis and lowest in the last (fourth month). The mean iodine contents of salt packed in LDPE and HDPE varied significantly ($P < 0.05$), salt packed in HDPE showed higher average iodine contents than that of salts packed in LDPE [18]. Hence WHDPE lost more iodine within six months compared to HDPE and LDPE. Beyene (2010) studied the effects of storage time and packaging materials on the mean iodine content of iodized salt. He stored the iodized salt in three types of packaging materials HDPE, LDPE and WHDPE. Similar results were also obtained in our study that HDPE retained iodine from iodized salt better than the other packaging material used i.e LDPE [19]. Another study found to decrease during storage, the powdered salt and brown crystal salt had iodine in the recommended level. On the contrary, white crystal salt contained only half (7 ppm) that recommended at the retail level (15 ppm). Similarly in our study the iodine retention was maximum in powder salt followed by other two types of salt. He conducted study on iodine losses in iodized salt following different storage periods. They estimated the Iodine retention in three types of iodized salt, powdered salt, white crystal and brown crystal salt at an interval of 15 days following commonly practiced storage methods. Powdered salt had maximum iodine retention (91.16%) followed by brown crystal salt (84.24%) and white crystal salt (76.71%) [20].

CONCLUSION

The iodine content of powder salt was high. During storage period the iodine content decreased. Among the packaging materials used the iodine content was maximum in high density polyethylene. The iodine retention was maximum in high density polyethylene. The powder salt retained iodine better than the other two salts types used. The iodine retention gradually decreased during storage periods. Among the packaging material used the salt in low density polyethylene showed higher moisture content. During storage intervals the average moisture content increased. The granular salt (grade II) showed maximum moisture content among the three salt types.

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