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Understanding Iodine Stabilizers in Iodized Salt

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Abstract— **A pillar of worldwide initiatives to help tackle iodine deficiency disorders (IDDs) is iodized salt. Still, the instability of iodine is a major obstacle since during production, storage and cooking it can be lost and thereby reducing the potency of iodized salt. Stabilizers like dextrose, sodium thiosulfate, and potassium iodate are crucial for keeping iodine stable in salts. Emphasizing their mechanisms of action, uses, and public health connotations, this review examines the chemistry of iodine stabilizers in iodized salts. Research have shown that stabilizers make weak complexes or redox interactions with iodine, therefore increasing its salts retention. Particularly in nations or areas with high heat and humidity, the use of stabilizers in iodized salt could greatly increase iodine bioavailability. This study emphasizes the significance and chemistry of iodine stabilizers in iodized salt to guarantee that edible salt iodine fortification initiatives succeed.**

Index Terms— **Iodine, Stability, Stabilizer, Iodine Deficiency, Potassium Iodide, Potassium Iodate.**

I. Introduction

Some general human health and thyroid activity depend on iodine. Millions of people worldwide are suffering from iodine deficiency disorders (IDDs) including goiter, cretinism, and cognitive impairment (Siddiq et al, 2022). Salt iodization is now being carried out in line with the World Health Organization's universal salt iodization campaign (Zhao & van der Haar, 2004) and remains seen as the most economical, safest, effective, and long-term solution to iodine deficiency disorder (IDD). Among infants, young children, expectant and nursing mothers, iodine is a crucial mineral needed for correct physical and intellectual development. Infant iodine deficiency slows brain development, which in turn causes stunted growth and delayed development (WHO, 2004 and 2007). Pregnant women risk stillbirths and miscarriage (Delong, 1994). The most convenient and least expensive means of avoiding iodine deficiency is to use properly iodized salt when cooking at home (Wu et al., 2002). Still, iodine's volatility and environmental sensitivity—including heat and humidity—can cause great losses during cooking, storage and processing (Deresa et al., 2023). Iodized salt contains iodine stabilizers to help with iodine retention and absorption whereby this difficulty is dealt with.

Ariyo et al (2023) mentioned that universal salt iodization was considered largely successful in Nigeria following adequate fortification of over 90% of domestic salt within ten years of implementation. Studies have found continuous compliance with the recommended level of 30ppm in some Nigerian retail common branded salts, however, iodine is either completely absent or lower than recommended in non-branded salts (Etesin et al, 2017). Interestingly, the market share of non-branded/non-iodized salt has been on the rise in Nigeria from less than five percent in 1994 to about 25 percent presently (Ariyo et al, 2023). Presently, West Africa including Nigeria has the lowest coverage of iodized salt and about 25% of the population consumes salt without any iodine (United Nations Children's Fund, 2019). Studies by Umenwanne and Akinyele (2000) have put the proportion of household consuming salt without iodine at about 30 percent while Zimmermann and Andersson (2020) reported global compliance to salt iodization program and stated out that Nigeria is lacking in data in this regard.

Iodine (I) is the heaviest stable halogen in the periodic table, with atomic number 53. It is a non-metallic element that exists as a diatomic molecule (I_2) in its pure form. Iodine is unique among the halogens due to its solid state at room temperature and its characteristic purple vapor. Its chemistry is marked by its ability to form a wide range of compounds, including iodides, iodates, and polyiodides, as well as its role in redox reactions and complex formation. Iodine is a lustrous, purple-black solid at room temperature. It sublimes readily to form a violet gas, and it is sparingly soluble in water but dissolves well in organic solvents like ethanol and chloroform. Iodine is less reactive than other halogens (fluorine, chlorine, bromine) but still participates in a variety of chemical reactions. It has an electronegativity of 2.66 and can exist in oxidation states ranging from -1 to +7. Iodine forms diatomic molecules (I_2) and can interact with other elements to form iodides (I^-), iodates (IO_3^-), and periodates (IO_4^-). Iodine can act as both an oxidizing and reducing agent. Examples are the reduction of iodine to iodide in the presence of sodium thiosulfate and the oxidation of iodide to iodine by chlorine.

Ekott and Etukudo (2025 B) stated that iodine as a halogen and substance that sublimes, losses of iodine were not unexpected over time, and there have been several published studies on the stability of iodine in salt. Diosady et al (1997) stated that high humidity reduces stability, while the use of a good vapour barrier, which prevents the penetration of moisture and the evaporation of iodine, clearly improved the stability of iodine in iodized salts. Ekott and Etukudo (2025) analysed the work of Diosady *et al* (1998) who studied trace components of iodized salt samples and correlate the trace components with the observed iodine stability. Ekott and Etukudo (2024) found no consistent correlation between iodine stability and specific impurities in their study. Their analysis revealed complex interactions between salt impurities and potassium iodate, with multiple competing reactions occurring simultaneously. While the data suggested a tendency toward reduced iodine retention with higher magnesium and sulphur content, the anticipated protective effect of carbonates was not evident at the concentrations present in the tested samples. Ekott and Etukudo (2019) conducted studies using iodometric titration and reported that salts consume thiosulfate equivalent to the

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level of iodine present in it. Ekott and Etukudo (2019) found that thiosulfate consumption rates in two salt brands at room temperature strongly correlated with iodine stability. Habib *et al* (2023) conducted studies on more salt brands and reported sharp decrease in iodine concentration over a period of 50 hours (about 3 days) from production.

In most developing countries salt is sold in both in consumer packages of up to 2 kg and in bulk. Jabbour et al (2015) and Diosady et al (1997) studied the impact of storage condition on iodine stability in salt and reported that solid, non-woven polymer bags were the best moisture barriers and, if properly sealed and intact, would maintain the moisture level of the salt throughout the distribution system, thus minimizing the loss of iodine following the absorption of moisture and subsequent chemical reactions.

For effective reduction of iodine losses, recommendation for storage of salt in an effective moisture barrier, such as solid low-density polyethylene (LDPE) bags have been made by researchers such as Diosady *et al* (1998), Ekott & Etukudo (2024), and Ekott & Etukudo (2025 A). They revealed that with solid low-density polyethylene packaging, the losses of iodine from salt stored for up to six months can be kept in the range of 10% to 15%, but the losses generally increase significantly over the next six months of storage, and therefore the time required for distribution, sale and consumption should be minimized to ensure effective use of the added iodine. These findings aligned with the recent studies by Habib *et al* (2023) who reported that loss of iodine content in packed salt was increasing with duration of storage. Rigorous moisture management in iodized salt throughout manufacturing and distribution by improved processing, packaging, and storage is critical to the stability of the added iodine (Habib *et al,* 2023). In order to make allowances for the probable losses of iodine, National programs must quantify iodine losses in domestically produced salt under real storage conditions, since packaging quality directly affects degradation rates.

Maramag *et al* (2007) conducted elaborate studies on different salt samples and reported that all salt samples lost iodine over 4 weeks of exposure in an open heap or repacked in low-density polyethylene bags; the loss ranged from less than 1% to 25% for aged salt and from 5% to 34% for fresh. Iodine loss was also observed in the stored salt over the 6-month storage period, ranging from 9% to 24% for aged salt and from 33% to 49% for fresh salt. The iodine reduction rate was higher in fresh salt than in aged salt after 4 weeks of exposure and 1 month of storage. Maramag *et al* (2007) suggests that consuming an unaged, iodized salt offers a better opportunity for higher iodine concentration. This calls for redetermination of the shelf life of iodized salt. This awareness is necessary as highlighted by Idem, Ukoh and Ekott (2017) in the case of diabetes mellitus; Etukudo, Ekott and Ukpanah (2024) in the case of Potassium Bromate in Breads and Etukudo, Ekott and Okon (2024) in the case of Potassium Iodate in Breads.

II. Chemical Forms of Iodine and Stability Issues

Salt iodization program uses iodine in the form of potassium iodide (KI) or potassium iodate (KIO_3). These compounds of iodine are used for salt fortification due to their good iodine availability and low cost (Ekott and Etukudo, 2017). May *et al* (1990) and Etesin *et al* (2017) have reported that KI is highly soluble and easily absorbed, it is prone to oxidation to molecular iodine (I_2), which can volatilize, leading to significant iodine loss. The report added that KIO_3, being a more stable oxidized form, is often preferred due to its higher resistance to environmental degradation and better retention in salt. Diosady et al (1998) and Deresa *et al (*2023) worked extensively on moisture, light exposure, high temperature, and impurities (e.g., metal ions) act as catalysts in the degradation of iodine compounds and reported that these factors influence iodine stability in salts. They further reported that prolonged storage and poor packaging conditions exacerbate iodine loss, reducing the nutritional efficacy of iodized salt (Siddiq *et al,* 2022). Understanding these factors is crucial for improving iodine retention strategies. The application of iodine stabilizers has help improve the stability of iodine with reports shown in tables 1. Reports also show that KI in salt can lose **>50% iodine in 6 months** under poor storage without stabilizers. **However, with KIO_3**, losses are **<10% over 2 years** even in humid climates. Table 1 compares potassium iodide with potassium iodate.

Table 1. Comparing Potassium Iodide with Potassium Iodate

Factor	**KI (Potassium Iodide)**	**KIO_3 (Potassium Iodate)**
Oxidation Risk	High (converts to I_2 and evaporates)	Low (remains stable)
Humidity Sensitivity	Degrades faster in moist conditions	More resistant
pH Sensitivity	Unstable in acidic conditions	Stable at varying pH
Cost	Cheaper	Slightly more expensive
Global Usage	Common in the past	Now preferred by WHO & most countries

III. Mechanisms and Chemistry of Iodine Stabilizers

By preventing iodine oxidation, complexation with metal ions, and pH-induced degradation, iodine stabilizers function in maintaining the stability of iodine in iodized salt (Akpan and Udoh, 2029). Stabilizers can be categorized as reducing agents, chelating agents, pH regulators, **sequestrants and complexing agents**. **The chemistry of each of the category differs but all aimed** to mitigate iodine loss. The following subsections describe the mechanisms by which these stabilizers operate.

3.1 Role of Reducing Agents

Reducing agents such as sodium thiosulfates ($Na_2S_2O_3^{2-}$) and ascorbic acid ($C_6H_8O_6$), function by preventing the oxidation of iodide to volatile molecular iodine (I_2). The reaction mechanism typically involves the reduction of I_2

back to I^-, preventing iodine loss. In the presence of excess oxygen, iodide oxidation occurs more readily, which can be countered by incorporating antioxidants (Etesin *et al,* 2017; Mendham *et al,* 2000).

$$2I^- + O_2 + 4H^+ \rightarrow I_2 + 2H_2O \quad [1]$$

Reducing agents reverse this oxidation (Equation 1) by converting I_2 back to I^-, as shown in equation 2.

$$I_2 + 2e^- \rightarrow 2I^- \quad [2]$$

Equation 2 helps maintain the bioavailability of iodide form in salt. This implies that in the presence of excess oxygen, iodide oxidation occurs more readily, which can be countered by incorporating antioxidants.

3.2 Complexation with Organic Compounds

Pesek *et al* (2024) reported that Dextrose and other **Polysaccharides** form weak complexes with iodine species through hydrogen bonding and charge-transfer interactions, reducing the volatility of iodine and thereby enhancing its retention in salt matrices. Dextrose stabilizer prevents the formation of free iodine which may vaporize from the salt. These salt additives, combined with appropriate packaging materials, ensures that iodized salt retains its ability to be used for combating IDDs over a long period of time (Alexa, 2013).

$$Dextrose + I_2 \rightarrow Dextose\text{-}I_2\ (weak\ complex) \quad [3]$$

This process stabilizes iodine and extends shelf-life under humid conditions by preventing excessive sublimation and degradation. Ekott and Etukudo (2017) reported that the hydroxyl groups in dextrose and other sugars interact with iodine, creating transient bonds that mitigate iodine loss. Furthermore, polysaccharides such as starch and cellulose derivatives have been explored as stabilizing agents, offering additional binding sites for iodine molecules and improving retention rates. Amino acids, particularly those containing sulfur or nitrogen groups, also contribute to iodine stabilization through coordination interactions that limit iodine volatilization. Ekott and Etukudo (2025) stated that these organic stabilizers present a promising avenue for improving the effectiveness of iodized salt in long-term storage and varied environmental conditions. Stabilizers like dextrose and sodium thiosulfate improve iodine retention by up to 85% over 60 days.

3.3 pH and Ionic Strength Effects

Phosphates and carbonates act by buffering the salt matrix, maintaining an optimal pH that prevents the disproportionation of iodate or oxidation of iodide. These alkaline compounds such as sodium carbonate (Na_2CO_3) helps maintain a neutral to slightly basic pH, which reduces the oxidation of iodide. Acidic conditions accelerate iodine loss, making pH control crucial for stability (Etesin *et al,* 2017; Cook *et al,* 2022). The presence of metal ions such as iron or copper can catalyze unwanted oxidation reactions, leading to the incorporation of chelating agents as additional stabilizers.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3H_2 + 3H_2O \quad [4]$$

Equation 4 is the buffering reaction which helps maintain a neutral to slightly alkaline pH, reducing iodine loss.

3.4 Sequestrants and Complexing Agents

Sequestrants such as calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) bind moisture and metal ions that catalyze the degradation of iodide. These compounds act as desiccant, reducing moisture levels in salt, help maintain a dry environment by protecting iodine from hydrolysis, and thereby slowing the oxidation process.

3.5 Chelating Agents

Metal ions, such as iron and copper, catalyze the oxidation of iodide. Chelating agents like ethylenediaminetetraacetic acid (EDTA) and citric acid bind to these metal ions, preventing their catalytic activity. The general chelation reaction can be represented as equation 5.

$$M^{n+} + Chelator \rightarrow [M - Chelator]^{n+} \quad [5]$$

Where M^{n+} represents a metal ion, and the chelator

stabilizes it, thereby inhibiting unwanted redox reactions (Greenwood and Earnshaw, 1997).

Tables 2, 3 and 4 present the environmental and formulation factors in stability, environmental and formulation consideration for stability, and environmental mitigation for stability, respectively. The tables show the different mitigation and stabilization strategies for optimal iodine retention in iodized salt.

Table 2. Environmental and Formulation Factors in Stability

Factor	Impact on Stability	Mitigation Strategies
Humidity (>70% RH)	↑ Iodine loss via hydrolysis	Polyethylene packaging desiccants
Temperature	↑ 10°C doubles decomposition rate	Climate-controlled storage
Salt Purity	Metal impurities cause 20–98% loss	Pre-treatment with

		oxidizers/chelators
Iodine Form	Iodate (IO_3^-) > iodide (I^-) in stability	Use KIO_3 in humid climates

Table 3. Environmental and Formulation Considerations for Stability

Factor	Stabilization Strategy	Chemical Mechanism
Humidity (>70% RH)	LDPE packaging + desiccants	Reduces hydrolysis and iodine loss
High temperature	Alkaline buffers + reducing agents	Prevents thermal decomposition
Metal impurities	Chelating agents	Binds catalytic metals

Table 4. Environmental Mitigation for Stability

Factor	Stabilization Strategy	Efficacy
Humidity (>70% RH)	LDPE Packaging + desiccants (silica gel)	Reduces losses by 50–80%
High temperature	Climate-controlled storage (≤30°C)	Prevents 57% loss at 120°C
Salt purity	Pre-treatment to remove Fe^{3+}, Mn^{4+}	Reduces catalytic loss by 20–98%

IV. Implications for Iodine Bioavailability and Public Health

Iodine stability in iodized salt affects its ability to keep iodine deficiency diseases at bay. Iodine loss from volatilization or chemical decomposition might result in poor dietary intake (Ekott and Etukudo, 2019). Stabilizers help iodine to be retained, so it is ready for human metabolism. Some stabilizers, however, might cause unsought chemical reactions changing iodine absorption. For instance, too much use of chelating agents could affect the bioavailability of other vital elements such as magnesium and calcium. More work is required to assess these impacts in real world storage and usage settings. Public health initiatives must take into account not just iodine stability but also the general dietary influence of these stabilizing agents.

V. Conclusion and Future Directions

The use of iodine stabilizers in iodized salt are essential for guaranteeing the efficacy of iodized salt as a public health strategy aimed at the prevention of iodine related disorder in human. Iodine stabilizers and iodine species chemically interact through redox reactions, complex formation, and pH buffering, all of which help in iodine retention. To maximize iodine availability in iodized salt, an optimal selection and quantity of stabilizers, environmental factors as well as packaging of salt are required. Future studies should center on creating new stabilizers that provide better protection while reducing any possibility of adverse interactions with other dietary components. Furthermore, improvements in packaging techniques can help iodine conservation by decreasing contact with deteriorating environmental elements.

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