Original Research Article

Evaluation of Iodine and Goitrogens inSelected Vegetablesfrom Owerri Imo State in Nigeria

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ABSTRACT

The prevalence of iodine deficiency disorders remains a challenge in numerous developing nations despite widespread advocacy for iodized salt and iodine-fortified foods. As aresult, this studyassesses the iodine content of ten selected vegetables—water leaf, okra, green, tomatoes, lettuce, “okazi”, “ugu”, cabbage, “uha” leaf, and garden egg leaf. The result revealed varying iodine concentrations among these vegetables: 159.93±2.25 µg/kg for water leaf, 151.27±1.61 µg/kg for okra, and 160.43±4.37 µg/kg for green. Tomatoes exhibited 110.10±2.76 µg/kg, while lettuce had 181.27±1.76 µg/kg. “Okazi”, “ugu”, cabbage, “uha” leaf, and garden egg leaf showed iodine levels of 155.10±3.50 µg/kg, 153.43±2.47 µg/kg, 96.10±2.00 µg/kg, and 127.77±3.01 µg/kg, respectively. The evaluation for goitrogens demonstrated sufficient presence in these vegetables, with notable exceptions such as zinc, which was found in lower concentrations in “ugu”, lettuce, “okazi”, and cabbage, and was absent in “uha” leaf, garden egg leaf, green, water leaf, and okra. Based on these results, it was concluded that Owerri's vegetables exhibit relatively high iodine content within recommended dietary allowances. Consequently, ongoing vigilance is advised for the salt iodization program to prevent excess iodine intake, particularly among high-risk populations.

Keywords: Iodine deficiency disorders, Iodine content, Vegetables, Goitrogens, Salt iodization

1. INTRODUCTION

Iodine is an indispensable micronutrient crucial for human health, with an average body content of 14 mg, primarily concentrated in the thyroid gland [1]. Sea-derived foods, such as seaweeds, fish, and shellfish, are exceptional iodine sources. Among fish, cod, sea bass, perch, and haddock rank highest in iodine content, with kelp being particularly iodine-rich. Iodized salt, containing 76 mcg of iodine per gram, stands as the primary modern source of iodine intake[2,3]. Dairy and processed foods also contribute inadvertently through iodine-based disinfectants used in cleaning milking equipment and storage tanks. Additionally, animals grazing on iodine-rich soil serve as good sources [4].

Nutritionally, iodine plays a pivotal role as the essential component of thyroid hormones—thyroxine (T_4) and triiodothyronine (T_3)—crucial for growth and development [5,6,7]. Iodine deficiency primarily disrupts thyroid hormone production, leading to iodine deficiency disorders (IDDs), prevalent in regions with iodine-deficient soil or in underdeveloped nations. Severe prenatal deficiency (due to maternal iodine deficiency) results in cretinism, characterized by mental and physical retardation. In children, iodine deficiency commonly manifests as goiter formation, impaired school performance, and lower IQ. In adults, effects range from subtle symptoms to obvious goiter and associated hypothyroidism. As the 53rd element on the periodic table, iodine belongs to the halogen group with an electron configuration of $5s^{2}4d^{1}05p^{5}$. It has an atomic weight of 126.9045 and an atomic radius of 133.3 pm. Iodine exists in various chemical forms, including iodine (I), iodate (IO_3^-), and elemental iodine (I_2), with oxidation states of 5, -1, and 7. Iodine comprises thirty different isotopes, with 127I being the sole stable isotope occurring naturally [8,9].

In addressing iodine deficiency disorders, alongside prescribed medications, supplementation and herbal remedies are recommended. Vitamin C and B-complex supplements support immune function and thyroid health. Additional supplements are advised for sluggish thyroid function, including iodine-rich foods and the essential amino acid tyrosine, crucial for thyroid hormone synthesis. Herbal remedies can stimulate thyroid hormone release, aiding in the management of thyroid disorders.

1.1 Source of Iodine

Iodine is found in the mineral caliches, found in Chile, between the Andes and the sea [10]. Chile was the top producer of iodine with almost two-thirds world share in 2005 [11]. It is present at concentrations of approximately 500µg/kg in the earth's crust. In 1811, the French chemist Bernard Courtois serendipitously discovered iodine while producing saltpeter—a critical component of gunpowder—for the French army. During this process, Courtois isolated sodium and potassium compounds from seaweed ash, and the remaining residue was inadvertently exposed to an excess of sulfuric acid, resulting in a purple vapor that condensed into solid iodine. Gay-Lussac later confirmed iodine as an element. Physically, iodine is a dark-gray to purple-black solid that sublimes at standard temperatures, transforming into a purple-pink gas. It emits an irritating odor and possesses an orthorhombic crystal structure. Iodine is slightly soluble in water, with a boiling point of 185.24°C and a melting point of 113.60°C, and a density of 4.93 g/cm³ at 293 K. Iodine minerals are rare, with commercial deposits occurring usually in the form of iodates such as lautarite($ca(co_3)_2$)and dietzeite($Ca(10_3)_2$. $8CaCrO_4$). (Fuge, 1987). The concentration of iodine in most foods is low, but sea foods, both of plant and animal origin, is usually a good source of iodine because the ocean contains considerable iodine [9]. Sea foods include fish, oysters, sea weeds, kelps, and shellfish. Sea bass, haddock and perch are examples of iodine -rich animals consumed by humans [12]. Other source of iodine is from dairy products made from milk produced by cow grazing in coastal soil(soils in coastal regions are rich in the elements).

Additional iodine comes from milk supplements such as "ethylenediamine Di hydroiodide(EDDI)"; and iodophor solutions used as a sanitizing agent; dough conditioner in baking; and erythrosine used as red food coloring[13]. Salt for human consumption is often fortified with iodine and is referred to as iodized salt. Iodine supplementation may be a very important source for people who do not eat sea foods, animal flesh, animal products, iodized salt or who have a great need or requirement for iodine [14], like pregnant and lactating mothers. Radioactive iodine(small amounts)is gotten from nuclear power plant's operation[15] which can release minor amounts to air and water. Large amounts have been released during rare power plant accidents. Iodine is also released from atomic bomb explosions. Very large amounts are made in nuclear power plants for medical use. Some iodine disinfectants like povidone -iodine is another source because it is absorbed by the body and reaches the blood stream [16].

1.2 Iodine Metabolism

Iodine metabolism occurs in the thyroid. About 75%of the body's iodine is concentrated in the thyroid, while the rest is distributed throughout the body[17]. Iodine upon absorption in the blood stream is concentrated within the thyroid gland, against a strong electrochemical gradient, by the activity of the thyroidal iodine(I)pump. This is energy -dependent process. The ratio of iodine in thyroid to iodine in serum(T:S ratio)reflects the activity of this pump or concentrating mechanism. The activity is primarily controlled by thyroid-stimulating hormone(TSH). The T:S ratio in humans on a normal iodine diet is about 25 [19]. A very small amount of iodine also enters the thyroid by diffusion. The transport mechanism is inhibited by two groups of molecules. The first class consists of perchlorate(Clo 4), perrhenate (ReO_4) and pertechnetate(TcO^4). They compete with iodine for its carrier and are concentrated by the thyroid. An example of the second group is thiocyanate(SCN-). This is a competitive inhibitor of iodine transport but is not concentrated by the thyroid [18,20].

Thyroid iodine is oxidized to a higher valence state by the enzyme thyroid peroxidase;this enzyme requires H_2O_2as an oxidizing agent. Several compounds inhibit iodine oxidation, examples are the thiourea drugs. Oxidized iodine reacts with the tyrosyl residues in thyroid-binding globin(TBG).This reaction also involves thyroid peroxidase and is known as "iodination or organification". Iodide groups are added to the 31 position of the aromatic ring first and then the 51 position to form MIT and DIT, respectively. The coupling of two DIT molecules forms thyroxine(T_4), where an MIT and a DIT combines to form triiodo Thyrome(T_3). This process is an oxidative process; thus, it is assumed that the same thyroid peroxidase catalyzes this reaction. $T_3$and T4 are then released into the bloodstream and transported throughout the body [21,22]. They enter the tissue cells of the body by passive diffusion. These hormones play active roles in metabolic regulation, protein synthesis, cholesterol absorption, efficient conversion of beta carotene to vitamin A,increase in the number and size of mitochondria components resulting in an increased production of ATP(Who, 1994). Low T4 and T_3 levels in the body are sensed by the hypothalamus gland and stimulate the release of thyrotropin-releasing hormone(TRH) from the hypothalamus [22].TRH stimulates the anterior pituitary tosecrete thyroid -stimulating hormone(TSH)which provokes processes that synthesize and release $T_4$and $T_3$from the thyroglobulin protein. The normal thyroid gland produces about 80% T_4 and about 20%T_3. However, T_3 possesses about four(4) times the hormone strength as T_4[23].

2. MATERIAL AND METHODS

2.1 Reagents

- NaOH - Sodium hydroxide
- KNO_3 - Potassium nitrate, also called saltpeter
- NaCl - Sodium chloride
- As_2O_3 - Arsenic trioxide
- $(NH_4)_4(ce(SO_4)_4 \cdot 2H_2O)$ - Ammonium cerium(IV) sulfate,
- Concentrated H_2SO_4 - Concentrated sulfuric acid
- $[(NH_4)_2S_2O_8]$ - Ammonium persulfate

- Distilled H_2O - Distilled water
- Concentrated HC - Concentrated hydrochloric acid
- $HClO_4$ - Perchloric acid

2.2 Equipment/Apparatus

- Spectrophotometer
- Muffle furnace
- Crucibles
- Digestion tube
- Weighing balance
- Oven
- Heater
- Balance
- General Glass wares
- Stirring rod
- Sampling bottles
- Vortex mixer
- Fume cupboard

2.3 Sample Collection/Preparation

A total of ten(10)vegetable samples were used. These include fluted pumpkin leaf (Ugu), "Okazi", "Okra", water leaf, tomatoes, cabbage, "uha"leaf, lettuce, green, and garden egg leaf. Five(5)of the ten samples were obtained from Eke-Onuwa market, in Owerri -municipal of Imo State, while the other five were collected at Ihiagwa market, in Owerri -West of Imo State. The samples were collected fresh and dried under room temperature. The dried samples were then ground into powder form and stored in plastic containers.

2.4 Procedure

0. 5g of each sample were placed inside nickel crucibles, 1 ml of a mixture of 0. 5m NaOH and o. 1m KNO_3 was added to the samples, mixed and allowed to dry. The containers were then covered with Aluminum foil and placed in a muffle furnace. The samples were heated to 250℃, held for 15 minutes, heated further to 480℃, held for another 15 minutes and finally brought to 580℃. They were maintained at this temperature for one(1)hour per 200mg of samples after which they were allowed to cool to room temperature. The resultant ash was extracted with three successive 1ml portions of a 1ml M NaOH solution, made up in double distilled water. The solution was centrifuged at 2500g for 20 minutes using polypropylene centrifuge tubes.

2.5 Evaluation of Iodine

1ml each of extracts was placed in tubes. 2. 0ml of Arsenic reagent and 1ml of 1. 25mol/L H_2SO_4 were added sequentially to 1ml of the extracts. Samples were kept at room temperature for 10 minutes. 0. 5ml of ceric ammonium sulphate solution was added to the samples and kept at room temperature for 10 minutes. After this time, the percent transmission was read at 420nm in a 10-mm light path curette. The results were then calculated.

2.6 Evaluation of Goitrogens

2. 0g of each sample were transferred into a 75ml digestion tube. 5ml of the digestive moisture was added, swirled, and placed in a fume cupboard; digestion was made for 2 hours at 150℃. These were removed from the digestor, cooled for 10 minutes, and then 3ml of 6 NHCL was added to each tube. These mixtures were digested for another 11/2 hours. These were removed from the digestor, cooled, and made up to 50 ml with distilled water. Each tube was stirred vigorously using the vortex mixer. The samples were analyzed for mineral contents using the atomic absorption spectrophotometer.

3. RESULTS AND DISCUSSION

The results of iodine concentrations in various selected vegetables (Table 1) provide valuable insights into the potential dietary contribution of these foods towards meeting iodine requirements. The iodine content ranged from 110.10 ± 2.78 µg/kg in tomatoes to 196.10 ± 2.00 µg/kg in oha leaf. Notably, waterleaf (159.93 ± 2.25 µg/kg) and green vegetables (160.43 ± 4.37 µg/kg) exhibited similar iodine concentrations, as did lettuce (181.27 ± 1.76 µg/kg) and "ugu" (181.43 ± 9.75 µg/kg). These findings suggest that certain vegetables, such as lettuce and "ugu," could serve as richer sources of dietary iodine compared to others like tomatoes.The variability in iodine concentrations among vegetables highlights the importance of dietary diversity for iodine intake. Vegetables like oha leaf, lettuce, and "ugu" offer relatively higher iodine levels and could be prioritized in diets aimed at preventing iodine deficiency.

Table 1. Iodine Concentrations in Selected Vegetables

Samples	**ugI/kg**	**ugI/kg**	**ugI/kg**	**MEAN**	**SD**
Waterleaf	162.10	157.60	160.10	159.93	±2.25
Okro	153.10	150.60	150.10	151.27	±1.61
Green	164.10	155.60	161.60	160.43	±4.37
Tomatoes	107.10	112.60	110.60	110.10	±2.78
Lettuce	183.10	179.60	181.10	181.27	±1.76
Ukazi	159.10	153.60	152.60	155.10	±3.50
Ugu	177.10	192.60	174.60	181.43	±9.75
Cabbage	150.60	154.60	155.10	153.43	±2.47
Oha leaf	194.10	198.10	196.10	196.10	±2.00
Garden egg	128.10	130.60	124.60	127.77	±3.01

In Table 2, the concentrations of goitrogenic minerals in the selected vegetables further elucidate their nutritional composition. Zinc, with the lowest overall concentrations ranging from 0.00 mg/kg to 0.25 mg/kg, suggests potential dietary insufficiency of this mineral in these vegetables. Conversely, iron exhibits the highest concentrations, ranging from 182.70

mg/kg to 2004.23 mg/kg, indicating these vegetables as excellent sources of dietary iron.Calcium levels are notably varied among the vegetables, with values ranging from 9.09 mg/kg in ugu to 154.97 mg/kg in garden egg leaf. Similarly, magnesium concentrations vary widely, from 135.36 mg/kg in cabbage to 1275.70 mg/kg in water leaf.

Table 2. Concentration of Goitrogen in Selected Vegetables

Samples	Copper (Cu)	Zinc (Zn)	Iron (Fe)	Calcium (Ca)	Selenium (Se)	Magnesium (Mg)
Ugu	8.46	0.12	248.83	9.09	0.00	247.45
Lettuce	8.64	0.25	416.90	49.02	0.20	268.30
Garden egg leaf	28.96	0.00	182.70	154.97	1.00	514.47
Green	10.21	0.00	2004.23	127.80	0.60	1222.40
Uha leaf	10.50	0.00	176.60	59.91	1.60	260.71
Ukazi	17.46	0.21	1723.00	68.18	0.10	215.94
Water leaf	7.22	0.00	510.56	68.54	0.20	1275.70
Okro	3.07	0.00	250.47	99.87	1.30	416.38
Cabbage	7.56	0.14	210.33	37.28	0.30	135.36

The presence of goitrogenic minerals like selenium and copper, albeit in modest amounts, underscores the nutritional complexity of these vegetables. Selenium, for instance, is important for thyroid function despite its relatively lower concentrations compared to other minerals like iron and magnesium.The observed differences in iodine and goitrogenic mineral concentrations across various vegetables emphasize the need for dietary variety to ensure adequate intake of essential nutrients. Incorporating a combination of iodine-rich vegetables like lettuce and "ugu," along with a range of minerals from diverse sources, can contribute significantly to overall nutritional health and help mitigate iodine deficiency and related disorders.

In Africa, an estimated one-third of the population—comprising over 200 million individuals across 38 of the continent's 51 countries—reside in iodine-deficient regions [24,25]. Within West Africa, with the potential exception of Mauritania, all countries grapple with iodine deficiency disorders [25,26]. Iodine deficiency disorders, as defined by [27,33], encompass the range of detrimental effects stemming from inadequate iodine intake, occurring when iodide intake falls below 20 µg/day [28,30]. The study assessed the iodine concentrations in selected vegetables commonly consumed in Owerri, Nigeria, to gauge their contribution to iodine intake among local residents. Additionally, the study investigated the presence of goitrogenic substances in these vegetables. A total of ten vegetable samples were analyzed for this study.

The study outlines the iodine concentration (µg/kg) findings for these vegetables. Notably, "Uha" leaf exhibited the highest mean iodine concentration at 196.10 ± 2.00 µg/kg, closely followed by "Ugu" and lettuce at 181.43 ± 9.73 µg/kg and 181.27 ± 1.76 µg/kg, respectively. Conversely, garden egg leaf and tomatoes displayed the lowest mean iodine concentrations at 127.71 ± 3.01 μg/kg and 110.10 ± 2.78 μg/kg, respectively.Table 2 presents the results of goitrogen concentrations (mg/kg) in these vegetables. The findings demonstrate that all vegetables contain copper, with garden egg leaf exhibiting the highest concentration (28.96 ± 2.26 mg/kg) and "Okra" showing the lowest (3.07 ± 0.58 mg/kg), consistent with Turnland's work in 1994 highlighting improved copper absorption from vegetable consumption.

The study also revealed that garden egg leaf, water leaf, green, "Uha" leaf, and "Okra" lacked zinc, while others contained trace amounts of the mineral, with lettuce exhibiting the highest concentration (0.25 ± 0.18 mg/kg). This suggests that vegetables may not serve as reliable zinc sources to meet recommended daily allowances. Iron and magnesium were found to have the highest concentrations across these vegetables, which underscores the rationale behind medical advice for anemic patients to consume ample vegetables. Iron is pivotal for blood formation and oxygen transport, while magnesium plays a vital role in over 300 enzymatic reactions.Moreover, garden egg leaf, green, and "Okra" displayed the highest calcium concentrations (154.97 ± 1.06 mg/kg, 127.80 ± 6.23 mg/kg, and 99.87 ± 2.92 mg/kg, respectively), whereas "Ugu" recorded the lowest (9.09 ± 0.38 mg/kg). Selenium, crucial for thyroid gland function, was absent in "Ugu" and present in minimal concentrations in other vegetables. "Uha" leaf exhibited the highest selenium concentration (1.60 ± 0.50 mg/kg).

Overall, most of the vegetables analyzed contained goitrogenic compounds alongside iodine, with zinc notably lacking in five out of the ten vegetables. The presence of goitrogenic compounds is critical for thyroid hormone formation, and their deficiency contributes to iodine deficiency disorders [29,31].

4. CONCLUSION

In conclusion, the incidence of iodine deficiency disorders in Owerri, Nigeria, appears to be relatively low despite the country's association with IDD prevalence. This can be attributed to the adequate iodine consumption from food sources, particularly vegetables, as demonstrated in this research. The study revealed that these vegetables contain appropriate concentrations of iodine that meet the recommended dietary allowance, suggesting a potential role of iodine-rich soils in Owerri. It is crucial to closely monitor the salt iodization program to prevent excessive iodine intake, especially among individuals residing in high-risk population zones. While iodine deficiency diseases are serious and potentially deadly, they are largely preventable through dietary interventions.The vegetables analyzed in this study exhibited considerable iodine concentrations, yet biofortification efforts are recommended to enhance their iodine content further. Additionally, the use of other iodine supplements like iodized salt and iodide tablets is encouraged to ensure optimal iodine intake and prevent iodine deficiency disorders in susceptible populations. By implementing these strategies, we can work towards mitigating the impact of iodine deficiency and promoting better public health outcomes.Further research and monitoring of these nutrient profiles in vegetables are warranted to inform targeted dietary interventions and public health strategies.

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