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Risks of excess iodine intake in Ghana: current situation, challenges, and lessons for the future

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In Ghana, iodine deficiency was first reported in 1994 among 33% of the population. A nationwide Universal Salt Iodization (USI) program plus other complementary interventions were subsequently implemented as a response. Our paper reviews the current risks of excess iodine status in Ghana and identifies policy and research gaps. A mixed methods review of 12 policies and institutional reports and 13 peer-reviewed articles was complemented with consultations with 23 key informants (salt producers and distributors, food processors, regulatory agency officials, and healthcare providers) purposively sampled between May and August 2017. The findings show a strong policy environment indicated by regulations on food and salt fortification (Act 851), including the USI regulation. However, currently, only a third of Ghanaian households use adequately iodized salt. Recent evidence shows that voluntarily fortified processed foods (including condiments) supply a considerable amount of iodine to the food system. Limited biological impact data suggest possible household exposure to excessive dietary iodine (>15 parts per million). Currently, there is no systematic tracking of iodine content from fortified foods and other sources. Cross-sectoral actions are needed to understand this situation better. Key research gap is the lack of comprehensive data on iodine content and intake from other sources in Ghana.

Keywords: iodized salt; excess iodine intake; fortification; program implementation; Ghana

Introduction

Iodine is a micronutrient required for the production of thyroid hormones, triiodothyronine, and thyroxine. These hormones play essential roles in the systemic regulation of multiple metabolic pathways.[1] Deficiency due to inadequate intake of iodine results in multiple biological impacts, including goiter, congenital disorders, and cognitive impairment.[1] Biological outcomes linked with iodine deficiency are known collectively as iodine deficiency disorders (IDDs).[1,2] Daily dietary iodine requirement is estimated at 150 μg for adults and adolescents (≥13 years of age), 200 μg for pregnant and lactating women, 120 μg for children aged 6–12 years, and 90 μg for children aged below 5 years.[1,2]

Eggs, seafood, and seaweeds constitute a rich source of dietary iodine, depending on the abundance of iodine in the local environment.[3–6] Dietary iodine from plant food sources depends on native soil iodine, iodine content of inorganic fertilizer, and irrigation water. Similarly, the iodine content of animal source foods depends on iodine in feed.[3–7] Other iodine sources include supplements, medications, fortified foods (salt, bouillon cubes, and canned tomato), and hygiene products.[3,7,8]

Insufficient iodine intake among adults is associated with hypothyroidism, goiter, general learning disability, and congenital iodine deficiency syndrome.[4] Conversely, excess iodine intakes (>1100 μg) precipitate hyperactivity of the thyroid gland.[3] Similar to other micronutrients, both excessive and insufficient intakes of iodine elicit biological impact. Early deficiency can lead to subclinical effects with adverse effects on human performance and development.[2,3]

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Ghana is one of the countries in Africa that is affected by IDD.[9,10] IDD was first reported in Ghana in 1994 in a survey which estimated that 33% of Ghanaians had IDD.[11,12] Consequently, a national salt iodization program was implemented in 1996 to reduce IDD and its consequences.[10] The iodized salt standard for this program was established at 50 parts per million (ppm) of potassium iodate (KIO_3), at the point of production.[11] It was expected that losses during transit should lead to a point of use iodine concentration in salt $\geq$15 ppm.[12] In 2007, a survey in two sentinel districts (Jirapa and Bongo)[13] reported 80% household consumption of iodized salt since the implementation of the salt fortification program; however, only 38.5% and 36.3%, respectively, of household salt was adequately iodized. Goiter prevalence also declined from 56.4% to 10.6% in the Jirapa District and from 56.5% to 18.2% in the Bongo district between 1994 and 2007.[14] Ongoing national programs to address other micronutrient deficiencies in Ghana include fortification of oil with vitamin A, and of wheat flour with zinc, iron, vitamin A, and folic acid.[15]

Risks of adverse metabolic effects linked with iodine metabolism (hypo- and hyperthyroidism) in people with preexisting thyroid disease, and other vulnerable subgroups (elderly, neonates, and fetuses), have been previously documented.[4] High thyroid-secreting hormone levels, indicating excess iodine nutrition in Niger[16,17] and the United States,[18] were reversed when exposure to iodized water was detected and discontinued. However, permanent metabolic effects of excess iodine intake could occur if the iodine source is not detected and discontinued.[19] Excess iodine intake has been reported in China,[20] and among African refugees in Sudan,[21] Algeria,[22] and Somalia,[23,24] mainly associated with drinking water and the use of iodized salt.[25,26]

The Universal Salt Iodization (USI) program in Ghana mandates that all salt produced, imported, distributed, and marketed in Ghana should meet the set standards of iodine content in salt, quality, iodization, and packaging for human and animal consumption. In addition to salt iodization, complementary interventions (mandatory and voluntary food fortification interventions) contribute iodine into the Ghanaian food system.[27] However, there are currently no national data in Ghana on excess iodine intake and its biological impact. This paper reviews existing evidence on exposure to iodine in the food system in Ghana and describes policies, strategies, and programs linked with iodine nutrition in Ghana.

Materials and methods

Study design and sampling

A mixed methods design was utilized in our review and included a scoping review of policies, guidelines, reports, and journal articles on micronutrient fortification and iodine consumption in Ghana. In addition, consultations were held with key stakeholders who were identified through literature review, purposive sampling, and snowballing. The interviewed persons also included officials in government agencies (Ministry of Health (MoH), Ministry of Gender, Children and Social Protection (MoGCSP), Ministry of Trade and Industry (MOTI), the Food and Drugs Authority (FDA), the Standards Board Authority, the Council for Scientific and Industrial Research (CSIR), the Ghana Police Service, and major public health facilities), private salt production enterprises, food processing companies, and catering companies, and from related sectors, such as water and agriculture. Purposive sampling was used to identify the three largest teaching hospitals from across the three major ecological zones of Ghana for expert consultations.

Ethics and participation

The protocol for this review was approved by the Institutional Review Boards from the Ghana Health Service (GHS-ERC: 11/05) and Texas Tech University (IRB2017-485) (Lubbock, Texas). Key informants were interviewed only if their organizations gave approval for us to collect their information and the individuals provided informed consent for the interviews.

Data collection and tools

Data were collected between May and August 2017 using the following three methods.

Interviews. In order to identify implementation strategies and capacity gaps, a selection of relevant stakeholders at the national and subnational levels was identified. Stakeholders interviewed were either implementing a USI-related program (advocacy, promotion, and regulation), carrying out dietary

Table 1. Compiled interview guidelines administered to key informants

Sociodemography	Name of organization . . . . . Respondent's position in the organization . . . . . Education (include the highest obtained) . . . . . Gender: Male/Female
Key informant groups	**Questions**
Medical facilities and biomedical laboratories	1. In your experience, what biomedical or "other" (e.g., imaging) tests may you use to diagnose a suspected case suggesting/indicating excess iodine status of patients reporting to your facility? a. Probe: thyroid function test. 2. Which of the following cases have you observed or tested in the past 5 years? a. Elevated urine iodine level. b. Elevated blood level of thyroglobulin. c. Iodine-induced hyperthyroidism. **(request for a copy of records/reports of cases, if they exist)** 3. Are these tests/diagnoses done routinely for any conditions in your facility/department? If so, which conditions? 4. Kindly provide the reference to any other **units/departments** in your facility that could provide useful information on the risk of excess iodine status of patients reported in the past 5 years. 5. Are there any other procedures in your department where iodine status is monitored? What are these, please give details? 6. Is there any counseling done before or during diagnoses/surgeries? a. Probe for information given to patients or their families on the iodine status or iodine in diet? 7. What are the types of follow-ups/monitoring done with patients whose iodine status had been monitored/who underwent surgery/who had excess iodine/high TSH levels? a. Probe for the referral to the diet therapy units of the hospitals?
Food producers (small, large, and prepared food companies)	1. What foods do you produce at _____ 2. Which of these foods do you add salt to? 3. What type of salt do you use? a. Probe: iodized salt. 4. What is the source of the salt you use for production? 5. How much salt is used per unit quantity of various foods? (from the list of foods given) 6. How do you monitor the amount of the iodine in the salt used for production? a. What is the quality regarding the iodine content in the last 6 months? b. What type of storage facilities are used, if salt is bought in bulk? c. Is the iodine quality measured when salt is received and/or at the point of production? 7. Have you received any training for the workers/distributors regarding the iodine content in salt/iodine intake? a. Who gave the training and what was the content of the training? 8. What challenges do you encounter with the quality of salt you use for production?
Salt producers	1. How long has your company been involved with salt production? (Probe for iodized salt). 2. How much iodized salt/iodine is added at the production levels? 3. How much iodized salt do you produce in a day? 4. How do you test for the quality of the salt produced? . . . . (Probe for iodine content). 5. How do you distribute your products? 6. What challenges do you face in salt production? 7. Have you received any training for the workers/distributors regarding the iodine content in salt/iodine intake? a. Probes: Who gave the training? What was the content of the training? 8. What training is provided for the workers and distributors? (Probe for training focused on the iodine content of salt). a. The content of the training: How often are they done? b. When was the most recent training done? How many workers were trained? 9. Do you have any programs/promotions for consumers on iodized salt consumption? 10. If yes, what are the program contents and how often are these done? a. Probe on education on the iodine content/excess intake in meals? 11. What are the major challenges in the production and distribution of salt?
Implementing agencies	1. How is your organization linked with the Universal Salt Iodization program? 2. How long has your organization been involved with iodized salt programs? 3. What programs/activities do you implement regarding iodized salt production, distribution, or communication? a. What is the scope of the programs you deliver? b. Probe on education on the iodine content/excess intake in meals. c. Probe on program type. d. Probe on regions in Ghana covered. e. What is the source of funding? 4. What, in your view/experience, do you think are the major challenges in the iodized salt value chain? 5. Have you received any training for the workers/distributors regarding the iodine content in salt/iodine intake? a. Who gave the training and what was the content of the training? 6. What do you think are the gaps and challenges of iodized salt implementation? 7. What other programs/projects/intervention activities are likely to contribute to iodine intake? 8. How likely are these to cause excessive iodine consumption? 9. In your view/experience, what surveillance system exists to monitor iodine intake, particularly excess intake? 10. What lessons can be learned from current USI implementation to safeguard excessive intake of iodine?

Continued

Table 1. *Continued*

Regulatory agencies	1. What is your institutional mandate/role regarding the iodized salt value chain? 2. What, in your view/experience, are the major challenges in the production and distribution of iodized salt. 3. How is iodized salt quality monitored? a. Focus on the level of iodine in the salt at production, distribution, selling, and use. 4. What interventions do you implement to address salt iodine levels for consumers? 5. What interventions are there for bulk iodized salt users? 6. Have you received any training for the workers/distributors regarding the iodine content in salt/iodine intake? a. Who gave the training and what was the content of the training? 7. What do you think are the gaps and challenges of implementation? 8. What other programs/projects/intervention activities are likely to contribute to iodine intake? 9. How likely are these to cause excessive iodine consumption? 10. In your view, what surveillance system exists to monitor iodine intake, particularly excess intake? 11. What lessons can be learned from the current USI implementation to safeguard excessive intake?

iodine research, or involved in the food value chain that includes iodine (production, marketing, and utilization). Identified stakeholders were interviewed face-to-face, or via telephone, using semi-structured interview guides that were prepared for this review (Table 1). The interviews focused on key iodine-related interventions, intervention location and target groups, implementation challenges, and potential risks of exposure to excess iodine intake. A value chain perspective allowed tracking of iodine situation from production to utilization as well as relevant program governance and regulation. The interviews asked questions on potential sources of iodine from both food and nonfood sources (e.g., soil and municipal water supply system). All interviews were audiorecorded and transcribed verbatim.

Systematic peer-reviewed paper selection and scoping review. Peer-reviewed publications reviewed included scientific publications on iodine intake, iodine status, related knowledge, attitudes and practices of consumers, consumption levels, iodized salt production, and regulation. The inclusion criteria were focused on iodine and research conducted in Ghana. No duration limitation was included in the search criteria. Seven search phrases were included: "Iodine content AND iodine intake AND iodine status AND iodized salt AND goiter AND Ghana;" "Iodine content AND Ghana;" "Iodine intake AND Ghana;" "Iodine status AND Ghana;" "Iodized salt AND Ghana;" "Goiter AND Ghana;" and "Iodine AND Ghana."

The databases searched included PubMed, Scopus, ScienceDirect, Taylor & Francis, Wiley, JSTOR, and SpringerLink. Database searches were carried out between June 28 and July 15, 2017. After removing duplicates, 19 publications met the search criteria. Four additional relevant documents were identified during the write-up of the manuscript besides the online search, thus bringing the total reviewed publications to 23 papers. Upon further review of the abstract and full text, 13 of the 23 papers were relevant to this review and were included in the scoping review.

Document review. The available gray literature reviewed included institutional and scientific reports, policy, and the last two national USI strategies in Ghana. In addition, all iodine-related reports (12 documents in total) from the websites of the MoH, MOTI, the Ministry of Food and Agriculture, the GHS, the United Nations Children's Emergency Relief Fund (UNICEF), the World Health Organization, and the Food and Agriculture Organization of the United Nations were reviewed.

Two trained research assistants and the researchers were responsible for data collection.

Data analyses

All audiorecorded interviews were stored on an external digital storage drive and subsequently transcribed verbatim. Two research assistants, one of whom participated in administering the interviews assisted with transcriptions. One of the authors performed content analysis by grouping responses into themes. The other two researchers vetted analysis and reached agreements. Key issues were identified by all researchers, the current status and the key implementation gaps and challenges reported by the key informants were grouped

Table 2. Stakeholder responses from interviews on iodine-related programs in Ghana

Key issues	Current status	Gaps and challenges	Source of information	Reviewers' recommended actions and lessons
Policy environment	Existing legal framework on iodine nutrition requires fortification of all salt for human and animal consumption with KIO_3 (Public Health Act 253, 2012). National Salt Iodization Strategy III is being implemented to improve iodine nutrition nationwide. Police is mandated to enforce the Public Health Act.	The USI program is currently not funded. Low political will to support the USI program. High imports of low iodate salt reducing the competitiveness of the local producer because imported salt is cheaper. No import tax exemption/subsidy for KIO_3 because in the drafting of the law, KI was stated. However the KI is not stable in temperate zones; hence KIO_3, which is not covered by the tax exemption, is used for salt iodization.	FDA, GSA, GAIN, UNICEF, IIR-CSIR, the Nyanyano Salt Producers Society, and Pambros Salt Company Ltd.	More financial support from the government to include the human capacity to regulate and police the law.
Iodized salt production	Iodizes salt to 50–80 ppm (medium-scale factory). Some miners indicated that naturally mined salt contained iodine (as indicated by the test kit) so they stopped fortifying.	Mainly small-scale production with low mechanization. The high cost of KIO_3 makes it inaccessible at local chemical shops. The high cost of iodized salt due to high fortificant cost. Iodized salt imports affect local industry competitiveness. Lack of enforcement of standards is discouraging to the complying miners. The land tenure system and artisanal mining limit mechanization and competitiveness of local production with foreign salt miners. Reporting of nonfunctional test kits.	Pambros Salt Company Ltd., the Nyanyano Salt Producers Society, GAIN, FDA, GSA, and MOTI	Naturally mined salt testing needs to be done to ascertain the miners' statement.
Iodized salt distribution	Distributes salt both nationally and to other countries such as Burkina Faso and Niger.	Poor knowledge of iodization process and quality control. No or inadequate training is available.	Garbasco Enterprise (salt distributor) and Pambros Salt Company Ltd.	More training on maintaining the quality of iodized salt for salt distributors is required.

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Table 2. *Continued*

Key issues	Current status	Gaps and challenges	Source of information	Reviewers' recommended actions and lessons
Behavior change communication	A coordinated effort by the Ministries of: • Health (MoH) • Trade and Industry (MOTI) • Gender, Children and Social protection (MoGCSP) • Food and Agriculture (MOFA)	Current messages to use iodized salt are vague on quantities of salt usage. Misinformation through mass media.	GHS, MOTI, IIR-CSIR, GSFP, UNICEF, and WIAD-MOFA	Education messages need to be made more specific on quantities of iodized salt usage. Misinformation through media has to be addressed and regulated through a training program for health-related programs.
Regulation, standards, and enforcement	Carries out quantitative/qualitative testing. Determining the quality of iodized salt and also ensuring compliance through certification, inspection, and testing. Standards certification of iodine-containing products is voluntary for commercial producers. Periodic surveillance at production sites, markets, school-based programs, and import sentinel sites using rapid test kits. Keeping a registry of processed food products, nutrient composition, and iodized content.	Suboptimal enforcement of the law. Channels of apprehension of defaulters of iodized salt at the production and distribution are not clear. Limited human capacity to regulate fortification laws.	FDA, GSA, GHS, IIR-CSIR, UNICEF, and the Nyanyano Salt Producers Society	More training and resources need to be channeled into guarding of the Public Health Act 523 to ensure quality control in salt fortification. A clear channel of apprehension of defaulters of this act.
Utilization of iodine-containing products	One company reported testing the iodine content of salt used for product development. One company used salt for food production but had no system for quality control or no salt input measurement. Routine training for quality control and procurement department conducted in commercial fortification.	Iodine use in food industry is not monitored. School-feeding program recommends iodized salt procurement for caterers but is unable to enforce. Lack of standardization of Ghanaian recipes makes monitoring of salt intake through restaurants and eateries impractical. Many restaurant operators indicate that in the preparation of food for sale, they add "salt to taste."	Nestle® Ghana Ltd., GSFP, and Tasty Treats Catering Services	Training of restaurants, eateries, and school-feeding caterers on the need for the use of iodized salt and other iodine fortified foods is recommended. Training on recipe standardization will help assess the amount of iodized salt and bouillon cubes used in meals.
Other relevant programs/ interventions	Iodine in fertilizers is an emerging issue No information is available on iodine in animal feed. A pilot scheme (in the Brong Ahafo and Northern Regions) of multiple micronutrient (18 minerals and vitamins) fortification of biscuit, cereal (Tom Brown), and hot sauce (Shito) and labeled with the Obaasima seal. Fortified condiments such as bouillon cubes and other breakfast cereals. Salt was used in the processing of cereal both as an ingredient and disinfectant for cleaning grains and cereal.	Soil testing and location variations are not done. Regarding the pilot fortified foods, there was no indication of the consideration of iodine intake of the target group from other food sources. Urban and peri-urban women are targeted, so rural women may be left out. The implementer of the Obaasima seal suspects excess iodine intake is possible but needs evidence. Quality control of salt procurement is enforced; however, the iodine content of the final product is measured for bouillon cubes but not for the breakfast cereals.	GIZ, WIAD-MOFA, IIR-CSIR, Nestle Ghana Ltd, and Finers Foods Ltd.	Communities with the ANF4W pilot products need more education on iodine in the three products and other food sources. Soil iodine testing is recommended and should be led by the MOFA food labels indicating that the iodine content of all local or imported products must be enforced.

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Table 2. *Continued*

Key issues	Current status	Gaps and challenges	Source of information	Reviewers' recommended actions and lessons
Biological impact of interventions	Surgeries on goiter are done by ENT, surgery, and endocrinology departments. The major monitoring of goiter surgeries is the thyroid function test (TSH, T3, or T4). As part of presurgery investigations, the scan on the size of goiter, fine needle aspiration cytology (FNAC) testing, and full blood count are the other indicators that are assessed.	The little role is played by the diet therapy unit in the treatment of hypothyroidism hyperthyroidism, and goiter-related surgeries. UIC, which is indicative of iodine status, is not a current routine test practice in clinic/hospitals. Clinical data are stored as hard copies inpatient folders. Soft repository of clinical data is very new even in teaching/advanced hospitals in Ghana.	TTH, KATH, and KBTH	As part of the USI program, clinical practice has to be included in the monitoring of the program.
Coordination and institutional arrangements	FDA is mandated by law to regulate fortification of food including salt. MOTI coordinates an intersectoral National Salt Iodization Committee. GHS has a national program manager for salt iodization and nutrition on staff. International organizations, such as the UN, private banks, and businesses, provide financial support for USI programs.	Limitation on human resources for monitoring. More funding is needed from government.	GHS, MOTI, UNICEF, FDA, SDA, and IIR-CSIR	Privately owned businesses in Ghana could be explored as a funding source for USI-related activities.
Quality control	The staff of factories and production centers has received external training on iodization HACCP and quality control; one multinational company reported in-house training on all micronutrient standards. No training for iodized salt distributors. No monitoring of iodine along the iodized salt value chain.	Test kits in the country have expired. Training of salt distributors and market vendors is inadequate.	FDA, SBA, Nestle Ghana Ltd., Finer Foods Company, and Garbasco Enterprise (salt distributor)	Test kits are needed for monitoring of compliance iodized salt use, particularly among food industry (caterer and bakers). Need to monitor consumption patterns.
Stakeholder perception on iodine status	Iodine overconsumption is considered unlikely. More likely to have iodine deficiency through diet. No concern since excess iodine is believed to be excreted through urine. Some think that excess intake is likely but no evidence available to demonstrate this.	No data on national iodine status are available. No evidence on excess intake is currently available.	USAID, IIR-CSIR, GHS, and MOTI	A national evaluation of iodine status is needed.

ENT, ear, nose and throat; FDA, Food and Drugs Authority; GAIN, Global Alliance for Improved Nutrition; GHS, Ghana Health Service; GSFP, Ghana School Feeding Programme; GIZ, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German development corporation); HACCPs, hazard analysis and critical control points; IIR-CSIR, the Institute of Industrial Research-the Council for Scientific and Industrial Research; KATH, Komfo Anokye Teaching Hospital; KBTH, Korle-Bu Teaching Hospital; MoGCSP, Ministry of Gender, Child and Social Protection; MoH, Ministry of Health; MOTI, Ministry of Trade and Industry; SBA, Standards Board Authority; TTH, Tamale Teaching Hospital; UIC, urinary iodine concentration; UNICEF, the United Nations Children's Emergency Fund; USAID, the United States Agency for International Development; WIAD-MOFA, Women in Agricultural Development-the Ministry of Food and Agriculture; KI, potassium iodide.

into themes and reported (Table 2). Researchers recommended lessons and actions to address these gaps. The key informants who contributed each key issue were identified. Quotations in the report are necessary to illustrate the findings.

Of the 23 papers, 13 papers were relevant to the topic upon further review. Scoping reviews were done for the 13 peer-reviewed research publications. Data were extracted according to the year the study was published, the type of study, sample size and duration, a short description of the study, and the iodine-related key findings. The researchers drew educated deductions and lessons regarding excess iodine intake (Table 3).

Table 3. Scoping review of iodine-related scientific research publications on Ghana

Ref.	Study type	Study location	Target physiological group/sample	Sample size	Duration and project description	Iodine indicators measured	Related key findings	Reviewers' comments on excess intake/lessons
33	Community	The Northern Region	School-aged children 17 water samples	250	April 2014–April 2015	Median UIC Iodine content of salt, bouillon cubes, drinking water, and milk	25 (10.1%) children had IDD and 87 (35.4%) had a high UIC Iodized salt: 72% of samples contained <15 ppm 18.0% of iodized salt contained >40 mg/kg of iodine 10% of bouillon cubes contained ≥40 mg/kg of iodine 35.4% of children had UICs ≥300 μg/L There was negligible amount of iodine from drinking water and milk products[a]	18.0% of children were exposed to salt with high iodine levels 10% of bouillon had high iodine A third of the children had high UICs
45	Community	The Central Region	Pregnant women	120	2013–2014	Salt iodine content Median UIC	80 of 120 pregnant women reported iodized salt intake: • 42.5% of them had IDD • 33 (27.5%) of them had excess iodine in the body (UIC ≥500 μg/L)	All pregnant women with excess UICs were using iodized salt
46	Community	The Western Region (Bia district)	Households (meal preparer)	280 households	The survey among household members	Household iodized salt consumption	75.6% of households consumed iodized salt of 25 ppm 79.3% of the households exclusively use iodized salt	75.6% of households salt with high iodine content
56	Control trial	The Ashanti Region	Non-pregnant, nonanemic women and children (1–5 years)	318 women and child dyads	An 8-month intervention for women with Hb ≥100 g/L (n = 300) for three groups with equal samples • Iodized salt + weekly placebo • Iodized salt + weekly 70 mg iron supplement • Double fortified salt (DFS) + weekly placebo for 8 months Children with Hb ≥100 g/L were randomized into two groups: • Iodized salt (n = 105) • DFS (n = 52)	Anemia measured using hemoglobin Mean UIC	Anemia in women did not change in groups 2 or 3, but increased by 19.5% in the control group In children, anemia in group 3 decreased by 21.7% but remained unchanged in the control group Iodine deficiency reduced significantly in both women and children	Hyperthyroidism was not reported
43	Clinical records	The Greater Accra Region (Korle-Bu Teaching Hospital)	Adult population with thyroidectomy from 2003 to 2007	528 (470 females)	2003–2007 Goiter surgeries: weight and cytopathology	Goiter	Out of 528 cases, 470 (89%) were women and 58 (11.0%) were males 70 (13.3%) patients had hyperthyroidism (61 toxic nodules and 9 with Graves' disease) 441 (83.5%) were taking iodized salt (48.2% were taking before their swelling and 51.7% started after) Mean extracted weight was 161.4 g	13.3% of the patients had hyperthyroidism

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Table 3. *Continued*

Ref.	Study type	Study location	Target physiological group/sample	Sample size	Duration and project description	Iodine indicators measured	Related key findings	Reviewers' comments on excess intake/lessons
44	Community	The Greater Accra Region	10–15 years	112	Feasibility of using ultra-sonography in field studies in Ghana	Mean and median UIC Goiter	Mean and median UICs in children were 82.4 ± 8.5 and 67.9 μg/dL, respectively All children examined had normal thyroid sonogram Goiter by thyroid volume per age and sex was 1.8% Thyroid volume by surface area palpitation yielded 8.0% and sonogram gave no identification of goiter According to Ref. 57, goiter was 11.6%	None
58	Community	The Upper East Region	Children, 8–14 years old Women, 15–45 years old	1061	Assessed the goiter and UICs in children ($n = 540$) and women ($n = 521$)	Goiter Median UIC	72% of subjects had a UIC of >2 μg/dL: • 24% of them had UICs = 2–5 μg/dL • 4% of them had UICs = 5–10 μg/dL 68.8% of subjects had a goiter	None
40	Community (cross-sectional)	The Volta Region	Markets and homemakers	1961 households 350 market salt samples	August–September 2014 Household and market surveillance of adequately iodized salt	Households salt consumption and market salt quality Iodized salt-related knowledge (health and regulation)	68% of homemakers and 73% of traders knew the importance of consuming iodized salt 30.9% (≥15 ppm) of salt in markets was adequately iodized, 36.5% was inadequately iodized salt (<15 ppm), and 32.9% was non-iodized (0 ppm) salt 21.1% of 1340 household salt samples obtained were adequately iodized	30.9% of salt was adequately iodized (≤ 15 ppm) but the actual level of iodine could not be determined
41	Community	The Northern Region (Gushegu)	Households (meal preparer)	100 women	Survey of household iodized salt consumption and iodine-related knowledge	Households salt consumption	23% self-reported eating iodized salt and 20.0% were verified with a rapid test 20% of the household samples contained adequate iodized salt The survey revealed that the cost of iodized salt, lack of availability of the non-iodized salt, and not receiving any education were the reasons for the nonuse of iodized salt No knowledge of law against the sale of non-iodized salt and used to the taste of non-iodized salt	No mention of the amount of iodine in salt
15	Community (cross-sectional)	The Greater Accra Region	Systemic process assessment	NA	Key informants and stakeholder interviews and lessons learned on fortification of salt, wheat flour, and vegetable oil	None	Initially, in 1996, salt was mandated to be fortified with 100 ppm at the factory and expected to contain 50 ppm at retail In 2006, the levels were revised to 50 ppm at production Salt bank idea was a success in contributing to the fortification of salt	None

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Table 3. *Continued*

Ref.	Study type	Study location	Target physiological group/sample	Sample size	Duration and project description	Iodine indicators measured	Related key findings	Reviewers' comments on excess intake/lessons
48	Nonrandomized, 14-day intervention	The Upper East Region (Sekoti village)	School children, 10–12 years old	60	Intervention used marine fish–fortified and fermented maize porridge and pup Marine fish content was: • porridge = 1.34 mg/kg • banku = 1.82 mg/kg • banku and gravy = 1.73 mg/kg	UIC Goiter Iodine content of selected local foods and food additives	Mean change in UIC was from 34 to 79 μg/L ($P < 0.01$) Decrease in TSH levels was reported 60% of children had goiter Mean iodine content: • Saltpeter (50,400 μg/kg) • Steamed bean paste (tubani[b]) made with ashed sorghum stalk (74 μg/kg) • Tubani made with saltpeter (534 μg/kg) • Bean (234 μg/kg) • Tomatoes (949 μg/kg) • Millet meal (93 μg/kg)	Saltpeter contains high iodine content; however, the consumption level is unstudied
47	Community (cross-sectional)	The Eastern Region (Manya Krobo district)	Children, 2–10 years old	101	A micronutrient profile assessment	Mean UIC	UIC ± SD = 40.71 ± 3.6: • 6 (6.2%) children had normal UICs • 91 (93.8%) children had low UICs (>100 μg/dL)	No child was identified with a high UIC
49	Cross-sectional	Not indicated	Fish	14 fish types	Iodine content of 14 commonly consumed fish in Ghana	Iodine content of fish	Iodine content of fish ranged from 0.62 to 4.09 μg/g: • Round sardine had 4.09 μg/g • Frigate mackerel (*Auxis thazard*) had the lowest mean concentration of 0.62 μg/g • Shrimps had 3.5 μg/g iodine concentration	The consumption pattern of round sardines and shrimp is unknown

Hb, hemoglobin; IDD, iodine deficiency disorder; UIC, urinary iodine concentration.

[a]Seventeen water samples contained 0–3 μg/L, one borehole water contained 35 μg/L, and one well water contained 27 μg/L of iodine.

[b]Tubani is a local food in Ghana made from steamed bean paste. Saltpeter is added to the bean paste before steaming to give a desired soft gelatinous texture.

[Correction added on December 8, 2018, after first online publication: In the Table 3 notes, "iron deficiency anemia" was changed to "iodine deficiency disorder."]

A scoping review of 12 gray literature documents extracted and reviewed information on the key focus of this report, indicators used, and key issues related to iodine intake. For each report, the researchers summarized relevant evidence on excess iodine.

Results

Background

A total of 23 interviews were conducted (17 were public health stakeholders and six were clinical staff from the three training hospitals). Table 2 reports the key issues raised by the stakeholder. The 13 peer-reviewed research publications ranged from 1998 to 2017 with varying sample sizes. One study used clinical records, one was a clinical controlled trial, one was a process assessment of the implementation of the national food fortification program, and the remaining 10 were cross-sectional community-based surveys (Table 3). An additional 12 documents were made up of 10 organizational reports or national surveys, and two of the three reviewed policies (Table 4). Key results are discussed below.

Policy environment

Since 1994, the three national policies on iodine indicate that all salt for human and animal consumption must be iodized in Ghana. In 1996, the Food and Drugs Act 523 (Amendment)[27] was enacted to regulate salt fortification. Later, in 2005, there was renewed commitment to promote salt iodization. The National Food Fortification Alliance (NFFA) was formed to coordinate

Table 4. Review of published reports and strategies related to iodine consumption in Ghana

Document type	Source/authors, publication year	Paper focus	Sample size/study design	Indicators measured/discussed	Key iodine-related issues	Researchers' comments on excess iodine intake/lessons
Report[59]	FAO and FIVIMS, 2008	Nutrition country profile	Review	Goiter prevalence UIC	Goiter and UIC prevalence as reported in other studies (see Ref. 11) More data are needed to evaluate the national IDD in Ghana	None
Report[65]	UNICEF, 2006	Multiple indicator cluster survey: monitoring the situation of children, women, and men	5893	Household consumption of iodized salt Salt iodine concentration	About half (49.2%) of households used no or non-iodized salt: • 18.4% of them used salt with iodine content <15 ppm • 32.4% of them used salt with iodine content ≥15 ppm Those with higher formal education (secondary and higher) were more likely to have adequately iodized salt and the richest in the wealth index quintiles	The exact amount of salt was not tested. Only the qualitative report was included (salt iodine concentration was ≥15 ppm)
Report[61]	MoH, GHS, and WHO, 2016	Public health risk mapping and capacities assessment in Ghana	None	None	The ingestion of KI is indicated as a preventive measure to block radioactive iodine emissions from entering the thyroid gland as a result of nuclear facility emergencies among other preventive measures	KI is only used in emergency situations and radioactive nuclear accidents Radioactive nuclear accidents were ranked last (19th) in Ghana compared with other hazards
Website[62]	UNICEF-Ghana, 2017	Nutrition, a silent killer	None	Household consumption of iodized salt	35% of households use adequately iodized salt	None
Report[42]	The National Salt Iodization Committee, Ghana, 2013	Nyanyano and the Salt Bank		None	As part of the Presidential Special Initiative (PSI) on salt, the salt bank concept developed to increase iodization of salt from clusters of salt winners The Nyanyano salt bank was the first to be established under the PSI salt project[a]	None
Bulletin[63]	UNICEF, 2015	The UNICEF-Ghana internal statistical bulletin	None	Household consumption of iodized salt	22% of Ghanaian households use non-iodized salt 34% of them use salt that is inadequately iodized	None
Draft report[64]	MOTI, edited by Aggey *et al.*	Development of USI strategy III for Ghana. A review of the salt industry in Ghana. USI commitment and bottlenecks	NA	USI implementation strategy	A deliberately slow stepwise approach to implementation of using the USI in Ghana, attempting to reach 90% of households over 5 years, should be adopted	None
Policy document[29]	CSIR- FRIIMAlG-AM/2009/009, 2009	Achieving USI: Ghana national strategy II 2009–2011	NA	USI implementation strategy	The main aim is to continue with a high-level advocacy to ensure the USI remains a national priority and is intrinsically linked with national priorities such as poverty education, child survival, universal primary education, and the millennium development goals	None

Continued

Table 4. *Continued*

Document type	Source/authors, publication year	Paper focus	Sample size/study design	Indicators measured/discussed	Key iodine-related issues	Researchers' comments on excess iodine intake/lessons
Policy[31]	UNICEF, 2017	USI strategy III and action plan 2016–2020	NA	USI implementation strategy	Strategy III for the Ghana USI program is to increase Ghana iodized salt production and export levels, and to achieve optimum iodine nutrition in the Ghanaian population through salt iodization	None
Report[66]	Ghana Statistical Service, MICS, 2011	Multiple indicator cluster survey with an enhanced malaria module and biomarker	11,925 households	Household iodized salt consumption using both rapid test kits and titration methods	22.2% of households were consuming non-iodized salt (0 ppm) 33.5% of them were consuming adequately iodized salt (between 0 and 15 ppm) 34.5% them were consuming adequately iodized salt (≥15 ppm)	A third of households are consuming salt with >15 ppm
Report[50]	GDHS, 2003	Ghana Demographic and Health Survey	6251 households	Household consumption of iodized salt	9% of households had no salt in the household 59% of households consumed non-iodized salt 13% consumed inadequately iodized salt (<15 ppm) 28% of households were consuming adequately iodized salt (≥15 ppm)	A third of households are consuming salt containing >15 ppm of iodine
Report[32]	GDHS, 2014	Ghana Demographic and Health Survey	4549 households	Household consumption of iodized salt	66% of households used inadequately iodized salt 39% of households used adequately iodized salt 62% of households with children used iodized salt Children in urban areas were more likely to consume iodized salt (69%) compared with children in the rural (56%) setting In general, 72% of households in the urban setting used iodized salt compared with 58% of households in a rural area	None

[a]The Nyanyao salt bank began operations on July 1, 2009 but ran out by 2010 due to the change in the political leadership in 2009.
CSIR, Council for Scientific and Industrial Research; FAO, Food and Agriculture Organization of the United Nations; FIVIMS, Food Insecurity and Vulnerability Information and Mapping Systems; GHS, Ghana Health Service; GDHS, Ghana Demographic and Health Survey; MOH, Ministry of Health; MOTI, Ministry of Trade and Industry; KI, potassium iodide; WHO, World Health Organization; UIC, urinary iodine concentration; UNICEF, United Nations International Children's Emergency Fund; USI, Universal Salt Iodization.

fortification activities. Accompanying this renewed commitment, the first policy strategy for 2005–2007,[28] with targets of reaching at least 90% of households with salt fortified with KIO_3 at 15 ppm, was developed. The policy mandated iodine fortification at 50 ppm during production so that with storage losses, a level of 25 ppm will persist during distribution and retailing, and 15 ppm iodine to salt ratio will be available at the household level. The 15 ppm indicated in the policy would provide 100% of the recommended daily allowance based on an estimation of 10 g of daily salt consumption. The second policy (CSIR-FRIIMAIG-AM/2009/009) was for a period 2009–2011 and emphasized that the USI remained a national priority. The second policy linked efforts from the USI to child survival, universal education, and the millennium development goals.[29] Subsequently, the current Public Health Act 851 (2012) was enacted[30] and requires that all salt for human and animal consumption be fortified with KIO_3. The third and current policy strategy[31] is functional

in the period 2016–2020. This third strategy focuses on expanding production of quality salt, improved quality of iodization for optimum nutrition and export, as well as the increased government commitment.

The three policy strategy documents were sequentially developed to support the implementation of the USI in Ghana (Table 4). Furthermore, the government has supported the voluntary fortification of commercial food products. However, there is no legislation on voluntary fortification.

Interventions providing iodine/iodized salt at the national and subgroups levels

Table 2 indicates the key interventions implemented to address IDD in Ghana. This study identified two main categories of programs implemented.

The first program is the national USI strategy that enforces implementation of the law requiring all salt for human and animal consumption to be fortified. Iodized salt in Ghana is mainly locally produced or imported. The government has supported small-scale producers (the main supply for local households) to acquire technology to ensure adequate fortification using KIO_3. The latest policy strategy for USI (Strategy III, 2016–2020)[31] includes activities to expand production of quality salt (clean and optimum water content of crystals), improved quality of iodization, and increased government commitment to the USI program. Salt is a good vehicle for iodine fortification since its consumption is almost universal in Ghana. However, only about a third of the population consume adequately iodized salt (15 ppm and above).[32]

The second is the voluntary fortification program, which is carried out by commercial food processors and distributed nationally. The companies voluntarily fortify food products with iodine by adding iodized salt as an ingredient (if the product includes salt) or in the food processing methods, such as washing of grains. Commercial products that are iodine-fortified condiments include bouillon cubes, cereals, canned tomato paste, canned fish, and other processed food products with added iodized salt. The use of fortified foods varies across the different economic levels in Ghana. The use of fortified foods may be more common in urban and peri-urban settings. For instance, households in rural northern Ghana commonly consumed bouillon cubes. The estimated median per capita iodine intake from bouillon cubes was 88.3 (50.9–110.4) μg/day.[33]

A food-based initiative, the Affordable Nutritious Foods for Women (ANF4W), is jointly implemented by the German Development Corporation (GIZ), private food processors, and the Government of Ghana. ANF4W has introduced three fortified novel food (biscuits, breakfast cereal, and hot sauce) products that aim to improve micronutrient (18 minerals and vitamins, including iodine) intake among urban and peri-urban women in Ghana. The initiative has developed a micronutrient quality seal known as *Obaasima*.[34] These foods are already in the markets in the Brong Ahafo and Northern Regions on a pilot basis. The ANF4W project developed three foods informed by an ethnographic study conducted in both regions. Peri-urban participants indicated that they were willing and able to pay to access processed foods compared with rural participants.[35] The Obaasima seal adopted the guidelines from the international multiple micronutrient preparation (UNIMMAP) formulation of the UNICEF/WHO/UN University.[36] A recent 2017 micronutrient study reported multiple micronutrient deficiencies among nonpregnant women of reproductive age. Deficiencies in iron (13.7%), vitamin A (1.5%), folate (52.8%), and vitamin B12 (6.9%) were reported; however, no iodine deficiency was reported in this survey.[37] The Obaasima seal provides 33 μg of iodine per serving.[38,39]

Advocacy and awareness about iodine nutrition

The USI program incorporated a behavior change communication component. In 2014, the GHS and its partners developed an advocacy campaign on the USI. This campaign targeted consumers, and the goal was to address misperceptions related to iodized salt. The campaign used messages to address behaviors related to iodized salt handling, storage, and marketing/retailing. Social marketing, radio, and television were the key channels used for this advocacy effort. However, education on the behavior change and communication messages were mainly disseminated at the national level. Being a new concept, the USI campaign messages focus on the promotion of the use of iodized salt with messages encouraging Ghanaians to "buy and use iodized salt." The gap in the promotion message was that it was nonspecific regarding the amount of salt to use.

Mass media is currently one of the major sources of education for many people in Ghana.[32] However, an official from GHS indicated during the interview that due to inadequate knowledge, there were reported instances of misinformation provided to the public via unregulated mass media outlets regarding the health benefits of iodized salt.

The available empirical evidence, however, suggests mixed outcomes concerning iodized salt awareness and use. In the Volta Region, two-thirds of traders interviewed reported knowledge of the importance of consuming iodized salt and 75% of households consumed iodized salt.[33] However, in the Northern Region, only 20% of households reported iodized salt use. The awareness of the fortification law in both regions was low among traders and households.[40,41]

Quality control and capacity gaps

Food manufacturing companies reported quality control and procurement training on salt iodization. However, restaurants and school-feeding programs reported that no specific quality control training on the procurement of iodized salt was provided to them. Restaurants also reported that there was no standardized measurement of the amount of iodized salt used in any particular recipe. Salt was "usually added to taste." Regulatory agencies reported they had trained salt producers, on hazard analysis and critical control points (HACCPs) and quality control. A salt producer corroborated the delivery of HACCP training during our interviews. Regarding the voluntary fortification, there is the in-house training of procurement officers and the implementation of quality control checks at the point of raw material procurement (including iodized salt) and at the end of production. Food processors transported and distributed these products (especially, bouillon cubes) across the entire country.

Although there is a potential to produce the targeted 5 million tons of salt annually, current production averages 300,000 tons per year from 82 licensed concessions. There are three levels of salt production systems in Ghana: (1) medium-scale salt factories, (2) small-scale producers, and (3) artisanal (micro-) producers. The small- and microscale producers are typically informal concessions and contribute 47% of national production. In Nyanyano, a village with a cooperative of microscale producers, the government piloted a salt bank strategy to improve quality in the iodized salt industry. The strategy involved aggregating artisanal salt produce and then iodizing at the centralized locations (salt banks). Although the pilot was considered successful, it was not sustained due to financial insolvency as indicated in the 2013 Nyanyano and salt bank report,[42] and corroborated in interviews with the officers from the Nyanyano Salt Producers Society and Pambros Salt Industries Ltd. The current land tenure system is preventing land acquisition for salt mining. The high cost of premix (KIO_3) was another challenge (Table 2).

To enforce legal standards of fortified salt, iodine test kits named iCheck^{TM} Iodine (BioAnalyt, Teltow, Germany) rapid test device provides qualitative evidence of the level of iodine. Test kits are provided by the government of Ghana with support from UNICEF. The main challenge with quality control is the inconsistent use of the test kits by the regulatory agencies to enforce the standards across all the salt production and marketing stages. During preparation of this review, there were no valid test kits available in the country.

As indicated by the GIZ official, the current implementation of ANF4W provides no incentives or subsidies for women to purchase them. However, the project embarked on demand creation activities to raise awareness and encourage repeated purchase through education and branded flyers. There is no evidence of training on quality control for food producers and distributors. Neither is there any evidence on communicating the risk of excess iodine intakes from various food sources to consumers.

Iodine intake from other food sources (water, food crops, meat, and soil)

As indicated in Table 2, there was no reported evidence that iodine was added to fertilizer, water supply, or animal feeds. Abizari and coauthors[33] have recently tested the iodine content of household water and milk products in the Northern Region of Ghana and reported only negligible iodine content. In exceptional cases, they found high iodine levels in water from a particular borehole (35 μg/L) and a well (27 μg/L).[33] There is currently no evidence to explore possible regional variations in soil nutrient content. There is, therefore, a need for soil testing to ascertain native iodine content, but also for other geonutrients.

Clinical evidence of iodine-related conditions and treatments

Although clinical data are not included in this paper, clinical experts indicated that iodine-related medical treatments are conducted by the ear, nose, and throat, surgery, and endocrinology departments in training hospitals. Dietitians were typically not included in specialized goiter or iodine-related treatments. The urinary iodine concentration (UIC), which is the most accurate test for iodine status, is not routinely done as part of the presurgical and pretreatment practice in hospitals. The procedures of goiter-related surgeries were done in the Korle-Bu Training Hospital.[43] From clinical records, Dakubo and coauthors indicated that out of the 528 goiter surgeries that were conducted between 2003 and 2007, 13.3% were for recurrent goiter. A survey in two sentinel districts indicated an overall reduction in goiter prevalence by 45.8% in Jirapa and 38.3% in Bongo from 1994 to 2007.[13]

Although biological impact data were not available, a surgeon at one of the local training hospitals indicated that clinical cases indicating excess iodine intake were rare. In field settings, goiter assessment is subjective to the test used.[44] Further research should explore rapid and accurate goiter identification in field studies.

Iodized salt consumption and iodine status

A survey in Jirapa and Bongo sentinel districts in 2007 indicated an 80% household consumption of iodized salt, although only 38.5% and 36.3%, respectively, of the salt sampled, were adequately iodized.[13] Recent studies, within the past 5 years, reported varying household iodized salt use based on a standard of 15 mg/kg iodine content or more to indicate adequacy of iodization. In the Volta Region, Agbozo and coauthors[40] have found that a third of salt in the markets and 21.1% in households were adequately fortified ($\geq$15 ppm). However, three studies elsewhere in the country have indicated possible high iodine content. Simpong and coauthors[45] reported 67% of households with pregnant women were using iodized salt in the Central Region of Ghana. They observed a wide variation in UIC (5.2–1165.9 μg/L) but noted, also, that 27.5% of pregnant women had excess UICs ($\geq$500 μg/L). All those with excess UICs were consuming iodized salt at the time of the study. In the Northern Region, it has also been reported that 35.4% of school-age children had excessively high UICs ($\geq$500 μg/L) and median UIC in the study was 242 (163–365) μg/L. Household testing showed that 18% and 10% of the households of these children were exposed to high iodine (>40 mg/kg) from salt and bouillon cubes, respectively.[33] Buxton and Baguune[46] have earlier reported in a survey of 280 households in the Western Region of Ghana, 75.6% of households were using salt with high iodine content (>25 ppm).

In the same study, they reported 72% of household salt had less than 15 ppm iodine. Thus, it was not surprising that the study reported a 10.1% IDD among the schoolchildren. In the Central Region, IDD prevalence was 42.5% among pregnant women. Another study found 93.8% of children (2–10 years old) with low UICs (<100 μg/dL) in the rural Eastern Region of Ghana.[47]

Additionally, other studies[48,49] indicated that fish and shellfish may be a good source of iodine in Ghana, especially mackerel (4.0 μg/g) and shrimp (3.5 μg/g). Maage and coauthors[48] also reported high iodine intakes from saltpeter (potassium nitrate) that is used as a food additive in Ghana.

Challenges and barriers of the implementation of the USI salt fortification

The enforcement of the regulation on iodization is weak due to multiple factors: the majority of locally consumed salt is produced by small-scale artisanal producers whose activities are hardly monitored, the high cost of importing fortificant (KIO_3), limited and unreliable availability of quality testing kits, and poor enforcement of quality along the value chain as reported by an ex-official from the Global Alliance for Improved Nutrition. Additionally, small- and medium-scale producers are more likely to implement quality control. However, some of the salt produced by these salt producers was exported to markets outside Ghana. An iodized salt distributor indicated that the testing for quality is carried out routinely by police personnel at designated checkpoints across main transit routes throughout the country. The limitation is that the test kits available at the time of the interview in Ghana had all expired. The FDA is mandated to lead the regulation of salt fortification Act 523[28] in support of other government and nongovernment organizations. However, according to the FDA official, there is currently inadequate communication and coordination between the regulators and enforcers of the law. There is

also a pervasive misperception about iodine. For example, a salt producer reported that the amount of iodine occurring naturally in the mined salt is enough hence they do not fortify the salt they produce anymore.

Discussion

Our paper reviews evidence on iodine status in Ghana with the view to identify the potential gaps linked with excess iodine consumption. The USI program in Ghana was much needed at the time of its inception in 1996. This is because a third (33%) of the 110 districts sampled had IDD,[11,12] and the national USI was implemented to address this gap. The target was to fortify 90% of salt consumed by humans and animals with KIO_3, which is a stable fortificant in tropical Ghana.

The data from the multiple indicator cluster survey[60,65,66] indicate that only a third of Ghanaian households were consuming iodized salt. In 2006 and 2011, more recent studies have shown a slightly lower rate in the Northern Region of Ghana[33] and a very high rate in particular settings in the Volta Region at about 75%.[40] The 2003 Ghana Demographic Health Survey indicated 28% iodized salt consumption.[50] Although the findings on consumption levels from Agbozo and coauthors are encouraging, data are not representative.

Nonetheless, with the reported increased availability of adequately iodized salt, comes a concern of the consistent availability of adequately iodized salt in markets to be safe for human consumption. However, adequate fortification at the market will happen when there is enough education of salt producers on how to iodize salt adequately. Also, strategies on how salt producers can easily procure the recommended KIO_3 need to be put in place. The challenge at this stage is the high cost of KIO_3 that is partly determined by world demand and partly due to the lack of tax waivers for its imports in Ghana. A small-scale miner indicated that salt mined naturally contains iodine hence they do not fortify. Quality control needs to be ensured at the production levels due to high levels of iodine ($\geq$25 ppm) reported at household and market levels.[15,42]

Although overfortification due to the lack of quality control was expected, the high cost of procurement of KIO_3 has been the major challenge consistently reported by the salt producers.[17] Thus, the likelihood of excess iodization beyond recommended levels appears limited. The poor quality control could rather lead to nonuniform mixing during fortification procedures, leaving portions of salt with high fortificant concentrations. However, consumers are likely to be exposed to biological risks if exposed over a longer duration.[26] The test kits used for the assessment of the iodine content of salt provided results in ranges. Thus, test results are not specific, which may pose a limitation in iodine content testing. The high iodine content in salt reported may seem the indication of compliance of the salt producers coupled with good storage practices at all levels, thus preventing the anticipated transit losses.[13] On the other hand, it raises concerns about quality control on the amount of fortificants added at the production stage. It is worth noting that the iodized salt samples in the study that observed high iodine concentrations obtained salt from households through participating children, but obtained bouillon cube samples from markets.[33] Thus, reducing risks of iodine losses in bouillon cubes.

A public health question that may arise is, How much does consistent intake of iodized salt >25 ppm contribute to excess iodine intake of different population groups? Given the premise that 15 ppm was recommended based on the estimation of 10 g of salt consumption, which is four times the recommended 2.5 g daily salt consumption, it is still unlikely that >25 ppm will result in the intake of iodine above the daily upper limit of 1100 μg.[4] Also, since the implementation of the USI in Ghana, the estimation of total daily salt intake in Ghana has not been examined.

Generally, other sources of iodine include seafood, bread and other baked goods, milk,[19] drinking water, and fertilizers.[19] In the Ghanaian context, negligible amounts of iodine were detected in water (treated and untreated) and milk products.[33] However, one sample of water each from a well and a borehole had high iodine levels. A Danish study mapped different drinking water sources and found a wide variation of total iodine content.[51] Similarly, a study in East Africa found high levels of iodine ($\geq$10 μg/L) in 9% of drinking water samples.[26] Thus, water mapping is critical in the assessment of total iodine intake. We did not identify any study that assessed the consumption patterns related to seafood in Ghana. Other sources of iodine showing a high content are the

bouillon cubes, which was associated with excess iodine intake and high UIC. Most school children got their dietary iodine from bouillon cubes used as an ingredient in meal preparation.[33] However, iodine in the bouillon cubes was added in the form of iodized salt as reported by the food processor interviewed. Suggestively, bouillon cubes may be a good source of iodine for the Ghanaian population. However, the promotion of bouillon cubes needs to be done with caution since the cubes also contain monosodium glutamate that is a food additive that may have harmful health consequences.[52] Additionally, in the same households where bouillon cubes are used, iodized salt may still be added in meals as a complementary seasoning. How much eventual per capita iodine was consumed in such a household is unknown. Maage and coauthors[48] also found high iodine from saltpeter, which is commonly used as a food additive in Ghana. The iodine in saltpeter is, however, reported to be biologically unavailable when consumed.[53] No national iodine consumption data were available to determine if the Ghanaian population is at risk of low or excess iodine intake.

The dietary communication interventions that may lead to excessive intakes of iodine include nonspecific education on iodized salt. The education through mass media has the advantage of reach; however, because education messages may not always be implemented by technical people, a high level of misinformation occurs. Misinformation in communities with high illiteracy rates will reduce intake of iodized salt because non-iodized salt is cheaper in markets. The two studies that assessed the knowledge levels of household members showed that there was a better knowledge of the health impact of iodine from iodized salt than the knowledge of legislative support.[40,41] Furthermore, many Ghanaian recipes are not standardized and quantities of iodized salt, and possibly bouillon cubes added in meals, are not measured. This is more so for restaurants and eateries as was reported in the interviews with the caterers from Tasty Treats Catering Services in Accra. Quality control is not as critical for this group of food processors as for larger manufacturing agencies.

In clinical practice, it was observed that goiter and hyperthyroidism cases were not linked to the diet therapy unit. This is because the thyroid function test was used to monitor both hypo- and hyperthyroidism patients and these conditions are not perceived to be directly related to diet. Patients of goiter surgeries go home with no follow-up messages or education on iodized salt or dietary intake recommendation. Dakubo and coauthors[43] found a prevalence of 13.3% of patients with hyperthyroidism, and 3.8% with recurring goiter and subsequent surgeries indicated on patient records they sampled. Although not all cases may be entirely due to diet, in this sample, iodized salt intake played a key role. Since the majority of iodine absorbed by the body is excreted in the urine, the UIC is considered a sensitive marker of current iodine intake and can reflect recent changes in iodine status.[19] The UIC is, however, recommended for individual assessments and not for population-wide evaluations. We had no access to any UIC data to make such inferences.

The Presidential Special Initiative on salt contributed to a vibrant implementation and innovations to achieve a truly universal iodization of salt.[31] This momentum seems to have stalled and indicates a need for more deliberate effort from the government to lead the salt iodization program. The international organizations and the UN have, to a greater extent, supported the USI in Ghana. They provide financial and technical support as well as multiple micronutrient fortification of selected foods. These fortified foods are recognized with the Obaasima seal label. Multiple micronutrient fortification is beneficial in many countries and fortification is one of the identified general nutrition interventions[54,67] that lead to a high impact on the nutrition of the populations. The *Lancet* series indicated that, in spite of the evidence of the effectiveness of fortification and other interventions, the lack of accountability and inadequate funding may be the reason why it is difficult to achieve the reduction in malnutrition.[54] The USI and other interventions implemented in Ghana have not been nationally assessed to measure impact.

Currently, a study piloting implementation of the multiple micronutrients in Ghana is undertaken and, the target group is women in urban and peri-urban settings. The consumption of the unfortified hot sauce (80.0%), cereal (96.3%), or biscuits (92.7%) in urban areas is high. However, the current consumption of ANF4W products is below 10% among women.[39]

Women who participate in this project are also still exposed to the use of iodized salt, salted snacks,

baking products, bouillon cubes,[33] and other processed foods with high iodine content. Thus, with the possibility of improving the nutrient intakes of participating urban and peri-urban women, the multiple micronutrient fortification programs may expose women to excess iodine intakes. Consumption of fortified foods in rural areas may be lower due to their high dependence on household processed oil, flour, and prepared snacks.[37,55]

Conclusion

Iodized salt use in Ghana was reported among a third of households. Households may be obtaining additional iodine through iodized processed foods, such as condiments. There is a need for strengthening the compliance of the fortification guidelines of salt at the production stage that seems not to be adhered to by salt producers. There is evidence that enforcing the Public Health Law (Act 851) is a challenge. Iodized salt with high levels of iodine in Ghanaian households has been reported ($\geq$25 ppm). Although higher than recommended, these levels[29] may still not expose individuals to the daily upper limits of 1100 μg. A study also reported that some schoolchildren had high UICs, which is indicative of excess iodine intake.[33] Furthermore, 528 goiter surgeries were conducted between 2003 and 2007, and 13.3% of all these clinical cases presented with hyperthyroidism. Thus, our review points to the need for more information and data collection to ascertain the risk of excess iodine intake through the USI, voluntary fortification of processed foods with iodine, as well as natural water (wells and boreholes). Additional interventions, such as the ANF4W, should consider the existing iodine-related interventions. No national consumption study has been undertaken to prove excess iodine intake at a national level; however, these results from the review are indicative of a possible excess intake of iodine and warrant more research. This conclusion was made based on the available but unrepresentative data.

Key findings and lessons

1. Limited evidence suggests that there is a potential exposure of households to excess iodine (>25 ppm) from salt and condiments at the household level. However, this needs to be confirmed with a survey designed to be representative nationwide. Further evidence is needed to validate this.
2. There is a need to translate a strong policy for controlling IDD into a functional and enforced iodized salt production and distribution system with appropriate quality control. There is currently limited coordination and human capacity to reach 90% of households with adequately iodized salt.
3. It is important to integrate contributions of iodine from other food sources (particularly processed food) in the national IDD control program and targeted IDD control programs.
4. Community-level food consumption and biological impact assessment are needed to determine success and lessons from the 20 years of the IDD control program in Ghana.
5. Prospectively collecting data on the biological impact of people exposed to iodized salt and also other sources of iodine at the community level is the best assessment of the impact of the USI; however, clinical data will provide other valuable information on disease trends and severity.

Recommendations

Public health programs

A renewed commitment on the iodized salt fortification through the National Salt Iodization Committee and the NFFA, and the regrouping of all stakeholders (government, relevant government, nongovernment, and international agencies, salt producers and distributors, relevant medical personnel, advocacy agencies and the media, and restaurants and eateries) is recommended to reflect on the 20 years of salt fortification implementation in Ghana.

The multidimensional nature of iodine consumption calls for a stand-alone national survey on iodine status, measuring the effectiveness of the implementation of the USI program throughout the value chain and the implementation gaps and lapses. This national survey will also help to include and evaluate other iodine sources, such as soil, processed foods, extruded snacks, and seafood consumption, all of which will affect iodine consumption. If the USI is integrated with the existing surveillance data collection, the important components that will help assess the risk of excess intake will be lost, and the need for the revision of the standards set for fortification may not be addressed.

The USI has a good strategy to improve collaboration with all relevant sectors; however, current lack of support from the government sector, specifically financial and structural support, remains a challenge. The USI urgently needs the government support as well as the innovative and strategic harnessing of funding from the private sector.

The quantities of salt added in cooking need to be included as a cautionary message in behavior change communication strategies so as to prevent overconsumption of iodized salt in households and commercial food vending. This caution should also integrate other iodine food sources in the daily diet.

The indication of naturally occurring iodine in salt mined in parts of Ghana needs to be quickly and urgently investigated so as not to negate efforts of the USI program thus far.

Clinical/hospital settings

In the clinical setting, linkages with diet therapy departments will help with follow-up messages, and monitoring of patients to prevent recurrent goiters (if they are diet related). Similarly, patients with hyperthyroidism will benefit from interaction with the unit to help manage exposure to excess iodine intakes. The UIC could be monitored henceforth as part of research data to help assess the actual iodine levels of patients with related conditions visiting the teaching hospitals.

The already established links for the three major training hospitals could be further explored to collate data from all three hospitals to get a better understanding of the long-term clinical impact of the USI. This needs to be explored to provide evidence on the iodine content from other sources.

Research gaps

The only national data available are on the iodine content of iodized salt (markets and households) and household consumption levels. However, there is very little research evidence on the other sources of iodine such as from seafood and processed fortified food.

Adding condiments such as bouillon cubes and saltpeter in meal preparation does not replace the use of iodized salt. Consumer education of the risk of excess iodine in meals prepared with condiments is warranted. Additional evidence is needed to examine further these findings.[25,33,45,48]

Also, a population-based impact study on the iodine status is urgently needed. However, it should include iodine consumed from other sources, apart from iodized salt. Similarly, the risk of cumulative intake of iodized salt is unknown and needs to be studied.

It is clear that iodine in the soil will impact on farm crops. The soil nutrient variation (specifically on iodine) across Ghana needs to be evaluated and used as part of the implementation evidence guiding the USI program. These data are currently not available.

Policies and policymakers

A cross-sectoral (business, agriculture, public health, and regulatory) national surveillance system should be implemented to assess the impact of iodized salt and consumption levels to understand how much impact the efforts have on iodine intake and status. Also, food consumption patterns should be included regularly (e.g., every 5 years).

Limitations of study

The peer-reviewed papers were systematically selected but were not assessed for the rigor of their scientific approach. A paper was included because of its relevance to the review topic, and a thorough review of the papers was done. The availability of clinical data from hospitals has biases of being collected from people already with disease conditions. However, data on thyroid function and goiter surgeries would have been used to establish epidemiological trends over the years. These data could also provide clinical impacts similar to what is described by Dakubo and coauthors.[43] The current data in clinical records is limited to iodine intake assessments because the thyroid function test is not the most accurate measure of a person's iodine status.[19] Thus, we recommend prospectively for research purposes in clinical practice for hypothyroidism, hyperthyroidism, or goiter surgeries that treatments should include a UIC as a presurgical or pretreatment practice.

Most of the studies were smaller and not representative of Ghana. Also, no recent national data exist; thus there is no evidence to indicate if the prevalence of IDD has been reduced compared with the earlier findings.

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for data acquisition, analysis, and interpretation. B.A.Z.A. drafted the manuscript, all authors reviewed and approved the final version of this work.

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Competing interests

The authors declare no competing interests.

Statement

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