Contents list available at CBIORE journal website

Journal of Emerging Science and Engineering

Journal homepage: https://journal.cbiore.id/index.php/jese/index

Research Article

Review of micronutrients in Sokoto, Nigeria: Insufficiency and effects on brain (Nervous system) functioning

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Abstract. In humans, micronutrients are special nutrients that are supposed to be obtained from diets in small amounts to aid body functioning, growth, and development. Micronutrients deficiency results due to low dietary nutrients intake and is currently a worldwide threat that affects humans in various ways, including learning or brain functioning. Sokoto State Nigeria due to its peculiarities such as arid land, poverty, poor education, single-diet nutrition, etc. should be of great risk of micronutrients deficiencies. The objective of this review paper is concerned about micronutrients deficiencies with regards to Sokoto State Nigeria and consequences on brain function. Micronutrients prevalence in Sokoto Nigeria, micronutrients in foods, insufficiency of nutrients in soil, consequences of excess micronutrients, micronutrients deficiencies, causes, etc. were described. Multifold approach to this myriad task should be put forward and tackled head-on; otherwise, the society (Sokoto) will languish continuously with maternal and child mortalities, abnormalities, mental derangements, aa well as poor productivity..

Keywords: Micronutrients, deficiencies, zinc, iodine, brain .

Received: 17th May 2024; Revised: 9th Dec 2024; Accepted: 4th January 2025; Available online: 8th January 2025

1. Introduction

Certainly, individuals need nutrients but the requirements are based on certain factors such as age, sex, and health status. The nutrients could either be macro or micro types. Micronutrients ensure healthy functioning of the human body and are required in small amounts (Narwal et al., 2017). Micronutrients consist of specific minerals and vitamins essential for human health, growth, and development (Shabbir et al., 2019). However, micronutrients are on many occasions unavailable for human intake due to certain factors. In fact, micronutrients deficiencies are seriously affecting more than 2 billion people around the world. In developing nations, micronutrients deficiencies are top most causes of avoidable blindness, neural defects, intellectual problems, and death (during birth and thereafter) (Ozdemir, 2016; Adamu et al., 2017; Erhabor et al., 2019).

Nevertheless, the groups very vulnerable to micronutrients deficiencies include, lactating mothers, pregnant women, and young children; because the populations need more nutrients considering body changes and body growth, as well as development (Abubakar et al., 2024). Pregnant women face risk of dying or giving birth to sick-child (mentally deranged), stillbirth, miscarriage, etc. Lactating mothers face risk of death, disease, and mental errors in the children (Huskisson et al., 2007).

Sokoto is a drought prone area, a semi-arid region that may possibly suffer food insecurity and malnutrition of all type (Lawal, 2013). Idris & Adulwasiu (2023) reiterated that, their work in rural areas of sokoto state (eastern part) show that, insecurity make farming very difficult, in turn lowering production and consequently leading to food insecurity. In previous works, Manyong et al. (2021) point poor dietary quality in complementary foods being given to children, and in turn a threat that may lead to malnutrition in children. Erhabor et al. (2018) in Sokoto, among children with protein energy malnutrition (PEM) concluded that the malnutrition found was low level of ascorbate, and in turn low weight, and marasmus is common PEM among the observed children. Isezuo et al. (2021) studied the outcome of treatment of patients dealing with malnutrition in tertiary healthcare facility in Sokoto State, and resolved that, there was high mortality, as well as poor follow up among the patients treated from malnutrition. Nkwoka & Muniru (2024) assessed nutritional status of children in Sokoto North, and the result reveals still high prevalence of malnutrition exist in the area. Meanwhile, Sokoto faced challenges in term of achieving educational goals among its people. Sani et al. (2024) show that there is poor academic performance among senior secondary school students in Wamakko, Sokoto. Jiya et al. (2024) shows consumption of empty calories (unhealthy diets) among adolescents in-school students in Sokoto. This could help in deteriorating academic performance, because empty calories may elicit malnutrition (Sarkingobir & Miya, 2024). Abubakar et al. (2024) called for more studies in Northern Nigeria, where Sokoto state lies, because their study indicates nutritional issues are more rampant in the area. In similar vein, Shehu et al. (2023) decried among other things, lack of nutrition, and education are among the major challenges facing children in Sokoto State. Essien et al. (2012) had earlier corroborated he effect of malnutrition in secondary school students in Sokoto,

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where the children with malnutrition sow poor academic performance more than their counterparts. Thus, the objective of this review paper is concerned about micronutrients deficiencies with regards to Sokoto State, Nigeria and consequences on brain function.

2. Micronutrients and Learning Centers of the Human Body

Ideally, micronutrients relate with the cognitive parts of the human body in a complex format. Micronutrients directly affect cognition by affecting energy metabolism in glia cells, neurons, neurotransmitters synthesis, receptors binding, and integrity of membrane ion pumps. Slight deficiency of micronutrients shows up as a diminished or affected cognitive activity (Huskisson et al., 2007). The following roles of Micronutrients are highlighted:

- Vitamin B_1- This vitamin mostly act as coenzyme of the carbohydrate metabolism (breakdown of glucose to energy) and is needed for nerve impulses transmission (Huskisson et al., 2007).
- Vitamin B_2- Riboflavin is transformed to flavin coenzyme and act in redox reactions (essential in fat, carbohydrates and proteins metabolisms). The riboflavin is essential in transforming vitamin B_6 and folic acid to specific coenzymes.
- Niacin is used to provide coenzymes such as nicotinamide dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). The NAD and NADP are essential to more than 300 enzymes. Niacin took part in the process to make riboflavin and vitamin B_6 active (Stenesh, 1998).
- Vitamin B_6- Vitamin B_6 is used to make pyridoxal phosphate and pyridoxamine phosphate (used in transamination). The vitamin plays essentially in the nervous system to synthesize adrenaline, dopamine, serotonin, GABA, tyramine etc.
- Folic acid- Folic acid forms act in many metabolisms such as homocysteine (and other amino acids) synthesis (Styrer, 1988).
- Vitamin B_{12}(cobalamin)- Cobalamin forms take part in the metabolism of some amino acids and odd-chain fatty acids.
- Biotin- Biotin serve in carboxylase as cofactor involved in fatty acids and other vitamins metabolism (Styrer, 1988).
- Vitamin C (Ascorbic acid)- This vitamin is for the synthesis of collagen, bile acids, neurotransmitters (calcitonin, noradrenaline, dopamine), iron absorption, folic acid metabolism, and work synergistically along with zinc.
- Pantothenic acid- Pantothenic acid participates mainly as coenzyme A constituent (Huskisson et al., 2007).
- Iodine- Iodine deficiency lead to low thyroid, goitre, cretinism, and mental derangements (Zimmermann, 2010; Narwal et al., 2017).
- Fe-Fe-Deficiency anemia is a principal type of poor dietary iron effect. Poor learning ability has been linked to Fe-Deficiency; because of disrupted oxidative stress overhauling system and changes in neurotransmitters synthesis (Halterman et al., 2001).
- Zinc- Poor zinc level may be linked to various enzymes; as well as poor learning outcomes. Also, zinc supplementation could improve learning outcomes (Kumar et al., 2016). The ability of zinc deficiency to cause effects on learning could be due to its symptoms such as anemia, dwarfism, hypogonadism (Shukla et al., 2014).
- Copper- Copper is an essential dietary need that plays role in maintaining redox balance of the brain. Particularly, copper also serve as cofactor to the dopamine-beta hydroxylase that serve in the synthesis of norepinephrine (Dawelbait et al., 2018). Reports show that, poor copper levels in the body is linked with cognitive problems (Pfeiffer, 1987; Gambling & McArdle, 2004).

3. Mechanism of Micronutrients Effects on Brain and other Parts of Nervous System

Central nervous system is the most dependent on its nutrients supply compared to others. The effects of micronutrients can be exerted on central nervous system in the following posited ways:

- During neurotransmitter synthesis- Vitamin B (complex, and vitamin C aid essentially to ensure synthesis of neurotransmitters, steroids, biogenic amines. In the CNS, vitamins B_2, B_6, B_{12}, folate, etc. act in the metabolism of dopamine and noradrenaline. Poor level of pyridoxine as well as thiamine leads to poor level of GABA (Huskisson et al., 2007).
- Alteration of receptor and neuromembrane- Lack of thiamine lead to destructed membrane potential; likewise, pyridoxine deficiency cause receptor binding alterations such as in the case of glutamate and glycine neurotransmitters (Huskisson et al., 2007).
- Homocysteine metabolism affected by vitamins- Parable, B12 vitamin deficiency affects synthesis of dopamine, serotonin, noradrenaline. This results in negative consequences to the brain (example affected cognition, and mood changes) (Huskisson et al., 2007).
- Energy metabolism- brain uses 25 percent of the body's glucose. Therefore, low level of B vitamins is a factor affecting glucose metabolism as well as affecting brain functions (Huskisson et al., 2007). Certainly, micronutrients insufficiency results in may negative outcomes (Stenesh, 1998).

4. Prevalence of Micronutrients Deficiencies in Sokoto

Hassan et al., (2010) in a study concerning antinutrients of *Sclerocarya birrea* fruit found appreciable concentrations of phytate, and tannins. In other vein, serum vitamin A, and zinc were determined in children in Sokoto town, and the finding indicates, 66.7% of the children suffer vitamin A deficiency, and severe zinc deficiency (Bilbis et al., 2002). Bilbis et al., (2010) assess serum antioxidants vitamins and minerals in 90 HIV subjects collected from Sokoto, and results revealed vitamins C, E, A, are low; likewise, the micronutrients zinc, and iron. The security of the infection correlates with low level of minerals (micronutrients) and vitamins.

Abubakar et al. (2014) in a study that examines flowers of *Gynandropsis gunandra* in Sokoto found an appreciable phytate amount; therefore, people consuming the flower may be affected by the presence of the antinutrient, which is capable of inhibiting proper absorption of micronutrients. Umar et al. (2015) in their work on African Palmyra palm shoots show that, there were

appreciable levels of phytate and hydrocyanic acid in the shoots studied. Ascorbate deficiency was investigated among a population of children in Sokoto, Nigeria; whereas, the result show that malnourished children had more ascorbate deficiency than the control (Erhabor et al., 2018). Na-Allah et al. (2017) in antinutritional study on *Moringa* show that, the plant leaves contain appreciable levels of tannins, phytates, alkaloid, and oxalates. Albeit, very minute, but, putatively under chronic exposure exert undesirable effects. Umar et al., (2017) in a study of adolescents girls in Sokoto state, show that poor iodine status could invariably affect academic performance of adolescent secondary school girls. This signifies the need for better iodine intake.

Meanwhile, a study determining the prevalence of anemia in children at a teaching university hospital in Sokoto using a sample of 300 children revealed 34.8% anemic, 44.6% iron deficiency anemia among others (Mainasara et al., 2017). The study suggested the need for iron and other nutrients supplementation to cure the affected anemic children (Mainasara et al., 2017). A study on levels of antioxidants, vitamins, and mineral compared among diabetics have generally low level of manganese, zinc, vitamins (A, E, C). Thus, the affected patients should be given intervention of vitamins and mineral supplementation (Wali et al., 2018).

A study about dietary diversity among farming households of Sokoto and Kebbi, Nigeria using a sample of about 1,500 households shows, most of the women and children have low dietary diversity; and concluded with the need for more awareness on the importance of dietary diversification, and consumption of rightful diet (Oyedepo & Adeola, 2018). An observation of antinutrients in *Capsicum annum* in Sokoto under different treatment methods (open and solar drying) show that, there are appreciable tannins, flavonoids, and polyphenols (Tambuwal et al., 2018). Erhabor et al. (2019) examined certain hematological parameters including selenium, and copper in children (sickle cell patients) at Specialist Hospital Sokoto; and show that, patients have lower selenium, and copper levels compared to healthy children.

An analysis of African locust bean seeds in Sokoto, shows that, there is presence of appreciable amount of phytate, tannins, nitrate, and cyanide in the seeds. Shehu & Kurya (2019) performed a study assessing *Solanum incanum* Linnaeus in Sokoto and the results show that, nitrates, phytate, tannins, and oxalates are appreciably present. Ayuba et al. (2020) in a work on effect of white sorghum processing show that, despite processing (such as soaking, and de-hulling) and un-processing, there were still appreciable levels of tannins, nitrate, and phytate. Abduljalil et al. (2023) determined the levels of fortificants in wheat sold in Sokoto. Vitamin A, iron, copper, and manganese were below the standard of levels approved by constituted authorities. Umar et al. (2024) aimed to assess iodine in sold salts in Sokoto, and assessed consumption of iodine rich foods, and assess knowledge about iodine nutrition. Mostly, there are enough iodine in salts, enough consumption of iodine rich foods, and poor iodine nutrition education among the respondents. More iodine awareness is needed in the state.

Summarily, based on the posited articles concerning micronutrients in Sokoto State Nigeria, the following themes are observed:

- There is scarce data published showing micronutrients in Sokoto, there is need for extensive works to laid foundation for more research and assist policy makers in making rightly guided decisions.
- The deficiencies include, zinc, vitamin A, Fe, Cu, I, vitamin C, vitamin E. This shows multi-nutrients deficiencies indicating a huge risk to the population affected.
- The vulnerable people affected directly include children, patients, women, and adolescents girls.
- There are levels of antinutrients in many diets in the state, that in turns could affect the nutritional status of populations in bad shape. Therefore, rigorous nutritional education interventions are needed, as well as right food processing before human consumption.

5. Presence of Micronutrients in Foods Sources (Plants and Animals)

Globally, regionally, and locally, verily, the essential sources of foods to humans remain from plants or animals or combinations. Some food sources are found in Tables 1 and 2. Locally, there may be different studies demonstrating sources of foods to humans. Tambari & Aminu (2019) shows leaves of *Parkia biglobosa* are rich in manganese, iron, and copper minerals that could be useful for human dietary consumption. A study performed by Olapade et al. (2005) shows goats in Nigeria contain rich values of iron, manganese, copper, zinc, as well as Iodine. Umar et al. (2024) in their study of food materials such as salt, foods, in Sokoto show that, salt contain enough iodine (in most cases), and poor iodine nutrition education, indicating the need for awareness creation. Fruits, milk, dietary products, and meat contain levels of iodine in their folds.

Table 1. Sources of Micronutrients from nutrients-densed healthy food

Number	Food type	Source
1	Brown rice	Plant
2	Oats	
3	Vegetables	Plant
4	Fishes	Animal
5	Nuts	Plant
6	Yam	Plant
7	Potatoes	Plant
8	Fruits	Plant
9	Milk	Animal
10	Meat	Animal

Source: Jennifer, (2020).

Table 2: Some plant-based micronutrients sources

Country	Crops	Crop parts	Micronutrient present
Ethiopia	Wheat	Grain	S
Mali	Maize, millet	Shoots, grain	Zn
Togo	Maize	Leaves	Mn, Zn, B, S
Zambia	Wheat, maize	Shoots, grain	Zn
Benin	Maize	Leaves	Zn
Uganda	Finger millet	Shoots	Zn
Nigeria	Sorghum, maize	Leaves, shoots	Zn

Source: Adopted from Kihara et al., (2019)

6. Insufficiency of Micronutrients in Soil

Micronutrients are being fed to the soil primarily through weathering sources obtained from Earth's crust, because crust contain available micronutrients in its fold. In soil, micronutrients behave in solution, free state, complexes, bonded to clay, and attached to organic matter or other sources. There are about 67 ppm of zinc, 17ppm of cobalt, 0.09b ppm of selenium, 1.4 ppm iodine, 28 ppm of copper, 775 ppm manganese, etc that are located in the Earth's crust; albeit, in soil definitely the concentrations of available micronutrients differ according to certain features (FAO, 2012; Iwueke etal., 2020).

Deficiencies or insufficiencies of micronutrients in soils happened when the parent material of the nutrients, and other sources (binded nutrients) could not sufficiently replaced the used or washed away nutrients. The deficiency could happen because of natural reasons (high alkalinity, high acidity) and human-made actions such as exhausted farming (for example, China and Indian soils face more than 30% deficiency of zinc; molybdenum deficiency occur in more than 10% of agricultural lands in India, and 47% of soils in China). Many African soils suffer one deficiency, or combinations of deficiencies due to geography and other issues. Soils that are deficient of nutrients could affect plant growth and consequently reduce the yield of micronutrients for human and animal consumption (Aberra & Kassa, 2017; Tochukwu, 2022). There are factors that significantly influence the presence and availability of micronutrients in soil, some of which are enumerated below:

- Organic matter- Organic matter contains soluble (humic acids) and insoluble compounds (fulvic acids), whereby, many organic compounds form complexes with micronutrients.
- Temperature- At low temperature there is usually a reduction in availability of micronutrients due to reduced microbial and root activities.
- Moisture- Decreased moisture may lead to decreased immobilization of colloidal particles, and absorption of micronutrients as well. Reduced moisture could lead to leaching as well, whereas, excessive moisture impedes diffusion of oxygen and manganese (Pfeiffer & Mailloux, 1987; Sagwal et al., 2023).
- pH- Soil pH influence solubility, solution concentrations, mobilization, etc in soils. Very high pH decrease micronutrients availability (Sagwal et al., 2023).

Nevertheless, importantly, crops require nutrients (human micronutrients) for growth and development.

7. Cultural Methods to Improve Soil Micronutrients

There is an array of methods utilized traditionally in improving soil nutrients such as the ones enumerated below:

- Shifting cultivation- Shifting cultivation is a method of farming, whereby a land is cultivated and consequently allowed to fallow for some years to regain used up nutrients.
- Crop rotation- This a systematic approach to farming involving a deep feeder crop succeeding a shallow feeder, thereof allowing shallow feeder succeeding a legume.
- Mono-cropping- Mono-cropping involved simultaneously cultivating two or more crops on the same land. It also refers to farming and rearing been carried out on one land (Essien et al., 2012; Yusuf et al., 2021).

8. Possible Solutions to Micronutrients Insufficiency

Intervention on soil

The initial step to combat micronutrients deficiencies is to cure the soil. Factors to be careful about include, temperature, pH, etc. An increase of pH from 5 to 6 incite available copper or zinc or others to reduce by factor of 100 (except molybdenum which is the opposite). Mycorrhizas are soil fungi that make nutrients available to plants but require zinc and copper for actions. Fertilization is man-made intervention that involves adding fertilizers or manures that provide crucially sufficient nutrients to the soil for plant growth (Meunier et al., 2006; FAO, 2012). Overfertilization of soils using phosphate that make Fe, Zn, and Cu unavailable should be prevented; application of manure is important to avoid deficiencies (Abdulmumin et al., 2017; Dawelbait et al., 2018; Kennedy et al., 2020).

Genetic modification of crops

Genetic modification of crops is another devised way of enhancing micronutrients. For instance, Golden rice provide Beta-carotene. Plant breeding has been reported due to it's potential to enhance zinc, and iron in rice, and beans; therefore, serve as an emerging approach to deal with micronutrients deficiencies (FAO, 2012).

Direct addition of micronutrients in human and animal foods

Another method to help in curtailing micronutrients deficiencies is to add micronutrients directly in foods taken by humans or animals. Biofortification of cereals is a renowned method of adding nutrients in cereal crops to provide a promising effects. Likewise, fortification of other foods such as biscuits, milk, beverages, etc have being successful in curtailing deficiencies among schooling children and relations (Metwally & Mazhar, 2007; Kim et al., 2021; Namikawa et al., 2023). Nevertheless, a complemented effort involved household dietary intervention by spurring households to diversify foods consumption, design foods traditionally. This has been proven with multiple benefits and tendency to address diverse deficiencies (FAO, 2012; Hamid et al., 2020). Biofortification can be achieved through following a number of steps, such as identifying a population, and nutrient targeted, screening of crop genes, improvement and evaluation of crop, testing nutritional efficacy as well as consumer acceptance of crop, crop distribution, and measurement of crop adoption and resulted nutrition improvement (Saltzman et al., 2014). Some major biofortification ensured include that of orange sweet potato that deliver provitamin A, maize that deliver provitamin A, cassava delivering vitamin A, rice delivering zinc, wheat that deliver zinc, beans delivering iron, etc (Saltzman et al., 2014).

Increase intake of enhancers and reduction of inhibitors

Encouraged intake of nutrients enhancers such as meat in the case of Fe, ascorbic acid to increase Fe absorption, etc are important. However, reduced intake of food inhibitors such as phytate in the case of Fe, oxalates in the case of iodine, are essential to contribute in preventing micronutrients deficiencies (Hassan et al., 2011; Shukla et al., 2014; Sani, 2015; Hamid et al., 2020).

Supplementation

Supplementation has been widely applied as micronutrients deficiencies overhaul, such as the case of giving folate to deficient pregnant women. Supplementation involves giving nutrients to vulnerable group. A supplement should have the following:

- Labels indicating type, quality, etc
- Safety according to manufacturing instructions
- Qualitative nature with purity, compositions, strength, and identity (Academy of Nutrition and Dietetics, 2018; Hajheydari et al., 2018).

Supplementation is best considered to prevent or treat deficiency, for example in pregnant women, 50 years and above old people, children, vegetarians, alcoholists, drug abusers, people with genetic problems affecting nutrients usage. However, supplementation should be done with caution in people with excess nutrients, such as post-menopausal women, adult women, etc. People taking other drugs such as Fe may experience decrease in zinc (Temple & Masta, 2004; AND, 2018; Tuncalp et al., 2020).

9. Concerns About Micronutrients Supplementation Abuse

Micronutrients drugs are being abused daily because of easy accessibility, self-medication, and other factors. The following micronutrients toxicity problems are discerned:

- Vitamin D toxicity- Toxicity due to surplus intake of vitamin D supplements is called hypervitaminosis D and is characterized with hypercalcemia, low hormone activity, and hypertension, renal failure, and hypercalciuria (FAO, 2012).
- Vitamin A excess- Intake of surplus vitamin A lead to toxicity called hypervitaminosis A known with symptoms such as bleeding, nausea, hair loss, altered mental status, blurred vision, vomiting, muscle pains, hypertension, etc. High intake of vitamin A can spur a syndrome called "retinoic acid syndrome" (RS). RS is featured with fever, dyspnea, edema, acute respiratory distress, and multiorgan failure (Stenesh, 1998).
- Vitamin B_6 toxicity- Excess consumption of vitamin B_6 spur peripheral neuropathy. The caused condition has features such as bone pains, loss of tendon reflexes, fasciculations, paresthesia, muscle weakness, and numbness (Styrer, 1988).
- Vitamin E toxicity- Excessive consumption of vitamin E spit bleeding.
- Fe excess- Excess Fe lead to toxicity with symptoms such as tachycardia, hypoxia, acidosis, arrhythmia, seizures, acute metabolic encephalopathy, etc
- Zinc excess- Zinc excess consumption trigger toxicity with symptoms such as GIT bleeding, dyspnea, lethargy, anemia, prostate cancer (Jernnifer, 2020; Aljohani et al., 2023).

10. Micronutrients Deficiencies

Micronutrients include vitamins and minerals essential for human to live healthily. Albeit, they are required in small amount, they are needed for various functions, therefore have to be provided to the body through foods. Vitamins could be B vitamins, vitamin C, vitamins A, D, E, K; while minerals include Fe, Se, Zn, Cu, etc. Indirectly, the deficiency could be assessed by estimating nutrients consumption at population level, extrapolating the risk of deficiency and possibility of deficiency prevalence. Directly, actual clinical or subclinical problems due to micronutrients are measured in populations or individuals. This include the use of signs and symptoms clinically or biochemical testing to diagnose deficiency problem, questionnaire methods could also be added (Stenesh, 1998; Ugwuja et al., 2007; Umar et al., 2015; Yahaya et al., 2015; Yusuf et al., 2021).

Vitamin A

Vitamin A function in normal vision, growth and development, immune function, epithelial cell integrity, and reproduction. This micronutrient is in food as retinol (from animal) and provitamin A carotenoids (from plants). Specific sources include, fish, vegetables, and fruits. People at risk of vitamin A deficiency include children battling with diseases such as measles, diarrhea, chicken pox, severe infection, and respiratory problems. Other risk factor includes, living in developing countries. Vitamin A deficiency is prevalent in

Asia and Africa. Severe signs of vitamin A deficiency include, night blindness, keratomalacia, and corneal terosis (Styrer, 1988; Welch & Graham, 2003).

Thiamine

Thiamine is a needed cofactor in carbohydrates, and branched-chain amino acids metabolisms. It is diverse in animal and plants sources such as liver, legumes, yeast. Signs of deficiency manifest as beriberi in populations of developing countries especially babies, mother's due to insufficient diet and specific antinutrients (sulphites, raw fish, betel nuts) (Stenesh, 1998).

Riboflavin

This vitamin is needed for normal functions of enzymes, development, and maintenance of epithelial cell integrity. Deficiency is seen as angular stomatitis, glossitis, cheilosis. The vitamin is found in eggs, legumes, dietary materials. However, population mostly relying on rice are affected with deficiency; likewise, people in hunger (food insecurity), African dwellers, and poor dietary consumers (Stenesh, 1998).

Niacin

Niacin is a central player in food energy usage and is found in plants, animals, fishes, cereals, and pulses. Signs of low niacin (pellagra) include diarrhea, dementia, and dermatitis. People at risk could be consumers of maize as staple food (without processing to release niacin) (Selvaraju et al., 2009).

Vitamin C

Vitamin C is needed for connective tissue maintenance, immune function, healing, and iron absorption. The vitamin is common in plant-based (foods such as fruits, vegetables), and animal-based food materials. Signs of deficiency of vitamin C include, scurvy, and death. People consuming low fruits and vegetables are mostly affected with deficiency (Renwuck et al., 2004; Rammurthy et al., 2018).

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Vitamin D

Vitamin D is required in calcium biochemistry and bone formation. Source of vitamin D is from synthesis using sunlight, and dietary food materials (such as eggs, liver, sardines, dairy foods, and salmon). Deficiency of vitamin D results in rickets in children. Risky populations that can easily suffer vitamin D deficiency include, Morocco, Pakistan, Ethiopia, deserts (including Sokoto, Nigeria), hibernating people, indoor people, and poor diet consumers (Renwuck et al., 2004; Rammurthy et al., 2018).

Iron

Iron is needed for hemoglobin making, myoglobin, and enzymes. Common sources include, meat, cereals, fruits, vegetables. Deficiency of Fe results in Fe-Deficiency Anemia, impaired cognition, and poor productivity. People at risk of low iron include, women of childbearing age, pregnant women, breastfeeding women, babies inappropriately weaned, inappropriately breastfed babies, people living in malaria regions (Rammurthy et al., 2018).

Iodine

Iodine is essentially needed for thyroid hormones synthesis, development of fetus and nervous system. Sources of iodine are common as fortified salt, meat, dairy products, vegetables, and fruits. Signs of iodine problem include, goiter, cretinism, neurologist defects (spasticity, ataxia, mental illness, deaf mutism), dwarfism, hypothyroidism; whereas, people mostly at risk of iodine deficiency include, mountainous dwellers, and Africans (FAO, 2012).

Zinc

Zinc is needed for growth and immunity, and it is present in red meat, eggs, nuts, and whole grains. Deficiency of zinc lead to diarrhea, growth failure, skin lesions, dwarfism, and hypogonadism. People at risk of zinc deficiency include, adolescents, pregnant women, infants, low dietary diversity cultural people, sickle cell anemic individuals (Temple & Masta, 2004; Cleghorn, 2007; Kennedy et al., 2020).

11. Possible Causes of Inappropriate Levels of Micronutrients in Food Materials in Sokoto

There are several reasons that lead to either excess or insufficient levels of micronutrients in foods in Sokoto depending on conditions. Some of the reasons are listed as follows: Pollution- Pollution is a major cause of excess elements in water, soil, as well as plant-based and animal-based foods. Umar et al. (2023) analyzed soils waste in Sokoto Fadama and found the presence of zinc, that is being dissipated. Aliyu et al. (2020) determined heavy metals in water at Usmanu Danfodiyo University main site and found the presence of copper, iron (high amount). Umar et al. (2023) examined the extent of heavy metals in soil and tobacco in Sokoto and result reveals that, there is sufficient evidence of pollution with metals such as copper, manganese, iron, and zinc among others. Another work that examines metals in water in schools in Sokoto East, Nigeria, shows that, there are elements such as zinc, copper, as well as iron (Sarkingobir et al., 2023).

Raji et al., (2010) in heavy metals analysis in Sokoto city indicated selenium and nickel were at excess concentrations. Certainly, presence of micronutrients in water, soil, and air due to pollution escalate their levels in plants or animals that are consumed by humans and often lead to toxicity. Similarly, activities such as bush burning, pesticides, addition of fertilizers, could raise micronutrients presence and cause toxicity to humans at the end of the food chain (Udo de Haes et al., 2012).

Parasitism

Parasitism is a situation whereby an organism (parasite) lives at the expense of the organism called host. Both the endoparasites and ectoparasites, on most occasions depend on nutrients of the host (either plants or animals) that will definitely starve the host and micronutrients deficiency may emerge (FAO, 2012).

Soil humus

A humus is an end-product given by organisms' decomposition actions. Humus is a black, and jelly-like substance found on soil surface and may affect the tendency of soil to hold micronutrients for plants uptake (FAO & WHO, 2013; Kihara et al., 2019).

Water

Water contains minerals dissolved in its fold. Therefore, soil that holds more water allows micronutrients to be taken up by plants (Norlan, 1983; FAO & WHO, 2013; Kihara et al., 2019).

Soil type

There are different soil types such as sandy, clayey, and loamy that are of different micronutrients holding capacity. Due to structures, clayey and loamy soils holds more water thereby allowing dissolved nutrients for plants uptake (FAO & WHO, 2013; Kihara et al., 2019; Aruaye Afeye Obada et al., 2021).

12. Conclusion

Sokoto State is indeed being affected by micronutrients deficiencies to say the least. Deficiencies of vitamins, Fe, I, and presence of antinutrients (in diets) are evident. These are staunch public health nutrition misfortunes that require efforts such as supplementation, biofortification, health education, research, fertilization (manuring), etc to save the remaining grace of the state and country at large.

Conflicts of interest

There are no any conflicts of interest whatsoever regarding this work.

Acknowledgements

The author uses this opportunity to thank the management of Sokoto State University Sokoto, the management of Shehu Shagari University of Education Sokoto and my family for supporting me during the development of this work. I'm are also equally grateful to the management of publisher university for supporting us to see this publication to fruition. Thank you all.

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