

Iodine Fortification Study of Some Common African Vegetables

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Abstract

Iodine Deficiency Diseases (IDDs) occupy important positions in the health problems of developing countries. Salt Iodisation has been the common approach to solving these problems. However, apart from the problems of lack of compliance by salt manufacturers, and inculturation of the consumers, health conditions aggravated by high salt intake by humans have become increasingly relevant. These problems can be eliminated if the commonly produced and consumed plants are fortified with Iodine. The prospects are in the inclusion of Iodine-containing compounds in the inorganic fertilizers used by farmers. In this study, Potassium Iodide and Potassium Iodate were used as inoculants. Five different concentrations—0.1 M, 0.2 M, 0.3 M, 0.4 M, and 0.5 M of Potassium Iodide and Potassium Iodate solutions were used to inoculate the soils on which the following edible African plants were planted: *Murraya koenigii*, *Ocimum gratissimum*, *Cucurbita pepo*, *Solanum nigrum*, *Amaranthus hybridus* and *Abelmoschus esculentus*, *Corchorous olitorius*, *Solanum lycopersicum*, *Zingiber officinale*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena*. Controls were also planted. After 14 days, alkaline dry ash method was used to determine the Iodine concentrations in the plants. The results showed that *Murraya koenigii* showed the highest absorption of Iodine 6.90 mg/kg at 0.3 M using KI, followed by *Amaranthus hybridus* 6.40 mg/kg at 0.1 M. *Solanum nigrum*, *Ocimum gratissimum* and *Zingiber officinale* also showed good absorption. Other plants except *Murraya koenigii*, *Ocimum gratissimum*, *Solanum nigrum* and *Zingiber officinale* showed very low tolerance to KI absorption. The result also showed that *Telfairia occidentalis* showed the highest absorption of iodine 8.20 mg/kg at 0.2 M of KIO_3 followed by *Cucurbita pepo* 6.40 mg/kg at also 0.2 M of KIO_3 . *Murraya koenigii*, *Ocimum gratissimum*, *Solanum nigrum*, *Zingiber officinale* also showed good absorption of KIO_3 . Some of the plants were not able to tolerate the absorption at higher concentration for both KI and KIO_3 . All the plants

were poisoned at concentration of 0.5 M for both KI and KIO₃. *Murraya koenigii*, *Ocimum gratissimum*, *Solanum nigrum*, *Zingiber officinale* can be used in iodine biofortification using KI and KIO₃ at concentration < 0.5 M. The overall result may be very significant, when it is considered that Iodine is a micronutrient, with a daily intake requirement of 100 - 150 µg/kg. It can be seen that there is hope in achieving this kind of biofortification.

Keywords

Iodine Deficiency Disease (IDD), Biofortification, Iodisation, Potassium Iodide, Potassium Iodate: *Murraya koenigii*, *Ocimum gratissimum*, *Cucurbita pepo*, *Solanum nigrum*, *Amaranthus hybridus*, *Abelmoschus esculentus*, *Corchorous olitorius*, *Solanum lycopersicum*, *Zingiber officinale*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena*

1. Introduction

Agriculture can inevitably play a big role in improving nutrition and health in developing countries. However, advancement in agriculture has often concentrated on increasing production to avert food insecurity, at the expense of improving the nutrient content of the food crop. As such, many farming systems currently cannot produce enough micronutrients to meet human requirements in a sustainable way [1]. Deficiencies in vitamins and minerals in our diets create major public health problems, mental as well as physical, especially in developing countries. Conventional responses (diet diversification, supplementation, fortification of manufactured foods) have had limited impacts [2]. Iodine is a trace element that is fundamental for human health: Iodine deficiency (ID) is the result of insufficient dietary iodine intake and in humans results in multiple adverse effects due to inadequate synthesis of thyroid hormone (whose classic sign is goiter, the enlargement of the thyroid gland) that has multiple functions such as enhancing protein synthesis, regulating energy transfer, accelerating growth and development, and maintaining the structure of central nervous system. The resulted physiological disorders and biological function abnormalities are called iodine deficiency disease (IDD). Despite myriad improvements to global food production systems in the context of human nutrition, about two billion people worldwide are affected by IDD, with those in south Asia and sub-Saharan Africa particularly affected. Iodine deficiency has many adverse effects on growth and development. Fruits and vegetables are usually poor sources of iodine; however, plants can accumulate iodine if it is either present or exogenously administered to the soil [3]-[9]. At least one billion people are at risk of IDD. Iodine deficiency, therefore, constitutes one of the most common preventable causes of mental deficiency in the world today. Most of the affected populations live in mountainous areas in preindustrialized countries, but 50 to 100 million people are still at risk in Europe [10] [11]. Salt iodization programs

have alleviated the scourge significantly in some regions, however, the use of iodized salt in food processing is still extensively inadequate and the volatilization of iodine during food storage, transport or cooking is high. Furthermore, the policies adopted by many countries are aimed at reducing salt intake in order to prevent hypertension and cardiovascular diseases and so multipronged approach will be needed to ultimately defeat this pervasive disease [7] [12] [13]. Iodine is present in soils as iodide, iodate and organic iodine compounds. Little iodine is present in the soil solution and most soil iodine is associated with organic matter, clays and oxides of Fe and Al [14]. In some areas surface soil becomes progressively poorer in iodine through accelerated deforestation, soil erosion and leaching processes [15]. The bio fortification of crops with iodine has therefore been proposed as a strategy for improving human nutrition. Producing iodine enriched crops through bio fortification could be an effective way to reduce the deficiency effects [8] [16]. Biofortification is the process of adding nutritional value to the crop. It refers to nutrient enrichment of crops to address the negative economic and health consequences of vitamin and mineral deficiencies in humans [17]. Biofortification, the increase of micronutrients in the edible parts of the plants, can be achieved by either mineral fertilization or plant breeding [18] [19]. Biofortification, the process of enriching staple foods with essential micronutrients, is one of the key alternatives recommended to increase iodine availability and consumption using the best traditional breeding practices and modern biotechnology. This approach has multiple advantages. First, it capitalizes on the regular daily intake of a consistent and large amount of food staples by all family members. Because staple foods predominate in the diets of the poor, this strategy implicitly targets low-income households. Second, after the one-time investment to develop seeds that fortify themselves, recurrent costs are low, and germplasm can be shared internationally. This multiplier aspect of plant breeding across time and distance makes it cost-effective. Third, once in place, the biofortified crop system is highly sustainable. Nutritionally improved varieties will continue to be grown and consumed year after year, even if government attention and international funding for micronutrient issues fade. Fourth, biofortification provides a feasible means of reaching undernourished populations in relatively remote rural areas, delivering naturally fortified foods to people with limited access to commercially marketed fortified foods that are more readily available in urban areas [1] [20]. Recent studies demonstrated that leafy vegetables such as spinach or lettuce can store iodine in their edible tissues, making them good candidates for iodine biofortification programs [16]. Biofortification is a feasible and cost-effective means of delivering micronutrients to populations that may have limited access to diverse diets and other micronutrient interventions [21] [22] [23]. Vegetables are fresh, edible portion of plant that are either eaten raw or in cooked form. They contain both essential and toxic elements over a wide range of concentrations [24]. *Murraya koenigii* is a culinary important plant of Indian origin, and also been a

component of many formulations used in the Ayurvedic system of medicine since many centuries. A scrutiny of literature reveals some notable pharmacological activities of the plant. Carbazole alkaloids which are abundantly present in the leaves, fruits, roots and bark of this plant, have been reported for their antidiabetic, anticancer, antibacterial, anti-nociceptive and antioxidant activities. Besides these activities, the plant is described to have a wide array of therapeutic activities [25]. *Ocimum gratissimum* is also used in the management of baby's cord and in the treatment of fungal infections, fever and cold [26]. *Cucurbita pepo* seeds and seed extracts represent a complex mixture of substances, and their effects may not be attributed to just a few ingredients. It is significant for the treatment of BHP, a condition that commonly affects men 50 years and older and involves enlargement of the prostate gland [27]. *Solanum nigrum* Linn. (Solanaceae) commonly known as "Black nightshade" that have been extensively used in traditional medicine in India and other parts of world to cure liver disorders, chronic skin ailments (psoriasis and ringworm), inflammatory conditions, painful periods, fevers, diarrhea, eye diseases, hydrophobia, etc. [28]. *Amaranthus hybridus* leaves combined with condiments are used to prepare soup [29]. *Abelmoschus esculentus* has found medical application as a plasma replacement or blood volume expander and also useful in genitor-urinary disorders, spermatorrhoea and chronic dysentery [30]. *ute* (*Corchorus olitorius* L.) is an indigenous leafy vegetable which leaves are very rich in amino acid and essential minerals and they form part of the meals of people of Asia, Middle East and parts of Africa [31]. Tomato (*Solanum lycopersicum* L.) is an important vegetable crop. It is a rich source of vitamins, minerals, and fiber, and a dietary source of antioxidants [32]. *Zingiber officinale* commonly known as ginger, is a spice consumed worldwide for culinary and medicinal purposes. The plant has a number of chemicals responsible for its medicinal properties, such as antiarthritism, antiinflammatory, antidiabetic, antibacterial, antifungal, anticancer, etc. [33]. The fluted pumpkin (*Telfairia occidentalis* Hook f.), a member of the Cucurbitaceae, is a strong climber and short-termperennial [34]. It is widely cultivated for its palatable and nutritious leaves which are used mainly as vegetable. The seeds are also nutritious and rich in an oil which may be used for cooking and soap manufacture [35]. *Talinum triangulare* (water leaf) is an herbaceous perennial; caules cent and glabrous plant widely grow in tropical regions as a leaf vegetable [36]. *Solanum melongena* L.) belongs to the Leptostemonum Clade (the "spiny" solanums) of the species-rich genus *Solanum* (Solanaceae). Unlike most of the genus, the eggplant and its relatives are from the Old World; most eggplant wild relatives are from Africa [37]. Eggplants, and the closely related *Solanum* species belonging to the subgenus *Leptostemonum*, are some of the most important vegetable crops in Asia, the Middle and Near East, Southern Europe, and Africa and are some of the key materials of various cuisines in these countries [38]. Various have reported incidence of Iodine Deficiency Disorders, in India, Vietnam, Iran, Bangladesh, Nepal, even in iodine-replete environment

like Eastern Europe, North America and endemic in the mountain regions of Armenia [38]-[49]. Incidences of IDD have been reported in some Sub Saharan African countries by Saha *et al.*, 2019 [50]. Many other African countries like in Sudan, an Emergency Food Security and Nutrition Assessment Survey (EFSNA) revealed the prevalence of IDD among adult women and children, More than 2 out of 10 school age children have goiter [51]. Some other researchers also reported Iodine deficiency being highly prevalent among rural South Sudan communities and a likely cause for goiters. Rural poor women are highly vulnerable [52]. Prevalent Endemic goiter was also reported by A cross-sectional survey conducted in Shebe Senbo District, Jimma Zone, Southwest Ethiopia and Ada district, Oromia region, Ethiopia [53] [54]. A systematic review of data from 2005 to 2015 conducted in 2017 also revealed prevalence of ID ranged from 9% to 18% in Ethiopia, Nigeria and South Africa [55]. Ogbera and Kuku, 2011 reported endemic goiter in some African countries like New Guinea, Cameroun, Northern Zaire, Central Africa Republic, Uganda, and Rwanda, and occurrence of heart failure in 42% of subjects with thyrotoxicosis in Lagos Nigeria [56]. Mshelia *et al.*, 2016 also reported the presence of iodine deficiency in Maiduguri, north-eastern Nigeria, especially in females [57]. Ogbera *et al.*, 2007 reported Thyroid disorders as significant causes of cardiovascular morbidity Nigeria [58]. Salami *et al.*, 2016 reported high prevalent thyroid diseases in a tertiary hospital in Nigeria especially in female [59]. From the above literature, it can be seen that despite increase in daily iodine intake through salt iodisation, endemic and prevalence IDDs are still present especially in Africa. And also considering health effect of increased consumption of Sodium chloride as potential cause of hypertension and cardiovascular diseases [60], importance of iodine fortification of common vegetables cannot be overemphasized and therefore this work.

Materials Used

PD303 UV Spectrophotometer, CF-30 Teco Centrifuge, Ohaus EX224 analytical weighing balance, Thermolyne F47925-80 benchtop Muffle furnace, nickel crucible, air-tight jar, measuring cylinder, beakers, KIO_3 , KI, KNO_3 , NaOH, Ceric ammonium sulphate, sodium arsenite, seeds of *Murraya koenigii*, *Ocimum gratissimum*, *Cucurbita pepo*, *Solanum nigrum*, *Amaranthus hybridus*, *Abelmoschus esculentus*, *Corchorous olitoruis*, *Solanum lycopersicum*, *Zingiber officinale*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena*, distilled water.

2. Methods

The seeds of *Murraya koenigii*, *Ocimum gratissimum*, *Cucurbita pepo*, *Solanum nigrum*, *Amaranthus hybridus*, *Abelmoschus esculentus*, *Corchorous olitoruis*, *Solanum lycopersicum*, *Zingiber officinale*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena* were bought from Eke Awka market in Awka, the State Capital of Anambra State, Nigeria. The seeds were planted in nurseries and the seedlings transplanted to one hundred and thirty two (132) beds. Each plant was planted in eleven beds, 20 ml of each of 0.1 M, 0.2 M, 0.3 M, 0.4 M and 0.5

M of Potassium iodide 0.1 M, 0.2 M, 0.3 M, 0.4 M and 0.5 M of potassium iodate was added to each of the plants. One each of the plants was left uninoculated (control). Dry Alkaline Ash Method of analysis, was used after 14 days. This was done by adding 0.5 g of each of the samples into a nickel crucible. 1 ml of a mixture 0.5 M sodium hydroxide and 0.1 M potassium nitrate was added to the samples, mixed and allowed to dry. The containers were covered, placed in a muffle furnace, heated to 250°C, held, for 15 minutes, and heated further to 480°C, held for 15 minutes, and finally brought to 580°C. The temperature was maintained for three hours, allowed to cool to room temperature. The resultant ashed was extracted with three successive 2 ml portions of a 1.0mM NaOH, made up double-distilled water. The solution was centrifuged at 2500 g for 20 minutes using polypropylene centrifuge tubes and the supernatant solution collected for iodine determination. 1ml of the sample solution was added to a cuvette at 35°C and 1 ml sodium arsenite, and 1 ml of ceric ammonium sulphate. A standard curve containing 0.5 to 10 ppm iodine was used. The intensity of the developed colour was measured at 420 nm. The iodine concentration in the samples was calculated from the standard curve. Concentrations of the control were deducted from the concentrations of the inoculated.

3. Results

See **Table 1** and **Table 2**.

Table 1. Result of absorbed I₂ for KI by the plants (mg/kg).

Plant	Absorbed I ₂ for 0.1 M KI	Absorbed I ₂ for 0.2 M KI	Absorbed I ₂ for 0.3 M KI	Absorbed I ₂ for 0.4 M KI	Absorbed I ₂ for 0.5 M KI
<i>Murraya koenigii</i>	6.50	2.33	6.90	Died	Died
<i>Ocimum gratissimum</i>	2.30	2.20	2.35	2.31	Died
<i>Cucurbita pepo</i>	2.80	2.50	Died	Died	Died
<i>Solanum nigrum,</i>	6.0	6.0	2.40	2.21	Died
<i>Amaranthus hybridus</i>	6.40	Died	Died	Died	Died
<i>Abelmoschus esculentus</i>	2.20	Died	Died	Died	Died
<i>Corchorous oltoruis</i>	Died	Died	Died	Died	Died
<i>Solanum lycopersicum</i>	Died	Died	Died	Died	Died
<i>Zingiber officinale</i>	1.60	1.62	1.62	2.0	Died
<i>Telfairia occidentalis</i>	Died	Died	Died	Died	Died
<i>Talinium triangulare</i>	Died	Died	Died	Died	Died
<i>Solanum melongena</i>	Died	Died	Died	Died	Died

Table 2. Result of absorbed I₂ for KIO₃ by the plants (mg/kg).

Plant	Absorbed I ₂ for 0.1 M KIO ₃	Absorbed I ₂ for 0.2 M KIO ₃	Absorbed I ₂ for 0.3 M KIO ₃	Absorbed I ₂ for 0.4 M KIO ₃	Absorbed I ₂ for 0.5 M KIO ₃
<i>Murraya koenigii</i>	2.40	5.70	2.18	Died	Died
<i>Ocimum gratissimum</i>	2.10	2.16	2.24	2.12	Died
<i>Cucurbita pepo</i>	6.10	6.40	6.20	6.20	Died
<i>Solanum nigrum,</i>	2.30	2.12	2.21	2.12	Died
<i>Amaranthus hybridus</i>	2.20	2.50	Died	Died	Died
<i>Abelmoschus esculentus</i>	Died	Died	Died	Died	Died
<i>Corchorous olitoruis</i>	Died	Died	Died	Died	Died
<i>Solanum lycopersicum</i>	1.8	1.33	1.60	Died	Died
<i>Zingiber officinale</i>	1.30	1.40	1.60	1.30	Died
<i>Telfairia occidentalis</i>	2.20	8.20	Died	Died	Died
<i>Talinium triangulare</i>	6.20	Died	Died	Died	Died
<i>Solanum melongena</i>	2.30	Died	Died	Died	Died

4. Discussions

The result of the analysis showed that *Murraya koenigii* showed a very good absorption of iodine using KI, and KIO₃ at concentrations not higher than 0.3 M. With highest absorption of 6.90 mg/kg for 0.3 M KI which was the highest absorption value using KI, followed by *Amaranthus hybridus* (6.40 mg/kg) at 0.1 M KI and *Solanum nigrum* (6.0 mg/kg) at 0.1 M and 0.2 M KI. Highest absorption of Iodine using KIO₃ was got with *Telfairia occidentalis* at 0.2 M (8.20 mg/kg), though the plant could not tolerate absorption of the salt beyond 0.2 M. The result also showed that *Cucurbita pepo* showed the very good absorption of iodine using KIO₃ 6.10 mg/kg, 6.40 mg/kg, 6.20 mg/kg and 6.00 mg/kg at concentrations of 0.1 M, 0.2 M, 0.3 M and 0.4 M respectively. The plant showed highest tolerance for KIO₃. *Murraya koenigii* also showed very good absorption (2.40 mg/kg, 5.70 mg/kg and 2.18 mg/kg) and tolerance for KIO₃ at concentrations of 0.1 M, 0.2 M and 0.3 M respectively. *Solanum nigrum*, *Ocimum gratissimum*, *Solanum lycopersicum* and *Zingiber officinale* also showed good absorption and very high tolerance for KIO₃ from 0.1 M to 0.4 M. *Corchorous olitoruis*, *Solanum lycopersicum*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena* were poisoned by the KI at all concentrations. *Corchorous olitoruis* and *Abelmoschus esculentus* also showed zero tolerance to KIO₃ absorption at all concentrations. Some of the plants were also not able to tolerate the absorption at higher concentration for both KI and KIO₃. The other plants, apart from *Murraya koenigii*, *Solanum nigrum*, *Zingiber officinale* and *Ocimum*

gratissimum were poisoned by the KI at concentrations greater than 0.3 M. Plants like *Corchorous olitoruis*, *Amaranthus hybridus*, *Abelmoschus esculentus*, *Murraya koenigii*, *Solanum lycopersicum*, *Telfairia occidentalis*, *Talinium triangulare*, *Solanum melongena* did not tolerate absorption of KIO₃ at concentration > 0.3 M. All the plants were poisoned at concentration of 0.5 M for both Ki and KIO₃.

5. Conclusions

The health and well-being of a population are significantly influenced by their nutritional status. A healthy and well-balanced diet, with a variety of high-quality foods ensuring the right proportions of different types of nutrients, is important both in the prevention and in the treatment of several diseases [4].

- Some of the plants showed very good absorption of iodine, when compared with the iodine daily intake requirement, iodine fortification of these vegetables is very important in order to reduce the incidence of IDD and also maintain a healthy diet in Africa.
- There is also need to increase phyto-availability, and reduce phytotoxicity of iodine compounds.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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