



Iodine Fortification Study of Some Common Nigerian Vegetables Using Copper Complex

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Iodine deficiency (ID) is the result of insufficient dietary iodine intake in humans, the deficiency not only leads to goiter formation but also to severe retardation of growth, development and maturation of nearly all the tissues of the body, especially those that are fast developing. The aim of this research is to evaluate levels of iodine intake by ten Nigerian vegetables using copper complex. Dry alkaline ash method was used in the determination. The results obtained showed that all the ten vegetables used absorbed high concentrations of iodine when inoculated with 0.09 M and 0.14 M $[Cu(I)4]^{2-}$. Iodine phytotoxicity was observed in all the plants when inoculated with 0.2-0.8 M of

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the copper complex as all the plants died. Increase in the concentration of copper complex from 0.09-0.14 M increased the absorption of iodine by *Amaranthus hybridus*, *Corchorous olitoruis*, *Gongronema lotifolium* and *Solanum melongena*. The reverse was observed with *Murraya koenigii*, *Ocimum gratissimum*, *Talinium triangulare*, *Abelmoschus esculentus*, *Cucurbita pepo* and *Telfairia occidentalis*. *Ocimum gratissimum* absorbed the iodine at 0.09M with value of 164.79 mg/kg, the vegetable also absorbed least at 0.14 M with a dose of 61.80 mg/kg. The intake of the iodine by the plants showed that the method can be used in the fortifying these Nigerian vegetables with iodine, thereby reducing the incidence of Iodine deficiency disorder in humans.

Keywords: Iodine; biofortification; vegetables; copper complex; absorption.

1. INTRODUCTION

“Increasing population, inadequate food and nutrition, hunger, malnourishment of vitamins and micronutrients etc. are the biggest challenges to address most of the nations across the world” [1]. “Humans require at least 22 mineral elements for their wellbeing. These can be supplied by an appropriate diet. However, it is estimated that over 60% of the world’s 6 billion people are iron (Fe) deficient, over 30% are zinc (Zn) deficient, 30% are iodine (I) deficient and 15% are selenium (Se) deficient” [2]. “Deficiencies in vitamins and minerals in our diets create major public health problems, mental as well as physical, especially in developing countries” [3]. “Micronutrient malnutrition affects more than one-half of the world’s population, especially women and preschool children. Reaching the Millennium Development Goals to reduce the under-5 child mortality ratio by two-thirds and the maternal mortality ratio by three-quarters between 1990 and 2015 will require additional technologies and approaches to improving nutritional status, which is an important determinant of these mortalities” [4]. “Iodine is a trace element that is fundamental for human health: its deficiency affects about two billion people worldwide” [5-7]. “It is a component of the thyroid hormones which determines the metabolic rate of the body” [8-11]. “Iodine deficiency (ID) is the result of insufficient dietary iodine intake in humans, resulting in multiple adverse effects due to inadequate thyroid hormone production, globally named iodine deficiency disorders (IDDs)” [12-14]. “Despite myriad improvements to global food production systems in the context of human nutrition, nearly two billion people worldwide still receive insufficient dietary iodine such that iodine deficiency disorder (IDD) still persists as one of the world’s most intractable micronutrient-related diseases” [15]. “To counteract the IDD, one of the most effective way is the iodization of kitchen salt but, even so, a third of the global population

is still unprotected from iodine deficiency” [16]. “The IDD is a major problem even in the developed countries, and biofortification with iodine is a good alternative to iodized salt to cope with such problem” [17]. “Usually 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” [5]. “The biofortification of crops with iodine is a recent strategy to further enrich the human diet with a potentially cost-effective, well accepted and bioavailable iodine source” [11]. “Since salt iodisation is insufficient to ensure global iodine adequacy, with an estimated one-third of humanity at risk of hypothyroidism and associated iodine deficiency disorders (IDD)” [18]. In most industrialized countries, excess consumption of salt has become recognized as a health risk [19], enrichment of crops with iodine would be able to address negative economic and health consequences of iodine deficiencies in humans. Vegetables have shown to have the potentials of absorbing both heavy metals [20-27] and essential elements [28-30] from the soil.

Ujowundu et al, 2009 studied Iodine fortification of Selected Plants Using Potassium Iodide and found that iodine biofortification of *Telfairia occidentalis*, *Talinium triangulare* and *Zea mays* if properly harnessed, may improve the iodine content of plants [31]. “In our previous work, we also studied Iodine Fortification Study of Some Common African Vegetables using potassium iodide and potassium iodate and found out that *Murraya koenigii*, *Ocimum gratissimum*, *Solanum nigrum*, *Zingiber officinale* can be used in iodine biofortification using KI and KIO₃ at concentration < 0.5 M” [32]. Caffagni et al., 2011 studied the iodine fortification of *Hordeum vulgare*, *Zea mays*, *Nicotiana tabacum*, *Solanum tuberosum* and *Solanum lycopersicum* using potassium iodide and potassium iodate and reported that *Solanum tuberosum* and *Solanum lycopersicum* were shown to be good targets for a fortification-rate study among the species screened [33].

“Another study of Iodine fortification of *Solanum lycopersicum* using potassium iodide and potassium iodate also suggested that tomato was a particularly suitable crop for iodine biofortification programs” [6,10]. “Iodine fortification of spinach, cabbage, coriander, potherb mustard, tomato, cucumber, long cowpea, eggplant, and hot pepper using algal organic iodized fertilizer showed that both leaf vegetables and fruit vegetables can absorb exogenous iodine from soil. The uptake amounts increase with the application intensity of algal organic iodized fertilizer” [34]. “Work that was carried out to enrich Polignano Carrot with iodine showed that the concentrations of iodine into biofortified carrots in open field can allow to satisfy the recommended daily allowance (RDA) by consuming 100 and 200 g of fresh product” [35].

2. METHODOLOGY

The seeds of ten African vegetables- *Murraya koenigii*, *Ocimum gratissimum*, *Cucurbita pepo*, *Amaranthus hybridus*, *Abelmoschus esculentus*, *Corchorous olitoruis*, *Gongronema lotifolium*, *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 seventy (70) beds. Each plant was planted in seven beds, 20 mL of each of 0.09M, 0.14M, 0.2M, 0.33M, 0.4M, 0.8M of $[Cu(I)_4]^{2-}$ was added to each of the plant. One each of the plants was left uninoculated (control). The iodine content was evaluated using Dry Alkaline Ash Method as described by Anarado et al., [32], was used after 14 days. This was done by adding 0.5 g of each of the samples into a nickel crucible. Exactly 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 1.0 mM 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. 1 mL 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 AND DISCUSSION

The result of the analysis (Table 1) showed that all the ten plants used suffered iodine phytotoxicity when inoculated with $[Cu(I)_4]^{2-}$ at concentration above 0.14M. It was observed that most of the plants' leaves turned yellow after few hours of inoculation at higher concentrations and died within twenty-four hours. Though there was phytotoxicity, the vegetables showed very good absorption potential of iodine with $[Cu(I)_4]^{2-}$ at lower concentrations since all the plants absorbed more than 6000 mg/kg of iodine at lower concentrations. The inability of the plants to survive at higher concentrations is against the report of Kiferle et al., [36]. They revealed that in open field, the use of increasing concentrations of both iodine salts (KI and KIO_3) gradually enhanced iodine accumulation in leaves of *Ocimum basilicum*. At concentration of 0.09 M $[Cu(I)_4]^{2-}$, *Ocimum gratissimum* absorbed most of the iodine (164.79 mg/kg), followed by *Cucurbita pepo*(7867.80 mg/kg) and the least *Corchorous olitoruis*(62.18 mg/kg).As the concentration of $[Cu(I)_4]^{2-}$ increased from 0.09 M to 0.14 M, the concentration of iodine absorbed by *Murraya koenigii*(74.87-72.33 mg/kg), *Ocimum gratissimum*(164.79-61.80 mg/kg), *Cucurbita pepo*(78.68-65.99 mg/kg), *Abelmoschus esculentus*(71.06-65.53 mg/kg), *Telfairia occidentalis*(74.33-68.80 mg/kg) and *Talinium triangulare*(72.21-67.26 mg/kg) decreased, but the concentration of iodine absorbed by *Amaranthus hybridus*(63.45-67.26 mg/kg), *Corchorous olitoruis*(62.18-69.79 mg/kg), *Gongronema lotifolium*(73.60-77.41 mg/kg) and *Solanum melongena*(63.45-65.99 mg/kg) increased. When compared with the results of our previous research; *Murraya koenigii* absorbed 6.90 mg/kg and 5.70 mg/kg of iodine when inoculated with 0.3 M KI and 0.2 M KIO_3 respectively. Increase in the concentrations of both KI and KIO_3 at 0.5 M resulted in the death of the plants, which is in line with the results of the present study. However, the increase in the absorption using $[Cu(I)_4]^{2-}$ at and 0.09 M and 0.14 M was more than 1000%. *Ocimum gratissimum* also absorbed very high concentration of iodine with $[Cu(I)_4]^{2-}$ at 0.09 M

Table 1. Result of absorbed Iodine by the plants (mg/kg)

Plant	0.09M[Cu(I)₄]²⁻	0.14M[Cu(I)₄]²⁻	0.2M[Cu(I)₄]²⁻	0.33M[Cu(I)₄]²⁻	0.4M[Cu(I)₄]²⁻	0.8M[Cu(I)₄]²⁻
<i>Murraya koenigii</i>	74.87	72.33	Died	Died	Died	died
<i>Ocimum gratissimum</i>	164.79	61.80	Died	Died	Died	died
<i>Cucurbita pepo</i>	78.68	65.99	Died	Died	died	died
<i>Amaranthus hybridus</i>	63.45	67.26	Died	Died	died	died
<i>Abelmoschus esculentus</i>	71.06	65.53	Died	Died	died	died
<i>Corchorous olitoruis</i>	62.18	69.79	Died	Died	died	died
<i>Gongronema lotifolium</i>	73.60	77.41	Died	Died	died	died
<i>Telfairia occidentalis</i>	74.33	68.80	Died	Died	Died	Died
<i>Talinium triangulare</i>	72.21	67.26	died	Died	died	died
<i>Solanum melongena</i>	63.45	65.99	died	Died	died	died

when compared with 2.35 M and 2.24 M using 0.3 M KI and KIO₃ respectively. The increase in absorption was more than 7000% when compared with its absorption at 0.09 M[Cu(I)₄]²⁻. Salau et al., [37] had earlier reported that *Talinium triangulare* absorbed very little amount of iodine (0.49 + 0.01 µg / 100 g) when compared with the iodine absorption *Telfairia occidentalis* (23.94 ± 1.88 µg / 100 g). Our result showed that even at low concentration, the absorption of iodine by the vegetables was higher than the needed and sufficient levels of iodine consumption in humans (Adults- 200 µg) [38].

4. CONCLUSION

The vegetables used in this research showed very good iodine absorption capacity using [Cu(I)₄]²⁻ even at very low concentrations. When compared the results from our previous work, the copper complex has shown to be a better way of introducing iodine into our common Nigerian vegetables. Consequently, could be a very good way of addressing iodine deficiencies in humans. However, lower concentrations of the copper complex should be employed to reduce the doses of iodine in the vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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