Full Length Research Paper

Effects of Potassium Iodate Application on the Biomass and Iodine concentration of Selected Indigenous Nigerian Vegetables

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Iodine is a trace element in soil and water that is involved in some important metabolic functions in human development. In many areas of the world, the surface soil becomes progressively poorer in iodide through accelerated deforestation, flooding and soil erosion. Hence, the food grown in iodine deficient regions can never provide enough iodine for the people and livestock living there. This study was aimed at increasing the level of iodine in commonly consumed vegetables by iodination of irrigation water with potassium iodate. The results obtained showed that, the increase in iodine concentration in fluted pumpkin ranged from 89.02 ± 0.31 to 140.36 ± 1.08 µg/100 g in week 4 and 102.86 ± 0.60 to 115.89 ± 0.05 µg/100g in week 6. The increase in iodine concentration in the vegetable marrows ranged from 60.879 ± 0.32 to 76.786 ± 0.16 µg/100 g in week 4 and 62.078 ± 0.09 to 107.679 ± 0.24 µg/100 g in week 6. The increase in iodine concentration in water leaf ranged from 61.59 ± 0.24 to 73.41 ± 0.83 µg/100 g in week 4 and 62.06 ± 0.09 to 96.25 ± 0.025 µg/100 g in week 6. From the results, the vegetables treated with 40 µg/l potassium iodate showed the highest iodine level in week 4. These results from this iodine biofortification studies, suggest that the iodine added to the soil increased iodine uptake by the vegetables. Suggesting that iodination of irrigation water is an advantageous and cost-effective method of supplying iodine, since it requires simple technology.

Key words: Fortification, iodine deficiency disorders, iodination, irrigation, potassium iodate.

INTRODUCTION

Iodine is an essential trace element in human nutrition (Delange, 1994) and it is involved in growth and development of bone, muscle, height and weight, and maintains the stabilization of energy and material metabolism (Fuge and Johnson, 1986; Hetzel, 1989; Fisher and Delange, 1998). Deficiency of iodine resulting from inadequate dietary intake is related to a spectrum of diseases collectively known as iodine deficiency disorders (IDDs) (Hetzel, 1983). IDDs can be corrected by resupplying iodine in the diet (Delange, 2000; Kanshe, 1999). The iodine content of food depends on the iodine content of the soil in which it is grown and since iodine is irregularly distributed over the earth's crust, there are variations in

the iodine content of food in different geographical locations (Koutras et al., 1985). Thus the food grown in iodine deficient areas cannot provide enough iodine for the people and livestock living there, especially in areas where the surface soil have progressively become poorer in iodide through erosion and leaching processes (Singh, 2004).

Vegetables have always occupied a prominent place in the human diet. It is either cooked separately in soups and stews or eaten raw as salads. Vegetables are nutritious and delicious to eat and can satisfy hunger. They are made up of a high percentage of water and an appreciable percentage of dietary fiber, fat and oils, minerals and vitamins. In Nigeria, some vegetables have for centuries been cultivated and eaten and they have become staples in our diet. Three of these vegetables: *Telfairia occidentalis* (fluted pumpkin), *Talinium trangulare*

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(water leaf) *and Cucurbita pepo* (vegetable marrow) which are commonly consumed in Nigeria, especially in the southeastern region were used for this fortification study. *T. occidentalis* (family Cucurbitacea) is a vigorous perennial vine, grown widely in the southern state of Nigeria, Ghana and Sierraleone (Burkett et al., 1968; Badifu et al., 1995). The leaves are also rich in essential and non-essential amino acids, vitamins and minerals (Fasuyi, 2006). *C. pepo* also belongs to the family of Cucurbitaceae. It is widely grown in Malaysia, West Africa, especially Nigeria and the leaves are a good source of nutrients like proteins, fats, carbohydrates calcium and iron. *T. triangulare* (family Portulacaceae) is grown widely in West Africa and Malaysia. *T. triangulare* leaves are used in the preparation of soups and stews and in herbal medicine preparations (Opabode and Adebooye, 2005).

Salt iodization has been proven to be effective in the treatment and prevention of IDDs (Lamberg, 1985; WHO/NUT, 1994). A large percentage of households in the world use iodized salt and it has shown to be effective in the treatment and prevention of IDDs (Lamberg, 1985; WHO/NUT, 1994; UNICEF, 2007). The use of salt has its attendant problems which include: recurrent cost of pro-duction, delivery network, storage ability and monitoring (Babikir, 1994) and some health implications (Feid-Ramussen, 2001; Delange et al., 1999; Laurberg et al., 2001). In such situations, alternative methods of IDD prevention such as iodization of water used for the irrigation of plants may be necessary for some category of people who may not benefit from iodized salt either for health or other reasons. Iodization of irrigation water has also been shown to require simple technology (Cao et al., 1994; Foo et al., 1996). We may therefore say that salt fortification with iodine is not enough to eliminate IDDs. This highlights the importance of multiple approaches for iodine fortification in the food chain. Also, since IDDs are primarily the result of inadequate amounts of iodine in soil, water and food, resupplying iodine to the soil medium will surely increase the iodine available for plant uptake.

The objectives of this study were to develop a method of improving the iodine content of these three leafy vegetables: *T. occidentalis*, *T. trangulare and C. pepo* by the application of iodized irrigated water to the soil and to examine the effects of the applied iodate on the vege-tables growth by determining the proximate compositions which is an important factor that makes them staples in the southeastern locality of Nigeria.

MATERIALS AND METHODS

Reagents

All chemicals and reagents used were of analytical grade and the reagents were free from iodine. Double distilled water was used in the preparation of all solutions and for subsequent dilutions.

Cultivation of plants and treatment

The seeds of three vegetables: *T. occidentalis* (fluted pumpkin), *T.*

trangulare (water leaf) and *C. pepo* (vegetable marrow) were used in this study. The seeds were purchased at Ezibodo market in Owerri West LGA of Owerri, Imo State and were identified by a plant taxonomist at the Crop Science Department of the Federal University of Technology, Owerri. Twelve beds were prepared for the cultivation and treatment. Three concentrations: 10, 40 and 80 µg/l of potassium iodate (KIO_3) was added to the irrigation water, while the control had no KIO_3.

The beds were divided into 3 groups of 4 beds. Each plant was planted in four beds. Three beds received 1 L of 10, 40, 80 µg/l of KIO_3 and the bed that served as the control received 1 L of borehole water without KIO_3 treatment. The sprinkler method was used in supplying water to the plants and this was done at two days intervals for four weeks. At the end of the 4th week, the plant samples were collected for iodine concentration analysis. The plants were nurtured for another two weeks without further KIO_3 treatment and samples were also collected for iodine analysis at the end of the sixth week.

Sample preparation

The leaves collected were oven dried at 40°C, ground to powder using warring blender, packaged in air-tight glass jar and stored at room temperature until analysis was carried out.

Iodine determination

Iodine was determined with alkaline dry ash technique (Fisher et al., 1986). This was done by adding 0.5 g of each sample into nickel crucibles. 1 ml of a mixture of 0.5 M sodium hydroxide and 0.1 M potassium nitrate was added to the samples, mixed and allowed to dry. The containers were then covered with aluminum foil and placed in a muffle furnace. The samples were heated to 250°C, held for 15 min, heated further to 480°C, again held for 15 min, and finally brought to 580°C. They were maintained at this temperature for 3 h, after which they were allowed to cool to room temperature. The resultant ash was extracted with three successive 2 ml portions of a 1.0 mM sodium hydroxide solution, made up of double-distilled water. The solution was centrifuged at 2500 g for 20 min using poly-propylene centrifuge tubes and the supernatant solution collected for iodine determination. The heat destroyed the organic matrix. The sodium hydroxide was used to keep the iodine in a nonvolatile form, while the potassium nitrate is used to increase the oxidation of the organic matter. Then, 1 ml of sample solution was added to a cuvette at 35°C and 1 ml of arsenic reagent was added. The reaction was started by the addition of 1 ml of ceric reagent. The initial reaction rate was calculated from the change in absor-bance at 420 nm. The iodine concentrations of the samples were determined from a standard curve.

Proximate analysis

The proximate composition of the leaf extract for carbohydrate, ash and moisture were determined as described by AOAC (1995). Crude protein, fibre and fat content were determined by methods described by Pearson (1976). Total ash content was determined by furnace incarnation using the method of James (1995). All determi-nations were done in triplicates.

Statistical analysis

The experimental design was completely randomized. Data obtained were analyzed using the analysis of variance (ANOVA). Significant difference between the data was determined at $p < 0.05$.
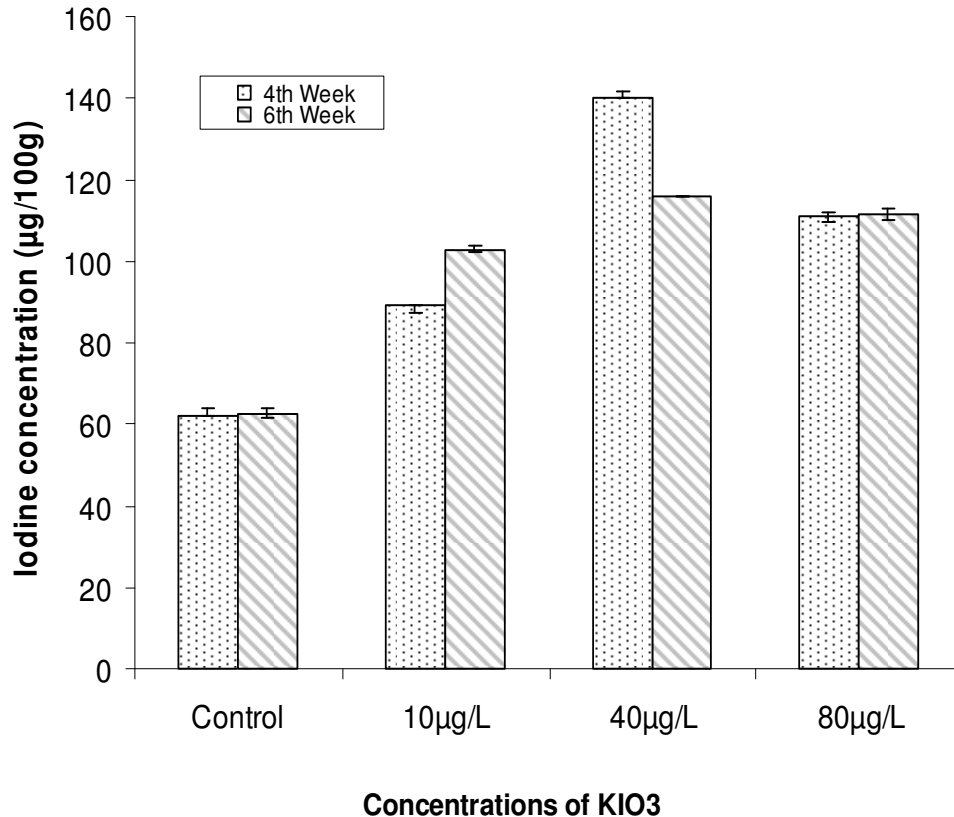
Figure 1. Iodine concentration in fluted pumpkin in weeks 4 and 6 after fortification with KIO_3.

RESULTS

Figure 1 shows the results of iodine concentration obtained from fluted pumpkin in week 4 and 6 in the various KIO_3 treatments. The increase in iodine concentration in fluted pumpkin ranged from 89.02 ± 0.31 to 140.36 ± 1.08 µg/100 g in week 4 and 102.86 ± 0.60 to 115.89 ± 0.05 µg/100 g in week 6. The highest iodine level of 140.36 ± 1.08 and 115.89 ± 0.05 µg/100 g was obtained in week 4 and 6, respectively, from the 40 µg/l KIO_3 treatment. The increase in iodine concentration of fluted pumpkin was significant ($p = 0.03$) from 0 - 40 µg/l KIO_3 treatments.

Figure 2 shows the result of iodine concentration in vegetable marrows in week 4 and 6 after KIO_3 treatment. The increase in iodine concentration ranged from 60.879 ± 0.32 to 76.786 ± 0.16 µg/100 g in week 4 and 62.078 ± 0.09 to 107.679 ± 0.24 µg/100 g in week 6. From the result, the vegetable marrows treated with 40 µg/l KIO_3 had the highest iodine level of 76.78 ± 0.16 and 107.68 ± 0.24 µg/100 g in week 4 and 6, respectively. The increase in iodine concentration in vegetable marrows was significant ($p = 0.02$) from 0 - 40 µg/l KIO_3 treatment but on further treatment with the 80 µg/l KIO_3, the increase in iodine concentration was not statistically significant ($p = 0.12$).

Figure 3 shows the result of iodine concentration in water leaf. The result showed that increase in iodine concentration in water leaf raged from 61.59 ± 0.24 to 73.41 ± 0.83 µg/100 g in week 4 and 62.06 ± 0.09 to 96.25 ± 0.025 µg/100 g in week 6. From the result, the water leaf treated with 40 µg/l KIO_3 had the highest iodine level of 76.78 ± 0.16 and 107.68 ± 0.24 µg/100 g in week 4 and 6, respectively. The increase in iodine concentration in water leaf was significant ($p = 0.01$) from 0 − 40 µg/l KIO_3 treatment but on further treatment with the 80 µg/l KIO_3, the increase in iodine concentration was not statistically significant ($p = 0.11$).

Tables 1, 2 and 3 shows the results of the percentage proximate composition of fluted pumpkin, vegetable marrow and water leaf, respectively. These results showed a significant difference ($p < 0.05$) in the nutrient contents of the three vegetables at the various treatments and control. The differences in the proximate composition showed great fluctuations such that a trend was difficult. But on dry biomass basis, no significant difference was observed for fluted pumpkin ($p = 0.98$), water leaf ($p = 0.98$) and vegetable marrow ($p = 0.99$) at the different concentration of KIO_3 treatments.

DISCUSSION

These results showed that treatment of soil with KIO_3 resulted in significant increase in the iodine concentration in the leaves of the vegetables. These observed increases
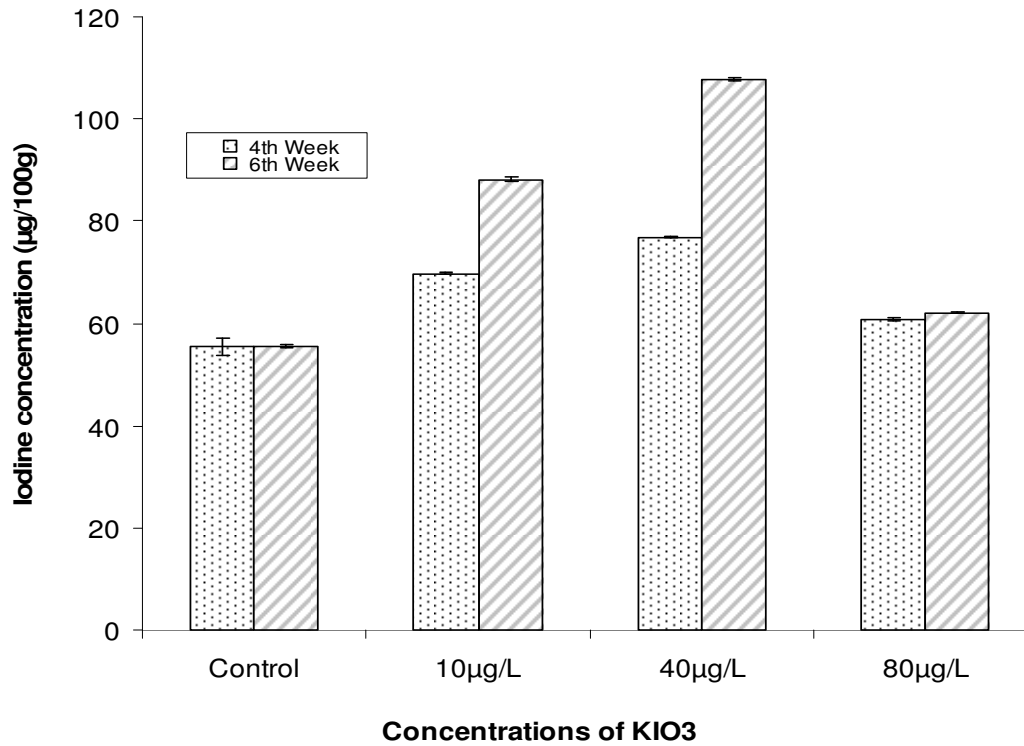
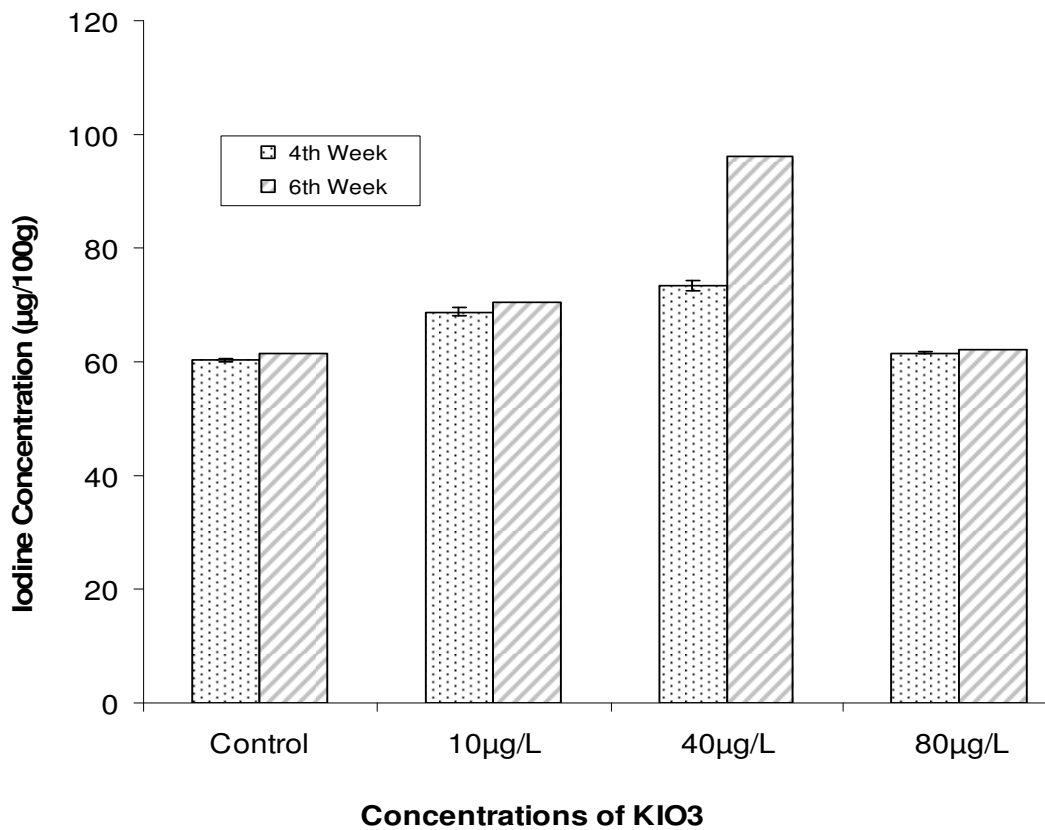**Figure 2.** Iodine concentrations in vegetable marrow in weeks 4 and 6 after fortification with KIO_3.

Figure 3. Iodine concentration in water leaf in weeks 4 and 6 after fortication with KIO_3.

Table 1. Proximate composition (%) of fluted pumpkin.

Treatment with KIO_3	Ash	Crude fibre	Crude protein	Moisture	Ether extract	Carbohydrate
Control	9.12 ± 0.02[a]	10.12 ± 0.02[a]	32.31 ± 0.44[a]	11.93 ± 0.95[a]	10.24 ± 0.15[a]	26.20 ± 0.37[a]
10 µg/l	8.80 ± 0.04[b]	7.62 ± 0.08[b]	18.26 ±0.33[b]	17.16 ± 0.23[b]	17.03 ± 0.16[b]	30.20 ± 0.24[b]
40 µg/l	12.32 ±0.04[c]	14.36 ± 0.05[c]	21.4 ± 0.38[c]	8.42 ± 0.60[c]	9.30 ± 0.16[c]	33.57 ± 0.24[c]
80 µg/l	12.63 ±0.15[d]	16.12 ± 0.10[b]	23.48 ± 0.40[d]	5.51 ± 0.24[d]	6.50 ± 0.42[d]	34.85 ± 0.19[d]

Values (in %) are mean of three determinations ± SD. Values in the same column with different superscript are significantly different ($p < 0.05$).

Table 2. Proximate composition (%) of vegetable marrow.

Treatment with KIO_3	Ash	Crude fibre	Crude protein	Moisture	Ether extract	Carbohydrate
Control	16.05 ±0.05[a]	8.70 ± 0.38[a]	21.14 ± 0.33[a]	11.16 ± 0.07[a]	8.68 ± 0.52[a]	33.34 ± 0.46[a]
10 µg/l	8.24 ± 0.04[b]	8.36 ± 0.34[b]	24.69 ± 0.06[b]	12.23 ± 0.32[b]	7.26 ± 0.24[b]	38.24 ± 0.30[b]
40 µg/l	9.28 ± 0.02[c]	9.11 ± 0.11[c]	24.16 ± 0.15[c]	12.13 ± 0.24[c]	7.08 ± 0.19[c]	37.18 ± 0.36[c]
80 µg/l	10.22 ± 0.03[d]	11.53 ± 0.41[d]	21.03 ± 0.23[d]	12.47 ± 0.41[d]	7.23 ± 0.19[d]	36.16 ± 0.17[d]

Values (in %) are mean of three determinations ± SD. Values in the same column with different superscript are significantly different ($p < 0.05$).

Table 3. Proximate composition (%) of water leaf.

Treatment with KIO_3	Ash	Crude fibre	Crude protein	Moisture	Ether extract	Carbohydrate
Control	17.05 ± 0.05[a]	13.46 ± 0.40[a]	29.90 ± 0.57[a]	10.82 ± 0.38[a]	8.56 ± 0.37[a]	20.68 ± 1.03[a]
10 µg/l	12.05 ± 0.04[b]	22.29 ± 0.29[b]	20.53 ± 0.47[b]	14.56 ± 0.41[b]	11.22 ± 0.23[b]	19.35 ± 0.38[b]
40 µg/l	15.02 ± 0.03[c]	15.29 ± 0.19[c]	19.78 ± 0.65[c]	16.19 ± 0.53[c]	11.83 ± 0.16[c]	21.85 ± 0.73[c]
80 µg/l	17.05 ± 0.05[d]	10.47 ± 0.40[d]	17.15 ± 0.87[d]	8.22 ± 0.21[d]	11.92 ± 0.18[d]	35.22± 0.23[d]

Values (in %) are mean of three determinations ± SD. Values in the same column with different superscript are significantly different ($p < 0.05$).

in the plant iodine concentration, are in line with the report by Cao et al. (1994). These results also show the effectiveness of xylem transport of iodine to the edible parts of the vegetables. The results also showed the effect of residual iodine in the soil when application was stopped after the 4th week. Although increases in iodine concentration of the plants were observed at the 6th week, they were less than the observed increase during the period of treatment; these observations contradict the work of Jiu-lan et al., (2004) in which increases were observed months after iodination was stopped. The results showed that in the three vegetables, the most significant increase was observed in the 40 µg/l KIO_3 treatments. The drop in the iodine concentrations in the vegetables after the 80 µg/l KIO_3 treatment suggest that KIO_3 dosage greater than 40 µg/l may be inhibitory to uptake of iodine from the soil by the vegetables. Whitehead (1975) reported that iodate (IO_3^-) is electrochemically or biologically reduced to iodide (I^-) before uptake by plant roots. Therefore, the poor uptake of iodate by the vegetables treated with 80 µg/L KIO_3 could be as a result of inhibition of iodate reduction reaction in the plant roots by the high concentration of KIO_3. These observations are in agreement with the reports of Mackowiak and Grossl (1999) and that of Zhu et al. (2003). The 80 µg/l KIO_3 treatment,

could also be seen as too high for terrestrial plant survival since iodine concentration found in drinking water ranged from 1-15 µg/l, whereas, at sea level, iodine concentrations >50 µg/l may be obtained (WHO, 1998; Koutras et al., 1985). Also, the poor uptake may be as a result of the oxidizing power of the vegetables roots. At high concentration of iodate, the plants may convert iodide ion resulting from iodate to molecular iodine ($4I^- + 4H^+ + 0_2 = 2I_2 + 2H_2O$) which have a low solubility, and thus suppress absorption. This mechanism is based on the reports by Goto and Tai., (1957) and Hidekazu et al. (2005) on the varieties of rice plants.

The results also showed that each vegetable have different capacity to concentrate iodine in its tissues, given the same geographical condition. In fluted pumpkin, 226 and 186% increase was observed in weeks 4 and 6, water leaf had 122 and 159% increase and in vegetable marrow, 138 and 194% was observed. The ability of different plant to concentrate micronutrient at different levels given the same geographical condition has been reported by Howarth (1999) and Salau et al. (2008).

The results of the proximate composition of the vegetables in Tables 1 to 3 showed a significant difference ($p < 0.05$) in the nutrient contents of the three vegetables at the various treatments and control. Biomass is a good

measure of the extent to which organisms thrive in a particular habitat or environmental condition. The non significant effects on the dry biomass of these vegetables suggest that the KIO3 treatment did not affect photo-synthetic processes and the uptake of other important minerals. These processes makes vegetables a potential source of nutrients and some essential macro and micro-nutrients needed for the well being of man. (Akindahunsi and Salawu, 2005; Nwaogu et al., 2006; Ujowundu et al., 2008).

The results of this study support the reports made by Jiu-lan et al. (2004), Mackowiak and Grossl (1999) and Pandav, (2000), Ujowundu et al. (2009).. It is important to reiterate here, that though salt iodization is an important and proven strategy for the elimination of IDD, the dietary habit of some people may be a major problem of salt iodization. This dietary habit could be due to certain health disease like hypertension in which the patients are advised to take little or no salt (Hamilton et al., 1998; Leek and Druyer, 1999; Stephen and Hoptron, 2006). The consumption of iodine fortified vegetables may serve as a solution to this barrier because it improves the iodine content of foods naturally (Ujowundu et al. (2009). The irrigation method would allow the soil and plants to absorb and buffer the applied iodine in a very natural way and eliminating excessive peak level of added iodine. Also, iodination of irrigation water is an advantageous and cost-effective method of supplying iodine since it requires simple technology.

The results of this study have shown that iodine forti-fication of these indigenous vegetables through treatment of soil with potassium iodate irrigated water, resulted in significant increase in their iodine concentration. There-fore, a practical application of this strategy may be useful in reducing iodine deficiency-related health problems in our local communities.

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