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Metal contents of some selected vegetables grown in Bodoland territorial region of Assam, India

Bimal Boro[a,b], Sanjay Basumatary[a] and Basanta K Das[b*]

[a]*Department of Chemistry, Bodoland University, Kokrajhar-783370, Assam, India*
[b]*Department of Chemistry, Kokrajhar Government College, Kokrajhar-783370, Assam, India*

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A B S T R A C T

Metals play a crucial role in the metabolic pathways during the growth of vegetable plants. The presence of heavy metals or trace metals also takes a vital role in the nutrient quality of a vegetable. The vegetables are an inevitable part of the human diet and provide essential nutrients to maintain the normal functioning of human health and growth. The application of fertilizers and pesticides facilitates the accumulation of heavy metals by the vegetables grown in the fields. Consumption of heavy metals beyond the permissible limit along with vegetables may impact human health. Moreover, the production of nutritious food and its safety is an important aspect of the measure of any nation's economy. Considering all these points, the present work was undertaken to analyze the heavy metal contents in the six mostly produced and consumed vegetables grown in Bodoland Territorial Region (BTR), a tribal-dominated region of the state Assam, India. The vegetables analyzed were fern leaves (*Diplazium esculentum*), jute leaves (*Corchorus olitorius*), green arum leaves (*Colocasia esculenta*), pointed gourd (*Trichosanthes dioica*), yard long bean (*Vigna unguiculata* ssp. Sesquipedalis) and spiny gourd (*Momordica dioica*). The metals analyzed were Cu, Fe, Ni, and Zn. The presence of heavy metals was detected in all the vegetable samples.

1. Introduction

The heavy metals are taken up by plants in their toxic form very easily from contaminated soil and water and get accumulated in leaves and fruits. Soil and water get contaminated with heavy metals by anthropogenic activities. The metals enter the surface and groundwater, soil, and ultimately crop plants. Heavy metals cause serious concerns for human health when crops contaminated with them are consumed.[1] Accumulation of metals through diet is reported all over the world, and health hazards associated with these metals are also known.[2] Intake of heavy metals above the permissible limits affects various organs like the kidneys, liver, etc. They may also create problems with bones and blood. The health effects like gastrointestinal effects, renal impairment, neurological disorders, cardiovascular troubles, bone problems, convulsions, paralysis, etc. may occur due to the prolonged intake of heavy metals like cadmium, copper, lead, and chromium.[3] Studies have shown that heavy metals may be carcinogenic, teratogenic, mutagenic, and neurotoxic.[4] Determination of nutrients and heavy metals in vegetables is therefore very important. People get nutrients from the food they eat daily where vegetables are an important ingredient. Heavy metals do not contribute to the energy necessary by the human body directly but they play an important role in metabolic regulations. Regular consumption of a variety of vegetables along with other food items also completes the necessity of nutrients of human body and protects from various malnutrition diseases.[5] Different types of trace metals or heavy metals play different roles in the metabolic regulations of the human body.[6,7]

* Corresponding author.
E-mail address bkdkgc@gmail.com (B.K. Das)

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The major pathway of heavy metal contamination for humans is through the intake of food. The major pathway of heavy metal exposure for humans is contamination through diverse food chains.[8] Heavy metal contamination may disorder important biological processes in plants. Prolong use of wastewater for irrigation can cause the accumulation of trace metals in soil which can be further translocated to food crops and thus enter the food chain.[9-11] The metals like Cu, Fe, Ni, and Zn are required by vegetables in trace amounts, and in excess, these act as toxic metals.[12] One of the reasons for the occurrence of trace metals in vegetables is geogenic or anthropogenic factors.[13] The presence of metals in vegetables depends on various factors like soil quality, environmental condition of the region, use of pesticides, chemical fertilizers, etc. Man, and animals accumulate metals in various ways. Humans generally get them through their diet.[14] Therefore, it can be assumed that vegetables contaminated with metals may possess potential health risks to consumers, in addition to their ability to fulfill nutritional requirements. Trace elements are the natural constituents of the soil. Depending on various conditions, concentrations of these elements in the soil may increase or decrease. Ni is absorbed in plants through roots. It depends upon some factors like environmental conditions, pH, temperature, etc. Ni adsorption increases with an increase in phosphate content. It is found that Ni is accumulated in the vegetable part of the plant body and it is mobile throughout the plant structure, translocated and concentrated in the leaves but after the age of the leaves, it is moved to the seeds for accumulation. Zinc deposition in vegetables is due to increased heavy metal contamination of the soil.[15] Zn is more actively mobilized than Cu from roots to shoots.[16] Zinc plays an important role in many enzymatic reactions, like RNA polymerases and various hepatic enzymes.

2. Results and Discussion

The trace metal content of vegetables depends on the quality of the soil of the study area, the water used in the irrigation process, use of chemical fertilizers and pesticides. In this study, trace metals such as Cu, Fe, Ni, and Zn were assessed by atomic absorption spectroscopy in mg/kg (**Table 1**).

Table 1. Trace metals determined from collected vegetables.

Sample number	Vegetables	Cu (mg/kg)	Fe (mg/kg)	Ni (mg/kg)	Zn (mg/kg)
1	Pointed gourd	26.64 ± 4.17	163.41 ± 44.09	3.58 ± 1.98	39.12 ± 22.46
2	Yard long bean	30.67 ± 4.01	334.44 ± 165.22	2.25 ± 0.19	58.93 ± 15.48
3	Spiny gourd	19.06 ± 6.10	119.15 ± 14.85	3.09 ± 3.36	31.49 ± 18.42
4	Fern leaves	26.88 ± 2.93	138.56 ± 84.06	4.14 ± 0.96	28.74 ± 31.49
5	Jute leaves	27.80 ± 11.61	254.86 ± 242.32	2.06 ± 0.77	50.23 ± 29.94
6	Green arum leaves	20.31 ± 1.01	107.62 ± 45.02	4.21 ± 2.40	22.99 ± 25.64

Copper was found higher in yard long beans (30.64 ± 4.17 mg/kg) and lower concentration was detected in spiny gourd (19.06 ± 6.10 mg/kg) (**Fig. 1**). Copper is an essential element and is important in many regulatory mechanisms in plant bodies. Its recommended uptake limit in plants is 0.0–5.0 mg/kg.[17] The daily recommended limit is 2–3 mg/day and the acceptable range for human intake is up to 10 mg/kg.[18] Maximum iron was detected in yard long beans (334.44 ± 165.22 mg/kg) and minimum in the green arum leaves (107.62 ± 45.02 mg/kg) (**Fig. 2**). Iron is one of the essential metals required in various enzymatic reactions. Its daily requirement limit is 1.5-2.2 mg/day.[19]

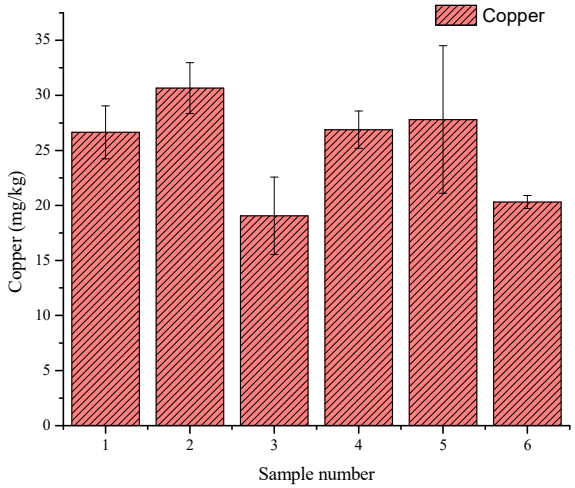

Fig. 1. The copper content of the vegetable samples analyzed.

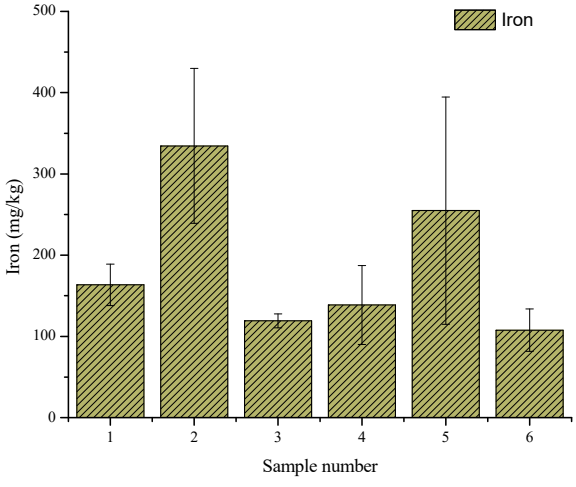

Fig. 2. The iron content of the vegetable samples analyzed.

The highest value of nickel was obtained in the green arum leaves (4.21 ± 2.40 mg/kg) and the lowest value was obtained in jute leaves (2.06 ± 0.77 mg/kg) (**Fig. 3**). Nickel is one of the toxic metals and is required in trace amounts for metabolic reactions in the human body. As reported,[20] the safety range of nickel intake is 3–7 mg/kg. The predominant route of nickel exposure in the human body is food intake. Nickel is an essential trace element in animals, although the functional importance of nickel has not been clearly demonstrated. It is considered essential based on reports of nickel deficiency in several animal species like rats, chicks, cows, goats, etc.[21] Nickel deficiency is shown primarily in the liver; the effects include abnormal cellular morphology, oxidative metabolism, and increase and decrease in lipid levels. Nickel is a trace element and generally causes allergies in people. Nickel allergy is a long-lasting, repeated problem; females are more affected than males. Nickel in the diet of a nickel-sensitive person can aggravate dermatitis. The study has shown that nickel sulfate when orally administered in the range of 600-5,600 mg as a single dose may provoke hand eczema.[22] A daily dietary requirement of 25-35 µg of nickel has been suggested as a daily dietary requirement.[23]

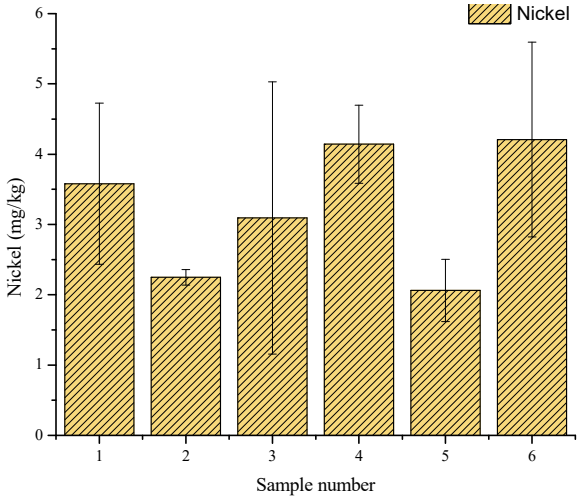

Fig. 3. The nickel content of the vegetable samples analyzed.

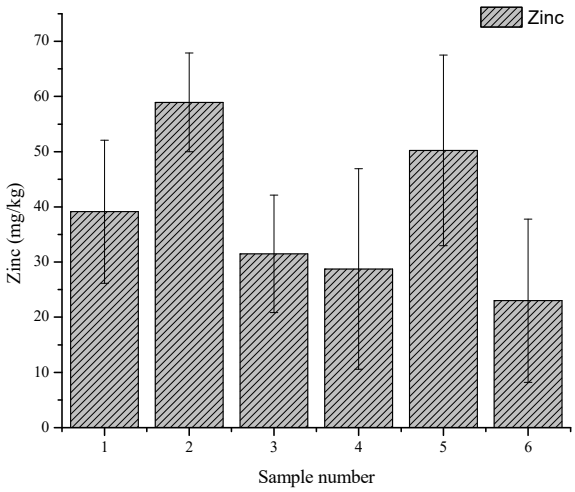

Fig. 4. The zinc content of the vegetable samples analyzed.

The highest amount of zinc (58.93 ± 15.48 mg/kg) was obtained in the case of yard long beans and the lowest (22.99 ± 25.64 mg/kg) was obtained in green arum leaves (**Fig. 4**). Green leafy vegetables and fruits are very weak sources of zinc because of their high-water content.[24] Zinc is a trace mineral, and needed in small amounts for the human body. It functions as a component of various enzymes in the maintenance of the structural integrity of proteins and in the regulation of gene expression. Zinc deficiency is a major problem in developing countries. Zinc deficiency can be inherited or acquired and typically presents with infectious, inflammatory, gastrointestinal, or cutaneous involvement.[25] Toxicity occurs almost exclusively from zinc supplements rather than food. There have been no reports of eating too much zinc from the diet alone.[17]

3. Conclusion

Literature shows that many vegetables in different parts of the world are contaminated with some heavy metals. The majority of the population gets their healthy and balanced diet from fruits and vegetables. To meet the increased need for crops, farmers are using chemical fertilizers and pesticides. In some places, polluted water is used as irrigation water. As a result, the soil and hence the vegetables and fruits grown in those places get contaminated. Similar is the case in the present study area. As the majority of the population of the study area is tribal, they followed traditional methods of cultivation earlier. But to meet up the necessity, some farmers are applying modern methods of cultivation and they may be applying chemical fertilizers and pesticides. As a result, contamination of vegetables in the study area has begun. Getting a higher amount of trace metals in the vegetables analyzed is a matter of concern. The regular uncontrolled consumption of vegetables grown in the present study can cause detrimental effects on the human population.

4. Experimental

4.1. Material and method

The six mostly consumed fresh vegetables (**Table 2**) were collected from some selected places from the Udalguri District of Bodoland Territorial Region (BTR) of Assam, India (**Fig. 5**). The samples were collected in the months of April, May, and June of 2022 in separate polythene packets and preserved at low temperatures in a refrigerator. The collected samples were thoroughly washed with tap water followed by distilled water to remove unnecessary adsorbed substances. Then the samples were cut into small pieces; air-dried for 2 days and kept in a hot air oven at 100ºC ± 1ºC for 4 h. After drying, the samples were ground to powder.

A solution of $HClO_4$ (65%), H_2SO_4 (65%), and HNO_3 (70%) with a ratio of 1:1:5 was used for the digestion of the vegetables. 1 g of dried powder was digested using 15 ml of the three-acid mixture and was heated at 80ºC till the solution became transparent then the solutions were cooled, filtered through Whatman filter paper no. 41, and diluted to 50 ml using double distilled water. The samples were analyzed for Cu, Cr, Ni, and Pb by using atomic absorption spectrophotometry (AAS) (Make: Thermo Scientific; Model: ICE 3000 Series; Software: Solar; Mode: Flame, Gas used: Air and Acetylene air, Acetylene). The analysis was done in three repetitions of measurements and the results are shown as average of triplicate readings ± standard deviation.

Table 2. Vegetable sample collected.

Sample number	Vegetable	Scientific name	Local name in Bodo
1	Pointed gourd	*Trichosanthes dioica*	Potol
2	Yard long bean	*Vigna unguiculata* ssp. Sesquipedalis	Sobai bima
3	Spiny gourd	*Momordica dioica*	Khanghrikhola
4	Fern leaves	*Diplazium esculentum*	Dingkhiya bilai
5	Jute leaves	*Corchorus olitorius*	Fathw bilai
6	Green arum leaves	*Colocasia esculenta*	Thaso bithorai

The Study Area

The vegetable samples were collected from some selected sampling stations in the Udalguri district of Assam. The sampling sites were chosen randomly.

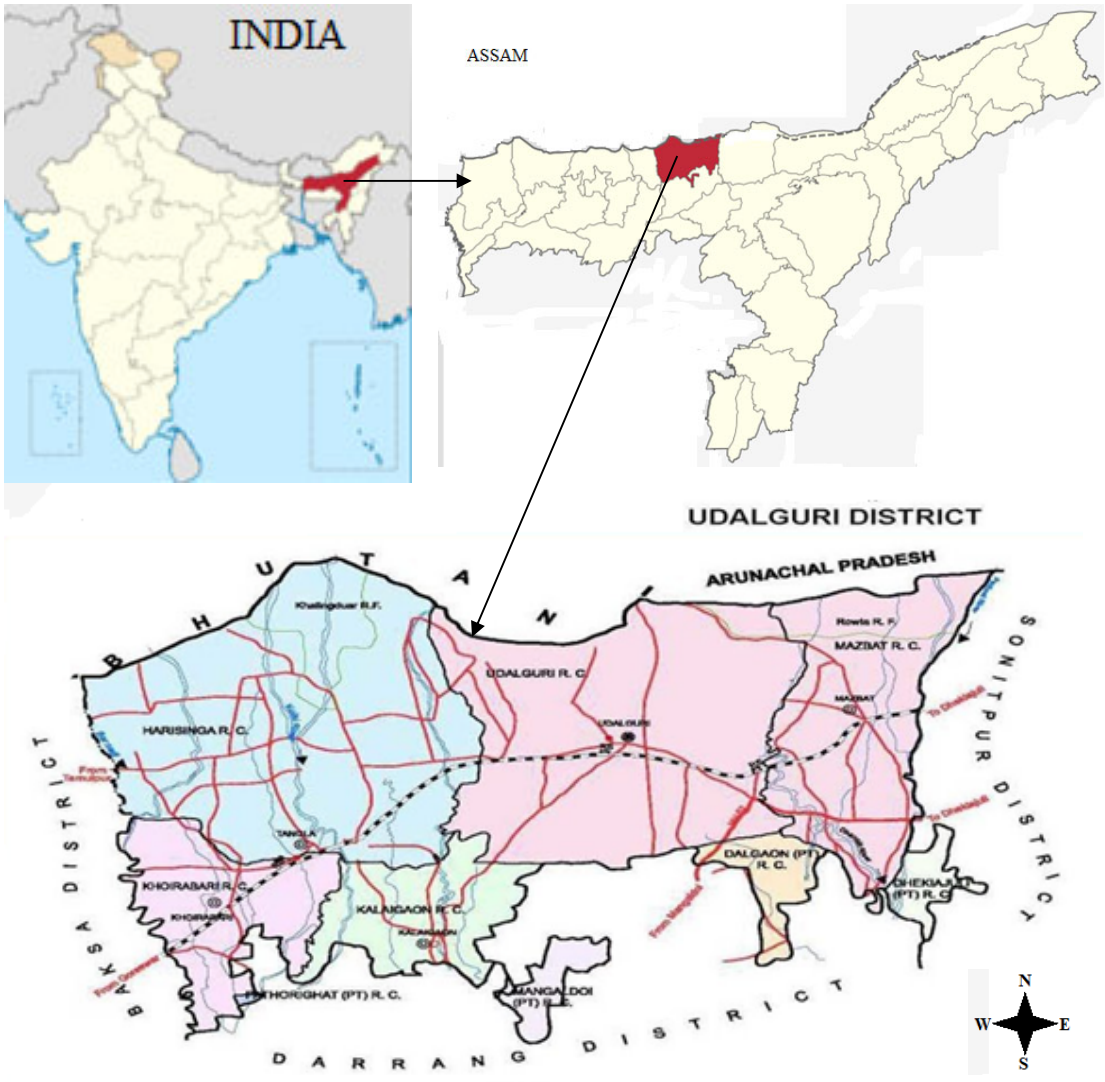

Fig. 5. Map showing Udalguri District.

Udalguri is a district of BTR in Assam that shares an international border with Bhutan and also a state border with Arunachal Pradesh at its North. The district has an area of 1,985.68 sq. km. and a population of 831,668. The majority of the population is tribal (The Bodos). People of the region generally cultivate their harvest by traditional methods. But due to the growing need for crops recently some people are using chemical fertilizers and pesticides to increase production. As a result, the possibility of contamination increases day by day.

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