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Assessment of Heavy Metals in Eggplant Fruit from Urban and Rural Areas of Bangladesh

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Abstract: Dietary intake of contaminated food with heavy metals may cause severe risk for the human health. Heavy metals affect adversely a human health. The current study assessed the concentrations of heavy metals including Cu, Zn, Pb and Ni in eggplant (*Solanum melongena* L.) of urban and rural areas in Bangladesh. The experimental samples of fresh eggplant fruits were collected from six local markets in Jashore, Bangladesh, and the tissues were extracted with nitric acid and hydrogen peroxide. Trace elements in eggplant fruits were estimated with atomic absorption spectrophotometer. Obtained result show that Heavy metal concentrations were high in the urban areas compared to rural areas. Heavy metals in the eggplant fruits of rural and urban areas were: Pb (2.74-18.64), Cu (10.20-67.16), Ni (46.63-148.46), and Zn (86.65-148.73) mg.kg^{-1} respectively. The concentrations of Pb, Ni and Zn in eggplant were at an excess of safe limits according to the Food and Agriculture and World Health Organizations. While, Cu was lower than the maximum safe limit. The present study concluded that growing eggplants in Jashore areas are heavily contaminated with Pb, Ni and Zn that would be hazardous for consumer's health. The result of this study will be beneficial for the agricultural policy makers in Bangladesh to take appropriate action and reduce the heavy metal toxicity among fresh food products.

Keywords: Atomic absorption spectrometer, Copper, Lead, Nickel, Nitric acid, Zinc.

Introduction

Heavy metal pollution of soil, fruits, and vegetables is a worldwide ecological problem, including in Bangladesh. Food chain pollution is a critical route for heavy metal exposure in humans (Khan *et al.*, 2008). Many factors have been considered for the accumulation and absorption of heavy metals by vegetables and fruits such as rising of heavy metals concentration in soil, atmospheric deposition, precipitation, and plant vegetation (Voutsa *et al.*, 1996). Agricultural technologies such as using fertilizers containing heavy metals, irrigation with sewage, and insecticides application can also be considered causes of heavy metal contamination (Singh *et al*., 2004; Sharma *et al*., 2006). The quality and safety of fruits and vegetables can be greatly hampered by heavy metals which cause several health disorders like food-borne diseases, coronary heart disease, kidney failure, impaired nervous system, and bone malformation (Santos *et al*., 2004). Regular intakes of contaminated food by heavy metals, including Cu, Pb, Zn, and Cu, can produce also carcinogenic effects in long term (Sarker *et al.,* 2022).

In South and South-East Asia, eggplant, *Solanum melongena* Linnaeus is one of the major vegetables (Awal *et al.,* 2017). Eggplant is readily grown in India, Bangladesh, Pakistan, China, Japan, and the Philippines because of the warm atmospheric condition. Eggplants belonging to the family of Solanaceae and the genus of *Solanum.* Eggplant is a nutritious vegetable that is rich with minerals, vitamins, dietary fiber, folate, and ascorbic acid (Quamruzzaman *et al*., 2020). The majority of previous research works were focused in genetic and molecular properties of eggplant (Ali *et al*., 2011; Das *et al*., 2011).

Several studies had been conducted in many developed and developing countries regarding heavy metal analysis in fruits and vegetables. They have used many instrumental analytical methods for measuring the concentrations of heavy metals in various food materials. Among these techniques, the most widely used technique was Atomic Absorption Spectrometry (AAS). The technique basis of AAS is measuring the concentrated components through passing light with a specific wavelength from a radiation source that is a hollow cathode lamp (HCL). The detector will detect the light intensity level which will be absorbed by the atoms and recognized as the specific concentrated component in targeted samples (Abrham & Gholap, 2021).

According to the previous studies, we have used the AAS technique in our study to detect heavy metals in eggplant. Very poor data are available about the heavy metal content in vegetables that are found in the market sites of Bangladesh. Due to harmful health effects of heavy metals as well as considering these research gaps, we conducted our study to estimate the heavy metal contents of eggplant (*Solanum melongena*) of urban and rural areas of Bangladesh.

Materials & Methods

Placement of experiment

This research was carried out in the laboratory of the Nutrition and Food Technology department and Petroleum and Mining Engineering department of Jashore University of Science and Technology.

Collection of samples

1 Kg of eggplant fruit was collected from local markets in Churamonkathi Bazar, Solua Bazar, Ambottola Bazar, BSIC jhumjhumpur, Newmarket, and Chachra of Jashore Sadar Upazilla, Jashore, Bangladesh.

Preparation of sample for analysis

The collected eggplant fruits have been cleaned thoroughly with fresh tap water to remove unnecessary substances like soil and soil-related substances. After that, the eggplants were washed using distilled water and deionized water to removing the contaminants from plants outer skin. After completing the cleaning processes, the eggplants were dried completely with blotting paper at room temperature. Then, the eggplants were immediately transferred to desiccators to eliminate the loss of moisture. The inedible portion of the eggplant was then removed, and the edible portion was cut into smaller pieces. Then, the sample was dehydrated in the sun and crushed into small pieces by using a stainless-steel blender (B-163, Geuwa, Guangdong, Chinaand filtered using a 2 mm strainer. Finally, the filtrated powdered form of eggplant was stored in a closed container at ambient temperature until analysis.

Preparation of extract solution

1 gm of eggplant powder from each sample was weighted by four-level sensitive scale (AB204-S, Mettler Toledo, Greifensee, Switzerland), mixed with 10 ml of nitric acid (which was measured by using a sterilized pipette) into a 100 ml sterilized beaker and incubated for 24 hours at 25ºC. Then, Samples were concerted to 5 ml at 120ºC by using magnetic Stirrer equipment. The samples were cooled at 25ºC for 15 minutes. Further, 5 ml nitric acid was added and heated at 120ºC by using magnetic Stirrer equipment until the samples became 5 ml. Then, samples were cooled at 25ºC for about 15 minutes. After that, 3 ml hydrogen peroxide (which was measured by using a sterilized pipette) was added to the samples and concentrated at 120ºCto 5 ml and cooled at 25ºC for 15 minutes. The samples volume completed to 100 ml by distilled water filtered by filter paper and kept at 100ml volumetric flask.

Atomic Absorption Spectrometry (AAS) for estimating the amounts of trace elements (Lindenmayer *et al*., 2023).

AAS (Cary 60 UV–Vis, Agilent Technologies, Seoul, Korea) technique was used to estimate the heavy metals concentration in eggplant samples. AAS is an advanced technique for evaluating the numbers of existed chemical components in natural products (fruits and vegetables) through the evaluation of absorbing light that passed through the chemical components. The procedure was carried out by observing the color spectrum that evolved when such material was stimulated by light. Standard operating parameters were set before the operation. The hollow cathode lamps for Cu, Zn, Pb, and Ni were used as a radiation source. The concentrations of samples were measured according to the Beer-Lambert law and it was assessed employed a calibration curve which was acquired by utilizing the standard for recognized concentrations for generating this curve, a specific wavelength was preferred and the detector was used for measuring only the energy transmitted at that wavelength. If the concentration of the target atom in the sample increased, the absorption was also increased proportionally (Ajasa *et al*., 2004).

A series of samples that contain recognized concentrations of selected compounds was analyzed, and the corresponding absorbance was recorded. The measured absorption at each concentration was then plotted so that a straight line could then be drawn between the resulting points. From this line, the concentrations of the substances under investigation were extrapolated from the substances absorbance.

Statistical analysis

Data were shown as mean values of duplicates with the standard error of means. All assessments were performed in the duplications several times in the same location and planned randomly. The results of the experiment were statistically evaluated by using Microsoft Office Excel 2007 software and Statistical Package for Social Science (SPSS) version 20 software.

Results

For heavy metals concentration analysis in eggplant. Table (1) represents the required standards conditions for AAS (Atomic Absorption Spectrophotometer). The AAS values are presented in a nanometer. Copper had the highest AAS value (324.8 nm) followed by Nickel (232.0 nm), Lead (217.0 nm), and Zinc (213.9 nm).

Levels of four heavy metals like Copper (Cu), Zinc (Zn), Lead (Pb), and Nickel (Ni) concentrations observed in eggplant of rural and urban areas are shown in tables (2 and 3) respectively. The concentrations of heavy metals were presented in $mg.kg^{-1}$of dry weight unit representing the contents of heavy metals in eggplants for rural and urban areas. The contents of heavy metals in these areas were quite variable such as Cu (10.20-67.16 $mg.kg^{-1}$), Zn (86.65-148.73 $mg.kg^{-1}$), Pb (2.74-18.64 $mg.kg^{-1}$) and Ni (46.63-148.46 $mg. kg^{-1}$). The direction level of heavy metals acquired from different rural and urban areas was Pb < Cu < Ni < Zn (Table 1).

The level of Zn in all eggplant obtained samples from rural areas was higher than those of the urban areas; however, the levels of Pb, Cu, and Ni in all eggplant samples that obtained from the urban areas were higher than those of the rural areas.

The calibration curves of copper, zinc, lead, and nickel can be seen in fig. (1 A, B, C, and D). From these curves, it can be recognized a good connection liners between concentration of heavy metals and absorbance.

The comparison of heavy metals concentrations in eggplant in rural and urban areas to the standard safe limit that recommended by FAO/WHO in mg per kg dry weight can be found in tables (2 and 3). According to FAO/WHO the standard safe limit for Copper, Zinc, Lead, and Nickel is 73.5 $mg.kg^{-1}$, 99.4 $mg.kg^{-1}$, 0.3 $mg.kg^{-1}$, and 67.9 $mg.kg^{-1}$of dry weight, respectively.

We found the contents of heavy metals in eggplant were in greater amounts than the safe limits given by WHO/FAO. Tables (2 and 3) illustrate the heavy metals concentrations in different rural and urban areas, we can notice that the content of copper is below the maximum allowable limits that recorded by WHO and FAO. In the case of other heavy metals, in eggplant samples, all of them exceed the maximum allowable limits of WHO and FAO report (Abrham & Gholap, 2021).

Table (1): Instrumental standard condition for heavy trace metal analysis by AAS.

Heavy metals	Wavelength (nm)
Copper	324.8
Zinc	213.9
Lead	217.0
Nickel	232.0

Table (2): Concentration of heavy metals in eggplant from rural areas.

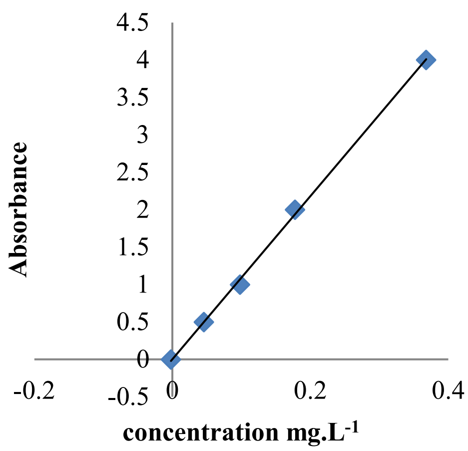
Heavy metals	Test amount mg.kg^{-1}of dry weight)			Limit recommended by WHO (mg.kg^{-1})
	Churamonkathi bazar Mean±SD	Solua bazar Mean±SD	Ambottola Bazar Mean±SD	
Copper	17.81±2.5c	10.20±1.45c	13.46±1.37c	73.5
Zinc	148.73±6.7a	115.02±4.8a	86.65±3.5a	99.4
Lead	7.68±0.05d	4.63±0.06d	2.74±0.03d	0.3
Nickel	71.46±3.7b	63.22±2.4b	46.63±2.7b	67.9

Note: Values are means ± standard deviation (n = 3); Means with the same letter in a column are not statistically different from each other ($p \leq 0.05$)

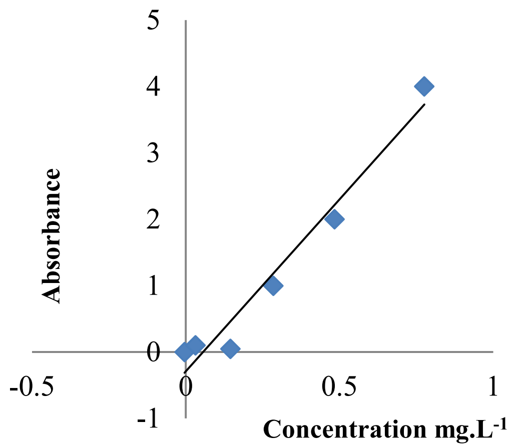
Table (3): Concentration of heavy metals in eggplant from urban areas.

Heavy metals	Test amount (mg.kg^{-1}of dry weight)			Limit recommended by WHO (mg.kg^{-1})
	BSIC, jhumjhumpur Mean±SD	Newmarket Mean±SD	Chachra Mean±SD	
Copper	67.16±1.85c	43.76±2.75c	28.36±2.24c	73.5
Zinc	128.73±6.7b	90.52±3.87b	108.65±4.8b	99.4
Lead	18.64±2.05d	12.48±1.76d	14.54±2.33d	0.3
Nickel	148.46±5.25a	132.22±4.67a	141.63±4.56a	67.9

Note: Values are means ± standard deviation (n = 3); Means with the same letter in a column are not statistically different from each other ($p \leq 0.05$)



(A-Cu)



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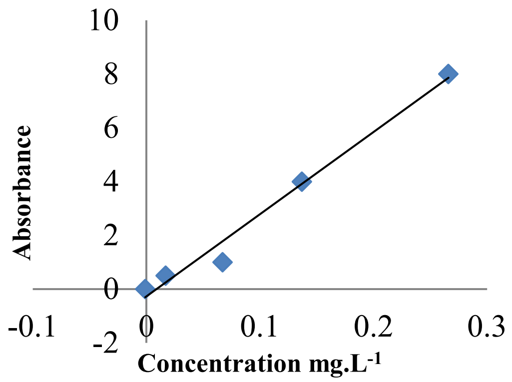
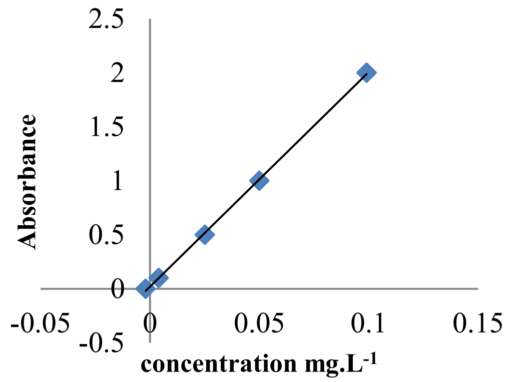


(C-Pb)



(D-Ni)

Fig. (1) (A, B, C & D): Calibration graph of Cu, Zn, Pb and Ni standard solution, respectively.

Discussion

From this study, we came to know that the concentrations of Cu in eggplant samples in different rural and urban areas were below the safe limit of FAO/WHO standard recommended for vegetables. So, it can be noticed from our study that the prevalence of Cu among eggplants is not in the harmful range that can cause risk to the consumers. Copper is an essential mineral for health; however, excessive consumption can have negative health consequences such as kidney damage and liver disease. According to a study in Bangladesh, it was reported that the concentration of Cu in vegetables in a fresh weight basis was 8.3 to 34 $mg.kg^{-1}$ which was below the safe limit of the FAO/WHO standard recommended for vegetables (Abrham & Gholap, 2021).

A study in Kayseri, Turkey, stated that the Cu concentration was within the permissible limit in the various samples collected from vegetables produced in Turkey (Demirezen & Aksoy, 2006). Another study conducted in Varanasi, India, found that the content of Cu (2.25-5.42 $mg.kg^{-1}$) in vegetables produced in wastewater areas was within the safe limit (Sharma *et al.*, 2006). Thus, both studies result are very much in line with the current study result.

We noticed that concentrations of Zinc (Zn) found in eggplant samples from various rural and urban areas exceeded the maximum safe limit given by the Food and Agriculture Organization (FAO) and World Health Organization (WHO). Another study in Bangladesh reported that the level of Zn in vegetables in a fresh weight basis was 16 to 119 $mg.kg^{-1}$ (Abrham & Gholap, 2021). Zinc shows a significant effect on the human diet. However, a higher amount of Zinc is disadvantageous for human health (Demirezen & Aksoy, 2006). Plant uptake is the vital pathway through which heavy metals enter the food chain. Though Zn has very low toxicity to humans, it can resist Copper metabolism through Zn poisoning (Antonious *et al.*, 2008). The highest content of Zn resistance level for human health is 20 $mg.kg^{-1}$. Nonetheless, Zinc may show that several adverse effects like tachycardia, vascular shock, dyspeptic nausea, vomiting, pancreatic disorder, diarrhea, and damage of hepatic parenchyma for human health through its severe exposure (Salgueiro *et al.*, 2000). Therefore, our study show that Zn concentration in eggplant samples of our local market is in a risk state, and that may cause adverse health effects to consumer health.

Our study revealed that the samples had Nickel (Ni) concentrations above the safe limit according to FAO and WHO. However, a study around the industrial area of Dhaka city in Bangladesh reported that the level of Ni in vegetables in a fresh weight basis was 1.6 to 12 $mg.kg^{-1}$ (Abrham & Gholap, 2021).

On the other hand, our study result is not so consistent to another study conducted in Bulgaria, and the study stated that the concentrations of Nickel (Ni) that determined in collected eggplant samples from the Municipality of Plovdiv in Bulgaria were within the permissible limit regulated by the World Health Organization (Demirezen & Aksoy, 2006). Nevertheless, Nickel has negative effects on human health such as respiratory disorders, and carcinogenic influence. That's why the results in our study regarding the concentration of Ni in eggplant illustrate an unhealthy trend.

The study found an excess amount of Lead (Pb) in eggplants samples acquired from different rural and urban areas of Jashore in Bangladesh. The concentrations of Pb were higher than the maximum safe limit given by FAO/WHO. This result is similar to another study conducted in Kayseri of Turkey which stated a higher amount of lead than the permissible limit in various samples of vegetables (Demirezen & Aksoy, 2006; Nasidi *et al*., 2021). According to the research work, small-scale industries, vehicular emissions, resuspended road dust, and diesel generator are responsible for Pb accumulation in the environment (Al Jassir *et al*., 2005). Also, various factors such as pH, particle size, and ion exchange capacity of soil stimulate the uptake of Pb by plants (Lokeshwari & Chandrappa, 2006; Qadir *et al*., 2022). A higher level of Pb presents several adverse health effects such as retarding cognitive development in children and increasing blood pressure (Demirezen & Aksoy, 2006). Based on our result, the present study shows an alarming trend of Pb concentration in eggplant, which may become one of the risk agents on public health in a near future.

Conclusions

Soil and plants could absorb heavy metals and accumulate them owing to the improper management of household and municipal wastewater, industrial effluent, sewage sludge and mining wastes. As a result, it causes harmful effects on human health after consumption of those vegetables. This study demonstrated the presence of a higher amount of Zn in eggplant collected from rural and urban areas of the Jashore district in Bangladesh. The present investigation showed that eggplant could accumulate a higher level of heavy metals including Pb, Ni, and Zn that were higher than the reported safe limits of FAO and WHO. Current result state that it could be unsafe for people to consume too much eggplant from those regions, heavy metals have a long-term lethal effect on human beings Consequently, even at minimal increases, they could cause severe risk to humans and other living organisms. Therefore, regular monitoring for such toxic heavy metals obtained in effluents and sewage, vegetables, and other food materials is required for preventing their excessive build-up in the food chain. Moreover, different remediation steps should be employed promptly to minimize metal contamination in edible vegetables of the study area. Further studies are needed to acquire detailed up to date information regarding heavy metal complications.

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Contributions of authors

M.A. : Planned study design, advised on sample collection, laboratory analysis, reviewed and revised the manuscript.

S.A. : Collected sample and conducted laboratory analysis and prepared draft manuscript.

P.H. : Conducted laboratory analysis.

A.H.R. : Prepared draft manuscript.

S.D.S. : Performed statistical analysis.

R.P. : Prepared draft manuscript and revised.

Md.T.E. : Reviewed the manuscript.

D.K.P. : Designed methodology and reviewed manuscript.

Md.A.Z. : Conceptualized and monitored the experiment and reviewed the manuscript.

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Conflicts of interest

All the authors state that none of them had conflicts of interest in this study.

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تقييم المعادن الثقيلة في ثمار الباذنجان من المناطق الحضرية والريفية في بنغلاديش

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المستخلص: يتسبب تناول الطعام الملوث بالمعادن الثقيلة في مخاطر شديدة على صحة الإنسان. المعادن الثقيلة تؤثر سلبا على صحة الإنسان. قيمت الدراسة الحالية تراكيز المعادن الثقيلة وهي النحاس والزنك والرصاص والنيكل في نبات الباذنجان (*Solanum melongena* L.) في المناطق الحضرية والريفية في بنغلاديش. جمعت العينات التجريبية لثمار الباذنجان الطازج من ستة أسواق محلية في جاشور، بنجلاديش، وتم هضم العينات بحمض النيتريك وبيروكسيد الهيدروجين. تم تقدير العناصر النزرة في ثمار الباذنجان باستخدام مقياس الامتصاص الذري. أظهرت النتائج المتحصل عليها أن تراكيز المعادن الثقيلة كانت عالية في المناطق الحضرية مقارنة بالمناطق الريفية. المعادن الثقيلة في ثمار الباذنجان في الريف والحضر كانت: الرصاص (2.74–18.64)، النحاس (10.20–67.16)، النيكل (46.63–148.46)، والزنك (86.65–148.73) ملغم. كغم$^{-1}$ على الترتيب. كانت تراكيز الرصاص والنيكل والزنك في الباذنجان أعلى من الحدود الآمنة وفقًا لمنظمة الأغذية والزراعة والصحة العالمية. بينما كان النحاس أقل من الحد الأقصى الآمن. خلصت الدراسة الحالية إلى أن زراعة الباذنجان في مناطق جاشور ملوثة بشدة بالرصاص والنيكل والزنك والتي من شأنها أن تكون خطرة على صحة المستهلك. ستكون نتيجة هذه الدراسة مفيدة لواضعي السياسات الزراعية في بنغلاديش لاتخاذ الإجراءات المناسبة وتقليل سمية المعادن الثقيلة بين المنتجات الغذائية الطازجة.

الكلمات المفتاحية: مطياف الامتصاص الذري، النحاس، الرصاص، النيكل، حامض النيتريك، الزنك.