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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Studies of Essential and Trace Elements in Some Fruits and Vegetables of Southwestern Bangladesh by PIXE Technique

M.R. Rahman[1,2], M.A. Shariff[3], M.O. Rahman[2], M.S. Uddin[3], A.K.M. Shafiq Ullah[3], M.A. Shameem[3], M.M. Hasan[3], S.J. Hasan[3] and M.A. Huq[3]
[1]Physics Discipline, Khulna University, Khulna, Bangladesh
[2]Department of Physics, Jahangirnagar University, Savar, Dhaka, Bangladesh
[3]Tandem Accelerator Facility, Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh

Abstract: Essential and trace elementals in some fruits and vegetables of southwestern Bangladesh have been measured using particle induced X-ray emission (PIXE) technique. The selected fruits and vegetables for study are usually consumed by all income groups of rural and city population. The samples were dried, pressed to make pellet and then bombarded with accelerated protons at 3.0 MV Tandem Accelerator facility of Bangladesh Atomic Energy Commission. The X-rays emitted in the irradiation were measured by HPGe-detector. The X-ray spectrum was analyzed using GUPIX software. A number of major and trace elements were found to be in varying concentrations in the investigated fruits and vegetables. The contents of K and Ca being notably large in some samples. No toxic elements were detected in the investigated samples.

Key words: Elemental analysis, fruits and vegetables, PIXE, GUPIX software

INTRODUCTION

Mineral elements play an important role for the nutrition of human being. Fruits and vegetables are one of the key sources of mineral elements. Excess or lack of mineral elements in fruits and vegetables may cause various disorders in human health and the people may suffer from various diseases. Increased fruits and vegetables consumption can improve the mineral regulation and reduce cardiovascular diseases and certain cancer risks. Trace elements do not provide any calorie but they maintain the body PH, osmotic regularity and used as coenzyme which regularize the metabolic processes. Therefore, assessment of micronutrients and essential trace elements levels of fruits and vegetables is a rising trend in nutritional studies over the world.

The development of analytical methods has led to detect elements in very low concentrations (Keen *et al.*, 2003). The use of ion beam analysis (IBA) techniques has grown recently since they combine the advantages of being non-destructive and multi-elemental analytical techniques (Johansson and Campbell, 1988). It is ease to study fruit and vegetable materials by PIXE technique, which is highly sensitive method for the multi-elemental analysis. PIXE has the advantage due to large cross-section for X-ray production and the background contribution from bremsstrahlung is low. The most important minor and trace elements can be determined in single run within short time. In addition, sample can easily be prepared for PIXE analysis. Few authors have used PIXE technique in the analysis of fruit and vegetable materials (Cunha *et al.*, 2006; Manuel *et al.*, 2008). The present work was undertaken to determine the essential and trace elements in various fruits and vegetables grown in southwestern coastline of Bangladesh where occasionally tropical storm (e.g., Sidr, 2007; Aila, 2009) hit and left many areas saline waterlogged for long time cause salinity of agriculture field. This waterlogged could change the soil composition which in turn might cause excess or lack of the mineral elements in fruits and vegetables. Salty soils are a common feature in southwestern coastline of Bangladesh and are an environmental problem. This may be a serious threat for the society in near future. Therefore, it is necessary to accumulate baseline data of crops grown in that area before and after salinization.

MATERIALS AND METHODS

Sample collection and preparation: Samples of various fruits (papaya, tomato, okra, guava, banana raw, green banana, tamarind, etc.) and vegetables (potato, onion, root turnip, radish spinach, red spinach, Malabar spinach, etc.) were collected in the season of February, 2013 from various areas of Dumuria (22°48.5' N, 89°25.5' E), Khulna, a southwestern coastline of Bangladesh. Figure 1 shows the geographical location of sampling site where no saline waterlogged take place so far comparative to other regions (Koyra, Dacope etc.) of the district. The samples were dried in an electric oven at a temperature of 80°C until constant weight attained. The dried samples were ground with agate mortar and thereafter, were pressed to make pellet with a diameter of 12 mm.

Corresponding Author: M.R. Rahman, Physics Discipline, Khulna University, Khulna, Bangladesh

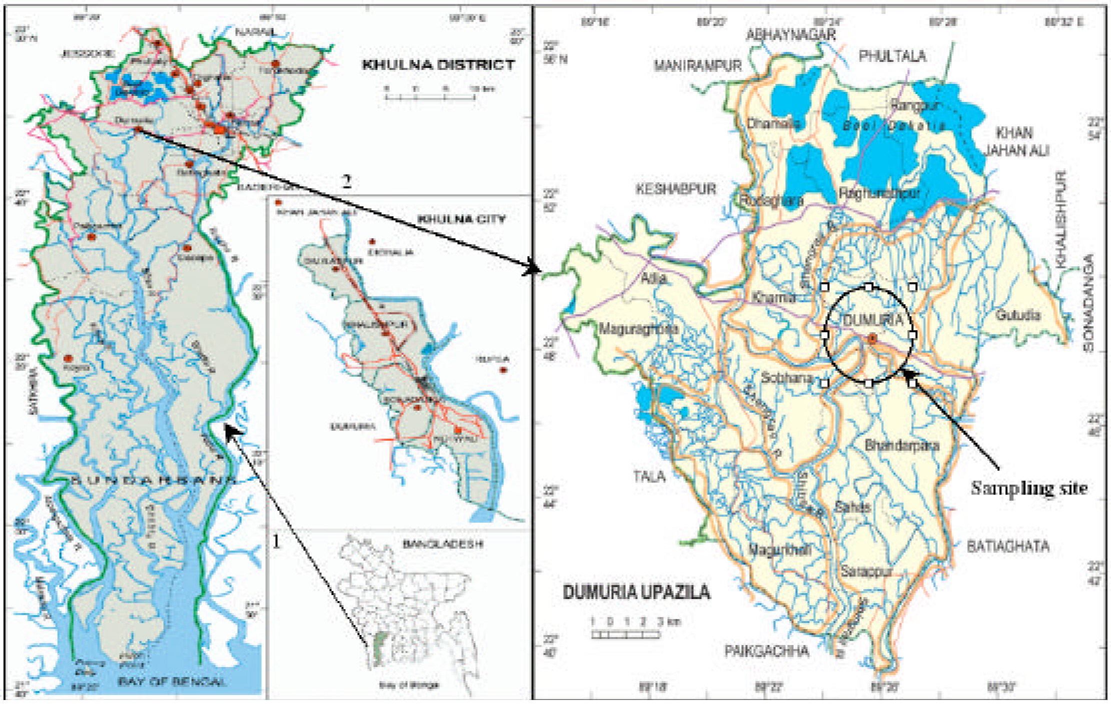

Fig. 1: Map of sampling location intensified by solid circle (right side)

Irradiation and data acquisition: The prepared sample in the form of pellet was irradiated with proton beam of 2.55 MeV using 3 MV Tandem Accelerator at the Institute of Nuclear Science and Technology, Atomic Energy Research Establishment (AERE), Savar, Dhaka. The collimated proton beam of size approximately 2 mm was used to irradiate the samples. During irradiation, the beam current was in the range of 10 to 20 nA. The X-rays emitted in the irradiation were measured using HPGe X-ray detector and associated data acquisition system.

Data analysis: The X-ray spectrum was analyzed by using GUPIX software (Maxwell *et al.*, 1995) which automatically fit the spectrum to obtain the elemental concentrations. The calculation of elemental concentration C_Z is based on the following well known equation (Campbell *et al.*, 1993):

$$C_Z = \frac{Y}{Y_t Q \varepsilon T H}$$

where, Y_t is the X-ray theoretical intensity (i.e. the yield per micro- coulomb of charge per unit concentration per steradian), Y is the X-ray experimental intensity or yield, Q is the measured proton beam charge, ε is the efficiency of the detector and T is the transmission through any filters or absorbers between the target and the detector. H is an instrumental constant equivalent to the product of the geometric solid angle of the X-ray detector and any systematic calibration factor present in the PIXE set-up. H values as a function of X-ray energies can be measured experimentally using wide range of pure single-element standards. Such a work has been carried out for the new PIXE set up (Shariff *et al.*, 2013) and has been used for the analysis of the samples of the present work.

RESULTS AND DISCUSSION

The concentrations of chlorine (Cl), potassium (K), calcium (Ca), titanium (Ti), manganese (Mn), iron (Fe), cobalt (Co), copper (Cu), zinc (Zn) and bromine (Br) in fruits and vegetables measured in this work are given in Table 1. The concentrations presented here are as found by GUPIX from dried pelletized samples. It is seen that the concentrations of the elements varied from one sample to another. The difference in the concentration of those elements among fruits as well as vegetables is attributed to factors such as the preferential absorbability of a particular fruit and vegetable for the corresponding elements, the age of the plant, the mineral composition of the soil, in which the plant grows as well as its ambient climatological conditions (Armah *et al.*, 2001). The chloride ion itself may be important for the blood pressure-raising action of sodium. A high intake of chloride ion, which tends to remain in the body, may trap positive sodium ions to balance the chemical charge. The minimum chloride requirement for a healthy adult is 700 mg/day (Warldlaw and Insel, 1999). The deficiency

Table 1: Elemental concentrations of the investigated fruits and vegetables

	Measured concentration (ppm or otherwise stated)									
Sample	Cl (%)	K (%)	Ca (%)	Ti	Mn	Fe	Co	Cu	Zn	Br
Fruits										
Papaya	0.90±0.15	4.39±0.05	5.62±0.05	ND	ND	1337±29	ND	ND	44.64±7	ND
Tomato	1.55±0.18	7.87±0.08	1.50±0.05	ND	ND	326±20	ND	25.49±6	ND	ND
Okra	0.92±0.18	3.95±0.06	5.04±0.07	ND	ND	526.7±32	ND	ND	74.75±16	ND
Guava	ND	2.86±0.05	0.74±0.04	ND	ND	326.3±25	ND	ND	ND	ND
Banana raw	ND	4.51±0.06	1.49±0.06	ND	ND	368.2±24	ND	ND	39.44±11	ND
Green banana	0.32±0.02	2.62±0.02	0.52±0.02	ND	ND	148.0±11	ND	ND	ND	ND
Pepper	0.48±0.13	3.60±0.05	0.95±0.05	ND	ND	441.8±28	ND	ND	ND	ND
Broad Beans	ND	3.13±0.05	2.62±0.05	ND	ND	637.8±29	ND	ND	ND	ND
Bottle Gourd	ND	6.27±0.07	2.45±0.06	ND	ND	306.4±23	ND	ND	ND	ND
Tamarind	ND	4.80±0.02	1.81±0.02	ND	ND	455.7±16	ND	ND	ND	ND
Jujube	0.19±0.03	1.63±0.01	2.08±0.02	ND	47.52±12	282.1±13	ND	ND	ND	ND
Eggplant	1.34±0.04	7.09±0.03	3.27±0.03	ND	ND	211.3±17	ND	41.26±10	41.84±11	ND
Bitter gourd	0.49±0.03	3.66±0.02	2.39±0.02	182.2±29	ND	907.4±21	ND	ND	40.09±7	ND
Stem and root vegetables										
Potato	1.71±0.13	8.28±0.07	0.74±0.03	ND	ND	237.5±15	ND	ND	46.21±7	ND
Onion	ND	1.86±0.05	2.73±0.05	1537±111	ND	7367±85	155.8±30	ND	ND	ND
Root turnip	ND	4.38±0.06	2.28±0.06	ND	ND	182.8±17	ND	ND	ND	ND
Leafy vegetables										
Radish spinach	2.94±0.25	9.16±0.10	8.96±0.09	461.7±96	209.8±49	3605±64	ND	ND	80.36±18	160.1±41
Bottle gourd spinach	1.26±0.04	6.03±0.03	4.22±0.03	678.1±45	ND	3758±40	ND	34.52±8	65.01±9	ND
Red spinach	1.10±0.21	4.04±0.07	5.48±0.07	365.6±87	167.6±46	3001±58	ND	ND	57.45±13	ND
Malabar spinach	3.20±0.22	4.35±0.09	6.88±0.07	391.4±85	ND	2695±54	80.39±21	ND	40.7±11	ND
Mustard spinach	1.87±0.20	3.03±0.07	6.38±0.07	587±90	150±42	2622±54	ND	ND	56.69±13	ND
Cilantro	1.47±0.22	6.64±0.08	5.56±0.08	ND	ND	1080±39	ND	ND	ND	ND

*ND-Not detected

Error has been calculated using GUPIX

of chlorine causes anorexia, weakness, growth failure, severe convulsions, etc. The highest Cl content is found in Malabar spinach (32005 ppm) and the lowest in jujube (1913 ppm). K and Ca are the most abundant elements in the samples (major elements). It is observed that radish spinach contains the height amount of K (91627 ppm) and Ca (89570 ppm) and the lowest amount of K and Ca are exhibited by jujube (16303 ppm) and green banana (5222 ppm) respectively. The dietary recommended intakes (DRIs) of K and Ca for adults are 4500 and 1300 mg/day, respectively (DRIs, 2004). K has an important role in regulation of the water balance of the body (Anderson *et al*., 2008) and crucial to heart function (British medical journal, 1977). Ca is an essential element for maintaining healthy bones and teeth and also of neuromuscular systematic and cardiac functions.

Various concentrations of the transition elements Mn, Fe, Cu and Zn were found in the studied fruits and vegetables. These and other essential elements perform various complementary vital functions in the body to keep the organism healthy. The Fe content is fairly good in all samples varied from 148.0 ppm in green banana to 6136 ppm in onion. The requirement of Fe is in the range of 1.5-2.2 mg/day (DRIs, 2004). Worldwide nearly 3.7 million people are iron deficient, the problem being serve enough to cause anemia in two billion people. Thirty five percent of the 0-5 year old children suffer from Zn or Fe deficiency (Xiaoe, 2005). The deficiencies of micronutrients in humans mainly result from their low concentrations and bioavailability in the diet. In this context, the high amount of iron content in these samples can play a significant role to reduce iron deficiency.

Zn is an important element responsible for many enzymatic processes and is involved in working of genetic materials, proteins, immune reactions; wound healing, development of the fetus and sperm production. It has been suggested that normal levels of Zn can prevent diarrhoea. According to the WHO recommendation fruits and vegetables are poor sources of Zn and ranged up to 1 ppm and dietary intake for Zn is 10 mg/day for an adult (DRIs, 2004). Zn content in radish spinach (80.36 ppm) is the highest among the studied samples. Mn is an antioxidant nutrient and is important in the breakdown of fats and cholesterol and also helps in the nourishment of the nerves and the brain. Mn safe limit for daily intake is 2.0 mg for an adult (DRIs, 2004) and its recommended range in fruits and vegetables are 0.42-6.64 ppm. Mn was found in radish spinach, red spinach and mustard spinach. Among them radish spinach contains the highest amount (209.8 ppm) of Mn. Cu is an essential trace element required for proper health in an appropriate limit. Its high uptake in fruits and vegetables can be harmful for human health and in the same way the lower uptake in human consumption can cause a number of symptoms e.g., growth retardation, skin ailments, gastrointestinal disorders etc. Among the studied samples the highest Cu content was found in eggplant with concentration 41.26 ppm which probably plays a role in prevention of inflammation; given that Cu is a useful anti-inflammatory agent. Cobalt is an indispensable element and is scattered in the atmosphere about 0.001% in bivalent as well as trivalent state. Co is usually contributed with vitamin B12 and its deficiency effect on the vitamin B12 consistency in the body. The daily recommended range of Co in human diet is 0.005 mg (ATSDR, 2004). Co deficiency also has an additional role in producing anoxia and injuring the heart muscles. Co intakes >30 mg/day can cause digestive and skin disorders in humans. In the present investigations Co was found significantly high in Malabar spinach and onion. The Sc, Cr, V, Ni, Ga, Ge, As, Se, Rb, Sr and Pb elements were not found in any one of the samples in the present study.

Conclusion: PIXE technique has been used for the elemental analysis of some fruits and vegetables commonly consumed in Khulna, a southwestern coastline part of Bangladesh. The concentrations of the Cl, K, Ca, Ti, Mn, Fe, Co, Cu, Zn and Br elements of those samples have been measured. It is found that K and Ca are the most abundant detected elements in the samples. The Fe content is also fairly good in all the samples. The result shows that the investigated fruits and vegetables contain elements of vital importance in man's metabolism and that are needed for growth and developments, prevention and healing of diseases. This work present a baseline study for further future work to find the toxicity or deficiency of essential and trace elements in fruits and vegetables grown in those regions where occasionally saline waterlogged happened. It is hoped that these data could provide as an important resource for further studies.

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