

MINERALS AND HEAVY METALS CONTENT STATUS IN SOME FRUITS IN INDIA

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Abstract

Fruits and vegetables are specially valued in human diet as these contain micronutrients, fiber, potassium, vitamin C, which work as antioxidants within the body as well as bio-functional components. Minerals and heavy metals content of ten tropical fruits namely Sapodilla, Stone-apple, Indian- gooseberry, Guava, Bilimbi, Elephant-apple, Tamarind fruit, Mango, Litchi, Strawberry were determined according to standard methods to address their concentration. Heavy metals, which constitute a major public health concern, are known to accumulate in food and fruits during plants growth. Fruits which are readily consumed because of their characteristic sweet taste and potential health benefits stand a major risk of heavy metal intoxication Results of this study suggest that the selected tropical fruits are rich source of minerals. Tamarind fruit is an ample source of iron, sodium, potassium, calcium and magnesium. Highest amount of manganese found in Mango, 06.16 ± 1.19 mg. Highest amounts of copper, zinc and sodium found in Guava, 19.30 ± 2.12 mg, 2.07 ± 0.15 mg and 62.78 ± 1.24 mg, respectively. Highest amount of iron, potassium, calcium and magnesium found in Tamarind fruit, 2.80 ± 1.43 mg, 621.00 ± 3.26 mg, 75.00 ± 2.41 mg and 90.00 ± 1.80 mg, respectively. However, heavy metals namely arsenic, cadmium, lead, mercury and chromium content of ten tropical fruits were determined to assess their concentration as these days rarely any food item is spared from the malicious practice of food adulteration. The consequences of this study indicate that these tropical fruits could be potentially used in alleviating micronutrients deficiency especially for the rural populace as a potent source of minerals and the daily intake of heavy metals through fresh fruits may not constitute a health hazard for consumers because the concentrations were below than the recommended daily intake of these metals but consumers should be aware of taking fresh fruit as these amounts can be harmful if the fruits are taken in large quantities.

Keywords: minerals, heavy metals, fruits, vegetables

Introduction

Fruits are generally one of the most consumed foods on a daily basis because of their sweet taste. Majority of fruits are generally sweet because of their richness in sugar. The sugar content of fruits varies depending on the type of fruit and the location of cultivation (Forney and Breen 2016). All sweet fruits are rich in fructose, but vary in their amount of glucose, sucrose and sorbitol (Murphy and Johnson 2021). Fructose also known as fruit sugar is one of the most abundant sugars found in fruits. It has the same caloric value as sucrose but is much sweeter in taste (Lee et al. 2010). Because of the richness in sugar, fruits have been of great economic purposes. They are very important raw material for brewery companies as the sugar content is usually extracted in the form of syrup for the production of soft drinks and juices (Ashurst et al. 2021). Apart from their characteristic taste and commercial uses, fruit consumption is highly recommended because of the nutritional (Willett 2014) and health benefits (Liu 2021). Fruits are rich in nutrients such as carbohydrate, protein, lipids, vitamins, minerals, fiber etc. which have various functional roles in the body (Craig and Beck 2019).

Consumption of fruits is essential for a diversified and nutritious diet. Sufficient consumption of fruit and vegetables significantly reduce the incidence of chronic diseases, such as cancer, cardiovascular diseases and other aging-related pathologies (Prakash et al., 2012). Fruits offer protection against free radicals that

damage lipids, proteins, and nucleic acids. Polyphenols, carotenoids (pro-vitamin A), vitamins C and E present in fruits have antioxidant and free radical scavenging activities and play a significant role in the prevention of many diseases (Prakash et al., 2012). A number of trace elements protect the cell from oxidative cell damage as these minerals are the cofactor of antioxidant enzymes. Zinc, copper and manganese are necessary for superoxide dismutases in both cytosol and mitochondria. Iron is a component of catalase, a heme protein, which catalyzes the decomposition of hydrogen peroxide (Machlin and Bendich, 2017). Small amounts of micronutrients are required for good physical condition along with energy food and protein. Sodium, potassium, iron, calcium and many trace elements together with antioxidant vitamins and minerals are vital for the body. Fruits and vegetables, particularly leafy, have noteworthy amounts of calcium, iron and potassium (Jahan et al., 2011). On the other hand, none can guarantee us whether this food item is safe or not as these days rarely any food item is free from food adulteration. Most of the adulterants that are intentionally added are invisible or they are made indistinguishable by astutely camouflaging by means of the color or texture. Food safety is essential to maintain nutrition, combat food/waterborne diseases, maintain food quality and stop food adulterations, being rampant in India. Heavy metals are a general collective term which applies to the group of metals and metalloids with an atomic density greater than 4 g/cm^3 . Although it is a

loosely defined term (Duffus, 2021), it is widely recognized and usually applies to the widespread contaminants of terrestrial and freshwater ecosystems. Nowadays some growers as well as traders in India are commercially using some chemicals namely Ripen, Gold-Plus, Profit etc. for the ripening of tomato, papaya, mango and banana, directly to the fields and processing areas. These chemicals change nutritional properties of fruits and vegetables as well as lead serious health hazards to human beings like cancer, skin irritation, diarrhea, liver disease, kidney disease, gastrointestinal irritation with nausea, vomiting, diarrhea, cardiac abnormalities etc (Hakim et al., 2010). Children are at particular risk to the harmful side effects of food adulteration, which may lead to serious liver and kidney diseases including various forms of cancer and hepatitis (Per et al., 2007). Publicity regarding the concentration of heavy metals in fruits and vegetables will create apprehension and fear in the public as to the presence of heavy metal residues in their daily food. Keeping in mind the potential toxicity and persistent nature of heavy metals, and the frequent consumption of vegetables and fruits, it is necessary to analyze these food items to ensure the levels of these contaminants meet agreed international requirements (Radwan and Salama, 2006). Information about the composition of food is important for nutrition education, training and research. It is also necessary for dietary recommendation and supplementation of food. The aim of this study was to determine the concentrations of minerals in selected fruits which are widely

consumed tropical fruits as well as to warn the people and government about the concentration and serious side effects of food adulteration.

Materials and Methods

This experiment was carried out at Institute of Food Science and Technology, India Council of Scientific and Industrial Research (BCSIR), Dhaka-1205. Ten types of fruits were analyzed in this study. These include Sapodilla, Stone-apple, Bilimbi, Indian-gooseberry, Guava, Elephant-apple, Tamarind fruit, Mango, Litchi and Strawberry. The selected fruits were collected from five different local markets of Dhaka city. Collected samples were fresh, matured, and free from insect's bites and other organoleptic deterioration. Five samples from each type of fruit were selected for the measurement of heavy metals content. Each value represents the average from five replications and the outcomes expressed as mean values \pm standard deviations (SD). All the results were expressed as milligram (mg) and microgram (μg) per 100 g of edible portion of fruits.

The freshly collected sample was washed with deionized water to eliminate visible dirt and removed the water quickly with a blotting paper. Then the sample was cut into small pieces, homogenized and accurate amount was weighed as required for different analysis. Five samples from each fruit were selected for measurement.

Ash content was determined by the process of Ranganna (1986) and then minerals

and heavy metals content was determined according to standard method. Sodium and potassium contents were determined by flame photometric method mentioned by Ward and Johnston (Jahan et al., 2011). Zinc, copper, manganese, iron and phosphorus content were determined by standard AOAC method (AOAC, 2021). Calcium (Ronald and Ronald, 2011) and Magnesium (CHEM, 2008) were determined by titration process. Copper, Iron, Manganese, Zinc were determined by the technique of Kirk and Sawyer (2011). Arsenic, Mercury, Cadmium, Lead and chromium were determined by Flame Atomic Absorption Spectrometric method (Kirk and Sawyer, 2011). Statistical analyses were carried out by using Statistical Package for Social Science (SPSS) for Windows version 16.0. The results obtained in the present study are reported as mean values (obtained from the five replications) \pm standard deviation (SD). The significance differences between mean values were analyzed by Duncan multiple range test at a significance level of $p < 0.05$.

Results and Discussion

Table 1: Mineral content status of ten fruits

Sample		n	Minerals Content							
English name	Scientific name		Copper (mg)	Iron (mg)	Manganese (mg)	Zinc (mg)	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Sapodilla	<i>Manilkara zapota</i>	5	0.34 ± 0.11 ^b	0.93 ± 0.40 ^a	0.12 ± 1.05	0.12 ± 0.24	09.00 ± 1.94 ^c	193.00 ± 1.22 ^a	18.01 ± 0.61	09.06 ± 0.49 ^c
Stone-apple	<i>Aegle marmelos</i>	5	0.02 ± 0.03	0.23 ± 0.79	0.23 ± 1.11	0.01 ± 0.18	06.65 ± 0.66 ^c	78.00 ± 2.05 ^b	30.00 ± 1.06 ^a	14.56 ± 0.55 ^b
Indian-gooseberry	<i>Phyllanthus emblica</i>	5	0.01 ± 0.10	0.68 ± 0.90	0.03 ± 0.21	0.07 ± 0.44	01.07 ± 0.23	163.10 ± 3.01 ^a	28.06 ± 1.09 ^b	78.00 ± 1.88 ^a
Guava	<i>Psidium guajava</i>	5	19.30 ± 2.12 ^a	ND	ND	2.07 ± 0.15 ^a	62.78 ± 1.24 ^a	13.65 ± 2.03	28.13 ± 1.42 ^b	2.69 ± 0.38
Bilimbi	<i>Averrhoa bilimbi</i>	5	0.14 ± 0.08	1.06 ± 0.67 ^b	0.01 ± 0.07	0.10 ± 0.03	03.08 ± 1.14	09.00 ± 0.70	06.45 ± 0.30	08.60 ± 0.34 ^c
Elephant-apple	<i>Dillenia indica</i>	5	0.06 ± 0.01	0.38 ± 0.03	0.06 ± 0.03	0.11 ± 0.20	00.60 ± 0.04	33.06 ± 2.22	14.29 ± 0.90	06.56 ± 0.26
Tamarind fruit	<i>Tamarindus indica</i>	5	0.06 ± 0.04	2.80 ± 1.43 ^a	0.07 ± 0.67	0.10 ± 0.25	21.00 ± 1.70	621.00 ± 3.26 ^{ab}	75.00 ± 2.41 ^{ab}	90.00 ± 1.80 ^a
Mango	<i>Mangifera indica</i>	5	ND	ND	06.16 ± 1.19 ^a	ND	34.03 ± 6.81 ^b	10.23 ± 1.94	19.45 ± 5.27 ^c	01.54 ± 0.51
Litchi	<i>Litchi chinensis</i>	5	0.10 ± 0.14	0.39 ± 0.10	0.05 ± 0.10	0.09 ± 0.20	02.14 ± 0.64	171.00 ± 2.36 ^a	09.89 ± 1.18	09.20 ± 0.54 ^c
Strawberry	<i>Fragaria X ananassa</i>	5	0.09 ± 0.08	0.38 ± 0.10	0.29 ± 0.27 ^b	0.08 ± 0.19	01.01 ± 1.48	168.00 ± 3.29 ^a	16.08 ± 1.08 ^c	08.20 ± 0.11 ^c

Minerals play an important role in maintaining proper function and good health in the human body. According to Hendricks (2018), approximately 98% of the calcium (Ca) and 80% of the phosphorus (P) in the human body are found in the skeleton. Inadequate intake of minerals in the diet is often associated with an increased susceptibility to infectious diseases due to the weakening of the immune system. Plants, animal foods and drinking water are an important source of essential elements (Chaturvedi et al., 2021). Table 1 shows the minerals content of selected tropical fruits. Copper, Iron, Manganese and Zinc is known as trace elements. The trace elements that were found in selected fruit samples are copper, iron, manganese and zinc. The highest amount of copper and iron was found in Guava and Tamarind fruit, 19.30 ± 2.12 mg and 2.80 ± 1.43 , mg respectively. The highest amount of manganese was found in Mango, 06.16 ± 1.19 mg and the

highest amount of zinc was found in Guava, 2.07 ± 0.15 mg per 100 g of fruit. According to USDA the daily recommended intake of iron is 8 mg for adult male and 18 mg for adult female. RDA for manganese is 2.3 mg/day for adult male and 1.8 mg/day for female (USDA, 2021). The U.S. recommended dietary allowance (RDA) for zinc is listed by gender and age group, the RDA for zinc (8 mg/day for adult women and 11 mg/day for adult men) appears sufficient to prevent deficiency in most individuals (IOM, 2021). Most fruits contain a small amount of zinc as the zinc in whole grain products and plant proteins is less bio-available due to their relatively high content of phytic acid, a compound that inhibits zinc absorption (King et al., 2006). Trace element is any substance that when present at low concentration compared to those of an oxidisable substrate significantly delays or prevents oxidation of that substrate. Trace elements sometimes act as an antioxidant. Antioxidant functions are associated with decreased DNA damage, diminished lipid peroxidation, maintained immune function and inhibited malignant transformation of cells (Maisarah et al., 2013). These minerals are also called microminerals which also worked as antioxidants, which are required in amounts less than 100 mg/day (IOM, 2021).

There are many epidemiological studies suggest that consumption of polyphenol-rich foods and beverages is associated with a reduced risk of cardiovascular diseases, stroke and certain types of cancer in which polyphenol is linked to the

antioxidant properties (Barros et al., 2007; Jagadish et al., 2009). The consumption of dietary trace-elements will help to prevent free radical damage. According to Olajire and Azeez (2011), trace-elements have the ability to scavenge free radicals by inhibiting the initiation step or interrupting the propagation step of oxidation of lipid and as preventive antioxidants which slow the rate of oxidation by several actions. Thus, consumption of these tropical fruits can be suggested as a food based strategy to alleviate or improve the unsatisfactory dietary iron intake of adolescents in the low-income areas. These fruits were also enriched with minerals like sodium, potassium, calcium and magnesium. Sodium content of selected fruits ranges between 00.60 ± 0.04 mg and 62.78 ± 1.24 mg per 100 g of edible portion. Sodium variability of fruits sometimes relies on soil sodium. Black soil contains fair amount of sodium. Among the fruits analyzed, the highest quantity of potassium was found in Tamarind fruit, 621.00 ± 3.26 mg. For the healthy adult, RDA for sodium and potassium intake is not more than 2,400 mg and 4700 mg respectively per day (USDA, 2021). Among the fruits analyzed, highest amount of calcium and magnesium was found in Tamarind fruit, 75.00 ± 2.41 mg and 90.00 ± 1.80 mg, respectively. Calcium with the name of “super nutrient” has been proven clinically associated with reduced risk of various non-communicable diseases such as osteoporosis, cardiovascular diseases and it also helps to reduce colorectal

cancer risk by promoting the apoptosis in human colorectal epithelium that reduce colorectal neoplasm (Ng et al., 2012).

Table 2: Heavy metal status of ten fruits

Samples		n	Arsenic (μg)	Cadmium (mg)	Lead (mg)	Mercury (μg)	Chromium (mg)
English name	Scientific name						
Sapodilla	<i>Manilkara zapota</i>	5	ND	0.046 \pm 0.02 ^a	ND	0.361 \pm 0.03 ^b	0.062 \pm 0.02 ^a
Stone-apple	<i>Aegle marmelos</i>	5	ND	0.064 \pm 0.03 ^b	ND	0.214 \pm 0.02 ^b	0.046 \pm 0.01 ^a
Indian- gooseberry	<i>Phyllanthus emblica</i>	5	0.019 \pm 0.01 ^a	ND	ND	ND	0.057 \pm 0.01 ^a
Guava	<i>Psidium guajava</i>	5	ND	ND	ND	ND	ND
Bilimbi	<i>Averrhoa bilimbi</i>	5	ND	ND	ND	ND	0.053 \pm 0.02 ^a
Elephant-apple	<i>Dillenia indica</i>	5	ND	ND	ND	0.634 \pm 0.04 ^b	0.048 \pm 0.02 ^a
Tamarind fruit	<i>Tamarindus indica</i>	5	ND	0.051 \pm 0.01 ^a	0.068 \pm 0.03 ^b	0.318 \pm 0.04 ^b	0.045 \pm 0.02 ^a
Mango	<i>Mangifera indica</i>	5	ND	ND	0.022 \pm 0.01 ^a	ND	ND
Litchi	<i>Litchi chinensis</i>	5	ND	ND	ND	ND	0.052 \pm 0.01 ^a
Strawberry	<i>Fragaria X ananassa</i>	5	0.105 \pm 0.03 ^a	ND	ND	ND	0.030 \pm 0.01 ^a

N/B: Results were expressed as mean values \pm standard deviation and values followed by different letters are significantly ($p < 0.05$) different from each other
ND = Not Detected

Fruits are highly valued in human diet for vitamins and minerals. Eating of artificially treated fruits is most harmful and responsible for many life-threatening diseases in human beings. Heavy metals are used as food contact materials, mainly in processing equipment, containers and household utensils but also in foils for wrapping foodstuffs. They play a role as a safety barrier between the food and the exterior. They are often covered by a surface coating, which reduces the migration in foodstuffs. When they are not covered these food contact materials can give rise to migration of metal ions into the foodstuffs and therefore could either endanger human health if the total content of the metals exceeds the sanitary recommended exposure limits, if any, or bring about an unacceptable change in the composition

of the foodstuffs or a deterioration in their organoleptic characteristics. Arsenic content found in selected fruit samples was within the acceptable range. Among the fruits analyzed arsenic was found in Indian- gooseberry and Strawberry ranging from $0.019 \pm 0.01 \mu\text{g}$ to $0.105 \pm 0.03 \mu\text{g}$. The highest amount of arsenic was found in strawberry, $0.105 \pm 0.03 \mu\text{g}$. It may be due to the solid waste disposal into land, arsenic contaminated water use during cultivation and mixing of chemicals. Analysis of food and intake data from the U.S. Department of Agriculture Continuing Survey of Food Intakes by Individuals indicates that the intake of Arsenic for all age groups ranged from 0.50 to 0.81 $\mu\text{g}/\text{kg}/\text{day}$ (Gunderson, 2015). Arsenic is an established human poison. Ingestion of doses greater than 10 $\text{mg}/\text{kg}/\text{day}$ or greater can be accompanied anemia and hepatotoxicity (Fincher and Koerker, 2017). Cadmium was found only in Sapodilla, Stoneapple and in Tamarind fruit ranging from $0.046 \pm 0.02 \text{mg}$ to $0.064 \pm 0.03 \text{mg}$. The effects of cadmium on humans are nephrotoxicity, osteotoxicity, cardiovascular-toxicity and effects on reproduction and development and genotoxicity. Kidney damage also occurs as a result of cadmium exposure. Occasional peaks in cadmium intake may cause a drastic increase in fractional absorption of cadmium. Ingestion of highly contaminated foodstuffs results in acute gastrointestinal effects in form of diarrhoea and vomiting. About 5% of ingested cadmium is absorbed (GMACE, 2021). The speciation of cadmium in foodstuffs may be of importance for the

evaluation of the health hazards associated with areas of cadmium contamination or high cadmium intake.

Lead was found only in Tamarind fruit and Mango. The highest amount of lead was in Tamarind fruit, 0.068 ± 0.03 mg. According to the national standard of China on Maximum Levels of Contaminants in Foods (published on January 25, 2021), maximum level for lead in fruits is 0.10 mg/kg (NSCMLCF, 2021). Availability of lead in fruits may be due to the use of ripening agents or due to the air surrounding the area is high in lead aerosol resulting from emission from automobile exhaust. The main sources of lead intake are foodstuffs like vegetables (up to 0.05 mg/ kg), cereals and cereal products (up to 0.09 mg/kg), fruit and fruit juices as well as wine, beverages and drinking water (GMACE, 2021). Due to the low safety factor, all use of lead in food contact materials should be abandoned or avoided. Parts made wholly or partly of lead and lead solder for repair should not be used in materials and articles intended to come into contact with foodstuffs including the use of lead in soldered cans. Consequently, limits for lead in foodstuffs should not include special allowances for canned foodstuffs. Mercury was found in Sapodilla, Stone-apple, Elephant-apple and in Tamarind fruit ranging from 0.214 ± 0.02 μ g to 0.634 ± 0.04 μ g. The highest amount of mercury found in Elephant-apple, 0.634 ± 0.04 μ g. The average daily intake of mercury is reported to be between 0.002-0.02 mg (GMACE, 2021). According to the national standard

of China on Maximum Levels of Contaminants in Foods (published on January 25, 2021), maximum level for mercury in fruits is 0.01 mg/kg (NSCMLCF, 2021). Mercury is one of the most toxic elements among the studied heavy metals and exposure to high level of this element could permanently damage the brain, kidneys and developing fetus (Castro-González and Méndez-Armenta, 2008). Mercury is among the metals of most concern for human health, especially organic mercury. Mercury in ambient air originates mainly from volcanic activity and industrial activity (GMACE, 2021). Methyl mercury is biosynthesised from inorganic mercury as a consequence of microbial activity. Much has been done in the last decade to limit or remove the sources of mercury contamination of foodstuff. Chromium was found in almost all selected fruit varieties except Guava and Mango. Highest amount of chromium found in Sapodilla, 0.062 ± 0.02 mg/100 g and the lowest amount was in Strawberry, 0.030 ± 0.01 mg. According to the national standard of China on Maximum Levels of Contaminants in Foods (published on January 25, 2021), maximum level for chromium in fruits is 0.50 mg/kg (NSCMLCF, 2021). The main sources of chromium are cereals, meat, vegetables and unrefined sugar, oil and fruits contain smaller amounts (GMACE, 2021). Most foodstuffs contain less than 0.1 mg chromium per kg. Toxic aspects of chromium are related to Cr (VI), due to its high absorption, easy penetration of the cell membranes and its genotoxicity and oxidizing properties (GMACE, 2021).

The recommended intake of chromium is higher than actual values, however, a specific evaluation on chromium should be conducted including evaluation on the aspect of allergy and chromium as at least one reference refers to chromium allergy (Veien et al., 2014). Despite the fact that arsenic, cadmium, lead, mercury and chromium was found in selected fruits but there concentration was lower than the safe level.

Conclusion

Fruits are highly valued in human diet for vitamins and minerals. This study indicates that the tropical fruits of Bangladesh are excellent source of minerals. The foremost findings of this study comprise that Tamarind fruit is a rich source of iron, sodium, potassium, calcium and magnesium which is one of the cheapest tropical fruit of Bangladesh and can be used to alleviate nutritional deficiency among the people specially woman and children of the rural areas. The results of this study indicate that the daily intake of arsenic, cadmium, lead, mercury and chromium through fresh fruits may not constitute a health hazard for consumers because the values were below the recommended daily intake of these metals. Though lead and cadmium, the most toxicity heavy metals were low index in the fruits, however, these amounts can be hazardous if the fruits are taken in large quantities. It is therefore suggested that the use of adulterants in fruits must be strictly prohibited in order to prevent excessive build-up of these metals in the

human food chain. Considering its hazardous aspects, the use of adulterants must be strictly monitored and controlled. It is not solely the responsibility of the government; the people must also become aware and avoid consuming contaminated fruits.

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