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Radiation Effects on Essential Minerals Content of Cucumber (*Cucumis sativus)*

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Abstract Food irradiation is one of the most popular preservation techniques used world-wide. In case of fresh fruits and vegetables it helps to make the product safe and extend the shelf-life without raising the temperature of the foodstuffs and with a minimal change in taste, texture and nutritional composition. In case of cucumber pickling is the traditional approach of preservation but irradiation can also be used industrially to fulfill the similar principle. This study is an attempt on that direction and was performed to observe the effects of radiation on essential minerals content of Cucumber (*Cucumis sativus).* Cobalt-60 is used as a radiation source in this experiment which is the most commonly used radionuclide for food irradiation. Results of this study indicate that the essential minerals content of Cucumber is sensitive to different doses of irradiation. This study also suggests that treatment with gamma radiation is negatively correlated but surprisingly positive correlations were also noticed in some cases.

Keywords: *gamma radiation, tandem accelerator, essential minerals, cucumber, food safety*

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1. Introduction

Fresh fruit and vegetables are important components of a balanced and healthy diet; their consumption is highly encouraged in many countries by health specialists to offer protection against a range of diseases. Foods that are consumed raw are increasingly being recognized as important vehicles for transmission of human pathogens that were usually linked with foods of animal origin [1,2]. Besides, during the processing steps of growth, harvest, transport, and further processing and handling, these products may be contaminated with pathogens from human or animal sources [3]. However, despite the high risk of foodborne diseases, the small fruits are not washed or cannot be washed before marketing because of the negative effect on their shelf life and quality [4].

Cucumber is an important constituent of Bangladeshi salads. These are generally peeled and sliced and are used for salad dressings or shred or cut into very small pieces to mix with other ingredients of salads. Also there are other uses of these salad components which include some local foods like halwa preparations, pickles, and parathas. A fresh Cucumber juice has now also becoming popular as a functional food available for dieting and health conscious people. Nutritional contents of fresh cucumber are shown on Table 1. It has a wide range of contributions in the diet ranging from salad dishes to diet control fruits. It is consumed raw and cannot be treated by any means to extend the shelf life. Therefore, there is a continuous need for innovative preservative technologies and sustainable trade and commercialization practices. Several methods have been tried to control the microbial contamination of various foods products such as fumigation with ethylene oxide or methyl bromide and radiation with gamma rays. Irradiation is among the safer and promising effective processes which are used to achieve some beneficial effects including disinfestations, improvement of shelf life and safety of food products by reducing the microbial load which requires radiation doses in the range of 1–10 kGy. It consists in exposing for a determined time period the packed or in bulk food products to control and optimize amounts of ionizing radiations [5].

Irradiation process prevents the growth of microorganisms and slows down the maturation of some fruits and vegetables by inhibiting biochemical reactions in the physiological processes of maturation. It is important to consider that this radiation process should not have toxicological side effects such as degradation of the organoleptic properties and nutritional contents or increase of the normal level of the radioactivity. Thus, the purpose of this physical treatment applied to the food field is to improve the nutritional and organoleptic quality and also to extend the shelf life. That's why, the exposure time and the absorptive radiation amount must be adequate to reach the required biological effects without deterioration of the qualities, being suitable for human use as well as commercialization [5].

Considering the high risk of contamination, preventative actions on the farm or during processing or packing, or use of a treatment like irradiation might reduce the risk of disease transmission from fresh produce [3]. Irradiation may be considered as an alternative technology for fresh food treatment which is somehow impossible to treat with other sterilization process [6]. Irradiation - a non-thermal process which have the ability to inactivate microorganisms at ambient or near ambient temperatures, as a result avoiding the deleterious effects that heat has on the texture, flavor, color, and nutrient value of food specially fresh foods. In addition, irradiation has the advantage that products are processed in the final processing stage, reducing the possibility of cross contamination until actual use by the consumer.

Table 1. Nutritional contents of Cucumber [7]

Nutrient	Amount (Per 100 g)
Energy (kcal)	13.1
Carbohydrate (g)	2.3
Fat (g)	0.05
Protein (g)	0.81
Fibre (g)	0
Water (g)	96.5
Ash (g)	0.38
Sum of saturated fatty acids (g)	0.02
Sum of monounsaturated fatty acids (g)	0
Sum of polyunsaturated fatty acids (g)	0.02
Beta-carotene (μg)	119
Vitamin C (mg)	10.1
Vitamin E (mg)	0.15
Folate (μg)	10.4
Calcium (mg)	17
Iron (mg)	0.27
Potassium (mg)	160
Magnesium (mg)	10
Sodium (mg)	3
Salt (g)	0.01
Zinc (mg)	0.17

The safety and wholesomeness of irradiated foods have been well established and revised from time to time [8]. It was confirmed by joint FAO/IAEA/WHO Experts Committee that irradiation at a dose of 10 kGy and above does not produce any noticeable nutritional or microbiological problems or toxicological hazards in food products [9]. There are plenty of reports and scientific articles available showing that irradiation of food products, in the form of electron beams or gamma rays, is effective in overcoming quarantine barriers in international trade, as a mode of disinfection, decontamination, and improvement of shelf life and nutritional attributes [10,11]. The aim of this study was to observe the effect of gamma radiation on the essential mineral contents of cucumber *(Cucumis sativus)* in order to assess the potential use of irradiation as a treatment process. Cucumbers were analyzed for essential elements using Instrumental Neutron Activation Analysis (INAA) by tandem accelerator.

2. Materials and Methods

2.1. Sample Collection

This research work was carried out in the laboratory of Food Technology Division, Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh. The selected fruits were collected from different markets and super stores in Dhaka. Collected samples were fresh and free from any kind of damage or deterioration.

2.2. Sample Preparation

The sample (cucumber) was peeled and sliced into uniform small pieces and blended. The samples were homogenized and made into paste and weighed into small uniform pieces. One portion was kept for control and another were used for radiation treatment.

2.3. Irradiation Treatment

The sample was packed into sterilized polyethylene pack and sealed. Finally four packets containing the sample were transferred to Gamma radiation room for radiation treatment. To observe the effect of radiation doses on essential contents and vitamin A content of cucumber, 1 control (or 0.0 kGy) and 4 different radiation doses (1.0 kGy, 2.0 kGy, 2.5 kGy and 3.0 kGy) were used. A Co-60 gamma irradiator was used as the source of radiation.

2.4. Tablets Formation

After being irradiated, the sample was kept at low temperature (-20°C) on a refrigerator for 48 hours. The sample was dried by freeze drying at -52°C temperature and 0.370 mbar pressure. Freeze dryer was used to avoid loss of minerals.

The freeze dried samples were milled by milling machine to form powder. Careful attention was given to avoid moisture gain during these processes. Then it was transferred to hydraulic pressure machine to make uniform sized tablets. The tablets were made by Hydraulic pressure machine with a diameter of 10 mm.

2.5. Mineral Contents Analysis

Finally tablets were transferred to Tandem Facilities Division (TFD) to analyze mineral contents of tablets by Tandem Accelerator (TA) in order to observe the effects of gamma radiation on cucumber. Tablets were stored at -20°C temperature when it is not in use for analysis.

3. Results and Discussion

This study was conducted to assess the change in mineral contents of cucumber occurred due to gamma irradiation at various doses. Contents of different minerals namely Potassium, Calcium, Chromium, Manganese, Iron, Nickel, Copper and Zinc were evaluated in this experiment. One control sample was used to differentiate the differences occurred due to various radiation doses. Four different radiation doses (1.0 kGy, 2.0 kGy, 2.5 kGy and 3.0 kGy) were applied in this experiment. Each value represents the average from five replications and the outcomes expressed as mean values of each concentrations (ppm).

Values for Copper, Iron, Manganese and Zinc at different treatments are illustrated in Figure 1-Figure 4. It is obvious that the values at control will be higher compared to different doses of irradiation treatment. This was followed for Copper, Iron and Manganese but in case of Zinc it was surprising that the values keep increasing with irradiation dose. Figure 4 shows a continuous increase in the amount of Zinc with higher dose of irradiation compared to control. The values of Copper at 2.5 kGy increased a bit compared to the dose of 2.0 kGy. It was unexpected that the value for Copper was not detected at 3.0 kGy. Meanwhile there was an up and down with increasing radiation dose for Iron and Manganese.

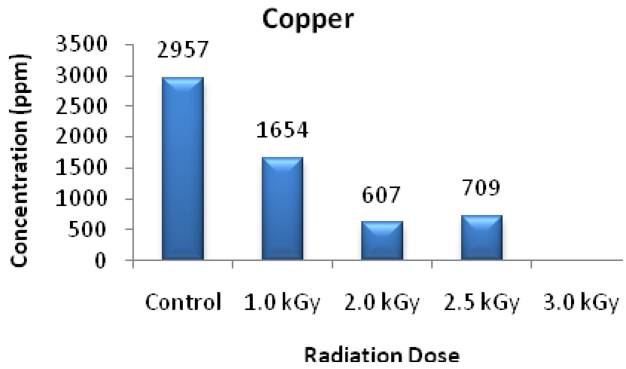

Figure 1. Values for Copper at different treatments

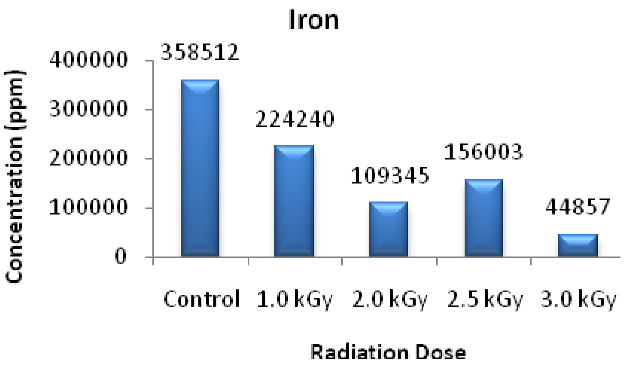

Figure 2. Values for Iron at different treatments

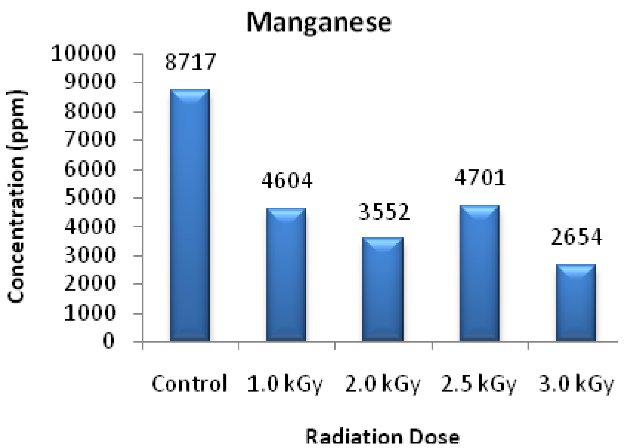

Figure 3. Values for Manganese at different treatments

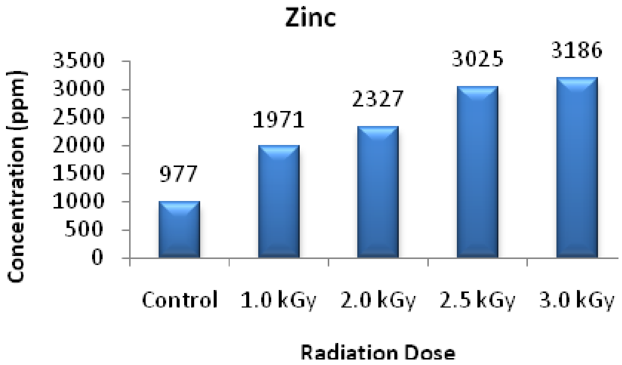

Figure 4. Values for Zinc at different treatments

The irradiation source supplies energetic particles or waves which pass through a target material where they collide with other particles. Around the sites of these collisions chemical bonds are broken, creating short lived radicals which cause further chemical changes by bonding with and or stripping particles from nearby molecules. When collision damage RNA or DNA, reproduction becomes unlikely and also cell division is often suppressed. As the radioactive source never have the chance to come in contact with food; so irradiated food is always safe from being radioactive. Also energy of radiation is limited below the threshold of induction of radioactivity, but it was found that radiation does reduce the nutritional content and change the flavor, produce radiolytic products, and increase the number of free radicals in the food. It is also reported that irradiation causes a multitude of chemical changes including introducing radiolytic products and free radicals [12].

Copper, Iron, Manganese and Zinc is known as trace elements which play an important role in maintaining proper function and good health in the human body. It is reported that inadequate intake of minerals in the diet is often associated with an increased susceptibility to various infectious diseases due to the weakening of the immune system. Plants, animal foods and drinking water are an important source of essential elements. Trace element is any substance which when present at low concentrations compared to those of an oxidisable substrate significantly delays or prevents oxidation of that substrate.

Trace elements sometimes act as an antioxidant and the functions are associated with decreased DNA damage, diminished lipid peroxidation, maintained immune function and inhibited malignant transformation of cells. These minerals are also called micro-minerals and required in amounts less than 100 mg/day. It is also reported that 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. Considering the importance of trace elements and if we consider a minimal loss of these minerals due to radiation treatment then we can suggest that radiation treatment at a dose of 1.0 kGy offer the least loss compared to control except the exception of Zinc which shows a proportional relationship with higher radiation dose. [13,14,15] This dose of 1.0 kGy is also suggested by FDA (Food and Drug Administration, USA) for fresh fruits and vegetables [16].

A high intake of trace elements and minerals is not suggested by specialists as this is associated with adverse health effects. So it is always important to consider the recommended dietary intake of various minerals and trace elements. Recommended Dietary Allowance (RDA) for copper is established to be 0.9 ppm/day for both adult male and female. USDA (United States Department of Agriculture) declares the daily recommended intake of iron is 8 ppm for adult male and 18 ppm for adult female. RDA for manganese is 2.3 ppm/day for adult male and 1.8 ppm/day for female. The recommended dietary allowance for zinc is listed by gender and age group which is 11 ppm/day for adult men and 8 ppm/day for adult women as this amount is found to be sufficient to prevent zinc associated deficiency in most individuals. Fruits are generally a poor source 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 [13].

According to USDA, RDA for potassium intake is not more than 4700 ppm per day for healthy individuals [13]. According to USDA food guideline, RDA for calcium is 1,316 ppm/day for adults [17]. It is important to notice that a high calcium intake, mainly from dairy products, may increase the risk of prostate cancer by lowering concentrations of 1,25-dihydroxyvitamin D_3[1,25$(OH)_2D_3$], a hormone thought to provide protective offer against prostate cancer [18]. National standard of China on Maximum Levels of Contaminants in Foods (published on January 25, 2005) declares maximum level for chromium in fruits is 0.50 ppm/kg [14]. On the other hand, some trace elements for example, nickel has not been shown to be essential for humans. Moreover, orally ingested nickel salts is found to cause adverse effects on kidneys, spleen, lungs and the myeloid system in experimental animals. The intake of nickel from the average diet is estimated to be about 0.15 ppm/day [19].

Potassium, Calcium and Chromium shows an uneven relationship with different radiation doses which makes it somehow really hard to predict the preferred radiation dose. The values for Potassium, Calcium and Chromium in different treatments are shown in Figure 5-Figure 7. Content of Nickel is shown on Figure 8 where radiation at a dose of 3.0 kGy shows the highest value for Nickel which is quite surprising as same as we observed for Zinc. If we have to choose only one preferred dose of radiation which is quite debatable in this case, we can suggest radiation at the dose of 1.0 kGy which shows quite good amount in this case though not the highest one in each case which is also suggested by FDA [16].

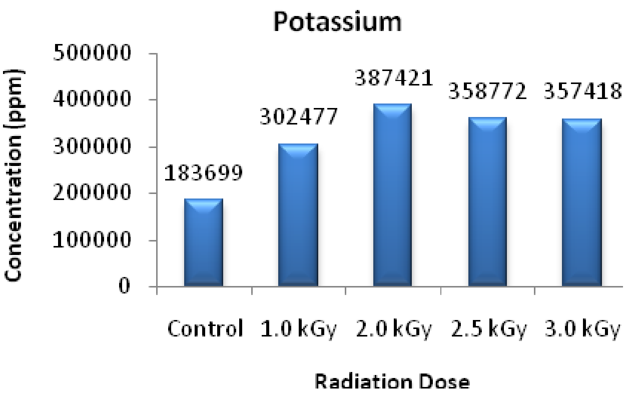

Figure 5. Values for Potassium at different treatments

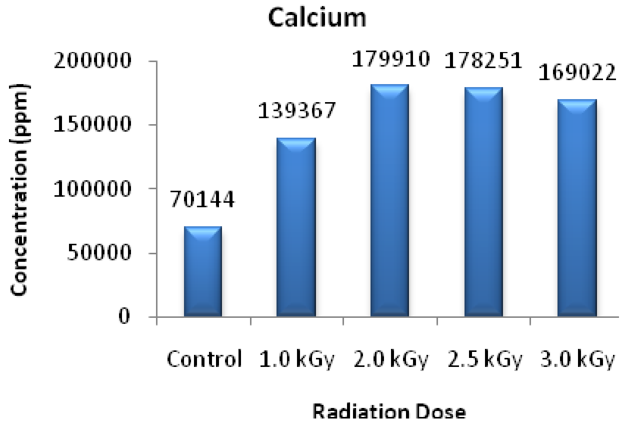

Figure 6. Values for Calcium at different treatments

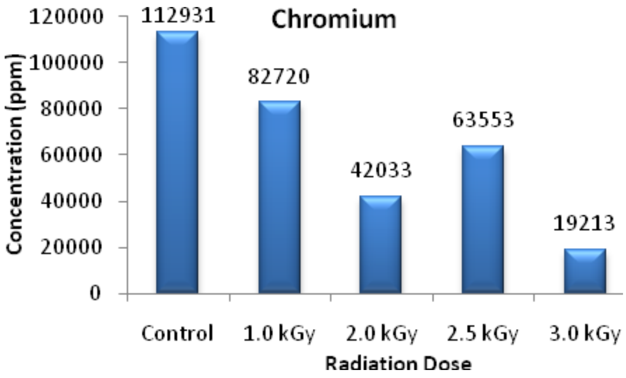

Figure 7. Values for Chromium at different treatments

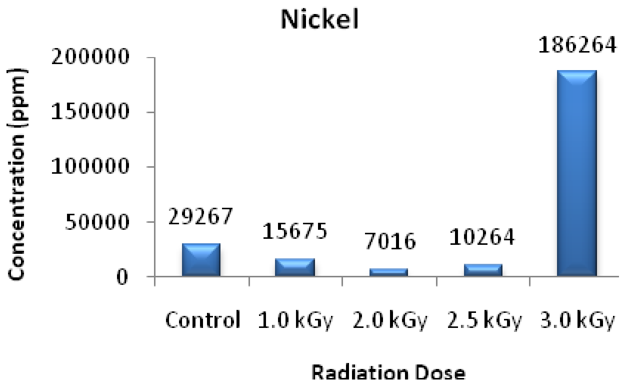

Figure 8. Values for Nickel at different treatments

The type of food and the specific purpose of the irradiation determine the amount of radiation. Exposure time is determined by the speed of belt which helps to control the radiation dose delivered to the food. The actual dose is measured by dosimeters within the food containers. In case of bulk or packaged food which passes through a radiation chamber on a conveyor belt. The food does not come into contact with radioactive materials, but instead passes through a radiation beam, like a large flashlight. Gamma rays are emitted from radioactive forms of the element cobalt (Cobalt 60) which is used in this experiment which is the most commonly used radionuclide for food irradiation. Cobalt-60 emits ionizing radiation in the form of intense gamma rays. This Cobalt-60 has several advantages: up to 95% of its emitted energy is available for use; it penetrates deeply, yields substantial uniformity of the dose in the food product, decays to non-radioactive nickel, considered to pose low risk to the environment. However, its 5.3-year half-life offers some disadvantages like cobalt-60 "pencils" require frequent replenishment. Radiation doses vary for different food products. In most cases, the limit is less than 10 kGy. When ionizing radiation strikes bacteria or other microbes, its high energy breaks chemical bonds in molecules that are vital for cell growth and integrity. As a result, the microbes die, or can no longer multiply causing illness or spoilage. This breaking of chemical bonds with radiation is known as radiolysis [16].

Irradiation does not make food products radioactive, does not compromise with nutritional quality, or noticeably change the texture, taste or appearance of food. Changes made by irradiation are so nominal that it is not easy to figure out whether a food is irradiated or not. Astronauts of NASA (National Aeronautics and Space Administration) eat meat that has been sterilized by irradiation to avoid getting foodborne illnesses when they fly in space [20].

Irradiation for food products is permitted in more than 60 countries, with about 500,000 metric tons of food products annually processed worldwide. Even though there have been concerns about the safety of irradiated food, a large amount of independent research has confirmed the safety of irradiated foods. Others criticize irradiation because of confusion with radioactive contamination or mostly because of negative impressions of the nuclear industry and current talk about nuclear issues. The regulations that dictate how food is allowed to be irradiated vary greatly from country to country. In Austria, Germany, and many other countries of the European Union only dried herbs, spices, and seasonings can be processed with irradiation with a specific dose, whereas in Brazil all foods are allowed to radiated at any dose [21].

In case of labeling of food products, FDA requires that irradiated foods have to be marked with the text “Treated with radiation” or “Treated by irradiation” or it have to bear the international symbol for irradiation. Bulk foods, such as fruits and vegetables, are required to be individually labeled or to have a label next to the sale container. Individual ingredients in a multi-ingredient food (e.g., spices) do not necessarily be labeled [20].

4. Conclusion

In conclusion, this work contributes to the knowledge of the beneficial application of gamma radiation on cucumber. Most of the reports are available on the effects of gamma rays on microbiological qualities while almost no reports are found to assess the effects of gamma rays on mineral content of fruits namely Cucumber. Thus, this investigation will help to give an overview which demonstrates that the gamma-radiation technique at a low dose 1-2kGy offer minimal loss of nutrients. This study revealed that the effect of gamma radiation on essential minerals content of Cucumber is negatively correlated but in some cases it shows positive correlation. Further study is suggested to investigate the changes in other factors like texture, sensory, taste and shelf-life of Cucumber. Also the authors believe that this study will be helpful to create awareness among consumers, government, media and manufacturers to practice radiation as a source or preservation and also to facilitate the trade of food products.

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