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Attenuation coefficients and absorbed gamma radiation energy of different varieties of potato, mango and prawn at different storage time and physiological condition

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ABSTRACT

Attenuation coefficients of different varieties of gamma irradiated potato (Kufri Chandramukhi, Kufri Jyoti, and Kufri Sindhuri), mango (Himsagar, Langra, Dashehri and Fazli) and prawn (Tiger prawn and Fresh water prawn) of different storage time and physiological stages were determined. After six months storage attenuation coefficient of Kufri Chandramukhi was decreased by 30.8% with decrease of density and moisture content. Decreasing trend of attenuation coefficient during storage was more prominent (almost 50%) in other two varieties of potato. On the other hand in all four varieties, unripe mango consisted of significantly less ($p \leqslant 0.05$) attenuation coefficient (around 11–14%) than the ripe one due to changes in physiological properties and density. Different varieties of prawn had different attenuation coefficients due to subtle differences in their proximate composition. Due to having different attenuation coefficients, different food components, even different varieties of same food component absorbed different gamma radiation energy though exposed to same radiation dose.

1. Introduction

Gamma radiation is very popularly used to inhibit sprouting of vegetables (bulbs and tubers), to enhance shelf life of fruits by influencing physiological phenomena, to control pathogenic organisms, insect and microbial disinfestations and to sterilise foods. It is evident that gamma radiation creates chemical, physical and structural changes in different food materials after interacting with them (Nayak, Suguna, Narasimhamurthy, & Rastogi, 2007). In the energy level which is used in food irradiation, among several interactions between gamma ray and food components, Crompton scattering predominates and the free radicals formation ultimately leads to biochemical changes in the major components of food as well as affects the major metabolic pathway. Gamma irradiation pretreatment has been reported to change and damage the interior tissue structure, thereby increasing the permeability of cells, which resulted in improved mass transfer during air drying (Wang & Chao, 2003b), osmotic dehydration (Rastogi, 2005) and solid liquid extraction (Nayak, Chethana, Rastogi, & Raghavarao, 2006a). Irradiation can also cause undesirable texture changes, loss of turgor pressure and/or hydrolysis of structural components in the cell wall (Mehta & Ezekiel, 2006). Effect of gamma irradiation on histological and textural properties of some vegetables was studied by Nayak et al. (2007). Several studies were carried out on the effects of gamma radiation on physiological, biochemical and structural properties of fruits (Lacroix, Bernard, Jobin, Milot, & Gagnon, 1990) and sea fish like prawn (Venugopal, Doke, & Thomas, 1999). The extent of these effects depends upon the amount of energy absorbed by any food commodities when it is exposed to gamma radiation. Again the energy absorbed by any food materials is related to the internal properties of that material and how it behaves and interacts with radiation. The attenuation coefficient of any food commodity is the reflection of its internal structure, composition and chemical and physiological nature. The quantity of energy absorption by any food materials after exposure to radiation depends upon the attenuation coefficient of that material. Therefore measurement of attenuation coefficient of food materials in which the effect of radiation will be studied is the most obvious and preliminary requirement.

The attenuation coefficient is a basic quantity used in calculation of the extent of penetration of materials by electromagnetic radiation or any other energetic particles. It is also called linear attenuation coefficient, narrow beam attenuation coefficient or absorption coefficient (Hubbell & Sheltzer, 1995). The attenuation coefficient describes the extent to which the intensity of an energy beam is reduced as it passes through a specific material (Carlsson, 1981). A small linear attenuation coefficient indicates that the material in question is relatively transparent, while a larger value

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indicates greater degree of opacity (Hubbell & Sheltzer, 1995). The attenuation coefficient of any material is influenced by several factors. It is highly dependent on the atomic number of the absorbing material. Atoms of the high atomic number absorber present larger targets for the radiation to strike and hence the chances for interactions are relatively high and the attenuation should therefore be relatively large. In the case of low atomic number absorber however the individual atoms are smaller and hence the chances of interactions are reduced (Pawar & Bichile, 2011). Attenuation coefficient also depends upon the density of the absorber. A low density absorber will give rise to less attenuation than a high density absorber since the chances of an interaction between the radiation and the atoms of the absorber are relatively lower (Chaudhari & Rathod, 2013). Lastly the attenuation coefficient decreases with the increase of gamma ray energy (Coupland & McClements, 1997). Extensive data on attenuation coefficient of different elements, compounds and mixtures of dosimetric interest had already been reported by many workers (Hubbell & Sheltzer, 1995; Carlsson, 1981). Attenuation coefficients of soil mixtures and various samples of solids and as well as liquid of biological interest including several amino acids, acetic acids, aldehydes, teflon etc. were already studied (Teli, 1998; Raje & Chaudhari, 2010; Chaudhari & Nathuram, 2010; Kirby, Davis, Grant, & Morgan, 2003; Pawar & Bichile, 2012). Research reports from around the world are also obtained determining attenuation coefficient of milk, edible oils and glucose solution (Chaudhari & Girase, 2013; Chanamai & McClements, 1998; Coupland & McClements, 1997; Chaudhari & Rathod, 2013).

But no reports are available regarding attenuation coefficients of potato, mango and prawn, the three most desired food commodities of not only India but of the whole world. In India gamma radiation treatment is a prerequisite for potato, mango and prawn. Radiation treatment assures potato storage throughout the year without any losses to achieve consumer demand and also executes exportation of mango and prawn to earn foreign money enhancing economic benefits. As per safety concern commercial radiation processing of these food commodities urgently needs researches on radiation induced damages of the nutritional properties which depend upon the radiation energy absorbed by them. Absorbed energy again directly related to the attenuation coefficients of the respective food materials. With this standpoint, in present text, attenuation coefficients of Indian varieties of stored potatoes, mangoes of ripe and unripe condition and prawns are estimated.

Potatoes of all varieties undergo several physiological changes in the post harvest storage period. The major change in potato tuber during storage is sprouting which is under genetic and environmental control (Sonnewald, 2001). Sprouting creates numerous changes in the potato tubers including evaporation of water, loss of weight and density, increase in reducing sugars due to starch breakdown, changes in free amino acids, amides and proteins, loss of vitamin C in accordance with changes in the metabolic balance (Ezekiel, Singh, & Datta, 2008). Storage of potato tubers also leads to degradation of cell wall material such as pectins and pectic compounds.

On the other hand ripening is a highly coordinated, genetically programmed and an irreversible phenomenon involving a series of physiological, biochemical and organoleptic changes (Prasanna, Prabha, & Tharanathan, 2007). The major changes occur within the mango fruit when it passes from the unripe stage to the fully ripe condition are the colour change in the exocarp due to degradation of chlorophyll and synthesis of anthocyanins, taste development in pulp because of increased gluconeogenesis, hydrolysis of polysaccharides, especially starch, decreased acidity and accumulation of sugars and softening of the whole fruits due to alteration of cell structure and changes in cell wall thickness, permeability of plasma membrane, hydration of cell wall, decrease in the structural integrity and increase in intracellular spaces (Prasanna et al., 2007; Redgwell et al., 1997). Prawns of different varieties also have subtle compositional and structural differences and gamma irradiation has several influences on the structural and physiological properties of prawns (Kilgen, 2001). Therefore the attenuation coefficient which is the function of the compositional and structural features will change with storage time, physiological stages and varietal difference.

In short, this study reflects the relation between the attenuation coefficients and the storage time, stages and compositional differences of different Indian varieties of potato, mango and prawn and also estimates the energy absorption after exposure in certain radiation dose.

2. Materials and methods

2.1. Materials

Potatoes (*Solanum tuberosum* L.) cv. Kufri Chandramukhi, Kufri Jyoti and Kufri Sindhuri were obtained from Block D, Bidhan Chandra Krishi ViswaVidyalay, Mohanpur, West Bengal and stored at 20 ± 1 °C temperature and 85–90% relative humidity at Humidity Cabinet (Prime Instrument) in low density polyethylene packets (37.1 μm) measuring 21.5 cm × 15 cm. Experiments were done with potatoes of just after harvest and after two months, four months and six months storage. Potatoes after proper cleaning with water were cut into specific thickness of 3 cm for experimentation.

Mangoes (*Mangifera indica* L.) of cv. Himsagar, Langra, Dashehri and Fazli at both unripe preclimacteric stage and at ripen condition were brought from the Mondouri Horticulture Research Station, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal and after washing they were used for the experiment.

Prawns of two different varieties, Tiger Prawn (*Penaeus monodon*) and Fresh Water Prawn (*Macrobrachium rosenbergii*) were procured from the local landing centre and transported using ice. Before experimentation the shell of the prawns were removed and they were beheaded, degutted and thoroughly washed in chilled water to remove the slime and extraneous matter.

2.2. Gamma ray spectroscopy

Gamma ray spectroscopy was performed by using the apparatus, Scintillation type 3"-3" Na-I (Tl) detector (Bicron make, Serial no-IQ411), amplifier, high voltage unit (HV4800D), detector bias supply (Ortec), multi channel analyser (Maestro-MCB1) and personal computer. Radioisotope Co-60 was used as the sources of gamma ray.

Collimated gamma ray from Co-60 was obtained by placing the radioactive source (Co-60) inside lead pot (wall thickness 1 inch) with a hole on its lid (1 inch thick). The arrangement was shown in Fig. 1(a) and (b). Gamma ray reaching the detector was counted for 1000 s. In the energy spectrum of the gamma rays, two different peaks at energy values of 1.17 MeV and 1.33 Mev emitted from Co-60 gamma source was obtained. Intensity of the peak at each energy level was estimated. A measure of extent of attenuation of gamma ray by the sample was obtained by subtracting the count under a particular peak obtained without and with a sample between the Co-60 source and detector. Background count was also obtained by performing the same experiment without placing any source. Care was taken to maintain the same source and sample geometry with respect to the detector throughout the experiment. The gamma ray spectra of energy versus count of without and with sample (potato, mango and prawn) is shown in