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Original Article

Determination of some useful radiation interaction parameters for waste foods

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A B S T R A C T

The mass attenuation coefficients (μ/ρ) of food waste samples (pomegranate peel, acorn cap, lemon peel, mandarin peel, pumpkin peel, grape peel, orange peel, pineapple peel, acorn peel and grape stalk) have been measured employing a Si(Li) detector at 13.92, 17.75, 20.78, 26.34 and 59.54 keV. Also, the theoretical values of the mass attenuation coefficients have been evaluated utilizing mixture rule from WinXCOM program. The results showed that the lemon peel has the highest values of μ/ρ among the selected samples. From the obtained mass attenuation coefficients, we determined some absorption parameters such as effective atomic number (Z_{eff}), electron density (N_E) and molar extinction coefficient (ε). It was found that the Z_{eff} values of all food wastes lie within the range of 4.034–7.595, whereas the N_E of the studied food wastes was found to be in the range of 0.301–1.720 × 10^{25} (electrons/g) for present energy region.

1. Introduction

Food waste consists of the food system from the farm, post-harvest, cultivating, retailing and the consumers. Food wastes are the single largest type of waste entering the landfills. Each wasted food means wasted money for businesses and housing. These waste foods are part of the hazards such as methane and greenhouse gases. One of the studies to provide for the recycling of these wastes may be a radiation shielding work area. In addition, food is exposed to radiation for preservation, control of insects, prevention of food-borne illness, extend the shelf life, delay of sprouting and ripening, and sterilization. It is very important to know the radiation attenuation characteristics of food at the applied radiation.

Food waste has been identified as one of the factors that has overburdened the global environment in recent years. A lot of wastes are being discarded in large amounts [1,2] considering the location and method of harvest. In recent times, compositional studies of food wastes suggest the presence of bioactive compounds, which are generally primary and secondary plants' metabolites. Some of the metabolites include phenolics, alkaloids, glycosides, volatile oils, mucilage, gums [3]. In addition, fruit peels' bioactive compounds contain a higher percentage of antioxidant activities [4] and can be used in the production of nutraceuticals and other products with a good fraction of fibers [5]. Because of the potential importance of the chemical composition of medicinal plants, many studies have been conducted [6–10].

Mass attenuation coefficient of different materials is very important for x-ray fluorescent (XRF) analysis because it helps in selecting the optimum reference sample during elemental analysis [11]. Different researchers have carried out works on determination of the mass attenuation coefficients of medicinal plants. Morabad and Kerur [12] experimentally determined the mass attenuation coefficients of some fruits, leaves, stem and seeds, which are known to be medicinal using a NaI(Tl) detector at 8.136, 13.596, 17.781, 22.581 and 32.891 keV. Their result showed a linear correlation in relation to the energies. Teerthe and Kerur [13] also worked on the x-ray mass attenuation coefficient of medicinal plants at low energies, their result is useful for XRF analysis and their experimental result compared well with the theoretical. Trunova et al. [11] worked on the measurement of the mass attenuation coefficient

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of some biological samples from 7 to 12 keV. Their result showed a significant variation among the biological samples. Variation between plant and animal tissue reached 47% and about 22% with different animal tissues. Tousi et al. [14] measured the mass attenuation coefficients of Eremunus – Rhizophora spp. particle boards using x-rays in the energy range 16.63–25.3 keV. The result from this work showed that Eremunus – Rhizophora spp. particle boards could be used as phantoms in diagnostic radiology.

Mass attenuation coefficients of food wastes like pomegranate peel, lemon peel, mandarin peel, pumpkin peel, grape peel, orange peel, pineapple peel, acorn peel, grape stalk and acorn cap are not available in the literature. So, this work has produced the mass attenuation coefficients, molar extinction coefficients, effective atomic numbers and electron densities of these wastes to help in the XRF analysis of any other similar wastes because of the potential usage of these wastes in medicine.

In the present work, mass attenuation coefficients (μ/ρ) of ten food waste samples were measured by using gamma-ray transmission method at 13.92, 17.75, 20.78, 26.34 and 59.54 keV photon energies. The gamma-ray attenuation measurements were measured using ^{241}Am point sources. The molar extinction coefficients (ε), effective atomic numbers (Z_{eff}) and electron densities (N_E) for the present food wastes samples were derived from the measured μ/ρ values. The experimental values of μ/ρ, ε, Z_{eff} and N_E were compared with those obtained theoretically using WinXCOM program. To best of our knowledge none of the studies have evaluated the photon attenuation characterizations of food waste samples and this encourages us to investigate the radiation attenuation parameters for the present samples. Therefore, understanding the physical interaction properties of food wastes with X- or gamma-rays has become essential for many industrial applications. Besides, the results obtained from this work can be useful in the design of new industrial radiation shielding products using waste foods and in the development of non-toxic shielding materials.

2. Materials and method

2.1. Sample preparation

The food wastes used in the study were obtained from local markets in Bingöl city in Turkey. After the food wastes were separated from their edible parts, the wastes were placed on unprinted papers and allowed to dry in airless, sunless laboratory conditions at 25 °C. After the drying process, the wastes were pulverized by grinding the laboratory type mill. Powdered food wastes were pelleted to 13 mm in diameter with the aid of a laboratory-type hydraulic pellet press. Perkin-Elmer brand elemental analysis instrument 2400 CHNS/O series II system was used to determine the chemical composition of food wastes. Total carbon, hydrogen and nitrogen in food wastes were determined by minor revisions according to European standard EN15104: 2011. The oxygen content in the samples was calculated by the following formula.

Oxygen (%) = 100-[carbon%+hydrogen%+nitrogen%]$_{\text{(Lighest moist basis)}}$.

The chemical compositions and physical densities of the food wastes are shown Table 1.

2.2. Experimental details

The mass attenuation coefficients (μ/ρ) of the food wastes were determined at 13.92, 17.75, 20.78, 26.34 and 59.54 keV using the transmission geometry as shown in Fig. 1. The measurements were conducted using the Si(Li) semiconductor detector system combined with multichannel analyzer (MCA), a radioactive point source, food waste (as the absorber) and collimators. The Si(Li) detector (Ortec SLP-04160P-OPT-0.3 model) has 12.5 mm^2 active area, Be window thickness 0.8 μm and 160 eV FWHM at 5.9 keV. The preamplifier (239-POF model) is mounted on the head of the detector. Also, the Si(Li) detector is combined with 4096 channels MCA (DSPEC-LF model) and high voltage source 1000 V with negative polarity. The detector system energy calibration was conducted using the test radioactive sources. 13.92, 17.75, 20.78, 26.34 and 59.54 keV photon energies from the ^{241}Am point source (370 kBq activity) were used in the experiments. A narrow beam was desired for this experiment, so the radioactive point source was shielded by the pin hole lead collimators. The collimation was necessary to minimize the scattered radiation reaching the detector crystal and the measurements were taken in a narrow beam geometry setup with suitable collimators. The radioactive point source was fixed at a distance of 9 cm from the Be window of the detector. In minimizing the statistical uncertainty, the counting time with and without the food waste samples was selected between 15200 s and 61200 s. The life time which equals to real time was used in the MCA. The final intensity (I) and initial intensity (I_0) of the food waste samples were measured experimentally under the same timing and experimental conditions. The corresponding energy peak positions were checked before and after the experiments; and no shift was observed. Hence, we can conclude that the all detector systems are stable throughout the experiments. The corresponding peak areas were obtained with the help of the Origin 7.5 (demo) program. Using this program, the peak area corrections were performed by subtracting the background counts. A typical spectrum of ^{241}Am with and without attenuation by pomegranate peel sample is shown in Fig. 2.

2.3. Theoretical background

When a beam of photons with an initial intensity (I_0) passing through a certain medium, the beam is attenuated exponentially according to the Beer–Lambert law given by the following relation:

Table 1
Chemical composition of food wastes.

Sample	Density (g/cm^3)	Hydrogen (%)	Carbon (%)	Nitrogen (%)	Oxygen (%)
Pomegranate peel	1.362	5.438	43.345	0.565	50.652
Acorn cap	1.063	5.771	47.995	0.754	45.481
Lemon peel	1.181	3.457	26.410	0.909	69.224
Mandarin peel	1.250	5.928	44.628	1.099	48.345
Pumpkin peel	1.219	5.885	42.031	2.058	50.026
Grape peel	1.100	6.019	45.090	1.920	46.971
Orange peel	1.400	5.621	56.757	0.761	36.861
Pineapple peel	1.109	5.845	54.838	0.659	38.658
Acorn peel	1.350	5.537	47.349	1.346	45.767
Grape stalk	1.368	5.923	44.397	1.765	47.915

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