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PHOTON ATTENUATION CHARACTERISTICS of CoQ10 and RESVERATROL

RESVERATROL ve COQ10'in FOTON ZAYIFLATMA KARAKTERİSTİKLERİ

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ABSTRACT

In this research, a number of coefficients, which characterize the probability of electromagnetic radiation interaction with the antioxidants, have been calculated. For this purpose, WinXCom computer program was run at energies from 1 keV to 100 GeV. The effective atomic numbers and electron densities were calculated using the mass attenuation coefficients of antioxidant. Finally, it was found that the values of μ_ρ decreased with increasing gamma energy by means of different interaction mechanism and the values of investigated parameters were found to be changed with the incoming photon energy and chemical content of the antioxidants The calculated values were compared with each other.

Key Words:
CoQ10, Resveratrol, effective atomic number, electron densities

ÖZET

Bu araştırmada, antioksidanlar ile elektro manyetik radyasyon etkileşim olasılığını karakterize eden bir dizi katsayı hesaplanmıştır. Bu amaçla, WinXCom bilgisayar programı 1 keV'den 100 GeV'ye kadar enerjilerde çalıştırıldı. Etkin atom sayısı ve elektron yoğunlukları, antioksidanların kütle zayıflama katsayıları kullanılarak hesaplandı. Son olarak, μ_ρ değerlerinin farklı etkileşim mekanizmaları nedeniylegama enerjisinin artmasıyla azaldığı ve incelenen parametrelerin gelen foton enerjisi ve antioksidanın kimyasal bileşimine bağlı olarak değiştiği bulundu. Hesaplanan değerler birbiriyle karşılaştırıldı.

Anahtar Kelimeler:
CoQ10, Resveratrol, etkin atom sayısı, elektron yoğunlukları

INTRODUCTION

Ionized radiations are widely used in the diagnosis and treatment of different illnesses in medical physics. These radiations, e.g. gamma and X-rays, may affect the atoms or molecules in the cell and these are causing free radicals and injury to different important components of cells (Kovacs and Keresztes, 2002). Antioxidants are the compounds which help to prevent cell injury caused by free radicals such as oxidants. The antioxidants have a great importance for a healthy body (Isıklı and Oto, 2017). Resveratrol and Coenzyme Q10 are among the most important antioxidants.Resveratrol is found in various kinds of fruits, plants and their commercial products. It is a natural polyphenolic compound. Resveratrol has been demonstrated to exhibit a variety of health-promoting effects including prevention and/or treatment of, inflammation, diabetes, cardiovascular diseases, neurodegeneration, aging and cancer (Truong et al., 2018).Coenzyme Q10 is an endogenous antioxidant which protects cells and tissues from the harmful effects of free radicals on proteins (thus DNA) and lipids (thus membranes) as well as other cellular components (Muta-Takada et al., 2009; Talevi et al., 2013). The knowledge of gamma radiation interacts with antioxidantsis very important for medical sciences.The mass attenuation coefficient, which characterizes the penetration effect of the gamma radiation in the matter, is a very importantcoefficient. μ_ρ is used to calculate various electromagnetic radiation interaction scoefficient ssuch as effective atomic number (Z_{eff}) and electron densities (N_{el}). Z_{eff} and $N_{el}$are significant parameters used to define the gamma penetration of a multi-element material in medical radiation dosimetry.

A great number of researchers reported results of effective atomic number in different materials for biological materials (Jayachandran, 1971; Rao et al., 1985; Yang et al., 1987; Manohara et al., 2008;Manohara et al., 2009). Sayyed et al., (2017) have investigated the radioprotective effects of

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six analgesic and anti-inflammatory drugs for total photon interaction in the energy range of 1 keV–100 MeV using WinXComIn this study, the values of mass attenuation coefficient (μ_ρ) for two different antioxidants namely Resveratrol and Coenzyme Q10 have been calculated using WinXComprogram.This program calculates photon interaction cross-sections and attenuation coefficients for any element, compound or mixture, at energies from 1 keV to 100 GeV (Gerward et al., 2001). Then the other considerable gamma interaction parameters such as Z_{eff} and N_{el} have been calculated in the wide energy range of 1 keV to 100 GeV. The results have been were compared with each other.

MATERIALS AND METHODS

In this study, some parameters that describe gamma interaction with Resveratrol and Coenzyme Q10 were calculated. Firstly, the values of mass attenuation coefficient (μ_ρ, cm^2g^{-1}) for antioxidants were calculated by WinXCom code based on the mixture rule (Gerward et al., 2004):

$$\mu_\rho = \sum_i w_i (\mu_\rho)_i \qquad (1)$$

where w_i and $(\mu_\rho)_i$ are the proportion by weight and mass attenuation coefficient of the ith element, respectively. For a compound the value of w_i is given as Eq(2):

$$w_i = \frac{a_i A_i}{\sum_j a_j A_j} \qquad (2)$$

where A_i is the atomic weight of the ith element and a_i is the number of formula units. The total molecular cross-section (σ_m,barn/molecule) values are calculated using Equations (3-4) (Gowda et al., 2005):

$$\sigma_m = \frac{(\mu_\rho)_{comp.}}{N_A} M \qquad (3)$$

$$M = \sum n_i A_i \qquad (4)$$

where M is the molecular weight, N_A is the Avagadro number and n_i is the number of atoms of the ith element. The values of total atomic cross-sections (σ_a, barn/atom) and electronic cross-sections (σ_{el}, barn/electrons) are calculated as follows (Gowda et al., 2005):

$$\sigma_a = \frac{\sigma_m}{\sum n_i} \qquad (5)$$

$$\sigma_e = \frac{1}{N_A} \sum \frac{A_i}{Z_i} f_i \mu_i \qquad (6)$$

where f_i and Z_i are the fractional abundance and atomic number of constituent element, respectively. The effective atomic number (Z_{eff}) for total photon interaction is given by (Gowda et al., 2005):

$$Z_{eff} = \frac{\sigma_a}{\sigma_e} \qquad (7)$$

And lastly, electron density, N_{el}(the number of electrons per unit mass, electron/g) can be computed using Eq.(8) (Gowda et al., 2005):

$$N_{el} = \frac{(\mu_\rho)_{comp.}}{\sigma_e} \qquad (8)$$

RESULTS

Mass attenuation coefficients

In this work, the mass attenuation coefficients of Resveratrol and Coenzyme Q10 were calculated and the result was presented in Fig.1.

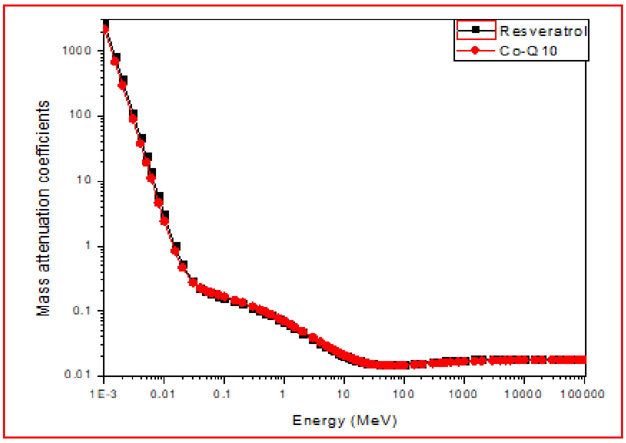

Fig.1. The mass attenuation coefficients of antioxidants versus gamma energy

It has been noticed that in the low energy region where the probability of photoelectric absorption effect is high, the mass attenuation coefficients have the highest value. Because, the cross section of photoelectric effect depends on atomic number as Z^{4-5}. In case of Compton scattering effect (at intermediate energies), it was seen that there is a decrease in the values of mass attenuation coefficients due to the linear dependence between the cross-section of Compton scattering and atomic number Z.

It must be mentioned that the maximum value for mass attenuation coefficient was found for Resveratrol, because average atomic number (<Z>) of Resveratrol is bigger than the CoQ10.

Effective atomic number and electron density

The molecular (σ_m), atomic(σ_a), electronic cross-sections(σ_e), effective atomic numbers(Z_{eff}) and electron densities (N_{el}) of the CoQ10 and Resveratrol were calculated at photon energies from 1 keV to 100 GeV and the variation of (Z_{eff}) and (N_{el}) values versus photon energy is presented in Figs. 2-3, respectively. It is seen from these figures that the (Z_{eff}) and (N_{el}) values depend on the photon energy and the behaviors of Z_{eff} and N_{el} are dominated by three photon interaction processes; photoelectric absorption, Compton scattering and pair production.The maximum values of Z_{eff} and N_{el} for compound were seen in the low energy region and Figs 2-3 show that the values of Z_{eff} and N_{el} of the compound are about constant in 0.1 MeV<E<5 MeV energy range where Compton scattering is the dominant interaction process. In the high energy region, 5MeV<E<100 MeV, the effective atomic number increases with increasing photon energy as pair production becomes the dominant interaction process. Above 100 MeV, pair production is dominating and values of Z_{eff} and N_{el} are again about constant.

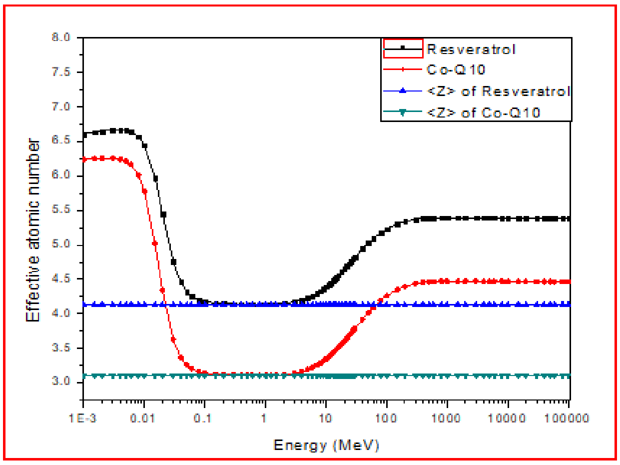

Fig.2. The effective atomic number of antioxidants versus gamma energy

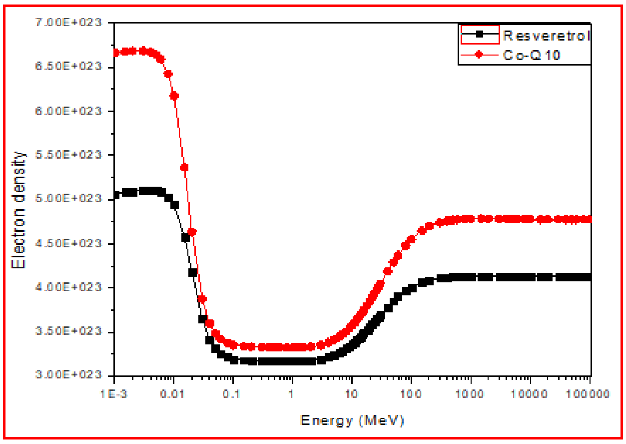

Fig.3. The electron density of antioxidants versus gamma energy

DISCUSSION

The present study has been carried out to examine gammaradiation penetration properties oftwo antioxidants namely Resveratrol and CoQ10. The values of μ_ρ (cm^2g^{-1}) were calculated in the energy range of 1.00E-3– 1.00E+03 MeVusing WinXComcomputer code.Then, the values of the effective atomic number (Z_{eff}) and electron density (N_{el})(the number of electrons per unit mass, electron/g) of antioxidantshave been calculated. The noticed variations of Z_{eff} could be explained by the three well-known photon interactions in the material. While the photoelectric absorbing effect and pair production processes occurring at lower and higher energy zones are dominant effects, on the other hand the Compton scattering process is the dominant one in the intermediate energy zone. In the low energy zone (E< 0.1 MeV) photoelectric absorbing effect which is proportional to Z^{4-5} is the main interaction, so maximum values of Z_{eff} have been found in this zone.In the intermediate energy zone (0.1 MeV < E <5 MeV) the values of the (Z_{eff}) of two antioxidants become nearly independent of incoming gamma energy. This is because of the dominance of Compton scattering process. The cross- section of Compton scattering was proportional to Z, so the minimum value of $Z_{eff}$for antioxidants was found in this energy zone. For the incoming gamma energy beyond 10 MeV, the value of the (Z_{eff}) slowly increases with increasing gamma energy and finally becomes almost constant with further increase of energy. This could be explained on the basis of dominance of pair production in this higher energy region.

The maximum value for Z_{eff} was observed for Resveratrol. This may be due to the reason that Resveratrol contains more oxygen (weight fraction = 0.21029) than CoQ10 (weight fraction = 0.0741).It is clearly seen from Fig. 3 that the variation of (N_{el}) for the antioxidants with gamma energy has demonstrated the same trend of Z_{eff}. Finally, it can be concluded that Resveratrol is more effective to attenuate gamma radiation.

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