JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

GAMMA RAY ABSORPTION- PROTECTION PROPERTIES OF SOME ANTHOCYANINS

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Abstract: This study is done to compute energy absorption geometric progression (G-P) fitting parameters and the corresponding energy absorption buildup factor ($BF_{absor.}$) to get some gamma ray shielding materials. For this purpose, some anthocyanins, such as Hirsutin Chloride (FSV1), Delphinin Chloride (FSV2), Cyanin Chloride (FSV3), malvin Chloride (FSV4), Pelargonin Chloride (FSV5) and Peonin Chloride (FSV6) are taken. All computation is done in the photon energy range 15×10^3 eV to 15×10^6 eV and for penetration depths up to 40 mfp (mean free path). Presently, accurate databases and interpolation program, such as XCOM have made it possible to calculate mass attenuation coefficients, equivalent atomic number, GP-fitting parameters and $BF_{absor.}$, with much improved accuracy and information content over wide ranges of photon energy. These variations are due to the dominance of different photon interaction processes in different energy regions and different chemical compositions of chosen anthocyanins. From the present investigations, it has been concluded that among the selected anthocyanins, FSV3 and FSV6 are the best gamma ray shielding material, due to its higher values of mass attenuation coefficient and least values for $BF_{absor.}$ in the selected energy range.

***Index Terms* - Anthocyanins, Buildup factor, Equivalent atomic number, Mass attenuation coefficient and G-P fitting formula.**

I. INTRODUCTION

In the modern era, due to development in technology there is great exposure of gamma rays all around us like in industries, medical diagnostic centers, nuclear research establishments and nuclear reactors. Due to hazardous nature of the energetic gamma rays for fat soluble vitamins the needed precautions must be taken by shielding the radiations. But in the study of design of the gamma radiations shielding, there is an undesired situation faced by radiation physicists and engineers due to secondary radiations that can occur due to buildup of photons from the collided part of the incident beam. For this reason, it is of importance to determine the buildup factors to make corrections for effective energy deposition in different shielding materials. So a detailed study is need of the day for the safe and acceptable use of gamma radiations, radioactive materials and nuclear energy.

Pomegranate (Punica granatum L.) is one of the oldest known edible fruits and is grown in Afghanistan, China, India, Iran, Japan, Mediterranean countries, Russia and the US. In Iran, pomegranate is eaten as fresh as well as processed for jams, jellies, syrups and pomegranate juice products. This fruit is one of the most important commercial fruits in Iran and its total production in year 2005 was ~670,000 tons.

Anthocyanins are glycosides of polyhydroxy and polymethyl derivatives of flavylium cation. Recent studies demonstrated that polyphenolic flavonoids exhibit a wide range of biological, pharmacological and chemoprotective properties as free radical scavengers preventing oxidation and cancer initiation.

In the recent years, the tendency of consumers to fresh fruit juices has been increased due to their better organoleptic properties than pasteurized ones. Previously, it was generally assumed that pathogenic microorganisms could not survive in high acid foods. However, recent outbreaks of foodborne illnesses from unpasteurized fruit juices have indicated the necessity of pasteurization for all fruit juices. Food irradiation is a process which exposing food to ionizing radiations and it can improve the safety of food. The Pomegranate juice contained considerable anthocyanins and has become a new functional food available for dieting and health. the effects of gamma irradiation (0–10 kGy) on the stability of anthocyanins and inhibition of microbial growth in pomegranate juice during storage were investigated. (1)

Rice belonging to family Poaceae is one of the most important cereal crops widely cultivated in different regions of the world. It is considered as one of the prominent staple foods of more than 50% of the world population and account for significant caloric intake as well as source of protein in many developing Asian countries. Two major sub-species of rice including Oryza sativa L. and O. japonica are primarily consumed in most of the Asian countries including Thailand, Philippines, China, and Japan etc . In Manipur, India the subspecies O. sativa L. Indica is most widely consumed and this state is now being highly recognized for many ethnic pigmented rice cultivars including reddish-orangeish, purple,black rice that have been traditionally known for their functional health benefits. Black rice is mainly produced in South-East Asian countries and recently profound interest has been shown in coloured rice due to its functional health protective properties attributed to the presence of health. Rice is one of the most important cereal crops that serve as staple food of more than 50% of the world population. In recent years great interest has been shown in pigmented & colored rice due to its culinary interest as well as associated health benefits. However, post harvest qualitative and quantitative losses in rice during storage through pests are significant; there fore strategies that are aimed at minimizing losses in the supply chain can have significant socio-economic impact as it may strengthen 'Food Security'. Fumigation is quite often employed but it is being gradually phased out owing to health and environmental concerns. In the current investigation, effect of different doses of gamma radiation (0.25-1.0 kGy) on the quality attributes (gel consistency, water uptake, total anthocyanin content, phenolics, protein and antioxidant activity) of different prominent ethnic pigmented rice cultivars (5 types) from the state of Manipur, India was evaluated. (2).

Anthocyanins comprise of a group of glycosidic pigments responsible for various colors, such as ranthocyanins red, violet and blue, in flowers, fruit (berries), stems, leaves and roots (beet-root) of plants. They are soluble in water and generally and generally occur in the aqueous cell – sap. Anthocyanins are amphoteric in nature; their acid salts are red, alkali salts are blue and free anthocyanins (or natural) are violet. The different shades of the flowers are due to the presence of some anthocyanine in different media (acidic, alkaline or neutral). functions of Anthocyanins: They increase the osmotic pressure of the cell sap. They also play some important role in the process of photosynthesis and respiration.Hirsutin Chloride It is isolated from primula hirsute. On hydrolysis with 10% HCL it gives HC and two molecules of glucose. It contains three hydroxyl groups and three methoxy groups. Delphinin Chloride It is mainly found in delphinium flowers. On hydrolysis it gives delphinidin chloride, two molecules of glucose and two molecules of p-hydroxybenzoic zcid. It was found to contain six hydroxyl groups and no methoxy group. cyanin chloride it was the first anthocyanin to be isolated in crystalline form as cyanin chloride. It is isolated from red rose and blue corn flowers .malvin chloride this anthocyanin has been isolated from the flowers of primula viscosa. On hydrolysis with HCL it gives malvidin chloride together with two molecules of glucose. It was found to contain four hydroxyl and two methoxy groups. Pelargonin chloride It is found in orange red to scarlet flowers, example, scarlet pelargonin and orange-red dahlia.in this forms tetra- acetate, its molecule must contain four hydroxyl groups but no methoxy group.peonin chloride It is found in the flowers of red poppy. On treatment with 10% HCL, it yields peonidin chloride and two molecules of glucose. It was found to contain four hydroxy and one methoxy groups. (3)

Buildup factor in which energy response function is that of absorption in the material and the quantity of interest is the absorbed or deposited energy in the shielding medium is known as BF_{absor} . Detailed review on applications of buildup factor and various calculations have been given by Harima [4]. The ANSI/ANS-6.4.3-1991 [5] standard reference data gives buildup factor data for various elements.

Recently, different researchers; Kurudirek and Topcuoglu (6), Kurudirek and Ozdemir (7), Sidhu et al. (8), Lucia et al. [9], Lee et al. [10], Manohara et al. (11) Mollah A.S. (12) Mahmoud T.A. et al. (13) Ghamdi H.A. et al. (14) Chaitali V.M. et al. (15) have studied the mass attenuation coefficients and $BF_{absor.}$.

In the present analysis the Molecular formula's of chosen anthocyanins are as shown in Table1 are taken from (3).

Table: 1- Molecular formula's of chosen anthocyanins [3]

Sr. No.	Name of anthocyanins	Molecular formula's
1	Hirsutin Chloride (FSV1)	$C_{18}H_{17}O_7Cl$
2	Delphinin Chloride (FSV2)	$C_{15}H_{11}O_7Cl$
3	Cyanin Chloride (FSV3)	$C_{27}H_{31}O_{16}Cl$
4	Malvin Chloride (FSV4)	$C_{17}H_{15}O_7Cl$
5	Pelargonin Chloride (FSV5)	$C_{27}H_{31}O_{15}Cl$
6	Peonin Chloride (FSV6)	$C_{28}H_{33}O_{16}Cl$

II. THEORY

2.1 Calculation of Mass Attenuation Coefficient

The absorption coefficient of anthocyanins is dependent on its content and gamma - ray energy. This work describes a study of content dependence on measurements of attenuation of gamma - radiation at gamma-ray energy of vitamins.

The attenuation of gamma rays expressed as: $I = Io \exp(-\mu x)$ (1)

Where Io is the number of particles of radiation counted during a certain time duration without any absorber, I is the number counted during the same time with a thickness x of absorber between the source of radiation and the detector, and μ is the linear absorption coefficient.

This equation may be cast into the linear form, $\log I = \log Io - \mu x$

i.e. $\mu x = \log (Io/ I)$

$$\mu = (1/x) \log (Io/I) \qquad (2)$$

The mass absorption coefficient of anthocyanins, μ_m defined as, $\mu_m = \mu/\rho$ (3)

Where, μ_m is the mass attenuation coefficient and ρ is the density of anthocyanins. The unit of μ is cm^{-1} and that of μ_m is cm^2/gm.

2.2 Buildup Factor

To compute the value of the buildup factors, the G-P fitting function parameters were obtained by the method of interpolation from the equivalent atomic number (Z_{eq}).

2.2.1 Computation of equivalent atomic number

Firstly, the values of Compton partial attenuation coefficient (μ_{comp}) and total attenuation coefficients (μ_{tot}) in cm^2/g were obtained for elements from Z = 1 to 25 and chosen vitamins in the energy of 0.015 to 15.0 MeV, using the state-of-the-art and convenient computer program XCOM (16). Further, by using a simple computer program, the ratio R (μ_{comp}/μ_{tot}) was obtained for selected samples. Then the value of equivalent atomic number (Z_{eq}) for these samples was calculated by matching the ratio R ($\mu_{cmop}/\mu_{tot.}$) of particular sample at a given energy with corresponding ratios of elements at the same energy. For the case the ratio lies in between the two ratios of known elements. The value of Z_{eq} was interpolated by using the following formula of interpolation (4) given in the following equation.

$$Z_{eq} = \frac{Z_1(\log R_2 - \log R) + Z_2(\log R - \log R_1)}{\log R_2 - \log R_1} \quad (4)$$

WhereZ$_1$ and Z_2 are the atomic numbers of elements corresponding to the ($\mu_{cmop}/\mu_{tot.}$) ratios, R_1 and R_2, respectively; and R is the ratio for the selected vitamin at a particular energy which lies between ratios R_1 and R_2.

2.2.2 Computation of G.P. fitting parameters

American National Standard has provided the exposure G.P. fitting parameters of 23 elements, one compound(water) and two mixtures (air and concrete) in the energy range of 15 keV -15.0 MeV and upto a penetration depth of 40 mfp (ANSI/ANS-6.4.3 1991) [5].

Using the interpolation formula, five G.P. fitting parameters (b, c, a, X_k and d) for selected vitamin were computed at the different incident photon energies using equivalent atomic number (Z_{eq}), in the chosen energy range 15 keV -15.0 MeV up to penetration depth of 40 mfp. The formula used for the purpose of interpolation (17) is as follows:

$$C = \frac{C_1\left(\log Z_2 - \log Z_{eq}\right) + C_2\left(\log Z_{eq} - \log Z_1\right)}{\log Z_2 - \log Z_1} \quad (5)$$

Here C_1 and C_2 are the values of G.P. fitting parameters corresponding to the atomic numbers Z_1 and Z_2 respectively at a fixed energy, whereas Z is the equivalent atomic number of the chosen vitamin at the same energy. Z_1 and Z_2 are the elemental atomic numbers between which the equivalent atomic number Z of the chosen vitamins lies.

2.2.3 Computation of $BF_{absor.}$

Further, the computed G-P fitting function parameters (b, c, a, X_k and d) were then used to compute the $BF_{absor.}$for the selected samples at some standard incident photon energies in the range of 0.015 to 15.0 MeV and up to a penetration depth of 40 mean free path, with the help of G-P fitting formula (18, 19) as given by the following eqs.

$$B(E,x) = 1 + \frac{(b-1)(K^x - 1)}{K - 1} \quad \text{for} K \neq 1 \quad (6)$$

$$B(E,x) = 1 + (b-1)x \quad \text{for} \quad K=1 \quad (7)$$

Where

$$K(E,x) = cx^a + d\,\frac{\tanh(x/X_k - 2) - \tanh(-2)}{1 - \tanh(-2)} \quad \text{for} \quad x \leq 40mfp \quad (8)$$

where x is source to detector distance in the medium (mfp). The parameter K (E, x) represents photon dose multiplication factor.

III. Result And Discussion

3.1 Dependence of shielding properties on mass attenuation coefficient (μ_m)

In fig. 1, μ_m values of anthocyanins of FSV3 for total and partial interactions have been plotted against the incident photon energy. In the present work, the variations of μ_m with incident photon energy for all interactions are discussed in the following paragraphs. μ_m for the total photon interaction processes is initially high and decreases sharply with increase in incident photon energy up to 55 keV. Above 55 keV the rate of decrease of μ_m(total) with incident photon energy is less and above 10 MeV μ_m(total) increases slightly with further increase in incident photon energy. This behavior is due to dominance of different interaction processes in different incident photon energies i.e. below 55 keV photo electric process is dominant, from 55 keV to 10 MeV Compton scattering and above 10 MeV pair-production process is dominant. It is observed that the value of μ_m(photo) decreases rapidly with increase in incident photon energy for all the selected materials. It may due to reason that photo-electric cross-section varies inversely with incident photon energy as $E^{3.5}$.

It is observed that the values of μ_m(coh.) decrease sharply with increase in incident photon energy for chosen sample FSV3. This decrease in values with increase in incident photon energy may be due to the reason that μ_m(coh.) is inversely proportional to incident photon energy E.

The variation of μ_m for pair production in nuclear fields is shown in fig respectively. In both cases, the values of μ_m(pp) increases slightly with increase in incident photon energy up to 100 MeV but beyond this incident energy the values of μ_m(pp) remains almost constant. It may be due μ_m(pp) is directly proportional to logE.

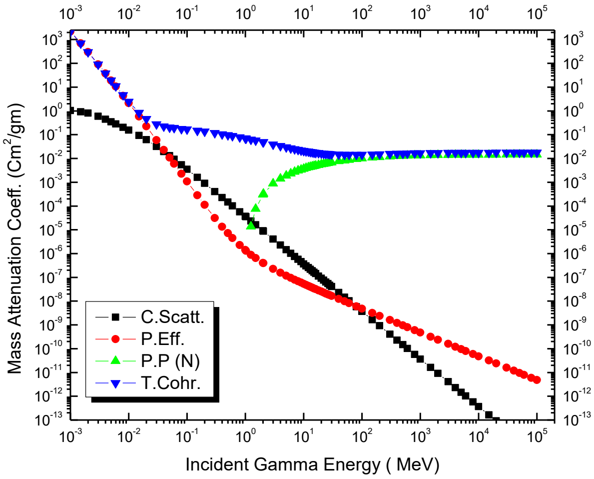

Fig.1: Variation of Mass attenuation coefficients (MAC) (μ_m) of anthocyanins cyanin chloride (FSV3) with incident photon energy (MeV) for different photon interaction processes.

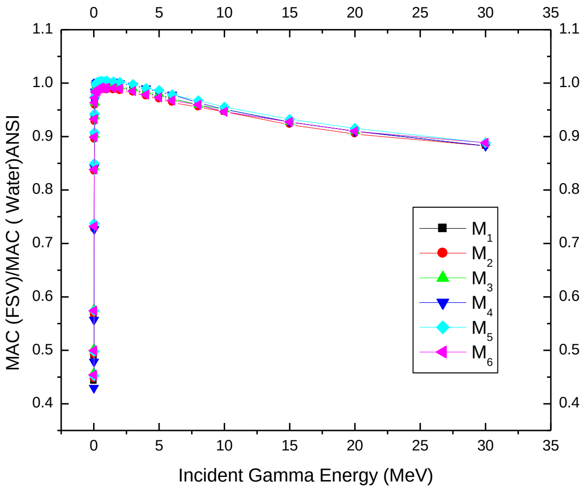

Fig. 2 Variation of ratio ($MAC_{(FSV)}/MAC_{(Water)\ ANSI}$) (M) with incident photon energy

Fig. 2 shows the ratio of $MAC_{(FSV)}/MAC_{(Water)\ ANSI}$ for the photon energy range 0.015 - 0.15 MeV for all samples. It increases sharply from 0.42 to 1 which mean in this energy range μ_m of FSV is less effective than μ_m of water given by ANSI. But in the energy region 0.15 – 15 MeV all ratios from M_1 to M_6 show approximately one (Unity) value which reveals that in this energy range the values of μ_m of FSV is similar to μ_m of water in ANSI.

Also, it is concluded that in the high energy region M_6 acquires higher values than other samples and hence Peonin chloride (FSV6) shows more shielding properties than others chosen samples.

3.2 BF_{absor} of Shielding Materials as a Function of Penetration Depth

The variation of generated $BF_{absor.}$ have been studied with penetration depth for all the selected anthocyanins for some selected incident photon energies 0.015, 0.15, 1.5 and 15 MeV up to a penetration depth of 40 mfp shown in Figs. 3 to 6 respectively.

At low and higher incident photon energies, the increase in value of $BF_{absor.}$ is at lesser rate as compared to the intermediate energy region.

It is observed that in fig. 3, the variation of $BF_{absor.}$ of selected anthocyanins is low at low incident photon energy (15 keV), buildup factor lies within the range of 1.461-5.338, even for the large penetration depth of 40 mfp. It may be due to the reason that in this energy region, photoelectric process is the dominant one and the small variation is due to the coherent scattering process.

It is shown in figs.4-6, further with the increase in incident photon energy, the increasing rate of the $BF_{absor.}$ with the penetration depth first becomes more rapid at the certain incident photon energy range of 150 keV, where the Compton scattering process is most dominant and afterward the increasing trend of buildup factor becomes slower and slower for higher energies up to 15 MeV is due to dominance of pair-production process.

The slower increasing trend in the lower and higher incident photon energy region was obvious as the dominant process in these incident photon energy regions were photoelectric effect and pair-production respectively, which results gamma photons are completely absorbed in the interacting medium., whereas in the intermediate energy region the dominant process is the Compton scattering, which results energy of mostly gamma photons is degrade. Among the selected anthocyanins, FSV3 with highest Z_{eq} shows the minimum value for the $BF_{absor..}$ in lower energy region upto 1.5 MeV whereas maximum values are observed at energy 15 MeV. Whereas in case of FSV4 with lowest Z_{eq} exact reverse trend can be seen.

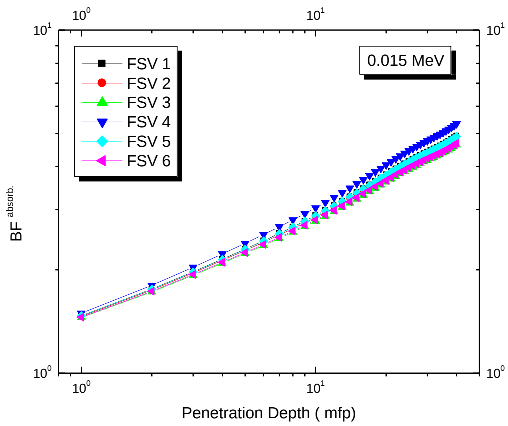

Fig. 3. Variation of generated $BF_{absor.}$ for chosen anthocyanins for selected incident photon energies 0.015 MeV up to a penetration depths of 40 mfp

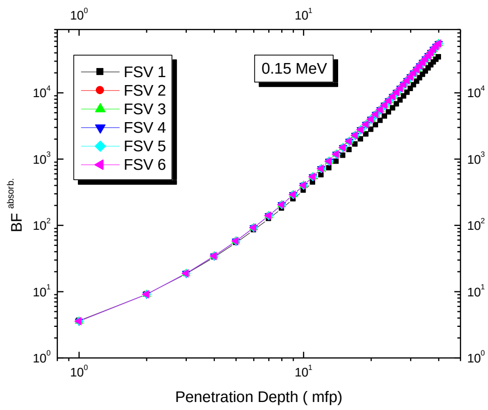

Fig. 4 . Variation of generated $BF_{absor.}$ for chosen anthocyanins for selected incident photon energies 0.15 MeV up to a penetration depths of 40 mfp

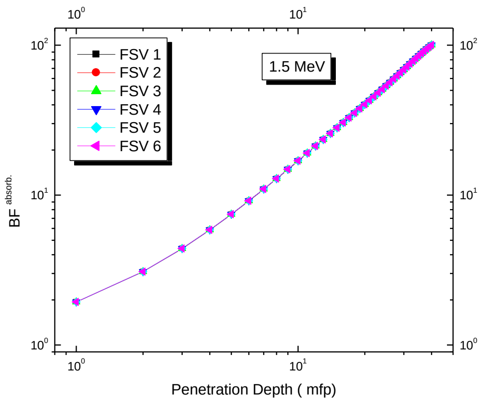

Fig. 5. Variation of generated $BF_{absor.}$ for chosen anthocyanins for selected incident photon energies 1.5 MeV up to a penetration depths of 40 mfp

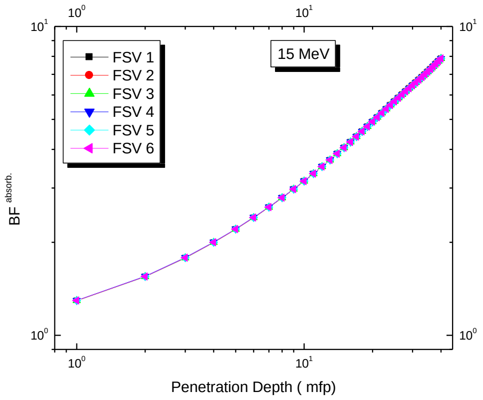

Fig. 6. Variation of generated $BF_{absor.}$ for chosen anthocyanins for selected incident photon energies 15 MeV up to a penetration depths of 40 mfp

IV. Conclusion

In the present study it is concluded that among the selected samples, FSV3 followed by FSV6 acts as best gamma ray shielding material, due to its higher values for mass attenuation coefficient and least values for $BF_{absor.}$ in the selected energy range.

4.1 The G.P. fitting parameters and $BF_{absor.}$ for selected six anthocyanins (25 energies and 40 penetration depths) may be useful in the future study of variety of shielding process.

4.2 The values of $BF_{absor.}$ remain low for selected penetration depths at 0.015 MeV, but at energies i.e. 150 KeV $BF_{absor.}$values are increases with higher rate with increase in penetration depth. How ever at higher energies $BF_{absor.}$ values are shows increasing trend becomes slower and slower.

4.3 It is observed that μ_m(total) of each selected material is initially high and decreases sharply with increase in incident photon energy up to 55 keV. In the incident photon energy region above 55 keV to 10 MeV the μ_m(total) of selected materials have almost same. Above 10 MeV, there is again slight variation in μ_m(total) with incident photon energy because in this energy region pair-production process dominance.

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