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The Use of Green Apple and Beetroot as Natural Radio-Protectors Against Health Effects of Ionizing Radiation

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ABSTRACT

Ionizing radiation is used to diagnose and treat a wide range of cancers and diseases. Normal cells exposed to radiation may have both acute and chronic biological adverse effects. blood components are one of most sensitive organs subjected to these adverse effects of ionizing radiation. Natural compounds such as products from fruits and plants can be used after exposure to ionizing radiation during diagnostic or therapeutic purposes to reduce the possible adverse effects. This study aims at evaluating the antioxidant protective role of beetroot and apple to reduce impact of ionizing radiation on the blood components. Sixty adult white male rats were evenly divided into four experimental groups, Group 1 (n= 15) was used as a control group. Groups 2, 3 and 4 (n=15 each) were injected intravenously with radioactive material Tc-^{99m} 130 ± 5 Mega Becquerel (MBq) (5 ± 0.5 Milli Curry (mCi)) as a source of ionizing radiation (gamma rays). Groups 2 and 4 were fed with apple fruit and beet seeds in addition to a small amount of commercial food. Rats in G3 were fed with commercial food pellets only and received the same volume of water. Rats in groups G1, G2 and G3 were sacrificed after7 days while those of G4 were sacrificed after 30 days. Osmotic fragility of RBCs and hematological parameters were investigated for each group. The structure characteristics of the blood cells for all groups were studied by recording the UV -Vis spectra. The study revealed statistically significant changes regarding RBCs indices along with increased osmotic fragility among rats of group 3 compared to those in groups 1, 2 and 4. The U.V. spectrum revealed a partial irregularity in the RBCs. The present study pointed out to the protective role of natural products namely, beetroots and green apple extracts, against the adverse impact of ionizing radiation on blood indices

INTRODUCTION

For more than a century now, ionizing radiation (IR) has been used for many diagnostic and therapeutic medical purposes. The intense energy carried by IR can affect atoms of the living organisms and thereby damage their genetic material and other vital functions of the cell[1]. Therefore, exposure to high levels of IR can cause acute as well as chronic long term health effects, while long term exposure to low dose of IR contributes to the overall health risk[2].

There is no chance of defense from ionizing radiation when an organism, as a unit, practically consumes radiated energy. No medicine has been invented in previous investigations that could be successfully implemented in the treatment of radiation diseases. Therefore, treatment of acute radiation syndrome is mainly symptomatic [2,3]. However, many researchers aimed to search for an effective method of radiation protection that would effectively prevent the emergence of radiation syndrome and protect cells and tissues from free radicals due to the interaction between radiation energy and matter [4,5].

In this context, fruit, has emerged in clinical use as a radio-protector to reduce radiation-induced injuries to normal tissues. Radio-protectors are agents administered prior to or at the time of exposure to radiation to avoid and minimize radiation damage to normal tissues [6]. It has been estimated that there are about 50,000 radio-protective chemicals with different grades of effectiveness [7,8].

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Apples and apple juice are an integral part of the human diet and are consumed by most of the population including children. Apple is a rich source of polyphenolic compounds of various structural classes, which possess a broad spectrum of potential cancer chemopreventive activities [9].

Red beetroot is a high-carbohydrate, high-fat, high-micronutrient, and high-bioactive constituent vegetable. In addition, it is rich in polyphenols [10].

Polyphenols are a chemical structural category distinguished by the presence of many phenol units. The radio-protective activity of phenolhydroxyl groups can be due to their ability to donate protons to reactive oxygen species (ROS), as well as their chemopreventive properties. Ferulic acid, casein acid, p-coumaric acid, syringic acid, and vanillic acid have also been purified from beetroots [11]

Therefore, this work aimed to study the radio-protective effect of apple and beetroot against health effects of ionizing radiation

SUBJECTS AND METHODS

Place and duration of study

The study was carried out in the Hot Lab of gamma camera in the critical care department, faculty of medicine, Cairo University during the period from November 2020 to April 2021.

Experimental animals

Sixty Adult White male rats were used in this experiment. The rats aged 6-7 weeks old at the start of the study and were similar in size with an average body weight of 200-250 gm. The rats were handled using standard methods and the approval for the study was obtained from the animal care ethics committee. All rats were subjected to observation to ensure acclimatization with laboratory conditions. The rats were kept in metal cages under normal conditions throughout the experiment. A constant airflow and illumination were provided during all the experimental periods. The experimental animals were randomly divided into four experimental groups, *Group 1*(G1) that was used as a reference and control. Group 2(G2), Group 3 (G3) and Group 4(G4) (45 rats) were injected intravenously with radioactive material Tc-^{99m}130 ± 5 MBq (5 ± 0.5 mCi) as a source of ionizing radiation (gamma rays), as it is well -known that Technetium99^{m} is widely used in medicine.

Rats in group 2 and group 4 were fed apple and beetroot in addition to a small amount of commercial food. Rats in G1, G3 were fed commercial food pellets only. The four groups received equal amounts of water. Rats in G1, G2, G3 were sacrificed after 7 days, while rats in G4 were sacrificed after 30 days.

METHODS

Every group in the study was subjected to

A-Blood collection, complete blood counting (CBC)

Auto Hematology Analyzer (Hematology analyzer kt-60(Genrui)) was used to obtain hematological parameters for all groups, including complete blood count for evaluating blood components such as platelet counts; platelets indices , (mean platelet volume (MPV) , platelet distribution width (PDW) and platelet larger cell ratio and(P_LCR),) white blood cells counts; WBCs classifications (Lymphocytes, Neutrophils, Monocytes, Basophils, and Eosinophil) and red blood cells (RBCs) count; RBCs indices (Mean corpuscular volume (MCV), Hematocrit (HCT) , mean corpuscular hemoglobin (MCH) MCH and mean corpuscular hemoglobin concentration (MCHC)) and manually examined blood film to study the changes in the shape of RBCs.

B. Osmotic fragility test

The osmotic fragility (OF) test was used to determine the magnitude of red blood cells hemolysis (RBCH) caused by osmotic stress.

Red blood cells can float if suspended in an isotonic solution (85 percent sodium chloride (NaCl). The fragility of red blood cells is said to increase or decrease when the rate of hemolysis is increased or decreased. Different amounts of sodium chloride were applied to whole blood, respectively. In the osmotic fragility test, whole blood added to varying concentrations of buffered sodium chloride solution were allowed to incubate at room temperature. The amount of hemolysis in each saline concentration was then measured using a spectrophotometer to read the supernatants. Blood samples from injected rats were analyzed at the same time as normal control blood. Parapet procedures were carried out using the Parapet process [12] as follows:

1. The dilutions of buffered sodium chloride were prepared and placed in the appropriate test tubes.
2. The preceding dilutions were mixed well-using Para film to cover each tube while mixing.
3. Five milliliters of each dilution were transferred to the second set of test tubes and were labeled from 1 to 14, this set of dilutions were used for the normal control blood and other blood groups
4. Fifty µL of the EDTA blood were added to each of the 14 test tubes.
5. Each test tube was mixed immediately by gentle inversion.

6. The test tubes were left standing at room temperature for 30 minutes.
7. The test tube was remixed gently and centrifuged at 3000 p.m. for 5 minutes.
8. The percentage of hemolysis was calculated for each supernatant as follows:
9. The percentage of Hemolysis = (Optical Density (O. D) of supernatant / O.D.of supernatant No.14) × 100
10. The percentage of hemolysis (H %) was then plotted as a function of the percentage of sodium chloride concentration (NaCl %).

C. Ultraviolet (UV)Visible Spectro-photometric measurements

Ultraviolet-visible spectroscopy was used to study the structural characteristics of the blood from all 4 groups. Blood diluted with normal saline was placed in Kartell disposable polystyrene cuvette of 10 mm path length. The cuvette was placed in Shimadzu UV – Vis. Spectrometer (Japan). The UV-Vis spectrophotometer was used for analysis of the spectra scanned in the region between 190 nm to1000 nm. The blood showed a characteristic absorption spectrum in the UV- visible range, which depended on the valence and spin state of the heme and was modifiable by changes in ligand bonds between the heme group and the globin part[13].

Statistical Analysis

The mean values of hematological parameters and hemolysis rate of all groups were expressed as mean ± SD. ANOVA test was used to compare between the various groups studied. P value ≤ 0.05 was defined as statistically significant. Statistical analyses were performed with statistical software (IBM SPSS Statistics Version 21).

RESULTS

A total of 60 rats were used in the study, which had been divided into four groups of 15 rats each. Evaluation of mean ±SD of red blood cells and their indices using ANOVA test, revealed significant statistical differences between study groups (P<0.05) (Table 1). However, multiple comparisons between groups using post hoc test showed a higher significant red blood cell count among rats in control G1 compared to other groups. On the other hand, G4 which received fruit radio-protectors for 1 month showed a significantly higher RBCs count compared to other 2 IR exposed groups (G2, 3) (P= 0.014, 0.000 respectively) as shown in Table (2). Although there was a higher count of RBCs in rats of G2 than those of G3, the difference was not statistically significant (P>0.05). This difference in RBCs count among the study groups was not reflected on the red blood cell indices namely, Hb, HCT, MCH, though higher in the control group. As regards MCV, it was significantly higher in the control group (86.3 ± 2.2) compared to 77.4 ± 3.1, 78.3 ± 3.9, 76.4 ± 5.9 in G 2,3,4 respectively (un-tabulated data). Differences between the mean ±SD of red blood cells were presented in Fig (1).

White blood cells are very sensitive to IR exposure. ANOVA of mean± SD of WBCs among the study groups revealed significant statistical differences (P<0.05) (Table, 3). Multiple comparisons showed no significant difference between rats in group 4 compared to their controls indicating a lower impact of IR on WBCs among rats that were fed fruit for a whole month (Table. 3). Rats in G2, 3 had significantly lower white blood counts when compared to the control group and G2. A similar pattern was detected as regards the white blood cell differential count namely, neutrophils and lymphocytes (Table 2). White blood cell count changes were presented in Fig (2).

The obtained results showed that the radiation was less likely to have a significant effect on platelets count and platelets indices as shown in Figure 3 and Table (3).

The results of blood film revealed changes in the shape of red blood cells membranes as shown in Figures (4, 5). The results of the blood film of G2 (Figure 4) indicated a normal form and shape of the RBCs with few cells showing irregularity in cell membranes (marked by an arrow). It was found that the RBCs of G3 were affected by radiation (Figure 5) where the irregularity in the cell membrane of G3 showed the results of the blood film for animals in G3 showing irregularity in several cell membranes

Table (1): ANOVA and multiple comparison (using post-hoc test) of mean± SD of RBCs and their indices among the 4 study groups (each, N=15)

Groups	**Mean** ±SD	**multiple comparison (post-hoc test)**		
		(I) Groups	(J) Groups	P
1	5.5± 0.6	1.0	2.0	0.000
			3.0	0.000
			4.0	0.006
2	4.2±0.6	2.0	1.0	0.000
			3.00	N.S.
			4.00	0.014
3	4.0± 0.	3.0	1.0	0.000
			2.0	N.S.
			3.0	0.000
4	4.8±0.3	4.0	1.0	0.006
			2.0	0.014
			3.0	0.000

P is considered significant inf (P≤0.

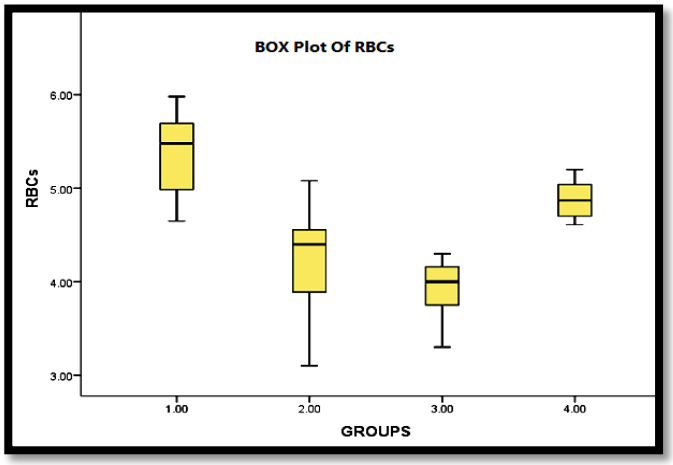

Fig. (1): The Box plot results of the differences between the mean ±SD of red blood cells among the 4 study groups (each, N=15)

Table (2): ANOVA and multiple comparison (using post-hoc test) of mean± SD of WBCs and their indices among the 4 study groups (each, N=15)

ANOVA of WBCs		Multiple Comparisons Post Hoc Test		
Groups	Mean ±SD			
		(I) Groups	(J) Groups	P
1	6.7± 0.7	1.00	2.0	0.007
			3.0	0.000
			4.0	N.S.
2	5.5± 0.9	2.00	1.0	0.007
			3.0	0.000
			4.0	0.035
3	3.9± 0.8	3.00	1	0.000
			2.0	0.000
			4.0	0.000
4	6.5± 0.9	4.00	1.0	N.S.
			2.0	0.035
			3.0	0.000

P is considered significant if (P≤0.05)

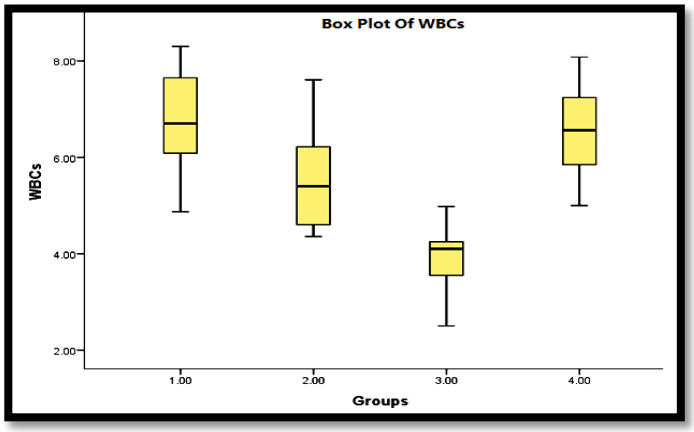

Fig. (2): The Box plot results of the difference between the mean ±SD of WBCs among the 4 study groups (each, N=15)

Table (3): ANOVA for platelets and their indices among the 4 study groups (each, N=15)

ANOVA of Platelets(ns)		Multiple Comparisons Post Hoc Test		
Groups	Mean ±SD			
		(I) Groups	(J) Groups	P
1	284.0±49.8	1.00	2.0	0.237(N.S.)
			3.0	0.408(N.S.)
			4.0	0.909(N.S.)
2	246.3±62.8	2.00	1.0	0.237(N.S.)
			3.0	0.986(N.S.)
			4.0	0.605(N.S.)
3	253.3±50.2	3.00	1.0	0.408(N.S.)
			2.0	0.986(N.S.)
			4.0	0.605(N.S.)
4	270.8±270.8	4.00	1.0	0.909(N.S.)
			2.0	0.605(N.S.)
			3.0	0.605(N.S.)

P is considered significant if (P≤0.05)

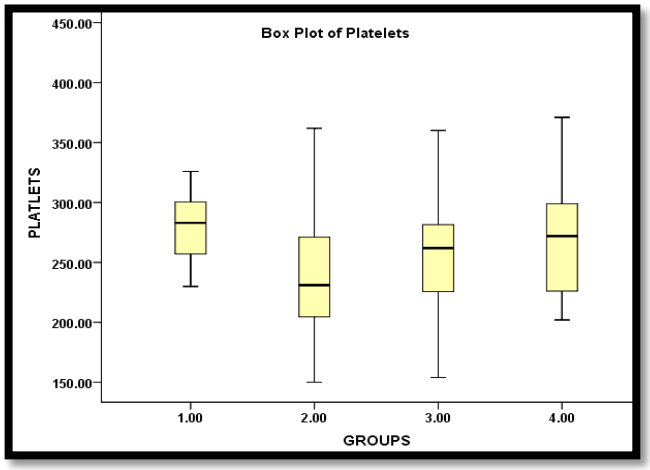

Fig. (3): The Box plot results of the difference between the mean ±SD of the platelets among the 4 study groups (each, N=15)

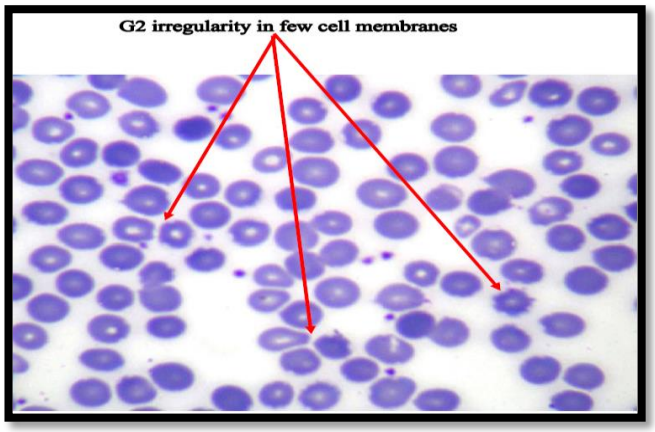

Fig. (4): The results of the blood film for animals in G2 showing irregularity in a few cell membranes

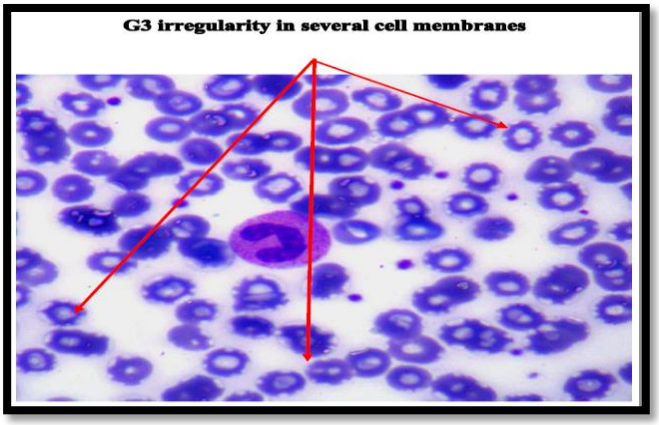

Fig. (5): The results of the blood film for animals in G3 showing irregularity in several cell membranes

The osmotic fragility (OF) test results showed a significant difference when comparing the mean± SD of G 1 hemolysis rate (72% ±3) to that of G3 hemolysis rate (82% ± 5) (P<0.05).

The mean hemolysis rate of G4 that received natural apple and beetroot extraction revealed a lower hemolysis rate compared to that of G2 (77 % ± 4 where P was N.S.). In addition, Group 4 had a lower hemolysis rate (74% ± 4, where P<0.05) compared to G3 (82% ± 5). There was a significant difference between G1 (control) and G3 compared to other groups.

The osmotic fragility curves, obtained from the study are presented in Figures (6, 7), respectively. The Figures present the osmotic fragility curve versus different NaCl concentrations. There is a significant rightward shift of the osmotic fragility curve of G3 and G2 when compared to G1.

When compared to the control group, the results of the fourth group (G4) which were sacrificed after thirty days of feeding with apples and beetroots showed almost a normal rate of hemolysis (P> 0.05). A statistically significant higher fragility was found among rats in G3 as compared to those in G2 & 4.

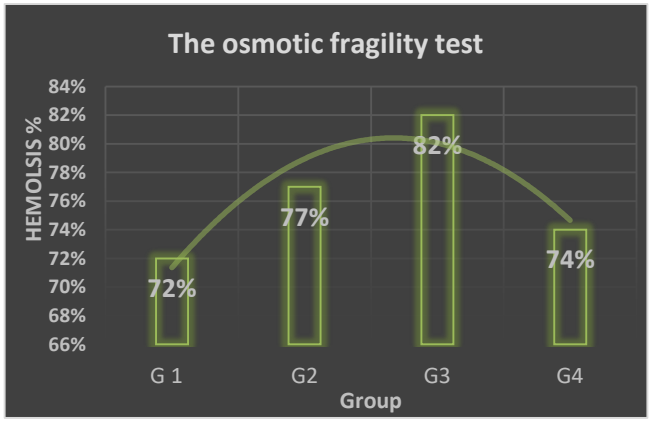

Fig. (6): Comparison between the osmotic fragility mean for G1 and G2, G3 and G4 after 7 and 30 days

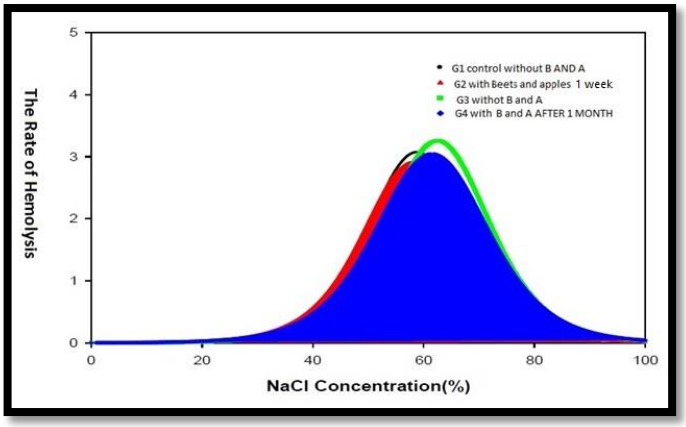

Fig. (7): Gaussian curves (the rate of hemolysis versus NaCl concentration) in in all groups

Results of UV-Vis Spectrum of blood

Ultraviolet-visible (UV-Vis) spectroscopy is a quantitative analysis tool that can be applied as a reliable biosensor for detecting the spectral differences in the blood samples. Also, UV-Vis's spectroscopy is inexpensive and reagent less techniques that require no sample preparation prior to analysis. The UV-Vis measurements may be a quick and easy way to provide insights into the change between various groups.

Figure (8) shows the spectrum of normal blood groups (G1).

The spectrum of whole blood specified by indicated peaks are:

1) Proteins with chromophore amino acids and other small chromophore molecules (280 nm).
2) The interaction between iron and the proximal histidine exhibits transition at 340 nm (globin-heme interaction (340 nm).
3) The intense soret band at (420 nm).
4) Oxyhemoglobin b -band (540 nm); and
5) Oxyhemoglobin a -band (, 575 nm).

According to Figures (8,9), the UV spectra of all groups G1, G2, G3, and G4 show the same number of characteristic absorption bands.

The UV spectrum for groups G2, G3, and G4, was compared to the control group (G1). G3 that was injected with the radioactive material and was fed with apples or beetroots, revealed the lowest UV intensity when compared to G1. The second group, which was sacrificed a week after the radioactive substance was injected and fed beetroots and apples, showed a lower level of UV intensity than that of G3 when compared to G1 and the results were not statistically significant .

Finally, the results of the G4 of rats, which were sacrificed after thirty days of eating apples and beetroots, showed similar values regarding the degree of intensity as G1 absorption, and the values were very close, almost normal, compared to the G1 of rats.

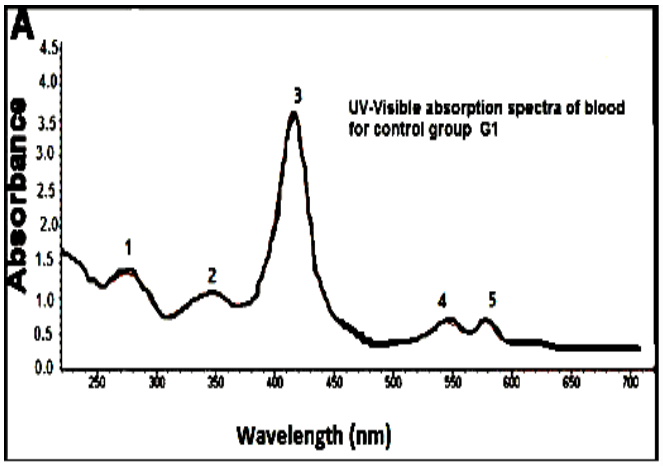

Fig. (6): UV-Visible absorption spectra of blood

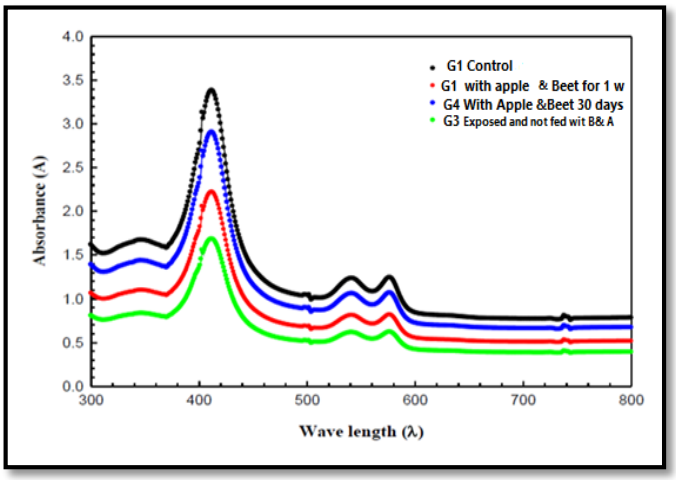

Fig. (7): UV spectrum of the blood for all groups G1, G2, G3 and G4

DISCUSSION

The most important way to assess the health status of the experimental animals is through blood parameters[14] . The goal behind the current investigation is to study the radio-protective role of natural materials namely, apples and beetroot, besides the possibility of using them as natural remedies for workers in radiology and nuclear medicine centers to protect them from the biological hazards of ionizing radiation.

Blood is a vital circulating tissue composed of cells suspended in a fluid (plasma) with the main purpose of maintaining homeostasis, can be inflicted with a decrease in circulating blood cell counts after exposure to ionizing radiation which is harmful to the individual's health. [15]

The aim of the study is to test the use of natural product extracts (apple - beetroot) against the biological effects of ionizing radiation.

The results of the current work revealed a significant depression in erythrocyte counts, and erythrocyte indices for G3 when compared to other studied groups. This decrease would lead to serious complications on the long run. (Table 2).

Some of the results from previous studies agreed with the current study and illustrated the effect of ionizing radiation on red blood cells. Their results showed that ionizing radiation can affect RBC structure and permeability. In rats, gamma radiation has a major impact on RBC count [16]. Because mature RBCs, lack nuclei, they are less sensitive to radiation damage [17،18]. Another study agreed with the current results, and they showed that RBCs cellular membrane suffered pronounced injuries after injection with Tc^{99m} that were detected from solubilization, osmotic fragility and blood film studies. The induced injuries in the RBCs proved to be dose dependent from Tc^{99m}. [19]

When the effect of ionizing radiation was studied on white blood cells, G3 had a depression in total counts of the white blood cells which could result in weakness of the immune system. The results revealed a significant decrease in the WBCs counts for G3 when compared with those of G1. These drops are seldom enough to cause clinical problems. Moreover, a significant decline in lymphocyte cell counts was noted in G3which would leave a victim more susceptible to infection. This is referred to as a mild radiation sickness.

For G2 and G4 the results showed counts similar to the control count as regards the value of the total WBCs and segmented neutrophils and lymphocytes. (Table 3).

Previous studies showed agreement with the current results after blood exposure to radiation, lymphocyte, DNA damage was observed, [20]. Injecting radioisotopes into animals causes hematopoietic syndrome, which leads to death due to effects on blood cells [18].

WBCs are also the most responsive blood cells to gamma radiation irradiation where WBCs are reduced in a dose-dependent method during radiation exposure, which is considered a health concern. After whole-body radiation exposure, rats have shown a dose-dependent decrease in WBC counts [21].

Results from the current work showed that radiation is less likely to have an insignificant effect on platelets count and platelets indices for different groups as shown in Table (4). A previous research found that radiation had no impact on the number of platelets, their

aggregation, or the expression of the platelets factor [22]. Platelets are unaffected by heavy radiation doses[17]. These results are in line with those of El-Dessouky et al. [23], who concluded that gamma radiation had no effect on platelets count.

The osmotic fragility test is used to test and analyze the physical properties of red blood cells after exposure to radiation. The shape of the RBCs is influenced by the body, surface frame, anatomy, and functional state of the red blood cell membrane, and it is the most important factor in the fragility test.

The mean values of the osmotic fragility test for the four different groups were used as a marker for variations in the mechanical properties of RBCs. The percentages of hemolyzed cells were planned as a function of the percentage of NaCl concentration in the results of osmotic fragility. The studied group G3 which was injected with the radioactive material and did not receive apples or beetroots had a high osmotic fragility of RBCs, and faster hemolysis. Other researchers [19, 20and 21] found similar results. This occurred due to the fact that in the vivo system, ionizing radiation creates a free radical atmosphere. Because of the abundance of these free radicals, they interact with fats and proteins through lipid peroxidation, causing hydrolysis of phospholipid heads and homologous linking of fats, as well as the formation of a disulfide bridge, which damages amino acid residues in membrane proteins and causes cross- linking of lipoprotein, and ultimately affects the permeability of the membrane. This reduces membrane deformation and increases membrane rigidity [24]. The membrane's components and mechanical properties change, resulting in structural and morphological changes mediated by radiation to the cytoskeleton's protein. It was also discovered that the loss of permeability and elasticity of the membrane leads to the damaging effects seen in the osmotic fragility curves in Figures (6,7) and the presence of abnormal cells membrane (Figures 4,5).

Figures (6,7) explain the osmotic fragility curve, which can provide useful information about changes in RBC membrane elasticity and ionic absorbency, both of which are essential in RBC metabolic activities. After being exposed to radiation, the osmotic fragility shifts, indicating changes in membrane permeability to water molecules. Estimating osmotic fragility is important because it provides information about the overall state of red cell metabolism as well as the strength of the membrane. The current study discovered a significant improvement in osmotic fragility in the rats in G2, G4 when feeding with apple and beetroot. These results were in agreement to other similar studies [25,26].

UV-visible spectroscopy was used in the present research because it is a quantitative analysis method that can be used as a reliable biosensor to identify spectral variations in blood samples **[**27**].** The obtained results found that G3 group that was injected with the radioactive substance and was not fed on apples and beetroots showed a severe decrease in the intensity of absorption compared to G1 and the difference was significant ($P \leq 0.05$). This was due to exposure to different degrees of oxidative stresses, while the second group, which was injected with the radioactive substance and fed with apples and beetroots, then sacrificed after a week, gave a better absorption intensity than G3 and P values were non-significant and were close to G1, while G4 which was sacrificed after thirty days of eating apples and beetroots, showed an intensity of absorption approximately normal and similar to that of G1 (Figures 8, 9).

As a result, blood absorption spectra are strongly dependent on radiation dose, with the lowest value spectrum possibly corresponding to the highest oxidative stress [28]. Ionizing radiation interacts with the blood at the molecular level, disrupting the organizing structure of protein molecules as well as dissolving polypeptide chains and their binding–and aggregation [29]. The radiation was shown to cause a significant dose-dependent breakdown of serum proteins. These findings reveal an image of blood component deterioration. In contrast to the radioactive types, the treated radioactive samples have a wider spectrum.

The results obtained from the G4 rats showed a significant improvement because they were not affected, as their cells were matched to the cells of the G1 mice, indicating the importance and effect of eating apples and beetroots within thirty days.

In a trial to understand the mechanisms of ionizing radiation in living cells, it was found that the ionizing radiation creates a free radical atmosphere comprising the most well-known hydroxyl radicals (radical dot OH) that can be generated either through water radiolysis or through Fenton's reaction (non-enzymatic Fe2+-H2O2 reaction). Because of the abundance of these free radicals, they interact with fats and proteins through lipid peroxidation, causing hydrolysis of phospholipid heads, homologous linking of fats, and the formation of a disulfide bridge, which damages amino acid residues in membrane proteins and causes lipoprotein cross-linking. Lipoprotein cross-linking influences membrane permeability. It increases membrane rigidity and decreases membrane deformation. The membrane's components and mechanical properties change, resulting in structural and morphological changes mediated by radiation to the cytoskeleton's protein [30].

For studying the role of mechanisms of radioprotection of radiation countermeasures the obtained results should be firstly compared to the results and the existing scientific research to show the extent of this compatibility with the results of the current study. Many studies have made it clear that to avoid serious health diseases, it is necessary to eat healthy and nutritious food[9].

Boyer et al.[31] proposed that apples have been linked to a lower risk of chronic diseases including cardiovascular disease, cancer, and asthma in various epidemiological studies. Apples have high antioxidant activity that can inhibit cancer cell proliferation, and reduce lipid oxidation, according to *in vitro* and animal studies. Apples contain a wide spectrum of phytochemicals, many of which have been shown to have effective antioxidant properties.

There are many studies indicating that green apple and apple juice may be important raw materials for the development of a chemical protective and therapeutic agents. Apple juice extracts and ingredients that have a variety of biological activities are used in cell culture and animal models to restore and protect living cells from harmful effects [31]. These benefits of apple ingredients and juice include antioxidants and their ability to reduce oxidative stress [32-33], protection from the damage caused by hydrogen peroxide inhibition of intracellular communication between spike junctions, as well as induction of apoptosis in various colon cancer cell lines [34, 35,36].

The unique combination of phytochemicals in apples, according to Eberhardt et al. [39], is responsible for inhibiting tumor cell development. When compared to eleven other widely consumed fruits, apples had the third highest antiproliferative activity [37].

Red beetroot is a high-carbohydrate, high-fat, high-micronutrient, and high-bioactive constituent vegetable [38]. Among the bioactive constituents are betaine, polyphenols, carotenoids, flavonoids, saponins, and the water-soluble pigments battalions[39]. Polyphenols are a chemical structural class distinguished by the existence of large numbers of phenol structural units. The distinctive physical, chemical, and biological properties are due to the number and characteristics of these phenol structures. Since red beetroot polyphenols have hydroxyl groups that donate protons to ROS, they have chemo-preventive properties. The phenolic acids, for example, ferulic acid, p-coumaric acid, syringic acid, and vanillic acid have been purified from beetroot [40,41].

Other reasons to illustrate the value of beet components include their ability to clean free radicals, repair the cell, and protect the cell membrane, as well as the fact that they contain components that resist tumors. Beetroots have some of the best components for protecting against radiation hazards.

Ferulic acid (FA) is a powerful membrane antioxidant known to be a selective free radical scavenger [43]. It has been shown to reduce apoptosis by losing mitochondrial membrane potential [44]. Twenty-five FA metabolites were found in plasma, most of them were also found in urine, while in stools, colonic metabolism resulted in simpler phenolic compounds [43]. Intake of ferulic acid reduced NADPH oxidase activity, superoxide release, apoptosis, and mononuclear cell necrosis in peripheral blood in mice [44]. Superoxide production was abolished by FA in mice [45]. Polyphenols have also been shown to improve lung inflammation in mice [46,47]. Red beetroots contain a substance that helps in the treatment of lung cancer, as they contain, flavonoids, which consist of two phenyl rings and a heterocyclic ring. The main flavonoids in red beetroot contain the following constituents (rutin, kaempferol, ramentin, raminostrin, and estragaline) [48]. Rutin has been shown to reduce focal areas of dysplasia in chemically induced mice to develop colon cancer [49]. It has also been shown to reduce oxidative stress and inflammation in a rat liver model. In addition, the protein-treated animals showed a decrease in up-down regulation of inflammatory markers [50].

Rahimi et al., [51] and Ninfali et al. [52] recently studied the radical scavenging behavior of betalains. Betalains have good anti-oxidant and free radical scavenging properties. Their antioxidant activity is equivalent to that of the commonly used synthetic anti-oxidant butylated hydroxytoluene. Betalains scavenge free radicals galvinoxyl, hydroxyl, and superoxide [53]. Incubating cells with betalains reduced *in-vitro* DNA damage caused by exogenous H_2O_2 in cultured human liver hepatoma cells [54].

Compounds with radioprotective effects can be produced naturally through several different mechanisms such as 1) scavenging free radicals; 2) enhancing DNA repair; and 3) synchronizing of cells , 4) modulating redox responsive genes; 5) modulating growth factors and cytokines; 6) inhibiting apoptosis; 7) drug repurposing; 8) communicating and chelating radionuclides; and therapeutic methods of tissue regeneration such as 9) gene therapy and 10) stem cell therapy. These processes are outlined below, and they may be used to evaluate new candidate compounds. Several strategies can be used to achieve optimum radiation safety. (Fig.8) [55].

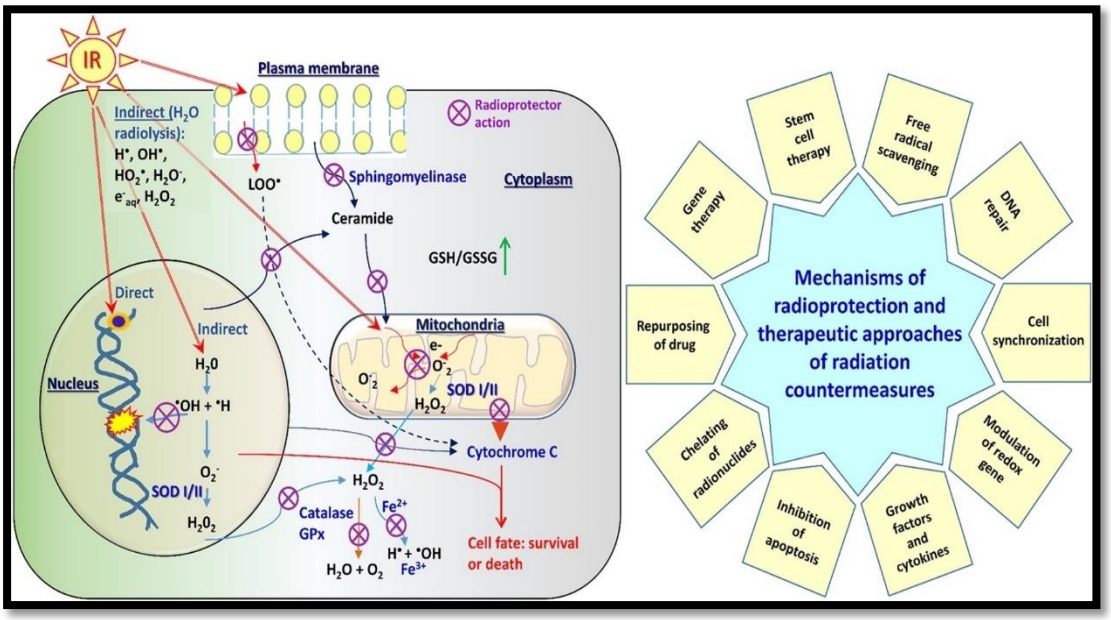

Fig. (8): schematic outline of the major biochemical events that occur within cells after exposure to radiation and the ten most important radiation defense system mechanisms. Radiation protection mechanisms are multifaceted, ranging from radical scavenging to gene therapy[55]

CONCLUSION

This study demonstrated the importance of consuming and using beetroots and apple juice as one of the most important natural sources for protection from the harmful effects of ionizing radiation and its harmful effects on blood components. Naturally found ingredients in cultivated fruits and vegetables have remarkable benefits for use in radiation protection. The advantage of using these compounds is their increased safety in relation to synthetic chemical compounds. Moreover, natural products have been shown to be effective in treating symptoms and diseases resulting from exposure to radiation, and this highlights the importance of using them for workers in the field of radiation and the work environment in which they are located.

RECOMMENDATIONS

1. The results of this research showed the harmful biological effects of radiation on those exposed to it. Thus, it is recommended that regular checks be made for workers at the nuclear medicine centers and radiological departments to monitor their health status to avoid the risks of such work environments.
2. The research also showed the importance of consuming apples and beetroots, especially green apples, on an ongoing basis, whether in the form of juice or eating the fruit in whole, as they contain antioxidants, phytochemicals, polyphenols and ferulic acid which can clean free radicals, repair the cell, and protect the cell membrane, as well as the fact that they contain components that resist tumors.
3. It is also recommended to complete the research on apples and beetroots for the possibility of making a compound containing their ingredients for use as a protective treatment against radiation-induced harm.

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