Iran. J. Radiat. Res., 2007; 5 (3): 105-112

Post treatment effect of *Grewia asiatica* against radiation induced biochemical changes in brain of Swiss albino mice

M. Ahaskar, K.V. Sharma, S. Singh, R. Sisodia*

Radiation and Cancer Biology Laboratory, Department of Zoology, University of Rajasthan, Jaipur, India

Background: The aim of the present study was to evaluate the radioprotective effect of *Grewia asiatica* fruit pulp extract (GAE) on Swiss albino mice exposed to gamma radiation. In the present study radioprotective efficacy of *Grewia asiatica* (rich in anthocyanin, carotenes, vitamin C, etc.) was studied against radiation induced biochemical alterations in mice cerebrum. ***Materials and Methods:*** For experimental study, healthy Swiss Albino mice were selected from an inbred colony and divided into four groups. Group I (normal) did not receive any treatment. Group II was orally supplemented (GAE) once daily at the dose of 700 mg/kg.b.wt/day for fifteen consecutive days. Group III (control) received distilled water orally equivalent to GAE for fifteen days than exposed to 5 Gy of gamma radiation. Group IV (IR+Drug) was administered orally (GAE) for 15 consecutive days once daily after exposed to single dose of 5Gy of gamma radiation respectively. Mice were sacrificed at different autopsy intervals viz. 1, 3, 7, 15 and 30 days and brain were removed for various biochemical estimations viz. glutathione (GSH), lipid peroxidation (LPO) and protein. ***Results:*** GAE post treatment renders protection against various biochemical changes in mice brain. Radiation induced augmentation in the levels of LPO was significantly ameliorated by GAE post-treatment. Radiation-induced depletion in the level of GSH, protein was checked significantly by GAE administration. ***Conclusion:*** These results indicate that *Grewia asiatica* fruit extract (GAE) is able to protect the brain of Swiss albino mice against radiation induced biochemical alterations.
Iran. J. Radiat. Res., 2007; 5 (3): 105-112

Keywords: *Grewia asiatica, antioxidant, lipid peroxidation, protein, radioprotection, reduced glutathione.*

INTRODUCTION

Radiation is known to produce various reactive oxygen species (ROS) in biological systems such as superoxide, hydrogen peroxide and hydroxyl radical and various types of tissue damage due to free radical reactions [1]. The range of antioxidant defenses available within the cell and in the extracellular fluid should be adequate to protect against oxidative damage. Radiation therapy (RT) is considered to be one of the most popular and important tools to cure cancer [2]. The radiosensitivity of normal tissues particularly organs away from the tumor sites are suggested to limit the therapeutic gain [3]. Detrimental effect of ionizing radiation occurs mainly due to free radicals generated through the decomposition of cellular water [4]. However, organisms have protective systems against free radical reactions, for example, endogenous antioxidants and antioxidative enzymes. All aerobic organisms are susceptible to oxidative stress simply because semireduced oxygen species are produced by mitochondria during respiration [5]. Brain is considered abnormally sensitive to oxidative damage [6] and in fact early studies demonstrating the ease of peroxidation of brain membranes. Brain is enriched in the more easily oxidizable polyunsaturated fatty acids such as docosahexaenoic acid and eicosapentaenoic acid as it has a limited ability to perform aerobic glycolysis; it is unusually vulnerable to hypoxia [7]. On the other hand, brain is not enriched in antioxidant defenses; it contains relatively low levels of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px) [8].

Corresponding author:
Dr. Rashmi Sisodia, 6A Maharani College Staff Quarters, Near Diggi House Jaipur, Rajasthan, India-302001.
Fax: *+91 141 2701137*
E-mail: *rashsisodia@yahoo.co.in*

Diets high in antioxidant properties are known to reverse some deficits in neuronal and cognitive function that occur in aging animals. Antioxidants are also known to reduce levels of pro-inflammatory factors in the CNS. A large numbers of compounds from various plant sources have been shown to posse's antioxidant properties [9-11]. Nutritional intervention to increase intake of phyto-antioxidants may reduce the threat of free radicals. India has a rich heritage of medicinal plants many of which have been explored for the various bioactivities since ages, but the radioprotective potential of the plants have been hardly explored. In this context *Grewia asiatica* (Phalsa) cultivated on a commercial scale mainly in the northern and western states of India [12-13], is known for its medicinal properties. The fruit is astringent and stomachic. Morton [14] reported that unripe phalsa fruit alleviates inflammation and is administered in respiratory, cardiac and blood disorders, as well as in fever reduction. Furthermore and infusion of the bark is given as a demulcent, febrifuge, and treatment for diarrhea. *Grewia asiatica* contains anthocyanin type cyanidin 3-glucoside [15], vitamin C, minerals and dietary fibers etc. [16]. The antioxidant properties of vitamin C are well known and anthocyanin has recently emerged as a powerful antioxidant.

Brain tissue is highly susceptible to oxidative damage due to its high utilization of oxygen and it's poorly developed antioxidative defense mechanism. The present study look for the protective effect of alcoholic extract of *Grewia asiatica* fruit in mice cerebrum against radiation induced oxidative stress.

MATERIALS AND METHODS

Animal care and handling

The animal care and handling was done according to the guidelines set by World Health Organization, Geneva, Switzerland and INSA (Indian National Science Academy, New Delhi, India). The departmental animal ethical committee approved this study. Swiss albino mice, 6-8 weeks old weighing 23±2 gm, from an inbred colony were used for the present study. These animals were maintained under controlled conditions of temperature and light (light: dark, 10 hrs: 14 hrs.). Four animals were housed in a polypropylene cage containing sterile paddy husk (procured locally) as bedding throughout the experiment. They were provided standard mice feed (procured from Hindustan Levers Ltd., India) and water ad libitum. Tetracycline water once a fortnight was given as preventive measures against infections.

Extract preparation (drug)

Fresh fruits of *Grewia asiatica* collected locally in summer season were washed, shade dried and powdered after removal of seeds. Methanolic extract was then prepared by refluxing for 48 hours (4×12) at 40°C. The extract thus obtained was vacuum evaporated so as to get in powdered form. The extract was redisolved in doubled-distilled water (DDW) just before the oral administration. For the various concentrations, a known amount of GAE was suspended in DDW and 50 µl of GAE suspension was given to each mouse by oral gavages as given by Ahaskar *et al.* [17].

Source of irradiation

The cobalt teletherapy unit (ATC-C9) at Cancer Treatment Center, Radiotherapy Department, SMS Medical College and Hospital, Jaipur, Rajasthan, India was used for irradiation. Unanaesthestized animals were restrained in well-ventilated perspex boxes and whole body exposed to gamma radiation at a distance (SSD) of 77.5 cm from the source to deliver the dose rate of 1.07 Gy/min.

Chemicals

Thiobarbituric acid (TBA), Glutathione (GSH), DTNB (5,5 dithio- bis 2-Nitrobenzoic acid) were purchased from Sigma Co. USA. 1,1,3,3, tetramethoxy propane, and other chemical used were of analytical grade and

were procured from Central Drug House (Pvt.) Ltd. Mumbai.

Dose selection

The dose selection of *Grewia asiatica* was done on the basis of drug tolerance study in our laboratory. Various dose of *Grewia asiatica* (100, 400, 700, 1000, 1300 mg/kg b.wt. of animal) were tested for their effects on the tolerance to 10 Gy gamma irradiation in Swiss albino mice. Thus, 700 mg/kg b.wt. /day was obtained as optimum dose and used for further experimentation.

Experimental design

Mice selected from an inbred colony were divided into 4 groups (30 animals in each Group).

Group I (normal): Mice of this group did not receive any treatment.

Group II (drug): Mice of this group were administered with GAE (700mg/kg of b.wt. /day) for 15 consecutive days once daily.

Group III (control): Mice received DDW (volume equal to *Grewia asiatica* solution) for 15 days and were then exposed to 5Gy of gamma-radiation.

Group IV (Experimental): In this group mice were whole body exposed to single dose of 5 Gy gamma-radiation as in group third then oral administration of GAE (700mg/kg of b.wt. /day) was made once daily for 15 consecutive days.

Six mice from each group were necropsied at various intervals, i.e. 1,3,7,15,30 days post Irradiation.

Removal of brain tissue

The mice were weighed and sacrificed by cervical dislocation. An incision was given at the sides of the jaws to separate the upper and the lower palates. The upper palate was cut in the middle and, after having cleared the surrounding tissue; the brain was excised and separated from the spinal cord at the decussation of the pyramids. The intact cerebrum was then removed carefully from the brain and homogenate was prepared and used for quantitative estimation of various biochemical changes.

Biochemical assay

Reduced glutathione (GSH) assay

Spectrophotometric quantification of reduced glutathione (GSH) has been carried out using 5, 5-dithiobis- (2-nitrobenzoic acid) (DTNB) reagent according to the method proposed by Moron *et al.* [18]. Briefly, 200 µl of tissue homogenate (20%) was added to 800 µl distilled water and then 2 ml of sodium phosphate-EDTA buffer (0.1 M sodium phosphate, 0.005 M EDTA buffer, pH 8.0), containing 0.6 M DTNB were added. The optical density of the yellow colored complex developed by the reaction of GSH and DTNB was measured at 412 nm using a UV-vis spectrophotometer.

Lipid peroxidation (LPO) assay

LPO was measured by the method of Buege and Aust [19]. Briefly, tissue homogenate was mixed with TCA-TBA-HCl and was heated for 15 min in a boiling water bath. After centrifugation the absorbance was recorded at 535 nm using a UV-Vis double beam spectrophotometer. The LPO has been expressed as MDA in n mole/ gm tissue.

Protein assay

Estimation of protein was based on the method proposed by Bradford [20]. 10% homogenate was prepared (1 gm of tissue in 9 ml of NaCl) and 0.1ml of the sample was taken for the assay. Three repeats of the assay from each animal were carried out. The absorbance was read at 595 nm.

Statistical analysis

The results obtained in the present study were expressed as mean±SEM. The statistical difference between various groups were analyzed by the Student's *t*-test and the significance was observed at the $p<0.02$, $p<0.01$ and $p<0.001$ level.

RESULTS

Lipid peroxidation

Significant ($p<0.001$) difference in brain lipid peroxidation levels was observed in

GAE alone treated animals (group II) as compared to group I (Normal). A significant increase ($p<0.001$) in brain lipid peroxidation levels was noted in gamma irradiated animals group III (Control) as compared to Group I (Normal) with a maximum increase of (199.215±1.057n mol/gm) on day 1. In the group where GAE supplemented after irradiation (group IV) at all the corresponding intervals LPO level declined significantly ($p<0.001$) in comparison to control group and the values reached normal level by the end of experiment (104.715±0.897n mol/gm) (table 1).

Table 1. Radiomodulatory influence of *Grewia asiatica* fruit extract on whole brain LPO±SEM (n mole MDA/gm protein) of Swiss albino mice at various post irradiation interval after 5 Gy radiation exposures.

Normal	103.551±0.633 (100%)				
Only drug	99.808±0.588[a] (96.39%)				
	1 Day	**3 Day**	**7 Day**	**15 Day**	**30 Day**
Control	199.215±1.057 (192.38%)	142.111±1.223 (137.23%)	147.034±1.454 (141.99%)	121.118±0.528 (116.96%)	109.576±0.927 (105.82%)
Experimental	99.775±0.159[a] (96.35%)	89.899±1.221[a] (86.81%)	93.867±0.515[a] (90.64%)	99.502±1.764[a] (96.08%)	104.715±0.897[b] (101.12%)

(a= P<0.001; b= p<0.01; c= p<0.02; d= p<0.05; n= not significant)

Glutathione

No significant alterations in glutathione contents of brain were observed between normal and GAE- treated animals. However, statistically significant ($p<0.001$) decrease in glutathione was noted in group III (Control) animals in comparison to group I. In GAE post-treated irradiated group (group IV) animals exhibited a significant elevation in glutathione as compared to group III and reached normal level at day 30 *post treatment*. (30.994±1.907n mol/100mg) (table 2). GAE treatment after radiation in group IV supplies marked protection against radiation.

Protein

Significant ($p<0.001$) difference in protein content existed between mice of group I (118.987±0.975mg/gm) and group II (136.097±1.913 mg/gm). In control (group III) there was a significant reduction upto 7 days *post treatment* in protein content, thereafter it increased sharply at day 30th *post treatment* and was (113.793±0.995 mg/gm). In irradiated GAE post-treated group (group IV) protein level was significantly higher ($p<0.001$) than corresponding control at all post irradiation intervals. In this group the protein level crossed the normal values by day 7 (120.216±0.533 mg/gm) and at day 30

Table 2. Radiomodulatory influence of *Grewia asiatica* fruit extract on whole brain GSH±SEM (n mole /100mg tissue) of Swiss albino mice at various post irradiation interval after 5 Gy radiation exposures.

Normal	30.403±1.769 (100%)				
Only drug	32.123±1.007[n] (105.66%)				
	1 Day	**3 Day**	**7 Day**	**15 Day**	**30 Day**
Control	24.168±1.579 (79.49%)	22.138±1.480 (72.82%)	21.253±2.265 (69.90%)	23.909±2.312 (78.64%)	24.795±1.510 (81.55%)
Experimental	29.972±1.375[c] (98.58%)	27.452±1.569[d] (90.29%)	28.337±1.998[d] (93.20%)	29.813±1.599[d] (98.06%)	30.994±1.907[c] (101.94%)

(a= P<0.001; b= p<0.01; c= p<0.02; d= p<0.05; n= not significant)

post treatment it was significantly ($p<0.001$) higher by 5.31% in comparison to normal. (table 3).

DISCUSSION

Results obtained from this study indicate that *Grewia asiatica* extract may act as radioprotective agent and render protection against radiation induced oxidative stress. Similar result of GAE against 5Gy gamma radiation in whole brain of mice was obtained by Ahaskar *et al.* [17]. In this Study, we found that post treatment of GAE significantly reduced more LPO level in brain where as it increase more GSH level than pre treatment of GAE.

Oxidative stress leads to lipid peroxidation, which is a highly destructive process and cellular organelles and whole organism, lose biochemical function and/or structural and architecture [21] which may lead to damage or death of cell. The preservation of cellular membrane integrity depends on protection or repair mechanisms capable of neutralizing oxidative reactions. Ono *et al.* [22] applied 5 Gy whole body γ-irradiation to mice. All the animals were euthanized after 24 and 48 hours. They also examined the levels of MDA in the brain tissues. MDA levels were found markedly increased to the control group. The presence of antioxidants in the plants suppresses the formation of free lipid radical and thus prevents the formation of endoperoxidation.

Under normal conditions, the inherent defense system including glutathione and antioxidant enzymes protects against the oxidative damage. GSH offers protection against oxygen derived free radicals and cellular lethality following exposure to ionizing radiation [23]. GSH is a versatile protector and executes its radioprotective function through free radical scavenging, restoration of the damaged molecule by hydrogen donation, reduction of peroxides and maintenance of protein thiols in the reduced state [24]. A significant decrease in GSH content in whole brain was observed following gamma irradiation (5Gy) by Ahaskar *et al.* [17]. In the present study the oral administration of GAE protects the GSH depletion due to irradiation. These results suggest that endogenous non-protein sulfhydryl content (GSH) in maintained by the extracts in the experimental group. GSH might be reacting with the peroxide intermediates; since peroxide intermediates cannot stimulate further lipid peroxidation by autocatalysis and enhance the damage.

Reduction in rate of the protein synthesis may be due to unfavorable condition like unavailability of one or more essential enzymes and/or reduction in sites of protein synthesis [25]. Decrease in the protein content after exposure to irradiation might be due to either decline in the rate of protein synthesis or an increase in the consumption of protein. It may also be the result of the depression of enzyme involved in the activation of amino acid and transferring to tRNA or by the inhibition of release of synthesized polypeptides from polysomes [26]. Increased protein concentration recorded in our study, shows that GAE supplemented irradiated

Table 3. Radiomodulatory influence of *Grewia asiatica* fruit extract on whole brain Protein±SEM (mg/gm) of Swiss albino mice at various post irradiation interval after 5 Gy radiation exposures.

Normal	118.987±0.975 (100%)				
Only drug	136.097±1.913[a] (114.38%)				
	1 Day	**3 Day**	**7 Day**	**15 Day**	**30 Day**
Control	105.952±0.621 (89.04%)	95.01±0.502 (79.84%)	84.167±0.725 (70.76%)	95.312±0.271 (80.10%)	113.793±0.995 (95.63%)
Experimental	111.274±0.969[a] (93.51%)	113.889±1.339[a] (95.71%)	120.216±0.533[a] (101.03%)	124.999±0.279[a] (105.05%)	125.308±0.263[a] (105.31%)

(a= P<0.001; b= p<0.01; c= p<0.02; d= p<0.05; n= not significant)

mice are a beneficial effect. This process showed the improvement in the ribosomal activities, which enhance protein synthesis. This can be treated as an antiradiation effect.

Earlier studies in our laboratory demonstrated the radioprotective effect of GAE was also determined by calculating the dose reduction factor (DRF), which was 1.53 by Ahaskar *et al.* [27]. Protective role of GAE in liver and blood of mice against 5Gy gamma radiation was also studied by Sharma *et al.* [28] they found that pretreatment of GAE significantly reduced the LPO level in liver and blood where as it increase the GSH level. Singh *et al.* [29] demonstrate that GAE pretreatment protects the hematopoietic system of mice against radiation-induced damage by inhibiting the glutathione depletion, decreasing lipid peroxidation level, and increasing hematological constituents in peripheral blood.

Fruits like ber, phalsa, apple and strawberry have been shown to possess moderate antioxidant activity ranging from 12-64 mM FRAP [30]. Matsumoto *et al.* [31] have shown that the antioxidative activity of plasma lasted longer than the presence of anthocyanin glycosides in the plasma. They assumed that anthocyanins were converted into some metabolites having antioxidant activity. Like other flavonoids, anthocyanins and anthocyanidins (the aglycone form) have antioxidant properties [32]. The antioxidant potency of anthocyanin extracts is concentration dependent [33]. The positive effects of anthocyanin pigments could be related to their potent antioxidant activity demonstrated in various *in vitro* and *in vivo* studies [32-36]. All evaluated anthocyanins were better agents against lipid peroxidation than α-tocopherol (up to seven times). Also, it was demonstrated that anthocyanins have scavenging properties against OH and O_2 [37].

Anthocyanins detected in the brain homogenate were a reflection of their presence in the tissue. These molecules could permeate the blood-brain barrier, in accordance with a recent *in vitro* study showing that brain endothelial cell lines took up cyanidin 3-rutinoside and pelargonidin 3-glucoside [38]. At this level, anthocyanins, known for their antioxidant properties [31], could exert protective activities against the oxidative damages responsible for numerous neurological disorders [39]. Cyanidin 3-glucoside, which was the predominant form (84%) in the brain, has been shown to possess a high antioxidant capacity [32, 40]. Its presence at the cellular level could compensate the oxidative vulnerability of neuronal cells in aging or neurodegenerative diseases [41-43].

Total intake of fruits, vegetables and fruit juices was positively associated with plasma levels of several carotenoids and vitamin C. Mechanisms of antioxidative action of vitamin C are direct scavenging and blocking of ROS, as well as regeneration of other antioxidative systems [44]. The biological benefits of certain carotenoids may be due to their potent antioxidant properties attributed to specific physico-chemical interactions with membranes. McNulty *et al.* [45] test this by measuring the effects of various carotenoids on rates of lipid peroxidation and correlated these findings with their membrane interactions, as determined by small angle X-ray diffraction approaches. The findings indicate distinct effects of carotenoids on lipid peroxidation due to membrane structure changes. These contrasting effects of carotenoids on lipid peroxidation may explain differences in their biological activity.

The protection afforded by GAE might be due to the synergistic effect of antioxidants present in it. The present study shows that GAE exerts its radioprotective effect in two ways: first; it is able to curb the initial damage caused due to radiation (by antioxidant activity) and second, GAE may offer radioprotection even when administered after irradiation. The mechanism by which GAE exerts its radioprotective property might be due to decreasing radiation induced lipid peroxidation level in unirradiated animals and by subsiding the generation of the radiation induced lipid peroxidation in terms of MDA as well as By checking or preventing/controlling the depletion of

endogenous glutathione and protein.

From the present study it can be concluded that regular supplementation of GAE may exert an antiradiation influence in the body.

ACKNOWLEDGEMENT

We thankfully acknowledge SAP and Department of Zoology, University of Rajasthan, Jaipur for liberal use of facilities and Radiotherapy Unit, SMS Hospital, Jaipur (India), for the radiation facility and dosimetry.

REFERENCES

1. Adler V, Yin Z, Tew KD, Ronai Z (1999) Role of redox potential and reactive oxygen species in stress signaling. *Oncogene,* ***18****: 104-111.*
2. Brock WA, Geara FB (1995) Clinical Relevance Of Normal Tissue Radiosensitivity, Radiation Research, 10th ed. *Wurzburg, ICRR, Society,* ***2****: 843-846.*
3. Agrawal A, Chandra D, Kale RK (2001) Radiation-induced oxidative stress: 2 studies in liver as distant organ of tumor bearing mice. *Mol Biochem,* ***224****: 9-17.*
4. Winterbourn CC (1993) Superoxide as an intracellular radical sink. Free. *Radic Biol Med,* ***14****: 85-90.*
5. Floyd RA (1992) Free radical damage to protein and DNA: Mechanisms involved and relevant observations on brain undergoing oxidative stress. *Ann Neurol,* ***32****: 22-27.*
6. Skaper SD, Fabris M, Ferrari V, Dalle-Carbonare M, Leon A (1997) Quercetin protects cutaneous tissue-associated cell types including sensory neurons from oxidative stress induced by glutathione depletion: cooperative effects of ascorbic acid. *Free Radic Biol Med, 669-678.*
7. Robbins MEC, Zhao W (2004) Chronic oxidative stress and radiation-induced late normal tissue injury: a review. *Int J Radiat Oncol Biol Phys,* ***80****: 251-259.*
8. Dringen R, Gutterer JM, Hirrlinger J (2000) Glutathione metabolism in brain. *Eur J Biochem,* ***267****: 4912-4916.*
9. Bhattacharya SK, Satyam K, Ghoshal S (1996) Antioxidant activity of glycowithanolides from Withenia somnifera. *Ind J of expl Biol,* ***35****: 236.*
10. Yen, Grow-Chin, She, Chig W, Pin-der D (1996) Extraction and identification of components from the levels of Mulberry. *J Agri Food Chem,* ***44****: 1687-1690.*
11. Bhatia AL (1998) The anti-aging role of vitamin A and β-carotene. *Indian J Gerontology.*
12. Hays WB (1953) Fruit growing in India. 2nd Revised edition. Kitabistan, Allahabad, India.
13. Sastri BN (1956) The wealth of India: Raw materials#4. *Grewia* Linn. Tilliaceae. In Council of Scientific and Industrial Research, New Delhi, India. *260-266.*
14. Morton JF (1987) Phalsa, Fruits of warm climate. Julia Morton, Miami, F.L, *276-277.*
15. Nair MG, Deueitt DL, Wang H, Krempir DW, Mody DK (2005) Dietary food supplement containing natural cyclooxygenase inhibitors and methods for inhibiting pain and inflammation. United States patent application.
16. Yadav AK (1999) Phalsa: A Potential New Small Fruit for Georgia. Janick J (ed). *Publisher? Place of publication? 348-352.*
17. Ahaskar M, Sisodia R (2006) Modulation of Radiation induced Biochemical Changes in brain of Swiss Albino Mice by *Grewia asiatica. Asian J Exp Sci,* ***20****: 399-404.*
18. Moron MS, Depierre JW, Mannervik B (1979) Levels of GSH, GR and GST activities in rat lung and liver. *Biochim Biophys Acta,* ***582****: 67-78.*
19. Buege JA, Aust SD (1978) Methods in Enzymology, Academic Press, *New York.* ***52****: 302-314.*
20. Bradford MM (1976) A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principal of protein-By binding. *Annal Biochem,* ***72****: 248-254.*
21. Kale RK, Sitaswad SL (1990) Radiation induced lipid Peroxidation in liposomes. Radiat. *Phys Chem,* ***36****: 361-364.*
22. Ono S, Cai L, Cherian MG (1998) Effects of gamma radiation on levels of brain metallothionein and lipid peroxidation in transgenic mice. *Radiat Res,* ***150****: 52-57.*
23. Biaglow JE, Varnes ME, Epp ER, Clark EP (1987) Title of Chapter? In: Anticarcinogenesis and Radiation Protection, Eds. Cerrutti PA, Nygaard OF, Simic MG, Plennum Press, New York. *387.*
24. Bump EA, Brown JM (1990) Role of glutathione in the radiation response of mammalian cells in vitro and in vivo. *Pharmacol Ther,* ***47****: 117-136.*
25. Bacq ZM, Alexander P (1961) Fundamentals of Radiobiology, English Language Book Co. and Pergamon Press. New York.
26. Kim SH, Kim JH, Djorddevic D (1970) Effects of X-irradiation on RNA and protein synthesis in HeLa cells. *Radiat Res,* ***42****: 577-589.*
27. Ahaskar M, Sharma KV, Singh S, Sisodia R (2007) Radioprotective effect of the fruit extract of Grewia asiatica in Swiss albino mice against lethal dose of γ-irradiation. *Asian J Exp Sci,* ***21****: 295-308.*
28. Sharma KV, Ahaskar M, Singh S, Sisodia R (2007) Modulation of Radiation Induced Biochemical Alteration in Swiss albino mice by Grewia asiatica (Phalsa). *Pharmacology online,* ***1****: 46-54.*
29. Singh S, Sharma KV, Sisodia R (2007) Radioprotective Role of Grewia asiatica in Mice Blood. *Pharmacology online,* ***2****: In press.*
30. Kaur C and Kapoor HC (2005) Antioxidant activity of some fruits in Indian diet. In ISHS Acta Horticulture; VII International Symposium on Temperate Zone Fruits in the Tropics and Subtropics-Part Two. 696.
31. Matsumoto H, Nakamura Y, Hirayama M, Yoshiki Y, Okubo K (2002) Antioxidant activity of black currant anthocyanin aglycons and their glycosides measured by chemiluminescence in a neutral pH region and in human plasma. *J Agric Food Chem,* ***50****: 5034-5037.*
32. Wang H, Cao G, Prior RL (1997) Oxygen radical absorbing capacity of anthocyanins. *J Agric Food Chem,* ***45****: 304-309.*
33. Gabrielska J, Oszmiański J, Komorowska M, Langner M (1999) Anthocyanin extracts with antioxidant and radical

scavenging effect. *Z Naturforsch,* ***54c****: 319-324.*
34. Tsuda T, Watanabe M, Ohshima K, Norinobu S, Choi SW, Kawakishi S, Osawa T (1994) Antioxidative activity of the anthocyanin pigments cyanidin 3-O-β-D-glucoside and cyanidin. *J Agric Food Chem,* ***42****: 2407-2410.*
35. Wang H, Nair MG, Strasburg GM, Chang YC, Booren AM, Gray JI, DeWitt DL (1999) Antioxidant and antiinflammatory activities of anthocyanins and their aglycon, cyanidin, from tart cherries. *J Nat Prod,* ***62****: 294-296.*
36. Ramirez-Tortosa C, Andersen OM, Gardner PT, Morrice PC, Wood SG, Duthie SJ, Collins AR, Duthie GG (2001) Anthocyanin-rich extract decreases indices of lipid peroxidation and DNA damage in vitamin E-depleted rats. *Free Radic Biol Med,* ***31****: 1033-1037.*
37. Delgado-Vargas F, Jiménez AR, Paredes-López O (2000) Natural pigments: Carotenoids, anthocyanins, and Betalains-characteristics, biosynthesis, processing, and stability. *Food Science and Nutrition,* ***40****: 173-289.*
38. Youdim KA, Dobbie MS, Kuhnle G, Proteggente AR, Abbott NJ, Rice-Evans C (2003) Interaction between flavonoids and the blood-brain barrier: in vitro studies. *J Neurochem,* ***85****: 180-92.*
39. Joseph JA, Denisova NA, Bielinski D, Fisher DR, Shukitt-Hale B (2000) Oxidative stress protection and vulnerability in aging: Putative nutritional implications for intervention. Mech. *Ageing Dev,* ***116****: 141-153.*
40. Amorini AM, Fazzina G, Lazzarino G, Tavazzi B, Di Pierro D, Santucci R, Sinibaldi F, Galvano F, Galvano G (2001) Activity and mechanism of the antioxidant properties of cyanidin-3-O-β-glucopyranoside. *Free Rad Res,* ***35****: 953-966.*
41. Joseph JA, Denisova NA, Arendash G, Gordon M, Diamond D, Shukitt-Hale B, Morgan D (2003) Blueberry supplementation enhances signaling and prevents behavioral deficits in an Alzheimer disease model. Nutr. *Neurosci,* ***6****: 153-162.*
42. Goyarzu P, Malin DH, Lau FC, Taglialatela G, Moon WD, Jennings R, Moy E, Moy D, Lippold S, Shukitt-Hale B, Joseph JA (2004) Blueberry supplemented diet: Effects on object recognition memory and nuclear factor-kappa B levels in aged rats. Nutr. *Neurosci,* ***7****: 75-83.*
43. Sweeney MI, Kalt W, MacKinnon SL, Ashby J, Gottschall-Pass KT (2002) Feeding rats diets enriched in lowbush blueberries for six weeks decreases ischemia-induced brain damage. *Nutr Neurosci,* ***5****: 427-431.*
44. Griffiths HR and Lunec J (2001) Ascorbic acid in the 21st century: more than a simple antioxidant. *Environ Toxicol Pharmacol,* ***10****: 173-182.*
45. Mc Nulty HP, Byun J, Lockwood SF, Jacob RF, Mason RP (2006) Differential effects of carotenoids on lipid peroxidation due to membrane interactions: X-ray diffraction analysis. *Biochim Biophys Acta,* ***1768****: 167-174.*