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Effectiveness of *Aloe vera* on the antioxidant status of different tissues in irradiated rats

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This study was performed to evaluate the role of *Aloe vera* (*Aloe barbadensis* Miller) on the antioxidant status in different tissues of animals whole body exposed to 7 Gy gamma radiations, delivered as a shot dose. *Aloe vera* (leaf juice filtrate) was supplemented daily to rats (0.25 ml/kg body weight/day), by gavage, 5 days before irradiation and 10 days after irradiation. Experimental investigations performed 3, 7 and 10 days after exposure to radiation showed that *Aloe vera* treatment has significantly minimized the radiation-induced increase in the amount of malondialdehyde in liver, lungs, and kidney tissues of irradiated rats. Significant amelioration in superoxide dismutase (SOD) and catalase activities was observed from the 3rd up to the 10th days for lungs, on the 7th and 10th days for kidneys and at 10 days for liver. Data obtained showed that for the different tissues, improvement in the decrease of reduced glutathione (GSH) contents was obvious on the 10th day after irradiation. Treatment with *Aloe vera* was also effective in minimizing the radiation-induced increase in plasma glucose levels throughout the experimental period, while it has not ameliorated the increase in plasma insulin levels. It could be concluded that the synergistic relationship between the elements found in the leaf of *Aloe vera* could be a useful adjunct for maintaining the integrity of the antioxidant status.

1. Introduction

Aloe vera (Liliaceae), also known as *Aloe barbadensis* Miller, is native to Africa, but today the plant is found worldwide. The plant contains more than 75 essential compounds including vitamins, minerals, enzymes, proteins, amino acids, and carbohydrate polymers such as glucomannans and pectic acid, plus sterols, lignin, saponins, and anthraquinones. It is the specific mixture of the ingredients that is responsible for giving the plant its wide range of healing powers. The components are derived from its leaf, which consists of the rind containing sap, the latex layer containing its bitter juice, and the parenchyma or gel layer [1].

The properties of *Aloe vera* gel applied externally or taken internally have been described in numerous scientific studies. It was shown to possess anti-inflammatory [2, 3], anti-bacterial [4], anti-diabetic [5], anti-viral and anti-tumor activity [6].

Reactive oxygen species (ROS) such as such as hydroxyl radicals ($^{\bullet}OH$), superoxide anion radicals ($O_2^{\bullet -}$), and hydrogen peroxide (H_2O_2) produced during normal metabolic functions or as a consequence of response to abnormal stress are implicated in the pathogenesis of aging and disease including cancer. The body produced several enzymes including superoxide dismutase (SOD), catalase, and glutathione peroxidase (GSH-Px) that neutralize many types of free radicals. Superoxide dismutase catalyzes the reduction of ($O_2^{\bullet -}$) to H_2O_2 which is degraded by catalase into water and oxygen. Another protective mechanism against H_2O_2 is GSH-Px, the activity of which depends on the presence of adequate amounts of reduced glutathione (GSH). Exposure to ionizing radiation is characterized by excessive production of ROS associated with an increase in the process of lipid peroxidation [7, 8] and a decrease in the activity of antioxidant enzymes of the body with the consequent damage of cellular bio-membranes [9, 10].

The objective of the present work was to evaluate the effect of *Aloe vera* (leaf juice filtrate) on the radiation-induced variations in SOD and catalase activities, and GSH contents in the liver, lung and kidney tissues of rats. The increase in malondialdehyde (MDA) level was also followed to measure the extent of lipid peroxidation in the three different tissues of irradiated animals. Furthermore, the effects of *Aloe vera* treatment on radiation-induced changes in plasma glucose and insulin levels was observed.

2. Investigations, results and discussion

Aloe vera gel possesses a modulatory action on the antioxidant status [11], and the neurotransmission process [12]. It is a potent superoxide anion scavenger [13]. Additional studies showed that *Aloe vera* gel stimulates macrophages [14] and increases collagen turnover [15].

Data on experimental animals showed that long-term *Aloe vera* ingestion in rats fed a normal diet and given whole leaf juice (0.02%) in drinking water, does not cause any

Table 1: Antioxidant status in the liver of different animal groups

Groups of animals	Times post-irradiation		
	3 days	7 days	10 days
SOD activity (U/g fresh tissue)			
Control	732 ± 37	740 ± 35	731 ± 39
Aloe vera	748 ± 37	751 ± 40	754 ± 38
Irradiation	593 ± 55[a]	592 ± 43[a]	556 ± 41[a]
Aloe vera + irradiation	629 ± 49	666 ± 41	687 ± 39[b]
Catalase activity (U/g fresh tissue)			
Control	88 ± 4.40	86 ± 4.00	90 ± 3.99
Aloe vera	89 ± 5.10	86 ± 3.44	92 ± 3.59
Irradiation	52 ± 2.60[a]	63 ±3.20[a]	58 ± 2.90[a]
Aloe vera + irradiation	60 ± 3.00[a]	70 ± 3.50[a]	68 ± 3.50[b]
Glutathione content (mg/g fresh tissue)			
Control	22.50 ± 1.10	22.42 ± 1.20	22.57 ± 1.00
Aloe vera	21.10 ± 1.15	20.99 ± 1.25	22.03 ± 1.10
Irradiation	17.65 ± 0.85[a]	15.44 ± 0.80[a]	14.95 ± 0.80[a]
Aloe vera + irradiation	17.48 ± 1.10[a]	18.39 ± 1.00[a b]	18.50 ± 1.15[a b]
TBARS levels (μmole/g fresh tissue)			
Control	218 ± 11	215 ± 10	220 ± 12
Aloe vera	209 ± 10	201 ± 11	205 ± 11
Irradiation	358 ± 17[a]	294 ±14[a]	369 ± 16[a]
Aloe vera + irradiation	290 ± 13[a b]	250 ± 12[a b]	276 ± 13[a b]

Each value represents the mean of 6 record ± standard error
[a] Significance when compared to control
[b] Significance when compared to irradiated groups

Table 2: Antioxidant status in kidneys of different animal groups

Groups of animals	Time post-irradiation		
	3 days	7 days	10 days
SOD activities (U/g fresh tissue)			
Control	495 ± 25	510 ± 24	473 ± 20
Aloe vera	504 ± 24	530 ± 22	501 ± 20
Irradiation	399 ± 20[a]	386 ± 22[a]	321 ± 23[a]
Aloe vera + irradiation	392 ± 18	470 ± 14[b]	395 ± 17[a b]
Catalase activities (U/g fresh tissue)			
Control	66 ± 3.30	63 ± 2.90	65 ± 3.00
Aloe vera	67 ± 3.10	73 ± 3.00	68 ± 2.80
Irradiation	46 ± 2.30[a]	29 ± 1.40[a]	22 ± 1.00[a]
Aloe vera + irradiation	48 ± 1.70[a]	45 ± 3.00[a b]	49 ± 2.00[a b]
Glutathione contents (mg/g fresh tissue)			
Control	20.86 ± 1.00	21.49 ± 1.10	22.51 ± 1.20
Aloe vera	21.96 ± 1.20	21.12 ± 1.00	21.13 ± 0.90
Irradiation	16.99 ± 0.80[a]	16.52 ± 0.85[a]	14.95 ± 0.90[a]
Aloe vera + irradiation	17.09 ± 0.60[a]	17.82 ± 0.70[a]	18.69 ± 0.70[a b]
TBARS levels (μmole/g fresh tissue)			
Control	111± 5.50	111 ± 6.00	110 ± 4.00
Aloe vera	100 ± 5.00	109 ± 4.40	111 ± 5.00
Irradiation	200 ± 1.00[a]	163 ± 8.00[a]	213 ± 1.20[a]
Aloe vera + irradiation	149 ± 7.00[a b]	136 ± 6.50[a b]	145 ± 6.00[a b]

Each value represents the mean of 6 record ± standard error
[a] Significance when compared to control
[b] Significance when compared to irradiated groups

obvious harmful and deleterious side effects, in addition, it could be associated with some beneficial effects on age-related disease [16]. In the present study rats fed a normal diet and given 0.25 ml/kg body weight of *Aloe vera* leaf juice filtrate for 15 days, did not produce significant changes in SOD and catalase activities, GSH contents and MDA levels in the liver, lung, and kidney tissues of rats (Tables 1, 2, and 3). Plasma glucose and insulin levels showed approximately normal ranges (Table 4).

The overproduction of ROS in both intra- and extra- cellular spaces upon exposure of cells or individuals to hyperoxia, certain chemicals, radiation, or local tissue inflammation, results in oxidative stress. Oxidative stress is defined as the imbalance between pro-oxidants and antioxidants [17]. *Aloe vera* was claimed to protect against pro-oxidant-induced membrane and cellular damage [11]. Our results showed that treatment of irradiated rats with 0.25 ml/kg/day of the whole leaf juice has significantly minimized the radiation-induced increase in MDA from the 3rd up to the 10th days after irradiation, in the liver, lung and kidney tissues. Improvement in radiation-induced changes in SOD and catalase activities varies in the different tissues. Marked amelioration was recorded on the 10th day in the liver tissues (Table 1), on the 7th and 10th days in the kidney tissues (Table 2) while from the 3rd up to the 10th days in the lung tissues (Table 3). Exposure to radiation induced decrease in reduced GSH content and treatment with Aloe vera (leaf juice filtrate) pre- and post-irradiation showed marked amelioration on the 10th day for the different tissues (Tables 1, 2, and 3).

Aloe vera contains seven electrophoretically identifiable superoxide dismutases (SODs) [18], in addition to a basic

Table 3: Antioxidant status in lungs of different animal groups

Groups of animals	Time post-irradiation		
	3 days	7 days	10 days
SOD activities (U/g fresh tissue)			
Control	362 ± 18	357 ± 17	348 ± 15
Aloe vera	383 ± 20	389 ± 19	377 ± 18
Irradiation	528 ± 16[a]	493 ± 15[a]	456 ± 14[a]
Aloe vera + irradiation	452 ± 13[a b]	432 ± 12[a b]	400 ± 12[a b]
Catalase activities (U/g fresh tissue)			
Control	54 ± 2.70	58 ± 2.90	55 ± 2.60
Aloe vera	58 ± 2.75	60 ± 2.50	58 ± 2.62
Irradiation	110 ± 5.50[a]	97 ± 4.50[a]	78 ± 4.0[a]
Aloe vera + irradiation	83 ± 4.00[a b]	76 ± 3.50[a b]	68 ± 3.0[a b]
Glutathione contents (mg/g fresh tissue)			
Control	21.84 ± 1.05	22.11 ± 1.00	20.32 ± 1.10
Aloe vera	21.25 ± 1.10	20.61 ± 1.00	20.74 ± 1.00
Irradiation	15.67 ± 0.75[a]	15.81 ± 0.80[a]	15.77 ± 0.70[a]
Aloe vera + irradiation	16.46 ± 0.65[a]	16.95 ± 0.55[a]	18.56 ± 0.60[b]
TBARS levels (μmole/g fresh tissue)			
Control	146 ± 7.40	155 ± 7.00	140 ± 7.50
Aloe vera	139 ± 6.90	134 ± 8.00	130 ± 6.00
Irradiation	204 ± 8.00[a]	254 ±10.00[a]	303 ± 15.00[a]
Aloe vera + irradiation	173 ± 5.00[a b]	197 ± 9.00[a b]	196 ± 10.00[a b]

Each value represents the mean of 6 record ± standard error
[a] Significance when compared to control
[b] Significance when compared to irradiated groups

Table 4: Plasma glucose and insulin levels of different animal groups

Groups of animals	Time post-irradiation		
	3 days	7 days	10 days
Glucose levels (mg/100 ml)			
Control	120 ± 6.00	120 ± 5.00	110 ± 7.00
Aloe vera	112 ± 5.00	110 ± 7.00	102 ± 5.00
Irradiation	178 ± 9.00^{a}	199 ± 10.00^{a}	185 ± 9.00^{a}
Aloe vera + irradiation	$150 \pm 7.00^{a\,b}$	$152 \pm 7.00^{a\,b}$	$146 \pm 6.00^{a\,b}$
Insulin levels (μIU/ml)			
Control	0.21 ± 0.010	0.20 ± 0.020	0.21 ± 0.010
Aloe vera	0.20 ± 0.011	0.20 ± 0.015	0.22 ± 0.011
Irradiation	0.60 ± 0.030^{a}	0.31 ± 0.025^{a}	0.28 ± 0.015^{a}
Aloe vera + irradiation	0.60 ± 0.040^{a}	0.30 ± 0.020^{a}	0.29 ± 0.014^{a}

Each value represents the mean of 6 record ± standard error
[a] Significance when compared to control
[b] Significance when compared to irradiated groups

peroxidase, which scavenge H_2O_2 [19]. Furthermore, *Aloe vera* contains vitamins A, C, E, B12, and folic acid, besides β-carotene, choline and zinc, all found naturally [20]. The significant amelioration in the radiation-induced disorders of the antioxidant status of animals is probably due to the presence of these potent antioxidants that aids in the repair process.

Aloe vera has been claimed to be a useful adjunct for lowering blood glucose in diabetic patients [5, 21]. However, there have been controversial reports on its hypoglycemic activity, probably due to differences in the parts of the plant used [22]. Data of the present study showed that oral supplementation of the whole leaf juice of *Aloe vera* to irradiated rats can significantly minimize the increase in plasma glucose levels while there was no amelioration recorded for the increase in plasma insulin levels (Table 4). Exposure to ionizing radiation increases gluconeogenesis, so it could be postulated that *Aloe vera* minimizes the increase in blood glucose levels, at least partly, through a decreased hepatic gluconeogenesis [23].

It is concluded that *Aloe vera* by suppressing radiation-induced lipid peroxidation and by enhancing the antioxidant system could play an important role in modifying radiation-induced oxidative stress.

3. Experimental

3.1. Experimental animals

Male Swiss Albino rats, (100–120 g) obtained from the Egyptian Organization for Biological Products and Vaccines were used. Animals were maintained under standard conditions of ventilation, temperature, and humidity. Food as standard pellets, containing all nutritive elements, and liberal water intake were available.

3.2. Radiation facility

Whole body gamma irradiation was performed with a Canadian Gamma Cell-40 (^{137}Cs) at the National Center for Radiation Research and Technology, Cairo, Egypt, at a dose rate 0.61 Gy/min. Rats were exposed to 7 Gy delivered as a single shot dose to induce drastic biochemical changes.

3.3. Aloe vera treatment

Aloe vera (*Aloe barbadensis* Miller) was purchased from Diffusion Express, France. The product was provided as the filtrate juice of whole leaf and animals received by gavage 0.25 ml of the juice/kg body weight.

3.4. Experimental design

Animals were divided into 4 groups of 18 rats each.
Group 1: Animals of this group were healthy animals neither exposed to radiation nor treated with Aloe and were considered as control. *Group 2*: Animals received daily supplementation of 0.25 ml/kg body weight of Aloe vera juice for 15 consecutive days. *Group 3*: Irradiated animals exposed to 7 Gy delivered as a single shot dose of gamma irradiation. *Group 4*: Animals treated with Aloe vera juice for 5 consecutive days pre-irradiation and 10 days post-irradiation.
Six rats of each group were sacrificed 3, 7, and 10 days after irradiation. Blood samples were collected. Samples of liver, lung and kidney tissues were obtained.

3.5. Biochemical analysis

Superoxide dismutase activity was measured by the method of Niskikimi et al. [24]. Catalase activity was assayed by the method described by Bergmeyer et al. [25]. Reduced glutathione content was determined by the method of Beutler et al. [26]. Malondialdehyde as thiobarbituric acid reactive substances (TBARS) were measured according to Yoshioka et al. [27]. Plasma glucose level was determined by the method of Howanitz and Howanitz [28]. Plasma insulin was determined by the immunometric assay using immulite kits [29].

3.6. Statistical analysis

For statistical analysis of the data student's "t"-test was used to determine the probable level of significance. The results were considered significant at ($P < 0.05$).

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