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Effects of Gamma Irradiation on Chemical and Antioxidant Properties of Iranian Native Fresh Barberry Fruit

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Abstract**—**Gamma irradiation greatly reduces the potential microbiological risk of fresh fruits, resulting in improved microbial safety as well as extending their shelf life. The effects of 0.5-2 kGy gamma doses on some physicochemical, microbial and sensory properties of fresh barberry fruits (*Berberis vulgaris*) during refrigerated storage for 40 days were evaluated. The total anthocyanin and total phenolic contents of barberry fruits decreased in a dose-dependent manner immediately after irradiation and after subsequent storage. In general, it is recommended that, according to the effect of gamma radiation on physicochemical, microbial and sensorial characteristics, doses of 1.25-2 kGy could be used.

Keywords**—**Antioxidant property, barberry fruit, chemical properties, gamma irradiation.

I. Introduction

BARBERRY is an Iranian native valuable shrub including two important varieties of *Berberis vulgaris* and *Berberis integerrima*. Barberry fruit and their products are rich in bioactive compounds like phenolic. These functional compounds affected fruit and their products appearance, physical features and flavor characteristics [1], [2]. Barberry fruit was produced about 16539 tones in Iran in 2014 [3]. Beside consumption of fresh fruits, they are used in preparing jelly, syrup, jam, barberry juice, concentrate and carbonated drink. Also, barberry dried fruits are used as food additives [1], [2], [4], [5]. At refrigerator temperature in less than 10 days barberry fruit will lose their color, texture firmness and flavor, gradually, they will become acidified and spoiled, microbiologically. To increase shelf life besides microbial safety, information about required dose to disinfect agricultural products is necessary. However, some properties of products will be affected as a result of microbial inactivation at target doses [6]. Therefore, effects of gamma irradiation on some key chemical properties of Iranian native fresh barberry fruit during 40 days refrigerated storage were studied.

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II. Material and Methods

A. Chemicals

Folin-Ciocalteu's reagent, Sodium fluoride, Gallic acid, Potassium chloride, sodium acetate (Merck, Darmstadt Germany), DPPH radicals (Sigma Aldrich, USA) were purchased.

B. Barberry Sample Preparation

Berberis vulgaris fully ripped fresh fruits were picked in November 2014 from gardens of Gaenat city (South Khorasan province). Fruits were chilled by cool air, then, 150 g of fruits were packed in swing cubic porous polyethylene terephthalate package (five holes with a diameter of 0.5 mm to prevent CO_2 and moisture accumulation). Packages were transferred to Atomic Energy Organization of Iran in Tehran for irradiation by means of refrigerated food vehicles at 0-1 °C to a distance of 1300 km.

C. Barberry Fruit Irradiation

Barberry fruits were irradiated in Gamma cell-220 irradiator (Nordion, Canada) at doses of 0, 0.5, 0.75, 1, 1.25, 1.5, and 2 kGy with dose rate of 2.62 Gy/s at ambient atmosphere. Dosimetry was done chemically, by means of Ferric dosimeter. Two samples were allocated to each dose of irradiation. Immediately, after irradiating, samples were placed at 4 °C (relative humidity 90-95%). Microbial and sensorial tests were done in days 1, 5, 10, 15, 20, 30, and 40 after irradiation.

D. Determination of Total Phenolic Content

Barberry fruit was frozen in liquid nitrogen, and samples were kept at -20 °C until they were analyzed. For each test 100 g of frozen fruit was homogenized by mixer.

Phenolic compounds were extracted using ethanol, distilled water and acetic acid (70: 29.5: 0.5 vol/vol) containing 2 mM sodium fluoride as solvent. Total phenolic content was determined using a Folin-Ciocalteu reagent, and the results were reported as mg of gallic acid per 100 grams of fresh barberry fruit [7].

E. Determination of Total Anthocyanin Content

The total anthocyanin content was determined by differential pH method using two buffer systems including potassium chloride buffer 0.025 M at pH = 1 and pH = 4, and sodium acetate buffer at pH = 4.5 and their absorbance at wavelengths of 533 and 700 nm [7].

F. Determination of Antioxidant Activity (DPPH)

The antioxidant activity of the samples was measured based on the inhibitory strength of free radical formation using DPPH radical [6].

G. Statistical Analysis

Results were analyzed in a factorial experiment based on completely randomized design, and results were expressed as mean ± standard deviation. Analysis of variance was performed by ANOVA procedure, and significant differences ($p < 0.05$) between the means were determined by Duncan's multiple range tests using SPSS software 20. In this study, two samples were irradiated at each mentioned dose, and each sample was tested in triplicate.

III. Results and Discussion

A. The Effects of Gamma Irradiation Processing on Total Anthocyanin Content

Anthocyanins are water soluble polyphenols to which the red color of barberry fruit is attributed [2]. According to Fig. 1 the decrease in total anthocyanin content increased significantly with increasing irradiation dose from 0.5 to 2 kGy ($p < 0.05$). Also, total anthocyanin content decreased significantly during storage time ($p<0.05$). At the end of the storage period, the content of anthocyanin in control and irradiated samples at doses of 1.5 and 2 kGy was significantly less than other samples ($p<0.05$). Also, there was no significant difference between irradiated samples in dose range of 0.5-1.25 kGy.

Gamma irradiation causes water radiolysis which leads to produce molecular active species and free radicals. Free radicals break down chemical bonds inside anthocyanins molecules. This destructs the round structure of anthocyanins which discolored them [8].

In contrast to these results, irradiation may cause an increase in anthocyanins content in many of green and non-climacteric fruits because of the increase in activity of phenylalanine ammonia-lyase (PAL) enzyme. It seems that gamma irradiation induced ethylene production and as a result activity of PAL will increase in green fruits [9].

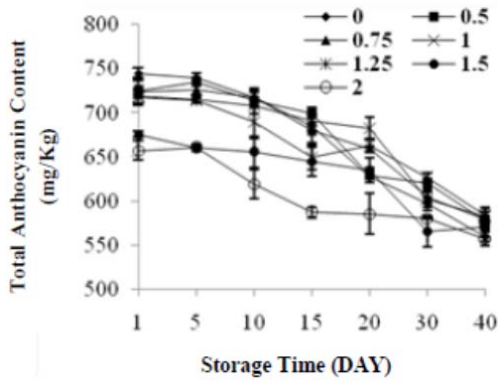

Fig. 1 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on Total Anthocyanin Content

B. The Effects of Gamma Irradiation Processing on Total Phenolic Content

Phenolic compounds affect nutritional and sensory properties of fruits [10]. Barberry fruit and its products are rich source of phenolic compounds particularly anthocyanins that affect their appearance properties [2]. According to Fig. 2, total phenolic content decreased significantly, about 6.4% by increasing radiation dose from 0.5 to 2 kGy. In all samples, the phenolic content decreased significantly during storage at 4 °C ($p < 0.05$). In control and irradiated samples at dose of 2 kGy, the reduction in phenolic compounds (24%) was higher than other samples. In contrast to, the irradiated sample at doses of 0.75-1.25 kGy had the lowest reduction (18%), at the end of the storage period. Increasing or decreasing phenolic compounds in agricultural products depend on irradiation dose, exposure time to radiation, extraction solvents, type of plant raw material and the time of evaluating phenolic compounds (immediately after irradiation or later) [11].

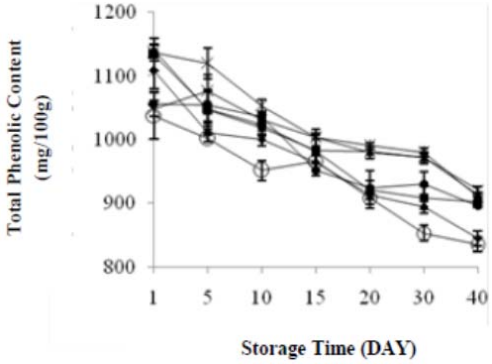

Fig. 2 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on Total Phenolic Content

C. The Effects of Gamma Irradiation Processing on Antioxidant Activity

The antioxidant activity of the samples decreased with increasing irradiation. DPPH radical scavenging from 35% in the control was decreased to 32% in the irradiated sample at 2 kGy, significantly ($p < 0.05$). Also, the antioxidant activity of the samples decreased significantly, during storage ($p < 0.05$). The reduction of antioxidant activity in control samples (29%) and irradiated samples at 1.5 and 2 kGy (26%) were significantly higher than other samples at the end of the storage time.

Increasing in phenolic compounds content and antioxidant activity of irradiated foods basically are attributed to enzymatic activities for example PAL and peroxidase enzymes, enhancing extraction of phenolic from plant texture, breaking down chemical bonds which leads to release soluble phenolic with low molecular weight [11]. Decreasing of phenolic compounds as a result of gamma irradiation may be attributed to their antioxidant role and scavenging free radicals and reactive oxygen species [10]. It should be noted that barberry fruit antioxidant activity is considerable, and it has been reported before [4], [5]. Barberry fruit antioxidant activity is related to its phenolic compounds (anthocyanins)

and ascorbic acid contents [5].

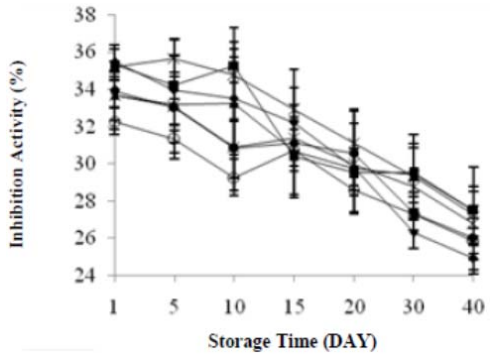

Fig. 3 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on antioxidant activity

D.The Effects of Gamma Irradiation Processing on Color Indices

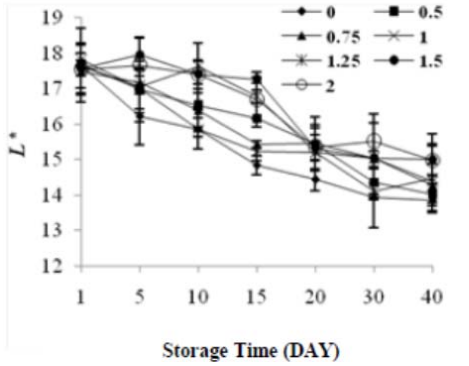

Fig. 4 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on L* color index

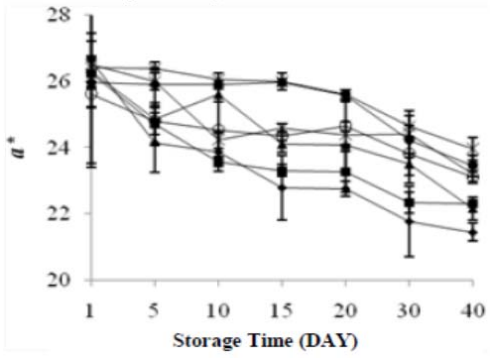

Fig. 5 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on a* color index

The attractive color of barberry fruit is attributed to its anthocyanins [2], which can affect its marketability. Reducing the content of anthocyanin pigment in barberry fruit can be effective on the color of the fruit and its products. In Figs. 4-6, the process of changing the color indexes is shown as *L* * (brightness / darkness), *a* * (red / green) and *b* * (yellow / blue). Immediately after irradiation, changes in *L* * and *b* * indices were not significant (p> 0.05). The value of *a* * at doses above 1.25 kGy decreased as a function of irradiation, significantly (p <0.05). Statistical analysis indicated a significant change in *L* *, *b* * and *a* * parameters during storage of barberry fruit samples (p <0.05). In general, *L* *, *a* * and *b* * color indices were reduced during the storage of barberry fruits, indicating a darkening of the color, redness and yellowing of barberry samples, and there was no significant difference between samples at doses less than 1 kGy. However, changes in these indices at doses higher than 1 kGy, especially 1.5 and 2 kGy, were significantly less than control sample (p <0.05), which could be due to the potential effect of irradiation on the reduction of enzymatic activity and fruit aging process. Such a process has been reported in strawberry irradiation up to 0.4 kGy [12]. Also, it has been reported that irradiation (0.5-1.5 kGy) did not have any significant effect on raspberry color, but color indices have been reduced during 5 days storage at 4 °C [13].

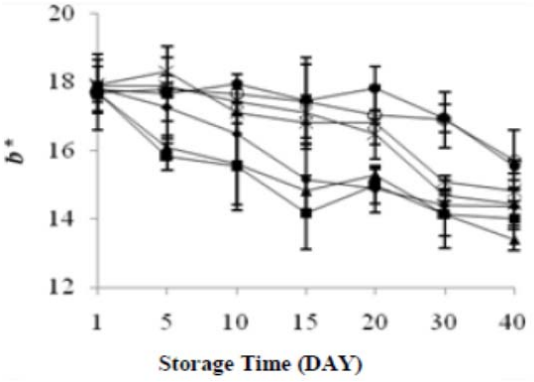

Fig. 6 Effects of gamma irradiation (0-2 kGy) and storage time (40 days at 4 °C) on b* color index

IV. Conclusion

Generally, according to the effect of gamma irradiation on different properties, doses of 1.25-2 kGy could be used to enhance shelf life and storage quality of fresh barberry fruits for 40 days at 4 °C.

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