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EFFECT OF GAMMA IRRADIATION ON PHYSICO-CHEMICAL AND NUTRITIONAL PARAMETERS OF CHESTNUTS[1]

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ABSTRACT

In this study, husked chestnut (Sarı Aşlama and Type 52509) fruits were subjected to gamma irradiation doses of 1, 3 and 5 kGy. Irradiated chestnuts and control samples were stored at 4±0.5°C temperature and 85-90% relative humidity for 30 days. In Sarı Aşlama cultivar, moisture (%), protein (g 100 g^{-1} dw) and fat (g 100 g^{-1} dw) values decreased at the end of storage ($p<0.05$); energy (kcal 100 g^{-1} dw) values exhibited a fluctuating trend throughout the storage with the greatest values at the end of 15th day ($p<0.05$). Singly irradiation treatment (1 kGy, 3 kGy and 5 kGy) did not effect on moisture content (%), crude protein (g 100 g^{-1} dw), total fat (g 100 g^{-1} dw), carbohydrate (g 100 g^{-1} dw), energy (kcal 100 g^{-1} dw) and firmness (N) values of Sarı Aşlama and Type 52509 chestnuts. The fact that the irradiation doses used in the study did not adversely affect the general quality parameters of chestnuts shows that these doses can be a useful application for the storage of chestnuts.

Keywords: *Castanea sativa*, quality parameters, storage

GAMA IŞINI UYGULAMALARININ KESTANELERDE FİZİKO-KİMYASAL VE BESLENME PARAMETRELERİNE ETKİSİ

ÖZ

Bu çalışmada kabuklu haldeki kestane (Sarı Aşlama ve tip 52509) meyvelerine 1, 3 ve 5 kGy dozlarında gama ışını uygulanmıştır. Işınlanan kestaneler, kontrol grubu ile birlikte 4±0.5°C ve %85-90 nisbi nemde 30 gün süreyle depolanmıştır. Sarı Aşlama çeşidinde depolama sonunda nem (%), protein (g 100 g^{-1} kuru ağırlık(ka)) ve yağ (g 100 g^{-1} ka) değerleri düşmüştür ($p<0.05$); enerji (kcal 100 g^{-1} ka) değerleri ise depolama süresince dalgalı değişimler göstermiş, en yüksek değerlerini 15. gün sonunda almıştır ($p<0.05$). Işın uygulaması tek başına (1 kGy, 3 kGy ve 5 kGy) Sarı Aşlama ve Tip 52509 kestanelerinde nem (%), ham protein (g 100 g^{-1} ka), toplam yağ (g 100 g^{-1} ka), karbonhidrat (g 100 g^{-1} ka), enerji (kcal 100 g^{-1} ka) ve sertlik (N) değerleri üzerine etki etmemiştir. Çalışmada kullanılan ışın dozlarının kestanenin genel kalite parametrelerine olumsuz etkide bulunmaması, bu dozların kestanelerin depolanmasında kullanılabilir bir uygulama olabileceğini göstermektedir.

Anahtar Kelimeler: *Castanea sativa*, kalite parametreleri, depolama

INTRODUCTION

Chestnut, a member of nuts, with about 40-45% water content has a special place in this group of fruits [26]. Because of high water content, preservation of chestnut is quite different from the other nuts.

Number of studies about preservation of chestnuts is quite limited. Limited number of researchers investigated the pre-harvest and postharvest changes in chestnuts [12, 13], effects of different package types and storage conditions [22, 1, 20] and the effects of different storage atmospheres [10, 28, 30].

Besides preservation of water content, prevention of microbial growth and seed germination are also considered as critical issue in preservation of chestnuts. In this sense, improvements in storage environment, proper packaging and supplementary treatments before the storage play an important role in preservation of chestnuts. Fumigation treatments play a key role in preservation of especially nuts and dried foodstuffs [7]. Methyl Bromide fumigation was once the most efficient means of fumigation. However, the use of methyl bromide was banned in several countries with Montreal Protocol enacted in 2015 [29]. With changing consumer demands, a need

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was emerged for the development and use of new methods alternative to chemical treatments. Irradiation treatments have recently experimented as an alternative to chemicals.

There are some earlier studies about the use of irradiation treatments in chestnuts. In some of these studies, irradiation treatments were used for disinfection [19, 18, 16, 27, 23], some others investigated the effects of irradiation treatments on the chemical composition of chestnuts [8, 4, 3, 6] or irradiation treatments were integrated into storage conditions [5, 9, 28, 15]. Apart from these studies, there are couple of studies about the definition of soaked chestnuts [11, 25].

In the present study, Sarı Aşlama chestnut cultivar commonly grown in the Marmara region of Turkey and the chestnut type of 52509 were used. No research had been done on the effect of gamma irradiation on physico-chemical and nutritional parameters according to chestnut cultivars. This study, it was aimed to evaluate the effects of irradiation applications according to the cultivars. Husked chestnut fruits were subjected to gamma irradiation treatments at 1, 3 and 5 kGy doses (recommended in Food Irradiation Regulation) and stored in nets for 30 days under 4±0.5°C temperature and 85-90% relative humidity conditions, the effects of different irradiation doses on physicochemical and nutritional characteristics of chestnuts throughout the storage were investigated.

MATERIALS AND METHODS

Preparation of Chestnut Samples

Sarı Aşlama chestnut cultivar and 52509-numbered chestnut type supplied from Yalova Atatürk Horticultural Research Institute (2015 harvest season) were used as the material of the present study. Disinfection or disinfestation was not performed and fruits were not coated with any materials.

Irradiation of The Chestnut Samples

Samples were sent to Gamma Pak Sterilization Co. located in Çerkezköy town of Tekirdağ (Turkey) province and irradiated with ^{60}Co at 1, 3 and 5 kGy doses. Absorbed doses were monitored with the use of a Harwell Amber Perspex dosimeter. Irradiated chestnuts were placed into nets (about 300 g) and stored for 30 days at 4±0.5°C temperature and 85-90% relative humidity.

Proximate Compositions

The % moisture, protein, fat, carbohydrate and ash contents were determined in accordance with AOAC [2]. Crude protein content was determined with the use of the Kjeldahl method, crude fat content with the use of N-hexane and Soxhlet method. Total carbohydrate content was determined by the calculation of the difference. Total energy was calculated as Energy (kcal) = 4x (g protein + g carbohydrate) + 9x (g fat) [5].

Firmness

The modified method of Cecchini et al. [10] was used in firmness measurements. Firmness measurements were conducted on shelled chestnuts. A texture analyzer (TA-TX Plus brand) device with a 2 mm diameter probe (Strain 20%) was used. Results were presented in Newton (N).

Experimental Design and Statistical Analysis

Experiments were conducted in randomized plots design with 3 replications. Dose factor (control, 1 kGy, 3 kGy and 5 kGy) and storage duration (initial, 15th and 30th day) were assessed together. Experimental data were checked with the Anderson-Darling test and variance homogeneity was checked with Levene's test. Data were then subjected to two-way ANOVA and significant means were compared with the use of Tukey's test. Minitab 17 statistical software was used in statistical analyses.

RESULTS AND DISCUSSION

Moisture

In Sarı Aşlama cultivar, the effects of storage durations on moisture contents were found to be significant ($p<0.05$) (Table 1). Moisture contents decreased with increasing storage durations. On the other hand, the effects of different irradiation doses on moisture contents were not found to be significant ($p>0.05$).

In type 52509 chestnuts, effects of irradiation doses ($p=0.055$) and storage durations ($p=0.409$) on % moisture were not found to be significant ($p>0.05$) (Table 2).

Barreira et al. [5] conducted a study on chestnuts and reported significant effects of storage durations on weight loss with the greatest value on the 30th day of storage. Kınay and Karaçalı [20] stored chestnut samples at 15-20°C temperature 60-65% relative

humidity and 0°C-90% relative humidity and reported increasing weight losses with increasing storage durations ($p<0.05$). Ma et al. [24] conducted a study on walnuts and reported that moisture content of irradiated and untreated walnuts decreased to 7-11% throughout the storage, 0.1 kGy doses yielded lower moisture contents than the other doses, but was not significantly different from the other treatments and the control treatment. Koç Güler et al. [21] conducted a study on natural hazelnut kernels and indicated that a decrease in moisture content throughout the storage was significant, but the effects of irradiation doses on moisture content were not significant.

Present irradiation treatments did not have significant effects on moisture change in both Sarı Aşlama cultivar and type 52509. Such insignificant effects of irradiation treatments on the moisture content of a nut with quite a high moisture content indicated that irradiation treatments at proper doses could be used in chestnuts.

Crude Protein

Effects of storage durations on the crude protein content of Sarı Aşlama cultivar were found to be significant ($p<0.05$) (Table 1). Decreasing protein contents were observed with increasing storage durations. On the other hand, the effects of different irradiation doses on crude protein contents were not found to be significant ($p>0.05$).

In Type 52509, effects of dose x storage duration interactions on protein contents were found to be significant ($p<0.05$) (Table 2). Accordingly, while significant changes were not observed in 3 and 5 kGy doses, reduced protein contents were observed in 1 kGy dose right after the application. However, values measured at the end of the 15th and 30th days were placed into the same statistical group as the others (Table 1).

Antonio et al. [3], conducted a review study on chestnuts and indicated in reference to Guo-xin et al. [17], that protein contents decreased with increasing irradiation doses. Barreira et al. [5], reported insignificant effects of irradiation doses and storage durations on protein contents of chestnuts ($p>0.05$). Ma et al. [24] reported that at the end of 120-day storage, while control and 0.5 kGy doses yielded similar protein contents, but respectively 6%, 5% and 8% lower protein contents were observed in 0.1, 1.0 and 5.0 kGy doses. Researchers also reported the greatest protein content for 5 kGy dose right after application.

Irradiation treatments did not influence the protein content of Sarı Aşlama cultivar, but reduced protein contents were observed in Type 52509 with a 1 kGy dose right after the application. Such findings indicated that irradiation treatments might have different outcomes in different cultivars. On the other hand, in Tip 52509, protein contents of irradiated samples throughout the storage were not significantly different from the control samples.

Total Fat

Effects of storage duration on the total fat content of Sarı Aşlama cultivar were found to be significant ($p<0.05$). Fat contents decreased with increasing storage durations. Irradiation treatment did not influence the total fat of Sarı Aşlama cultivar ($p>0.05$) (Table 1).

In Type 52509 chestnuts, effects of dose x storage duration interactions on total fat contents were found to be significant ($p<0.05$) (Table 2). Changes in proportional fat contents throughout the storage exhibited a fluctuating trend. The control group exhibited relatively a stable state throughout the storage. In 1 and 5 kGy doses, decreases were observed at the end of the 15th day, but similar values with the initial ones were observed at the end of the 30th day. In 3 kGy dose, high fat contents were observed on 15th day and similar values with the initial ones were observed at the end of the storage.

Barreira et al. [5], indicated significant effects of storage durations on fat contents of chestnuts and reported decreasing fat contents at the end of 30th day. Researchers also indicated that gamma irradiation doses did not have significant effects on fat contents ($p>0.05$). Fernandes et al. [15] reported significant effects of treatment doses and storage durations on fat contents of chestnuts. Ma et al. [24] indicated decreasing fat concentrations in walnuts throughout the storage and reported a rate of decrease respectively as 20%, 24%, 10%, 23% and 15% for 0.1, 0.5, 1.0 and 5.0 kGy doses.

While gamma irradiation doses did not have significant effects on the fat content of Sarı Aşlama cultivar, a fluctuating trend was observed in Type 52509. Then, it could be stated that treatment doses might yield different outcomes in different cultivars.

Carbohydrate

Effects of treatments doses and storage durations on carbohydrate contents were not found to be significant in both Sarı Aşlama cultivar and Type 52509 ($p>0.05$) (Table 1 and Table 2).

Fernandes et al. [15] indicated significant effects of treatment doses and storage durations on carbohydrate contents of chestnuts and reported decreasing carbohydrate contents with increasing

irradiation doses. Barreira et al. [5], indicated significant effects of storage durations, but insignificant effects of irradiation doses on carbohydrate contents and reported decreasing carbohydrate contents at the end of the storage.

Insignificant effects of irradiation treatments on carbohydrate contents of both chestnuts indicated that present doses could be appropriate for a storage duration of 30 days.

Energy

Effects of storage durations on energy values were found to be significant in Sarı Aşlama cultivar ($p<0.05$) (Table 1). Increasing energy values were observed with increasing storage durations. Irradiation treatment did not influence the energy value of Sarı Aşlama cultivar ($p>0.05$).

In Type 52509 chestnuts, effects of dose x storage duration interactions on energy values were found to be significant ($p<0.05$) (Table 2). A decrease was observed in 3 kGy treatment group at the end of 30-day storage. Energy values of the other dose groups and storage durations were similar to each other (Table 1).

Barreira et al. [5], reported decreased energy values at the end of the 30-day storage period ($p<0.05$) and indicated insignificant effects of irradiation doses on energy values of chestnuts. Fernandes et al. [15] indicated significant effects of both storage durations and irradiation doses on energy values of chestnuts.

Table 1. Effect of gamma irradiation doses on moisture (%), crude protein (g 100 g^{-1} dw), total fat (g 100 g^{-1} dry weight (dw)), carbohydrate (g 100 g^{-1} dw), energy (kcal 100 g^{-1} dw) and firmness (N) on Sarı Aşlama chestnut

Çizelge 1. Sarı Aşlama kestanesinde gama ışını dozlarının nem (%), ham protein (g 100 g^{-1} ka), toplam yağ (g 100 g^{-1} ka), karbonhidrat (g 100 g^{-1} ka), enerji (kcal 100 g^{-1} ka) ve sertlik (N) üzerine etkisi

	Dose *Doz* (kGy)	Storage Period (Days) / *Depolama Süresi (Gün)*			
		0	15	30	Overall average / *Genel ortalama*
Moisture *Nem* (%)	0	50.07±0.563	48.77±1.270	45.11±0.352	47.98±0.851 a
	1	48.14±4.050	50.83±1.450	44.97±2.310	47.98±1.640 a
	3	50.87±0.835	47.30±0.958	48.09±0.813	48.75±0.695 a
	5	50.48±0.537	48.59±1.190	47.89±0.283	48.99±0.546 a
	OA	49.81±0.951 A	48.88±0.648 AB	46.52±0.693 B	
Pdose = 0.804, pstorage period = 0.018, pdose*storage period = 0.369					
Crude Protein *Ham Protein* (g 100 g^{-1} dw)	0	9.44±0.086	10.64±0.247	8.85±0.326	9.64±0.290 a
	1	12.69±1.040	11.61±2.100	6.00±3.000	10.10±1.510 a
	3	9.49±0.400	9.61±0.190	8.62±0.041	9.24±0.202 a
	5	10.06±0.263	10.57±0.109	8.65±0.090	9.76±0.300 a
	OA	10.42±0.472 A	10.61±0.501 A	8.03±0.735 B	
Pdose = 0.822, pstorage period = 0.005, pdose*storage period = 0.140					
Total Fat *Toplam Yağ* (g 100 g^{-1} dw)	0	2.07±0.120	2.03±0.033	1.93±0.067	2.01±0.045 a
	1	2.20±0.100	2.20±0.100	1.90±0.000	2.10±0.064 a
	3	2.13±0.033	2.27±0.033	2.03±0.033	2.14±0.037 a
	5	2.07±0.033	2.17±0.120	2.00±0.000	2.08±0.043 a
	OA	2.12±0.038 A	2.17±0.043 A	1.97±0.022 B	
Pdose = 0.159, pstorage period = 0.001, pdose*storage period = 0.558					
Carbohydrate *Karbonhidrat* (g 100 g^{-1} dw)	0	78.330±3.050	83.867±0.297	80.829±0.447	81.010±1.200 a
	1	68.200±13.600	81.933±0.878	82.680±0.669	77.610±4.580 a
	3	77.690±3.230	83.546±0.625	82.090±1.400	81.110±1.360 a
	5	78.460±1.310	82.022±0.864	77.040±2.430	79.160±1.120 a
	OA	75.660±3.320 A	82.840±0.400 A	80.660±0.907 A	
Pdose = 0.709, pstorage period = 0.068, pdose*storage period = 0.681					
Energy *Enerji* (kcal 100 g^{-1} dw)	0	369.7±11.200	396.3±1.380	376.1±3.340	380.7±5.250 a
	1	343.4±49.600	394.0±11.600	371.8±14.500	369.7±16.900 a
	3	367.9±14.400	393.0±2.720	381.1±5.620	380.7±5.810 a
	5	372.4±4.87	389.9±2.690	360.8±9.580	374.4±5.300 a
	OA	363.4±11.800 B	393.3±2.700 A	372.5±4.560 AB	
Pdose = 0.818, pstorage period = 0.050, pdose*storage period = 0.920					
Firmness *Sertlik* (N)	0	25.470±1.420	30.420±3.360	26.420±1.800	27.43±1.400 a
	1	27.770±2.160	27.417±0.633	27.729±0.539	27.64±0.670 a
	3	26.250±1.430	28.734±0.916	31.340±5.020	28.53±1.750 a
	5	29.810±1.490	32.640±1.230	27.370±0.375	30.41±1.230 a
	OA	27.000±0.852 A	30.300±1.140 A	28.210±1.280 A	
Pdose = 0.319, pstorage period = 0.105, pdose*storage period = 0.266					

Mean± standard error of means / *Ortalama ± ortalamaların standart hatası*

Means not followed by the same capital letter in a row under each doses are significantly different ($p<0.05$).

Her bir dozda (satırda) ortak büyük harfi olmayan ortalamalar arasındaki fark önemlidir ($p<0.05$).

Means not followed by the same small letter in a column under each storage period are significantly different ($p<0.05$).

Aynı depolama periyodunda (sütunda) ortak küçük harfi olmayan ortalamalar arasındaki fark önemlidir ($p<0.05$).

Table 2. Effect of gamma irradiation doses on moisture (%), crude protein (g 100 g^{-1} dw), total fat (g 100 g^{-1} dw), carbohydrate (g 100 g^{-1} dw), energy (kcal 100 g^{-1} dw) and firmness (N) on Type 52509 chestnut

Çizelge 2. Tip 52509 kestanesinde gama ışını dozlarının nem (%), ham protein (g 100 g^{-1} ka), toplam yağ (g 100 g^{-1} ka), karbonhidrat (g 100 g^{-1} ka), enerji (kcal 100 g^{-1} ka) ve sertlik (N) üzerine etkisi

	Dose Doz (kGy)	Storage Period (Days) / *Depolama Süresi (Gün)*			
		0	15	30	Overall average / *Genel ortalama*
Moisture *Nem* (%)	0	51.80±1.020	52.77±0.482	50.92±0.946	51.83±0.502 a
	1	48.49±1.440	59.74±7.290	50.95±1.160	53.06±2.760 a
	3	50.25±0.874	47.87±1.940	46.57±2.750	48.23±1.140 a
	5	49.53±0.869	46.52±0.627	49.42±0.343	48.49±0.589 a
	OA	50.014±0.585 A	51.730±2.250 A	49.464±0.859 A	
Pdose = 0.055, pstorage period = 0.409, pdose*storage period = 0.100					
Crude Protein *Ham Protein* (g 100 g^{-1} dw)	0	12.24±0.485 Aa	11.54±0.179 Aa	11.52±0.324 Aa	11.77±0.212 a
	1	9.17±0.382 Bb	13.02±0.558 Aa	11.56±0.244 Aa	11.25±0.597 a
	3	11.43±0.174 Aa	12.07±0.213 Aa	11.80±0.067 Aa	11.77±0.123 a
	5	11.79±0.055 Aa	11.75±0.351 Aa	11.66±0.743 Aa	11.73±0.239 a
	OA	11.158±0.382 B	12.094±0.228 A	11.633±0.184 AB	
Pdose = 0.264, pstorage period = 0.006, pdose*storage period = 0.000					
Total Fat *Toplam Yağ* (g 100 g^{-1} dw)	0	2.03±0.033 Aa	2.10±0.100 Aab	2.17±0.120 Aa	2.10±0.050 a
	1	2.20±0.115 Aa	1.90±0.058 Bb	2.00±0.000 Aa	2.03±0.058 a
	3	2.03±0.033 Aa	2.33±0.033 Aa	2.00±0.000 Aa	2.12±0.055 a
	5	2.27±0.067 Aa	1.97±0.033 Bb	2.27±0.033 Aa	2.17±0.055 a
	OA	2.133±0.043 A	2.075±0.057 A	2.108±0.043 A	
Pdose = 0.117, pstorage period = 0.459, pdose*storage period = 0.000					
Carbohydrate *Karbonhidrat* (g 100 g^{-1} dw)	0	81.010±1.360	80.608±0.808	80.626±0.963	80.748±0.538 a
	1	78.740±3.380	78.200±2.480	82.130±1.070	79.690±1.390 a
	3	79.230±1.360	83.007±0.239	77.280±2.070	79.840±1.110 a
	5	77.180±2.050	83.039±0.876	78.940±1.790	79.720±1.200 a
	OA	79.040±1.020 A	81.212±0.843 A	79.744±0.856 A	
Pdose = 0.861, pstorage period = 0.220, pdose*storage period = 0.125					
Energy *Enerji* (kcal 100 g^{-1} dw)	0	391.3±4.050 Aa	387.5±3.020 Aa	388.1±3.870 Aa	389.0±1.930 a
	1	371.4±11.100 Aa	381.9±8.710 Aa	392.7±3.420 Aa	382.0±5.200 a
	3	381.0±5.310 ABa	401.3±0.883 Aa	374.3±8.300 Ba	385.5±4.690 a
	5	376.3±7.870 Aa	396.9±3.250 Aa	382.8±4.460 Aa	385.3±4.110 a
	OA	380.0±3.920 B	391.9±3.100 A	384.5±3.080 AB	
Pdose = 0.591, pstorage period = 0.033, pdose*storage period = 0.047					
Firmness *Sertlik* (N)	0	28.760±2.000	27.250±1.390	30.683±0.741	28.898±0.886 a
	1	31.780±1.750	31.050±1.390	31.250±2.770	31.360±1.030 a
	3	31.950±2.190	31.930±1.350	28.970±0.062	30.948±0.891 a
	5	32.990±1.050	28.530±1.760	35.520±1.980	32.350±1.310 a
	OA	31.371±0.902 A	29.689±0.849 A	31.610±1.040 A	
Pdose = 0.109, pstorage period = 0.232, pdose*storage period = 0.170					

Mean± standard error of means / *Ortalama± ortalamaların standart hatası*

Means not followed by the same capital letter in a row under each doses are significantly different ($p<0.05$).

Her bir dozda (satırda) ortak büyük harfi olmayan ortalamalar arasındaki fark önemlidir ($p<0.05$).

Means not followed by the same small letter in a column under each storage period are significantly different ($p<0.05$).

Aynı depolama periyodunda (sütunda) ortak küçük harfi olmayan ortalamalar arasındaki fark önemlidir ($p<0.05$).

The energy values of Sarı Aşlama cultivar were not influenced by irradiation treatments. However, decreased energy values of 3 kGy-treated Type 52509 chestnuts at the end of 30-day storage indicated that this dose could not be applied in these chestnuts.

Firmness

In Sarı Aşlama cultivar and Type 52509 chestnuts, effects of treatments doses or storage durations on firmness values were not found to be significant ($p>0.05$) (Table 1 and Table 2).

Antonio et al. [3] reported decreased texture values with high treatment doses at the end of 30-day storage. Cecchini et al. [10] indicated that chestnuts lost their elasticity under all storage conditions and tend to have greater firmness. Researchers also reported that in chestnuts stored under controlled atmosphere conditions for 60 days, reduced metabolic activities were observed due to low oxygen quantity and such a case then reduced weight loss and thus put forth maintenance of firmness for 60 days.

Insignificant effects of treatment doses on the firmness of chestnuts indicated that present doses could be used in Sarı Aşlama cultivar and Type 52509 chestnuts.

CONCLUSION

It was observed in this study that present gamma irradiation doses could be applied on Sarı Aşlama and Type 52509 chestnuts for investigated traits. Insignificant effects of irradiation doses (1 kGy, 3

kGy and 5 kGy) on the moisture content of Sarı Aşlama and Type 52509 chestnuts indicated that irradiation treatments could be applied to this nut fruit with quite a high moisture content.

Treatment doses did not influence the protein content of Sarı Aşlama cultivar, but 1 kGy dose reduced the protein content of Type 52509 chestnuts right after the application. Such a case revealed that irradiation treatments might yield different outcomes in different cultivars. Protein contents of Type 52509 chestnuts were not significantly different from the control group throughout the storage. It could be stated that gamma irradiation doses did not have negative effects on the protein contents of the chestnuts.

While different gamma irradiation doses did not influence the fat content of Sarı Aşlama cultivar, a fluctuating trend was observed in Type 52509 chestnuts. Irradiation treatments may yield different outcomes in different cultivars.

Insignificant effects of irradiation treatments on carbohydrate contents of both chestnuts revealed that present doses could be used for a storage duration of 30 days.

Irradiation treatments did not influence the energy values of Sarı Aşlama cultivar. However, in Type chestnuts, decreased energy values with 3 kGy doses at the end of 30-day storage indicated that this dose might be proper for Type 52509 chestnuts.

Treatment doses did not have significant effects on the firmness values of the chestnuts. Such a case indicated that present doses could be used in Sarı Aşlama and Type 52509 chestnuts.

The fact that the irradiation doses used in the study did not adversely affect the general quality parameters of chestnuts shows that these doses can be a useful application for the storage of chestnuts.

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REFERENCES

1. Algül, B.E., E. Ertan ve A. Dündar, 2016. Farklı ambalaj ve raf koşullarının kestane muhafazası üzerine etkileri. *Meyve Bilimi 1(Özel):19-25.*
2. AOAC, 1995. Cunniff, P., association of official analytical chemists. *Washington DC, 16. Edition.*
3. Antonio, A.L., M. Carocho, A. Bento, B. Quintana, M.L. Botelho and I.C.F.R. Ferreira, 2012. Effects of gamma radiation on the biological, physico-chemical, nutritional and antioxidant parameters of chestnuts - a review. *Food and Chemical Toxicology 50(9):3234-3242. doi.org/10.1016/j.fct.2012.06.024.*
4. Antonio, A.L., E. Ramalhosa, M.L. Botelho, B. Quintana, M.J. Trigo, A. Ferreira and A. Bento, 2011. Influence of gamma irradiation in the antioxidant potential of chestnuts (*Castanea sativa* Mill.) fruits and skins. *Food and Chemical Toxicology 49:1918-1923. doi.org/10.1016/j.fct. 2011.02.016.*
5. Barreira, J.C.M., A.L. Antonio, T. Günaydı, H. Alkan, A. Bento, M.L. Botelho and I.C.F.R. Ferreira, 2012. Chemometric characterization of gamma irradiated chestnuts from Turkey. *Radiation Physics and Chemistry 81:1520-1524. doi.org/10. 1016/j.radphyschem.2012.01.005*.
6. Barreira, J.C.M., M. Carocho, I.C.F.R. Ferreira, A.L. Antonio, I. Kaluska, M.L. Botelho, A. Bento and M.B.P.P. Oliveira, 2013. Effects of gamma and electron beam irradiations on the triacylglycerol profile of fresh and stored *Castanea sativa* Miller samples. *Postharvest Biology and Technology 81:1-6. doi.org/10.1016/ j.postharvbio.2013.02. 005.*
7. Bostan, S.Z. ve S. Koç Güler, 2012. Sert kabuklu meyvelerde ışın uygulamaları. *Akademik Gıda (Gıda Bilimi ve Teknolojisi Dergisi) 10(3):104-109.*
8. Carocho, M., A. Antonio, L. Barros, A. Bento, M. Botelho, I. Kaluska and I. Ferreira, 2012. Comparative effects of gamma and electron beam irradiation on the antioxidant potential of Portuguese chestnuts (*Castanea sativa* Mill.). *Food and Chemical Toxicology 50:3452-3455. doi.org/10.1016/j.fct.2012.07.041*.
9. Carocho, M., L. Barros, A.L. Antonio, J.C.M. Barreira, A. Bento, I. Kaluska and I.C.F.R. Ferreira, 2013. Analysis of organic acids in electron beam irradiated chestnuts (*Castanea sativa* Mill.): Effects of radiation dose and storage time. *Food and Chemical Toxicology 55:348-352. doi.org/10.1016/j.fct.2013.01.031*.
10. Cecchini, M., M. Contini, R. Massantini, D. Monarca and R. Moscetti, 2011. Effects of controlled atmospheres and low temperature on storability of chestnuts manually and mechanically harvested. *Postharvest Biology and Technology 61:131-136. doi.org/10.1016/j.post harvbio.2011.03.001*.
11. Chung, H.W., H. Delincee, S.B. Han, J.H. Hong, H.Y. Kim, M.C. Kim, M.W. Byun and J.H. Kwon, 2004. Trials to identify irradiated chestnut (*Castanea bungena*) with different analytical techniques. *Radiation Physics and Chemistry 71:*

179-182. doi.org/10.1016/j.radphyschem.2004.04.023.

12. Erdal, E., 2013. Kestanelerde (*Castanea sativa* Mill.) hasat öncesi ve sonrası dönemlerde meyve kalite özelliklerinin değişimi üzerine bir araştırma (Yüksek Lisans Tezi). *Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü Bahçe Bitkileri Anabilim Dalı, Aydın, 67s*.
13. Ertan, E. and G. Seferoğlu, 2003. The comparison of the biochemical characteristics of chestnut at fruit ripening and after traditional storage periods. *BioScience Research Bulletin 19(2):139-149*.
14. Ertürk, Ü., C. Mert and A. Soylu, 2006. Chemical composition of fruits of some important chestnut cultivars. *Brazilian Archives of Biology and Technology, 49(2):183-188. doi:10.1590/S1516-89132006000300001*.
15. Fernandes, A., J.C.M. Barreira, A.L. Antonia, A. Bento, M.L. Botelho and I.C.F.R. Ferreira, 2011. Assessing the effects of gamma irradiation and storage time in energetic value and in major individual nutrients of chestnuts. *Food and Chemical Toxicology 49:2429-2432. doi.org/10.1016/j.fct.2011.06.062*.
16. Guo, W., X. Wu, X. Zhu and S. Wang, 2011. Temperature-dependent dielectric properties of chestnut and chestnut weevil from 10 to 4500 MHz. *Biosystem Engineering 110:340-347. doi.org/10.1016/j.biosystemseng.2011.09.007*.
17. Guo-xin, Z., D. Qiong-ling, X. Yao-chang and L. Si-lian, 1980. Effect of ^{60}Co gamma irradiation on the storage of Chinese chestnut fruits, *Acta Bot. Sin. 22:404-406*.
18. Hou, L., J. Hou, Z. Li, J.A. Johnson and S. Wang, 2015. Validation of radio frequency treatments as alternative non-chemical methods of disinfesting chestnut. *Journal of Stored Products Research 63:75-79. doi:10.1016/j.jspr.2015.07.004*.
19. Hou, L., B. Ling and W. Shaojin, 2014. Development of thermal treatment protocol for disinfesting chestnuts using radio frequency energy. *Postharvest Biology and Technology 98:65-71. doi.org/10.1016/j.postharvbio.2014.07.007*.
20. Kınay, A. ve İ. Karaçalı, 2001. Kestane meyvelerinin taze olarak saklanmasında ambalaj tipleri ve depo koşullarının kalite üzerine etkileri. *Ege Üniversitesi Ziraat Fakültesi Dergisi 38(1):25-32*.
21. Koç Güler, S., S.Z. Bostan and A.H. Çon, 2017. Effects of gamma irradiation on chemical and sensory characteristics of natural hazelnut kernels. *Postharvest Biology and Technology 123:12-21. doi:10.1016/j.postharvbio.2016.08.007*.
22. Koyuncu, M.A., E. Ertan, E. Savran ve T. Dilmaç Ünal, 2003. Farklı ambalaj tiplerinin kestanenin (*Castanea sativa* Mill.) soğukta muhafazası üzerine etkileri. *Türkiye 4. Ulusal Bahçe Bitkileri Kongresi, 8-12 Eylül, Antalya, s:295-297*.
23. Kwon, J., Y. Kwon, M. Byun and K. Kim, 2004. Competitiveness of gamma irradiation with fumigation for chestnuts associated with quarantine and quality security. *Radiation Physics and Chemistry 71:41-44. doi:10.1016/S0969-806X(04)00188-4*.
24. Ma, Y., X. Lu, X. Liu and H. Ma, 2013. Effect of 60 Coγ - irradiation doses on nutrients and sensory quality of fresh walnuts during storage. *Postharvest Biology and Technology 84:36-42. doi:10.1016/j.postharvbio.2013.04.001*.
25. Mangiacotti, M., A.E. Chiaravalle, G. Marchesani, A. De Sio, C. Boniglia, E. Bortolin and S. Onori, 2009. Detection of irradiated chestnuts preliminary study using three analytical techniques. *Radiation Physics and Chemistry 78:695-698. doi.org/10.1016/j.radphyschem.2009.04.016*.
26. Soylu, A., 1984. Kestane yetiştiriciliği ve özellikleri. *Atatürk Bahçe Kültürleri Araştırma Enstitüsü, Yalova, Yayın No:59, 64s*.
27. Todoriki, S., M. Hasan, A. Miyanoshita, T. Imamura and T. Hayashi, 2006. Assessment of electron beam-induced DNA damage in larvae of chestnut weevil, *Curculio sikkimensis* (Heller) (Coleoptera: Curculionidae) using comet assay. *Radiation Physics and Chemistry 75:292-296. doi.org/10.1016/j.radphyschem.2005.08.001*.
28. Tzortzakis, N. and I. Metzidakis, 2012. Determination of heat stress and ultra-low oxygen in chestnut storage under control and modified atmospheres. *Food and Nutrition Sciences 3:387-393. doi:10.4236/fns.2012.33055*.
29. UNEP, 1992. United Nations Environment Programme, https://wedocs.unep.org/handle/20.500.11822/1/discover?filtertype_0=dateIssued&filter_relational_operator_0=equals&filter_0=%5B1990+TO+1999%5D&filtertype=dateIssued&filter_relational_operator=equals&filter=1992 (Date of Access: 23/12/2020).
30. Xu, J., 2005. The effect of low-temperature storage on the activity of polyphenol oxidase in *Castanea henryi* chestnuts. *Postharvest Biology and Technology 38:91-98. doi.org/10.1016/j.postharvbio.2005.05.011*.