

Determination of efficiency degrees on vigor and antioxidant content of after ripening treatment in eggplant seeds

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Abstract

The research was carried out over a period of two years to study the effects of ripening treatments at different temperatures on the viability, vigour and antioxidant composition of seeds of eggplant varieties 'Kemer 27', 'Aydın Siyahı' and 'Manisa Kır Çizgili' harvested at different periods. In the study, the controlled deterioration tests were kept at two different moisture content and the measurements of the electrical conductivity test were carried out in four different times. Antioxidant analyses were conducted individually for each maturity period. In both years, there were statistically significant differences in all maturation treatments of the cultivars 'Aydın Siyahı', 'Kemer 27', and 'Manisa Kır Çizgili' as determined by the controlled deterioration test with 18% and 20% seed moisture content, electrical conductivity, and antioxidant tests for all ripeness seed groups ($p < 0.05$). In the germination test of the control group seeds at 30 °C, the best results were between 58% and 99%, while the highest germination rates at the end of the controlled deterioration test ranged between 97% and 100%. After analysing the test results, it was found that the seed groups subjected to the 20/35 °C and 35 °C ripening processes performed better than the control group. Furthermore, it was found that the seeds obtained from the fruits harvested on the 75th day after anthesis (DAA) had higher viability than the other groups.

Keywords: after ripening; antioxidant; 'Aydın Siyahı'; 'Kemer 27'; 'Manisa Kır Çizgili'; seed maturity

Introduction

Eggplant (*Solanum melongena* L.), which has an important place in vegetable cultivation in Turkey and worldwide, is a member of the Solanaceae family. Eggplant seeds have a mucilage layer that can be observed especially after seed extraction. There is a proportional relationship between fruit set, fruit length, seed content, seed maturity, and the anthesis period. As fruit maturity increases, there is an increase in seed maturity, which leads to an improvement in seed germination and emergence performance, as well as viability and seed vigor (Passam and Balamtis, 1997; Perry, 1982). Due to various adverse factors related to cultivation or the region where cultivation is carried out, fruits harvested before reaching sufficient physiological maturity have been observed to continue seed development in vegetable species with fleshy fruits, supported by nutrient reserves in the fruit, due to being kept within the fruit (Petrova *et al.*, 1981). Eggplant seeds show an increase in seed

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moisture content during the early stages of development, attributed to rapid cell growth and differentiation, and later stages involve the synthesis of storage compounds, resulting in an increase in seed dry weight. In some cases, even before complete maturity, the seeds can acquire germination capability during the drying phase, leading to an increase in germination performance in some seed batches during early harvesting periods (Bradford, 2004). While seed vigor and viability increase with seed maturity, controlled deterioration and electrical conductivity tests reveal these differences in seed vigor. Controlled deterioration test (CD) is considered one of the most common vigor tests used to determine seed vigor. The effectiveness of controlled deterioration tests has been determined, and their relationship with seed maturity has been established in many vegetable species such as cucumber (Demir and Mavi, 2010), pepper (Eken and Mavi, 2014), and tomato (Ermiş *et al.*, 2015). Factors such as the decrease in leakage from the seed to the environment and the increase in seed cell development, as well as damage to seed tissues, can affect this test. Furthermore, studies conducted on vegetable seeds such as pepper (Eken and Mavi, 2014) and leek (Özden *et al.*, 2016), demonstrate that as seed maturity and vigor increase, the electrical conductivity (EC) value decreases (Demir and Ellis, 1992; Dias *et al.*, 2006; Martins *et al.*, 2012).

Post-harvest ripening is a physiological event that particularly occurs in summer species and has an impact (Weston *et al.*, 1992). While the effects of ripening treatments have not been detected in many vegetable species, it has been determined that seed quality increases during the storage process conducted after harvest, especially in the cucurbit family. Although the positive effects of post-harvest ripening treatments have been observed in the mentioned studies, the relationship between these effects and application temperature, duration, and level of maturity, particularly in terms of the seed's chemical content, has not been clearly explained and is found to be closely related (Ellis *et al.*, 1985; Weston *et al.*, 1992). The effect of post-harvest ripening tends to be more positive at higher temperatures compared to dormancy, although the seed does not need to have a high moisture content (Bai *et al.*, 2001). In addition, another effect is its potential to address irregular emergence issues in seedlings obtained from eggplant plants grown in protected cultivation for autumn production in Turkey. Post-harvest ripening treatments applied at specific temperatures and durations to underdeveloped or incompletely embryonated seeds resulting from a growing season with temperatures below the required level in autumn (early period) can enhance seed quality and increase the level of successful seedling establishment. In recent years, there has been an increase in studies on the biochemical content of plants and seeds in vegetable and fruit cultivation, showing their positive effects on human health and their ability to promote plant resistance to biotic and abiotic stress factors during cultivation. The levels of antioxidants, which are considered important bioactive compounds, can vary depending on the cultivated genotype and variety, harvest maturity, consumed plant part, and post-harvest processes (Deepa *et al.*, 2007). Polyphenols are important antioxidant phytochemicals, and in addition to their positive properties such as scavenging free radicals, they also contribute to changes in taste sharpness, bitterness, color, and aroma in fruits due to variations occurring during fruit growth and ripening (Estrada *et al.*, 2002). Considering their positive effects on human health and their contribution to the repair mechanisms in plants, the effectiveness of different harvest maturities and post-harvest ripening treatments on antioxidant changes should be investigated as a research topic, focusing on different genotypes and varieties. In eggplant cultivation, biotic and abiotic stress factors such as diseases, pests, and extreme temperatures can lead to early harvests. This study aims to address this problem faced by growers and the seed industry. Therefore, the objective is to determine how seed development is affected within the fruit during post-harvest ripening processes by collecting eggplant fruits at different harvest periods. Additionally, the aim is to identify the changes in seed vigor and biochemical content of these obtained seeds.

Materials and Methods

The study was carried out in the research laboratory and application areas of Uşak University, Faculty of Agriculture between 2018-2020. Seedlings of 'Kemer 27', 'Aydın Siyahı' and 'Manisa Kır Çizgili' varieties of eggplant (*Solanum melongena* L.) were grown in the field for 2 years. Seed extractions were carried out by applying 4 different ripening treatments to the eggplant fruits obtained from 4 different harvest periods (Figure 1).

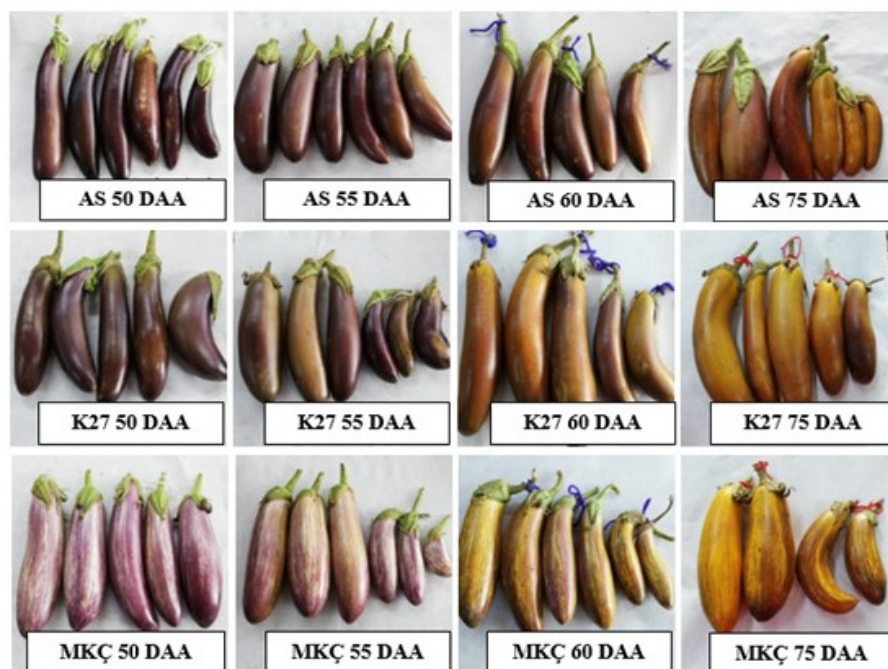


Figure 1. Images of the fruits of 'Aydın Siyahı' (AS), 'Kemer 27' (K27), 'Manisa Kır Çizgili' (MKÇ) variety harvested at different maturity periods

Biological material

Harvest periods

The fruits harvested at 50-55-60 and 75th days after anthesis (DAA) were used. The soil characteristics of the growing region are given in Table 1 and the climate characteristics are given in Table 2.

Table 1. Application field soil analysis results

	pH	Salt (ms/cm)	Lime (%)	Organic matter (%)	Soil texture (ml)	Total N (%)	Beneficial P (ppm)	Beneficial K (ppm)
0-30 cm	7.70	1059	9.1	0.84	65	0.042	0.56	250
Assesment	Lightly alkaline	Lightly salted	Medium chalky	Very little	Clay loam	Poor	Verry poor	Sufficient
Activated lime	0-30	-	-	-	-	-	-	-

Table 2. Application field soil analysis results

Climate data / (month)	January	February	March	April	May	June	July	August	September	October	November	December
Total rainfall (mm= kg/m ²)	70.5	36.4	35.7	18.4	54.6	43.4	15.2	23.6	14.6	26.9	63.4	92.9
Average temperature °C	3.2	6.05	8.6	12.9	16.9	20.6	23.3	24.4	20.3	12	9.6	3.7
Monthly average relative humidity %	76.9	69.9	63.2	54.2	58.4	58.9	48.1	45.5	48.6	53.6	67.3	80.3

Experimental procedures

After ripening periods

Eggplant fruits harvested in four different maturity (50-55-60-75 DAA) periods were kept in an oven for post-harvest ripening treatments in three different ways. The first group was kept in an oven at 35 °C for 10 days. In order to determine whether variable temperatures have an effect on ripening in the second and third groups, in different temperature treatments (The second group was kept at 20 °C for 5 days, then it was kept at 35 °C for 5 days. The third group was kept at 35 °C for 5 days. It was kept at 20 °C for 5 days.). Then, the extraction process was carried out to obtain seeds in the control group and all maturation groups. Control seeds were obtained by extraction from fruits harvested at each maturity period (Table 3).

Table 3. The treatment which performed on the day of harvest and after harvest for all three eggplant varieties

Harvest periods	After ripening method 1	After ripening method 2	After ripening method 3	Non-After ripening method
50, 55, 60, 75. DAA	35 °C, 10 days	20 °C 5 day + 35 °C 5 day	35 °C 5 day + 20 °C 5 day	Control

Controlled deterioration tests

Harvested seeds were subjected to aging test at 18% and 20% humidity at 45 °C for 24 hours. By using the formula based on seed weight, the moisture of the seeds was increased to 18 and 20% (ISTA, 2005). After the aging period, 4 × 50 replications / seeds were germinated at 25 °C. Germination test was carried out for 14 days in petri dishes, and the results were calculated by taking the germination percentages (roots emergence) of each replication.

Electrical conductivity test (EC)($\mu\text{Sm}^{-1}\text{g}^{-1}$)

For the electrical conductivity test, all cultivars were kept in 40 ml distilled water on 4 × 100 seeds for 2, 4, 6, 8, 10 and 24 hours at 20 °C. After each hour of application, all samples were measured with an EC meter (Hanna instruments EC 215) at room temperature (Agrawal and Dadlani, 1992). It has been observed that there are differences in the moisture content of the seeds depending on the variety and maturity period. While the highest moisture content was determined as 12% on the 60th harvest day, the lowest seed moisture was 5% on the 40th harvest day.

Extraction method and antioxidant analysis for antioxidant analysis

For the preparation of extracts, which is the preliminary stage of antioxidant analysis, the seed samples from all varieties were ground. Then, the ground seed samples were mixed with a solvent mixture (water: methanol, 60:40 v/v) in a 1:1 ratio. The mixture was vortexed for 1 minute, followed by centrifugation (7500 rpm, 4 °C, 10 minutes) for phase separation. After the specified time, the methanol-water phases were collected and used for total antioxidant capacity analysis (Sağlam, 2007; Zoral and Turgay, 2014).

The measurement of antioxidant capacity in plant extracts was performed according to the technique described by Apak *et al.* (2007). In a glass tube, sequentially, copper (II) solution, neocuproine solution, and ammonium acetate solutions were added in 1 mL each, followed by the addition of 100 µl of the extracted sample for analysis. After adding distilled water (1 mL) to bring the total volume to 4.1 mL, the contents of the tube were vigorously shaken. The solutions were kept in the dark at room temperature for 30 minutes, and at the end of the incubation period, the absorbance values at 450 nm in spectrophotometer against the reference solution were measured. The results were calculated based on the previously prepared Trolox standard curve ($R^2=0.997$). The results were expressed as micromoles per kilogram of seed.

Statistical analysis of the data was analysed with the Duncan test in the SPSS 17.0 package program. The differences were determined at the $p<0.05$ significance level.

Results and Discussion

Studies conducted on various vegetable species and the Controlled Deterioration (CD) test recommended by the International Seed Testing Association (ISTA) are considered as tests that reveal seed vigor. In our study, after the CD test conducted at 20% relative humidity for the 'Aydın Siyahi' variety, the highest germination rates were observed in the first year at 35 °C after the after-ripening (AR) treatment on the 60th DAA, with a rate of 83%. In the second year, the highest germination rate of 97% was observed on the 75th DAA after the AR treatment at 20/35 °C.

An increase in seed vigor and viability is expected with the increase in harvest maturity. When the results of both years were examined, it was determined that the differences in the AR treatment and harvest maturity at 35 °C were statistically significant for both harvest years (Figure 2). For the 'Kemer 27' variety, a more consistent relationship was observed among the germination rates when the results of both years were analysed. It was observed that the ripening treatments increased the germination rate even after the controlled deterioration test, compared to the control group where no ripening treatment was applied (Figure 3). In a study, significant differences were determined in the viability of pepper seeds with the CD test. The viability of seeds obtained 40 days after anthesis, 20 days after harvest and 60 days after anthesis, 1 and 10 days after harvest were found to be high, but no significant differences were found. While there was a 67% decrease in seed vigour with the CD test, germination decreased to 70% at both temperatures in the group harvested 80 days after anthesis. In addition, the seeds extracted 60 days after anthesis and showed maximum germination (85%) after CD test, while the viability of seeds extracted 40 days after anthesis and 20 days after harvest was 84% after CD test (Alan and Eser, 2008).

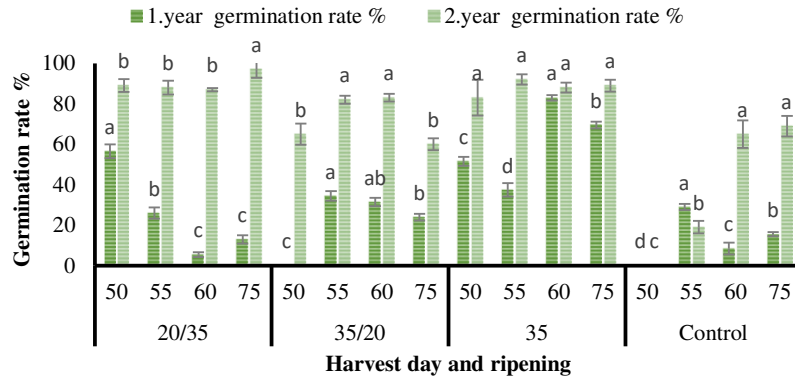


Figure 2. Changes in germination rate in ‘Aydın Siyahı’ cultivar as a result of the controlled deterioration test performed at 20% relative humidity as a result of the harvest day and ripening treatment of both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

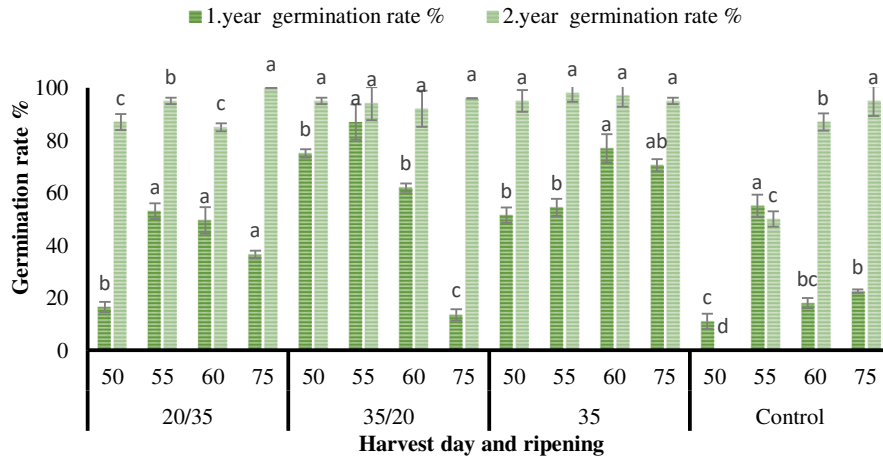


Figure 3. Changes in germination rate in ‘Kemer 27’ cultivar as a result of the controlled deterioration test performed at 20% relative humidity as a result of the harvest day and ripening treatments of both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

In contrast to the ‘Aydın Siyahı’ variety, the ‘Manisa Kır Çizgili’ variety showed different results according to the harvest years, particularly in early harvest periods (50-55 DAA). In the control groups where no after-ripening treatment was applied, almost no germination was observed, while the groups subjected to ripening treatments, especially during the 60th and 75th DAA, had germination rates ranging from 78% to 98% (Figure 4).

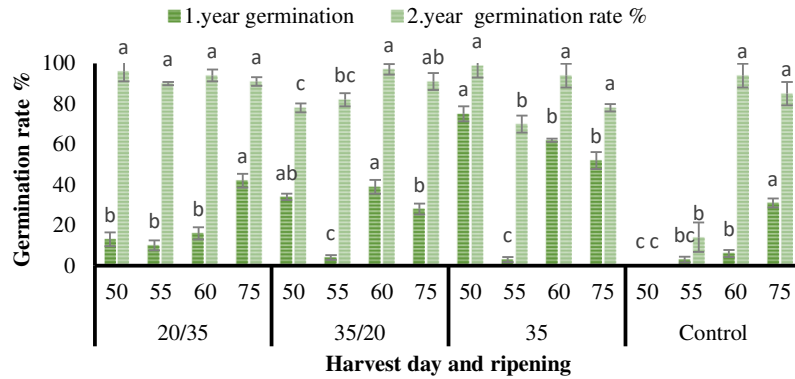


Figure 4. Changes in germination rate in 'Manisa Kır çizgili' cultivar as a result of the controlled deterioration test performed at 20% relative humidity as a result of the harvest day and ripening treatment of both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

Despite variations in germination rates between harvest years, it was determined that all ripening treatments for both 'Kemer 27' and Manisa 'Kır Çizgili' varieties resulted in an increase in germination rates by 3% to 99% compared to the control group in the 50-55 DAA period. Furthermore, the positive impact of harvest maturity on the results of the CD test supports the relationship between maturity and seed vigour (Figure 3; Figure 4). Eken and Mavi (2014) demonstrated in their study that there were differences in germination rates after the controlled deterioration test based on maturity periods. They found that in pepper, germination rates varied between 86% and 43% during the red-ripe stage in both harvest years, and that the increase in harvest maturity resulted in an increase in germination results after the controlled deterioration test. Demir and Mavi (2010) suggested that germination rates varied between 18% and 98% based on the CD test conducted at 48 hours with 20% seed moisture content. Considering that maturity is a harvest criterion and an important factor in seed germination, it was observed that early harvests increased seed viability, while maturity stages increased seed vigour and yielded positive results in vigour tests such as controlled deterioration (Figure 2; Figure 3; Figure 4).

According to the CD test conducted under 18% seed moisture conditions, the viability of the seed batches increased at both 35/20 °C and 35 °C temperatures compared to the control group. The increase in relative humidity, high-temperature treatment, and seed maturity all contributed to the positive outcome of the test. In the control group, particularly in the 50th and 55th DAA, a significant decrease in germination rates of 69-83% was observed, especially in the second year, compared to the ripening treatments (Figure 5). Celik and Kenanoğlu (2023), has found positive effects of post-harvest storage of eggplant fruits on improving the quality of their seeds.

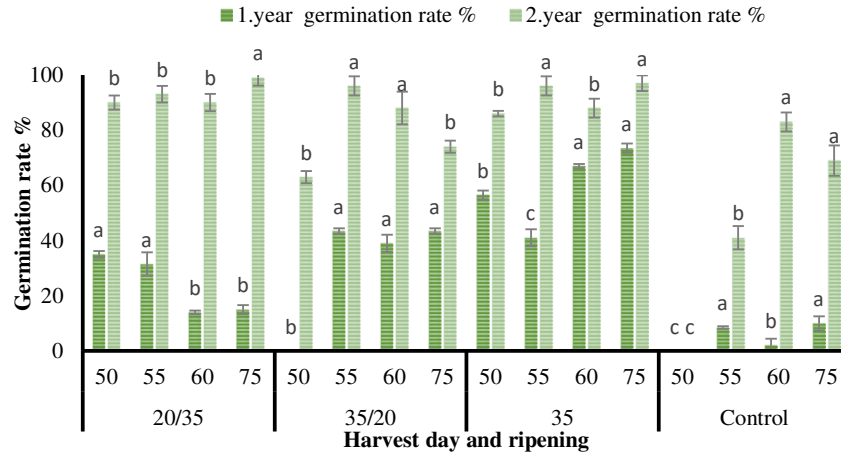


Figure 5. Changes in germination rate in ‘Aydın Siyahi’ cultivar as a result of the controlled deterioration test performed at 18% relative humidity as a result of the harvest day and ripening treatment of both harvest years

Statistical analysis was made among themselves for each ripening period and each harvest year

Barbedo *et al.* (1994) demonstrated that eggplant seeds obtained from fruits harvested 50 days after anthesis and subjected to 15 days of post-harvest storage were of higher quality. However, the same practice did not give the same results when the fruits were harvested 70 days after anthesis. In our study, all the harvests and subsequent treatments conducted on the ‘Aydın Siyahi’ variety were highly effective compared to the control group.

The results of the Controlled Deterioration (CD) tests conducted under 18% seed moisture conditions following the ripening treatments applied to the seed lots harvested at different maturity stages in the ‘Kemer 27’ variety are presented in Figure 6. Khanal *et al.* (2013) demonstrated that a slight difference in temperature between night and day (24 °C/17 °C) accelerated fruit ripening, while fruits obtained from day/night temperatures of 27 °C/14 °C exhibited higher levels of dry matter, soluble solids, and titratable acidity in tomatoes. In our study, the variable temperature treatments had different effects on seed maturity and viability levels.

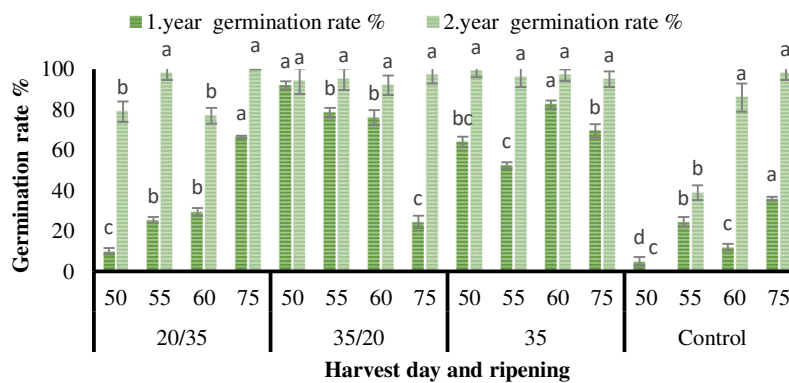


Figure 6. Changes in germination rate in ‘Kemer 27’ cultivar as a result of the controlled deterioration test performed at 18% relative humidity as a result of the harvest day and ripening treatment of both harvest years

Statistical analysis was made among themselves for each ripening period and each harvest year

In the ‘Kemer 27’ variety, the highest viability was determined in the seed lots subjected to the 20/35 °C ripening treatment during the 55th and 75th DAA (Figure 6). For the ‘Manisa Kır Çizgili’ variety, when comparing the viability of the seed lots in the CD test results, the viability was higher under the 18% seed moisture condition compared to the 20% condition. It was observed that the seed lots from early harvests showed the greatest decrease in viability under both conditions (Figure 4; Figure 5; Figure 6; Figure 7).

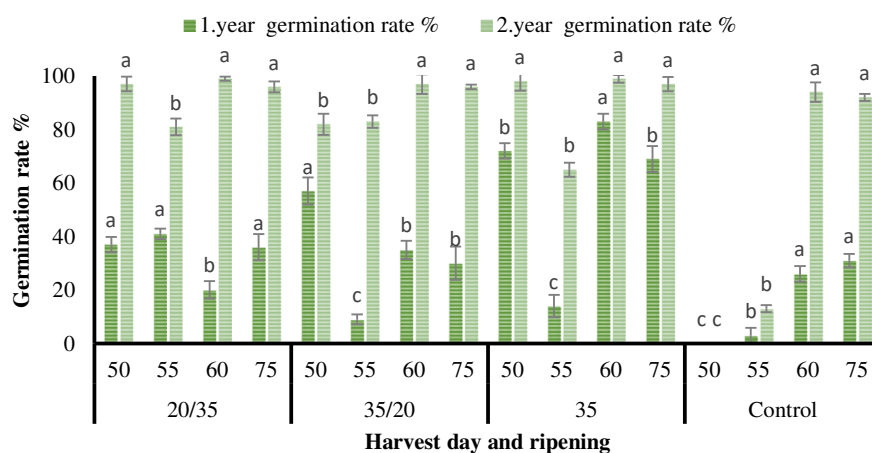


Figure 7. Changes in germination rate in ‘Manisa Kır Çizgili’ cultivar as a result of the controlled deterioration test performed at 18% relative humidity as a result of the harvest day and ripening treatment of both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

The use and efficiency of vigour tests depend on plant species, methodology development, and adjustment to obtain efficient procedures for evaluating the physiological potential of seeds. In a study conducted by Lopes *et al.* (2013), different methods were compared to assess the physiological potential of eggplant seeds. It was found that a controlled deterioration test conducted at 45 °C for 24 hours under 24% seed moisture content could be used for evaluation. However, when this test was applied at 45 °C for 24 hours and compared at three different moisture levels, as in our results, an increase in germination rate was observed in some seed lots.

With the increase in harvest maturity, there was a decrease in electrical conductivity values, especially in the range of 270-300 $\mu\text{S cm}^{-1} \text{g}^{-1}$. Seeds within this range are considered to have high viability and high seed vigour. Finding similar results, it was determined that the results of the electrical conductivity test were not affected because the pepper seeds obtained on the 40th day after anthesis were not yet mature and the membranes of the seeds extracted from the fruits harvested between 60 and 70 days were well-structured (Vidigal *et al.*, 2009).

A decrease in the electron leakage rate from the seed to the water is expected with an increase in seed maturity during the Electrical Conductivity (EC) test. When all the results are compared, although there were fluctuations in the control group, the maturity processes and the increase in maturity resulted in a decrease in EC test results (Tables 4-5-6). Eken and Mavi (2014) reported that the electrical conductivity values (EC) of seeds from different maturity stages of bell peppers were above 800 $\mu\text{S cm}^{-1} \text{g}^{-1}$ during the green maturity stage, indicating a loss of seed viability. However, during the red maturity and overripe stages, the EC value was below 400 $\mu\text{S cm}^{-1} \text{g}^{-1}$, indicating high seed viability and vigour in those seed lots.

In our study, ‘Aydın Siyahi’ and ‘Kemer 27’ varieties exhibited a range of 38-699 $\mu\text{S cm}^{-1} \text{g}^{-1}$, while the ‘Manisa Kır Çizgili’ variety showed an increase in electrical conductivity, especially in the 50th DAA period, due to insufficient embryo development in the seeds and unstable cell membrane permeability (Table 4; Table 5; Table 6).

Table 4. The relationship between the harvest day and ripening practices of both harvest years and the electrical conductivity value ($\mu\text{S cm}^{-1} \text{g}^{-1}$) in ‘Aydın Siyahi’ cultivar

Maturity	DAA	First year (EC value)				Second year (EC value)			
		2h	6h	10h	24h	2h	6h	10h	24h
20/35	50	97.8 bc	116.3 b	137.8 b	151.8 b	108.1 b	137.2 c	144.9 c	159.7 c
	55	76.2 ab	64.3 a	64.9 a	64.1 a	96.6 b	150.4 c	161.3 c	191.6 d
	60	112.6 c	114.9 b	128.2 b	133.1 b	58.4 a	76.4 a	81.4 a	86.3 a
	75	52.4 a	59.2 a	59.3 a	58.2 a	91.3 b	113.4 b	118.9 b	118.6 b
35/20	50	236.6 d	264.1 c	302.9 c	331.5 c	200.4 b	285.1 c	302.1 c	360.8 b
	55	107.2 c	110.1 b	120.6 b	130.9 b	90.7 a	125.4 b	128.5 b	135.9 a
	60	83.9 b	75.4 a	78.8 a	77.9 a	77.1 a	97.7 a	102.7 ab	102.7 a
	75	49.8 a	61.9 a	64.9 a	65.9 a	78.4 a	96.8 a	99.3 a	99.2 a
35	50	157.8 d	180.9 c	202.2 c	214.4 c	111.9 c	136.8 c	144.1 c	147.6 c
	55	75.5 b	83.6 b	89.6 b	92.8 b	75.8 ab	104.2 b	110.1 b	111.8 b
	60	116.5 c	102.1 b	105.4 b	104.9 b	56.8 a	73.8 a	80.2 a	81.6 a
	75	38.1 a	43.9 a	46.2 a	46.6 a	81.1 b	95.8 b	101.1 b	99.4 b
Control	50	511.4 c	569.5 c	644.3 d	699.4 d	292.7 c	354.2 d	383.8 d	484.5 d
	55	101.8 a	137.0 a	168.5 b	186.9 b	120.2 a	159.4 b	180.1 b	217.6 b
	60	316.7 b	335.2 b	383.4 c	417.7 c	103.1 a	116.2 a	125.2 a	130.7 a
	75	61.7 a	75.9 a	82.0 a	86.3 a	181.3 b	222.8 c	237.5 c	298.1 c

Statistical analysis was made among themselves for each ripening period and each harvest year. The differences were determined at the $p < 0.05$ significance level.

According to the results of EC measurements in seed lots harvested at different maturity periods in two year and subjected to different ripening treatments were evaluated statistically; Duncan test between harvest day and ripening groups, it was determined that EC value decreased with the period of the harvest day and there were statistically significant differences between harvest days. In ‘Aydın Siyahi’ variety, the most statistically significant group was observed on the 75th harvest day in the first year and on the 60th harvest day in the second year for control and all ripening groups. It was determined that the letter groups changed and their significance decreased as the harvest day shortened in all three varieties ($p < 0.05$) (Table 4).

Table 5. The relationship between the harvest day and ripening practices of both harvest years and the electrical conductivity value ($\mu\text{S cm}^{-1} \text{g}^{-1}$) in ‘Kemer 27’ cultivar

Maturity	DAA	First year (EC value)				Second year (EC value)			
		2h	6h	10h	24h	2h	6h	10h	24h
20/35	50	188.1 c	216.8 c	256.5 c	287.4 c	117.6 c	152.6 c	157.5 c	163.9 c
	55	97.8 b	112.3 b	119.1 b	117.4 b	94.4 bc	116.7 b	119.7 b	121.1 b
	60	88.5 ab	102.1 b	106.5 ab	106.1 b	70.5 ab	89.1 a	91.9 a	91.9 a
	75	70.8 a	76.7 a	77.7 a	73.9 a	56.2 a	89.4 a	93.4 a	91.9 a
35/20	50	107.5 c	143.7 b	155.7 b	162.4 b	98.5 a	141.4 b	147.7 b	154.2 b
	55	65.6 a	85.8 a	89.3 a	86.9 a	96.1 a	119.8 a	123.5 a	130.6 a
	60	120.6 c	143.2 b	155.3 b	167.6 b	95.4 a	116.7 a	119.7 a	118.9 a
	75	85.8 b	95.2 a	97.1 a	90.9 a	102.5 a	116.9 a	123.6 a	122.1 a
35	50	144.9 c	194.8 c	216.3 c	235.8 c	134.2 b	162.1 c	167.0 c	172.2 c
	55	50.1 a	92.8 a	97.7 a	100.6 ab	100.8 ab	119.9 b	123.5 b	128.6 b
	60	115.2 b	131.5 b	137.8 b	141.5 b	51.8 a	69.1 a	71.9 a	73.9 a
	75	64.2 a	69.6 a	70.9 a	61.6 a	62.2 a	77.3 a	80.3 a	82.1 a
Control	50	183.7 b	248.2 b	269.1 b	344.4 b	250.9 c	311.1 c	358.8 c	434.9 c
	55	75.9 a	89.8 a	95.7 a	94.0 a	122.7 b	181.3 b	213.4 b	277.9 b
	60	301.6 c	346.2 c	376.5 c	514.4 c	110.8 ab	128.6 ab	133.9 a	132.5 a
	75	87.84 a	90.9 a	94.1 a	102.1 a	77.9 a	102.9 a	107.7 a	108.4 a

Statistical analysis was made among themselves for each ripening period and each harvest year. The differences were determined at the $p < 0.05$ significance level.

In general, the most statistically significant group in ‘Kemer 27’ cultivar was 75th harvest day in both years for control and all ripening groups. It was determined that the letter groups changed and their significance decreased as the harvest day shortened in all three varieties ($p < 0.05$) (Table 5). And also, ‘MKÇ’ cultivar, the 75th harvest day was the most statistically significant group for all treatment groups and control seeds, except for the ripening group at 35 °C after harvest ($p < 0.05$) (Table 6).

Table 6. The relationship between the harvest day and ripening practices of both harvest years and the electrical conductivity value ($\mu\text{S cm}^{-1} \text{g}^{-1}$) in ‘Manisa Kır Çizgili’ cultivar

Maturity	DAA	First year (EC value)				Second year (EC value)			
		2h	6h	10h	24h	2h	6h	10h	24h
20/35	50	276.5 c	317.1 c	344.6 c	357.7 c	116.7 b	135.9 b	139.9 b	146.2 b
	55	160.3 b	185.7 b	196.9 b	200.9 b	107.4 b	127.9 b	132.9 b	138.2 b
	60	103.6 a	124.3 a	133.1 a	134.9 a	72.6 a	82.7 a	86.6 a	86.4 a
	75	84.9 a	107.9 a	110.1 a	108.3 a	65.9 a	94.4 a	96.5 a	94.9 a
35/20	50	198.9 b	234.3 b	260.6 b	276.7 b	154.3 b	182.1 b	194.8 b	228.7 b
	55	189.1 b	228.1 b	312.9 c	377.5 c	88.3 a	119.5 a	128.3 a	136.8 a
	60	90.2 a	107.3 a	112.9 a	113.3 a	89.4 a	102.7 a	103.9 a	104.6 a
	75	77.2 a	97.7 a	99.9 a	98.9 a	91.4 a	113.6 a	118.4 a	126.3 a
35	50	244.4 b	261.1 c	731.1 c	1159.4 c	117.9 c	139.6 c	144.2 c	147.8 b
	55	127.9 a	171.2 b	211.3 b	238.5 b	102.3 b	132.4 c	148.3 c	173.8 c
	60	99.9 a	119.1 a	123.3 a	122.1 a	71.4 a	80.9 a	84.5 a	85.4 a
	75	91.3 a	114.3 a	121.4 a	122.6 a	72.7 a	89.9 b	93.1 b	93.6a
Control	50	397.6 c	474.4 d	562.1 d	626.8 d	202.4 d	244.5 d	275.3 d	360.6 c
	55	181.1 b	225.5 c	270.8 c	301.8 c	122.6 c	177.6 c	198.3 c	271.9 b
	60	123.7 a	173.9 b	206.1 b	225.3 b	97.3 b	118.2 b	122.0 b	124.2 a
	75	105.5 a	127.7 a	138.1 a	141.3 a	68.5 a	86.6 a	88.5 a	92.5 a

Statistical analysis was made among themselves for each ripening period and each harvest year. The differences were determined at the $p < 0.05$ significance level.

In a two-year pepper study, seeds were found to have different moisture contents at physiological maturity, namely 53 and 72%, respectively. The highest electrical conductivity value gradually decreased from 20 days after anthesis to 65 days. As a result, maximum electrical conductivity was associated with the lowest germination percentage. Seed lots with high vigor were observed to have lower conductivity values between 65 and 75 days after anthesis (Vidigal *et al.*, 2011). These results, as reported by Demir and Ellis (1992) and Dias *et al.* (2006), indicate a decrease in electrolyte leakage during seed development due to increased integrity of the cell membrane structure. In our study, a decrease was also observed in electrical conductivity with an increase in maturity and ripening treatments. Specifically, the 75th DAA and 20/35 ripening treatments had lower EC values compared to the control group. The increasing DAA and ripening treatments can be seen as indicators of increased seed vigour in the EC test.

However, in recent times, along with vigour tests, research has focused on investigating changes in the biochemical composition of seeds to better explain physiology and understand the effects on seed quality and vigor. The strong antioxidant activities in the extracts obtained from the purple-coloured small eggplant fruits were found to be due to higher phenolic and anthocyanin content (Nisha, 2009). In our study, changes in antioxidant composition were also examined for ‘Aydın Siyahı’, ‘Kemer 27’, and ‘Manisa Kır Çizgili’ varieties for each harvest period, both in the control group and after ripening treatments (Figure 8; Figure 9; Figure 10). When examining the changes in antioxidant content for the ‘Aydın Siyahı’ variety, it was observed that the antioxidant content increased with maturity in both years, particularly the 35/20 ripening group yielded the highest results compared to the control group and other treatments. It revealed that seed dehydration during ripening and rehydration during imbibition lead to multiple single-stranded DNA breaks, especially in maize seeds, which are often due to absorptive damage (Ocvirk, 2014).

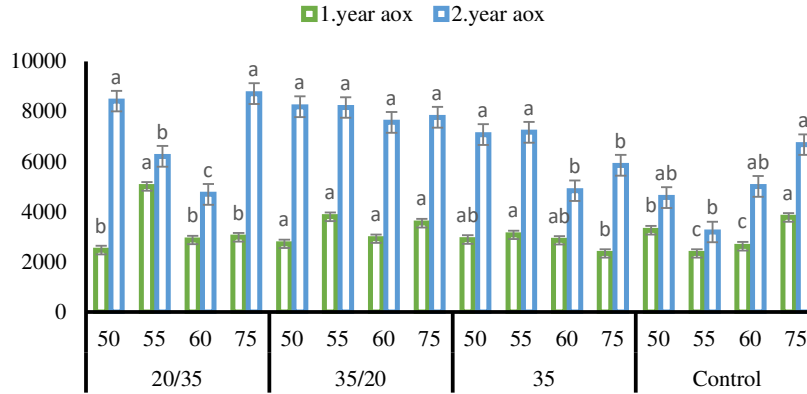


Figure 8. The relationship between harvest day and ripening applications and antioxidant composition (micromol/kg seed) of ‘Aydın Siyahı’ cultivar in both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

In a study, Deepa *et al.* (2007) reported the effect of harvest maturity and genotype on the antioxidant content of different pepper genotypes harvested at three different stages of ripeness. They reported that an increase in maturity in five species led to an increase in total antioxidant content. Similarly, in our study, it was observed that in all varieties, particularly in the 75th DAA, the antioxidant content was higher. In the early harvest periods, the seed development is supported by the ripening treatments. When compared to the control group, the 50th DAA showed an increase in the range of 144-1396 (micromol/kg seed) in the first year and 2700-4367 (micromol/kg seed) in the second year (Figure 9).

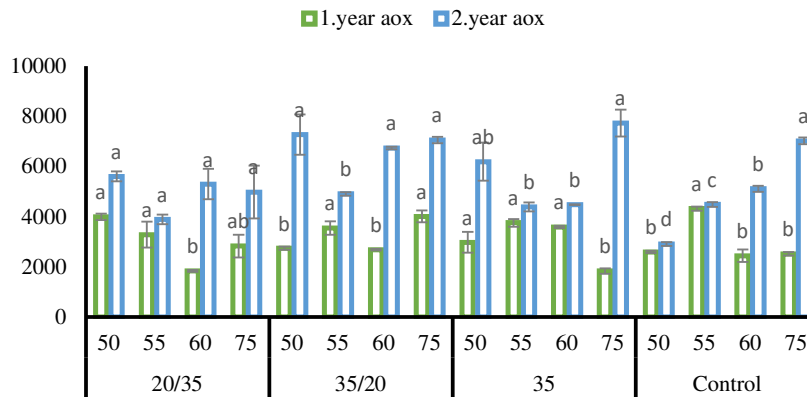


Figure 9. The relationship between harvest day and ripening applications and antioxidant composition (micromol/kg seed) of ‘Kemer 27’ cultivar in both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

The antioxidant values determined in the seed batches of the ‘Manisa Kır Çizgili’ variety harvested at different maturity stages and subjected to ripening treatments are given in Figure 10. In the results of the first year, the highest antioxidant value was observed in the seed lots subjected to 20/35 ripening treatment on the 75th DAA (5.589 micromol/kg seed). In the results of the second year, the 35 °C ripening treatment on the 50th DAA had the highest antioxidant content with a value of 8.613,6 (micromol/kg seed).

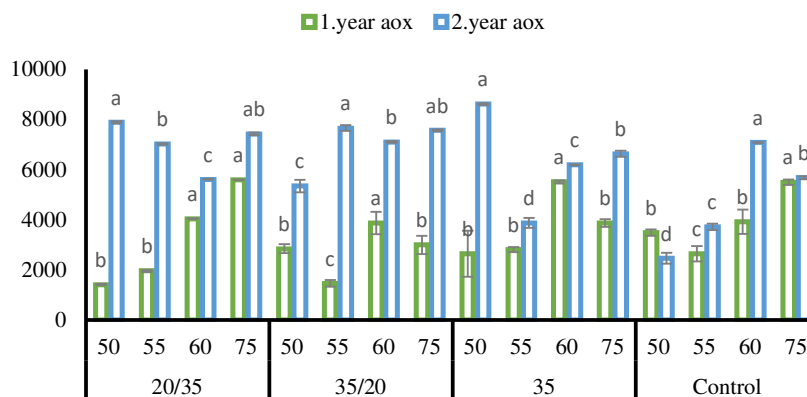


Figure 10. The relationship between harvest day and ripening applications and antioxidant composition (micromol/kg seed) of ‘Manisa Kır Çizgili’ cultivar in both harvest years
Statistical analysis was made among themselves for each ripening period and each harvest year

Harvest timing has an impact on the change in biochemical content. Generally, eggplants are harvested before reaching physiological maturity (Stommel and Whitaker, 2003). Research has shown that the quantity and quality of phytochemicals present in vegetables are significantly influenced by factors such as variety, ecology, soil, cultivation, and storage conditions (Antolovich *et al.*, 2000; Lee *et al.*, 2004; Naczki and Shahidi, 2004). Therefore, the quality of vegetables is supported by findings indicating the influence of maturity and ripening stages on their quality.

Conclusions

In our study, the results showed that ripening treatments increased seed viability in seeds of all varieties at different harvest maturity. In general, it was observed that the most statistically significant group was the 75th harvest day in ‘Aydın Black’, ‘Kemer 27’ and ‘Manisa Kır Çizgili’ varieties. It was determined that the letter groups varied and their significance declined as the harvest day shortened in all three varieties ($p < 0.05$). Seed viability and biochemical content increased with the prolonged harvest maturity period. In particular, ripening treatments at 20/35 °C and 35 °C had a positive effect on seed quality and germination rates of eggplant seeds after harvest. Eggplant varieties and their antioxidant potentials, which have an important place in nutrition worldwide, determine their nutritional quality. In this regard, the purpose of this study was to assess the influence of post-harvest ripening on the antioxidant properties of aubergine. Temperature and time treatments can be increased to more clearly show the reduction in germination rate using controlled deterioration test to determine seed viability. The lack of studies specifically analysing the relationship between seed antioxidant content and seed quality may encourage further research in this area. Since different maturity levels cause differences in seed viability, the germination temperatures used in the study did not always show the expected effect. Therefore, different germination and emergence temperatures can be evaluated in future studies.

Authors’ Contributions

Conceptualization: BBK, Methodology: BBK, Visualization: KÖ, Writing - original draft: BBK and KÖ, Writing - review and editing: BBK

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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