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Effects of hot water and UV-C on mineral content changes in two strawberry cultivars stored at different temperatures

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Abstract: In this study, two standard strawberry cultivars, Rubygem and Sabrina, were treated with UV-C (254 nm), hot water (60° C for 10 s), and UV-C + hot water after harvesting and stored in modified atmosphere packaging (MAP) at 0 °C and 5 °C. The variations in mineral contents including phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), sodium (Na), and zinc (Zn) were analyzed during storage periods. Analysis of variance for storage temperature, storage time, cultivar, and treatments showed that storing both cultivars at different temperatures followed by all treatments caused some increases in P and Mg contents as well as a decrease in Ca content. The treatments had both increasing and decreasing effects on Cu and Na contents. Moreover, increases in K, Mn, and Zn contents were observed in all treatments except for UV-C and UV-C + hot water applications for cultivar Rubygem.

Key words: Mineral content, storage, strawberry, temperature

1. Introduction

Horticultural crops are a source of vitamins and minerals that are potentially useful for human health (Ercisli et al., 2008b; Sengul et al., 2011).

Strawberry (*Fragaria* × *ananassa* Duch.) is a very important fruit in human diets. It is rich in vitamin C, minerals, folic acid, and phenolic compounds and contains high levels of natural antioxidants (Rice-Evans and Miller, 1996, Wang and Prior, 1996; Heinonen et al., 1998; Wang and Lin, 2000). It is also a low-calorie fruit that gives only 32 kcal energy per 100 g (Alvarez-Suarez et al., 2014), including fat-soluble vitamins (A and E) as well as some carotenoids (Giampieri et al., 2015).

The physicochemical properties and mineral contents of the fruit are not only related to botanical diversity, cultural practices, and ecological conditions but also to the maturity level, as well as postharvest storage conditions (Ercisli et al., 2008a, 2012; Mahmood et al., 2012). Strawberry is one of the most sensitive fruits that are not possible to store in cold temperatures for a long time. It can be only stored for 2–4 days at 2–5 °C, or for 10 days at 0 °C in 90%–95% relative humidity (Bal and Çelik, 2005).

In this study, the effects of different treatments including UV-C and hot water were studied on the quality, shelf life, and some mineral content changes of two commercial strawberry cultivars stored at different temperatures in modified atmosphere packaging (MAP) conditions.

2. Materials and methods

2.1. Preparation of strawberry cultivars

Two commercially cultivars, Rubygem and Sabrina, were grown in the ecological conditions of Tarsus (Mersin Province, Turkey) and harvested at the same maturity time. The fruits were precooled at 0 °C for 1 day.

2.2. Treatments

Fruits with the same maturity were divided into 4 groups according to treatments. The first group was the control group and was not treated. The second group was irradiated with a Vilber Lourmat UV-C lamp with 254 nm wavelength UV-C (0.25 kJ/m^2) on both surfaces for 5 min from a distance of 20 cm. The third group of fruits was kept at 60 °C for 10 s in a hot water bath. The fourth group of fruits was treated with UV-C and hot water together. Then all fruit samples were placed in a 250-g fruit bowl, wrapped in stretch film and kept in cold-air depots at 0 °C and 5 °C with relative humidity of 90%–95%.

2.3. Mineral content analysis

After treatment, the fruits were washed in tap water, dried, and placed in paper bags. Then the fruits were dried at 65 °C and milled in an IKA (Germany) grinding

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machine (Kacar and Inal, 2008). Later, 200 mg of milled fruit was placed in a 100-mL incinerator and 2 mL of nitric acid (67%) and 8 mL of H_2O_2 was added. Different mineral contents including phosphorus (P), calcium (Ca), magnesium (Mg), copper (Cu), manganese (Mn), and zinc (Zn) were measured by inductively coupled plasma optical emission spectroscopy. Potassium (K) and sodium (Na) were determined by the atomic absorption spectroscopy method.

2.4. Statistical analysis

The study was carried out as factorial experiments with four factors including time, treatments, temperature, and fruit variety based on a randomized design with 3 replicates. Analysis of variance was performed for storage time, treatments, temperature, and fruit variety. Means were then grouped according to the Duncan multiple range test at 5% probability level. Data were analyzed with SPSS.

3. Results and discussion

Both fruit cultivars lasted for 20 days at 0 °C; however, Rubygem fruits were able to last up to 12 days at 5 °C, while Sabrina fruits could only last for 8 days. Nevertheless, for all features, all comparisons were made at the level of subgroups and the results obtained were tabulated for each element because first-degree interactions were statistically significant.

The results on P contents showed that the treatments had different effects on storage time at different storage temperature as well as in fruit varieties. As shown in Table 1, in Rubygem fruits at 0 °C storage temperature, there were significant differences between hot water and UV-C + hot water treatments ($P < 0.05$), but at 5 °C the differences were all significant even in control conditions. In Sabrina fruits at 0 °C storage temperature, there are significant differences in all treatments, even controls, but at 5 °C, UV-C, and UV-C + hot water the treatments were statistically significant different ($P < 0.05$).

The results on K contents (Table 2) showed that in Rubygem fruits at 0 °C storage temperature, there were significant differences between hot water and UV-C treatments ($P < 0.05$), but at 5 °C the differences were significant only in control conditions. In Sabrina fruits at 0 °C storage temperature, there were significant differences between UV-C and UV-C + hot water treatments, but at 5 °C, only UV-C + hot water treatment showed a statistically significant difference ($P < 0.05$).

The results on Ca contents (Table 3) showed that in Rubygem fruits at 0 °C storage temperature, there were significant differences among all treatments except for UV-C application ($P < 0.05$), but at 5 °C the differences were significant in all treatments. In Sabrina fruits at 0 °C storage temperature, there was only a significant difference in UV-C + hot water treatment, but at 5 °C, no significant difference was observed in treatments.

The results on Mg contents (Table 4) showed that in Rubygem fruits at 0 °C storage temperature, there were significant differences between the control group and UV-C + hot water treatment ($P < 0.05$), but at 5 °C the differences were significant in all treatments except for UV-C application. In Sabrina fruits at 0 °C storage temperature, there were significant differences between UV-C and UV-C + hot water treatments ($P < 0.05$), but at 5 °C the difference between the applications on the 8th day was found significant and the Mg values in the UV-C group were lower than those of the other application groups ($P < 0.05$).

The results on Cu contents (Table 5) showed that when the storage temperature was 0 °C, the difference between the storage times in the UV-C and UV-C + hot water treatments was statistically significant ($P < 0.05$) in Rubygem fruits, but only in the UV-C + hot water application in Sabrina fruits. The lowest values were obtained on the 12th and 20th days in the UV-C application in the Rubygem variety at 0 °C. In the UV-C + hot water group, the highest value was obtained on the 16th day, although the difference from the first day was not significant. The difference between the other days was not statistically significant. In the Sabrina variety, the lowest value was again obtained on the 12th day, although this difference was not significant from the first day and the difference between the other days was not statistically significant. At 5 °C, a significant difference could only be observed in UV-C + hot water application in both Rubygem and Sabrina fruits.

Mn results are given in Table 6. In Rubygem fruits, there was only a significant difference at 5 °C in the control group ($P < 0.05$). According to this result, the first day's value was lower than the 8th and 12th days' values. However, in Sabrina fruits, a significant difference was observed between UV-C and UV-C + hot water treatments at both 0 °C and 5 °C ($P < 0.05$). The highest values were obtained on day 20 at 0 °C in both cultivars.

The results for Na values are given in Table 7. In Rubygem fruits, a significant difference at 0 °C storage temperature was only observed in UV-C treatment, while at 5 °C a significant difference was observed between control and UV-C + hot water treatments ($P < 0.05$). In Sabrina fruits at 0 °C storage temperature, a significant difference was shown only in the control group, while at 5 °C there was no significant difference observed. In addition, the difference between the storage temperatures on the 8th day in the control and UV-C groups was found to be statistically significant ($P < 0.05$).

The analysis of Zn contents (Table 8) showed that in Rubygem fruits differences among storage times in all treatments were not significant at 0 °C storage temperature,

Table 1. Descriptive statistics and comparison of results for P.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	4432.31	156.89	5365.94	85.66	C 4474.66	370.56	f C 4541.08	96.25
	8	#6083.96	147.26	4196.79	2546.49	ABC 5842.38	411.95	B 6598.90	40.43
	12	6003.11	370.56	6125.35	284.90	f BC 5469.89	162.66	B 6509.39	191.54
	16	9008.04	1750.79	6859.74	147.26	AB 6805.84	769.04	f A 7296.71	12.51
	20	7765.45	323.40	6981.98	352.28	A 7287.09	49.09	B 6727.88	223.30
Sabrina	0	B 4031.91	753.64	D 4371.68	367.68	B 2951.03	1382.15	D 5141.67	92.40
	8	A 6676.86	484.14	BC 6311.11	241.59	A 6471.85	298.38	B 6767.34	101.06
	12	A 6537.30	914.38	C 6140.75	535.15	A 6606.60	119.35	CD 5655.65	292.60
	16	bc A 6561.36	72.19	a AB 7448.79	139.56	ab A 7084.00	86.62	c BC 6071.45	221.37
	20	A 8402.63	94.33	A 7658.61	183.84	A 7820.31	181.91	A 7805.88	383.07
Varieties	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 4432.31	156.89	C 5365.94	85.66	B 4474.66	370.56	f 4541.08	96.25
	8	A 7197.29	0.29	B 6562.33	0.00	A 6884.76	391.74	6939.63	78.93
	12	A 7315.96	295.49	A 7343.88	80.85	A 6574.84	459.11	7060.90	342.65
Sabrina	0	4031.91	753.64	B 4371.68	367.68	2951.03	1382.15	B 5141.67	92.40
	8	7043.58	1112.65	A 7522.90	490.87	6906.90	440.82	A 6743.28	192.50

a, b, c, d: → In all tables, different small letters for the same cultivar, storage duration, and storage temperature represent significant differences among the treatments ($P < 0.05$).
A, B, C, D: ↓ In all tables, different capital letters for the same cultivar, storage temperature, and treatment represent significant differences among the storage durations ($P < 0.05$).
f: In all tables, difference from Sabrina cultivar in the same storage temperature, storage duration, and treatment is statistically significant ($P < 0.05$).
#: In all tables, difference from 5 °C temperature in the same storage duration, treatment, and cultivar is statistically significant ($P < 0.05$).

while at 5 °C, the difference was significant ($P < 0.05$) only in the control group. On the other hand, in Sabrina fruit at 0 °C storage temperature, the difference between the storage times was statistically significant ($P < 0.05$) only in UV application.

Inorganic molecules ensuring the continuity of life remain as ash after burning of foods. The ash analysis showed approximately 40 minerals, of which 17 are vital for the human body. Vital minerals are those that cause health deficiencies when lacking from the diet. Vital minerals are divided into macro or micro groups according to the amounts that the body needs. Macrominerals are calcium, phosphorus, potassium, magnesium, sulfur, sodium, and chlorine, while microminerals are iron, zinc, selenium, molybdenum, iodine, cobalt, copper, manganese, fluorine, and chromium (Soetan et al., 2010).

There are no comprehensive studies on the mineral content changes during strawberry cold storage, but it has been pointed out that mineral content changes based on many factors before and after harvesting, such as genotype, maturity, storage time, and temperature treatment (Cordenunsi et al., 2003; Alvarez-Suarez et al., 2014). Several important changes in mineral composition are related not only to the genotype, which determines the quality and quantity of the fruit, but also to maturity. Most chemical and compositional changes continue until fruit is harvested. On the other hand, it is known that the appropriate temperature between harvest and storage time is critical for the success of the applications. The low temperature and modified atmosphere are important for preventing mold growth and aging of the fruit, thus having an important role in extending the shelf life of strawberry.

Table 2. Descriptive statistics and comparison of results for K.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	15,668.70	917.61	C 16,219.10	2969.73	B 15,717.65	2398.22	21,529.31	4926.56
	8	29,606.75	4263.99	fA 29,471.25	1870.01	A 31,152.20	1895.22	# 27,319.79	404.62
	12	20,798.07	358.82	C 17,464.72	84.15	f B 16,957.95	201.75	16,928.94	1548.37
	16	26,991.93	6444.08	BC 20,887.55	1769.91	B 19,333.71	1668.71	18,936.22	6.64
	20	25,035.66	1222.16	AB 26,512.89	3306.04	f A 28,906.62	253.07	22,598.84	252.30
Sabrina	0	21,316.69	6732.84	C 14,325.92	1478.39	11,343.10	7207.88	B 18,084.34	238.58
	8	22,356.98	1464.96	BC 18,622.85	126.13	20,417.73	3498.83	B 21,397.23	2308.50
	12	17,960.07	2375.89	B 19,839.73	676.19	13,619.86	112.69	B 16,770.56	684.49
	16	20,092.31	2960.30	BC 18,745.93	2457.81	21,586.23	778.61	B 16,523.29	1024.74
	20	31,154.02	3055.05	A 29,844.17	1083.41	25,111.64	541.15	A 31,292.42	4838.31
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 15,668.70	917.61	16,219.10	2969.73	15,717.65	2398.22	21,529.31	4926.56
	8	A 29,248.14	0.14	21,153.66	3242.08	22,694.55	2136.59	21,080.06	1272.87
	12	B 19,328.62	2847.14	21,564.01	4279.77	19,693.19	612.47	18,099.47	2134.91
Sabrina	0	21,316.69	6732.84	14,325.92	1478.39	11,343.10	7207.88	B 18,084.34	238.58
	8	26,385.76	3036.20	21,309.37	6141.39	19,453.66	4544.71	A 20,456.43	331.16

Table 3. Descriptive statistics and comparison of results for Ca.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	A 4338.95	444.67	4827.90	271.42	A 4319.70	113.58	A 4120.46	239.66
	8	BC 2713.29	87.59	1984.48	1112.84	B 2292.68	128.98	B 2697.89	351.31
	12	# C 2232.04	79.89	2711.36	578.46	B 1937.71	48.90	B 2147.34	70.26
	16	B 3200.31	135.71	2303.46	618.69	B 2361.98	182.88	B 2421.65	269.50
	20	BC 2744.09	129.94	2198.35	26.95	B 2457.26	474.51	B 2544.85	154.00
Sabrina	0	3751.83	1024.10	4156.08	5.78	2380.26	973.09	A 5133.01	457.19
	8	2942.36	274.31	2999.15	269.50	3057.86	193.46	B 3177.21	29.84
	12	2918.30	456.23	2754.68	292.60	3091.55	284.90	B 2322.51	24.06
	16	2723.88	207.90	2966.43	361.90	2824.94	447.56	B 2778.74	256.99
	20	3657.50	215.60	3305.23	410.03	3778.78	71.22	B 3217.64	66.41
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + Hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	A 4338.95	444.67	A 4827.90	271.42	A 4319.70	113.58	A 4120.46	239.66
	8	B 2951.41	0.39	f B 2499.61	93.36	B 2314.81	193.46	B 2655.54	466.81
	12	a B 2966.43	34.65	b B 2388.93	165.55	c B 1908.54	49.18	bc B 2049.84	129.26
Sabrina	0	3751.83	1024.10	4156.08	5.78	2380.26	973.09	5133.01	457.19
	8	3130.05	500.50	3613.23	217.52	3369.71	360.94	2952.95	369.60

Table 4. Descriptive statistics and comparison of results for Mg.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 2132.90	25.03	2185.84	174.21	2116.54	6.74	B 2016.25	189.81
	8	A 2688.26	51.01	2797.41	213.29	2435.13	100.10	A 2711.36	102.99
	12	# B 2052.05	78.92	2082.85	107.80	f 1946.66	126.57	B 2206.05	21.17
	16	f B 2248.40	0.00	2124.24	14.44	2070.63	225.90	B 2272.46	27.91
	20	f A 2712.33	144.38	f2252.25	105.87	f 2332.14	124.16	B 2250.33	119.35
Sabrina	0	2039.15	565.37	C 2044.35	119.35	1543.08	865.09	B 2315.78	51.97
	8	3012.63	207.90	AB 2794.14	116.46	2848.04	416.76	A 3062.68	17.33
	12	2379.30	250.25	B 2562.18	125.13	2515.01	12.51	B 2363.90	125.13
	16	2723.88	11.55	AB 2862.48	215.60	2774.89	76.04	B 2444.75	123.20
	20	3591.09	126.09	A 3272.50	105.87	3300.41	89.51	A 3175.29	37.54
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 2132.90	25.03	2185.84	174.21	B 2116.54	6.74	B 2016.25	189.81
	8	A a 2746.20	5.00	b 2347.54	149.19	A a 2707.51	76.04	A a 2890.39	8.66
	12	A 2618.00	138.60	2461.11	85.66	B 2182.95	125.13	B 2307.11	56.79
Sabrina	0	2039.15	565.37	2044.35	119.35	1543.08	865.09	2315.78	51.97
	8	3429.39	293.56	3414.95	375.38	3360.09	345.54	2650.73	117.42

Table 5. Descriptive statistics and comparison of results for Cu.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	3.96	0.12	B 3.74	0.07	4.05	0.67	f AB 3.99	0.00
	8	f4.39	0.02	AB 4.16	0.00	4.00	0.19	C 3.45	0.41
	12	2.71	0.02	C 2.92	0.15	2.29	0.44	C 3.10	0.12
	16	4.76	1.18	A 4.65	0.39	4.00	0.90	A 4.65	0.33
	20	3.47	0.29	C 2.92	0.16	3.18	0.48	C 3.39	0.07
Sabrina	0	3.67	0.44	4.56	0.24	2.93	2.01	AB 3.36	0.04
	8	a 4.75	0.00	b 3.57	0.32	c 2.37	0.42	# b A 3.61	0.15
	12	2.91	0.49	4.75	1.55	2.59	0.03	B 2.83	0.02
	16	4.26	0.29	3.77	0.21	3.93	0.27	A 3.91	0.11
	20	3.92	0.12	4.08	0.45	4.16	0.06	A 3.76	0.27
Cultivars	Storage time (days)	Storage Temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	3.96	0.12	3.74	0.07	4.05	0.67	f A 3.99	0.00
	8	4.34	0.04	3.12	0.38	3.56	0.42	f A 4.21	0.06
	12	2.98	0.40	2.76	0.29	2.30	0.17	B 2.63	0.47
Sabrina	0	3.67	0.44	4.56	0.24	2.93	2.01	A 3.36	0.04
	8	3.49	0.84	2.67	0.49	3.19	0.16	B 2.58	0.01

Table 6. Descriptive statistics and comparison of results for Mn.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + Hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	55.02	1.77	49.49	2.29	56.32	2.42	52.48	9.82
	8	62.21	11.91	50.17	0.00	51.64	1.59	55.59	0.40
	12	# f 41.74	1.36	44.35	0.00	45.53	2.58	43.50	1.74
	16	65.57	0.00	54.65	5.68	60.04	12.40	67.45	5.77
	20	62.48	2.30	48.27	0.09	61.57	7.59	53.80	4.72
Sabrina	0	46.42	15.43	C 38.69	1.66	40.35	30.45	B 49.80	0.40
	8	64.92	5.00	BC 53.33	4.26	44.76	3.77	B 54.49	3.98
	12	57.18	1.88	BC 49.84	2.37	49.20	8.60	B 43.38	5.75
	16	65.46	1.49	AB 62.24	3.23	57.83	12.03	B 52.99	3.92
	20	75.23	6.10	A 74.09	10.24	68.42	4.92	A 70.22	4.54
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 55.02	1.77	49.49	2.29	56.32	2.42	52.48	9.82
	8	A 63.02	0.00	f 43.18	1.81	55.62	5.01	56.85	7.31
	12	A 62.23	1.36	52.10	2.22	45.60	0.40	55.35	5.15
Sabrina	0	46.42	15.43	B 38.69	1.66	40.35	30.45	B 49.80	0.40
	8	56.08	2.02	A 55.57	0.40	63.51	4.29	A 56.56	1.12

Table 7. Descriptive statistics and comparison of results for Na.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	f a 1220.91	0.00	B b 905.21	48.70	b 804.01	85.62	b 708.11	78.75
	8	# f 501.83	27.73	# B 592.17	196.97	1012.95	52.08	918.00	16.06
	12	862.99	89.00	B 796.70	64.34	f 757.68	47.97	874.05	281.35
	16	1237.23	486.01	B 834.51	71.02	976.31	156.04	1521.29	193.03
	20	1169.05	244.73	A 1286.01	53.31	1178.42	403.00	1023.81	200.13
Sabrina	0	B 811.78	72.88	899.87	173.00	714.28	216.38	717.11	185.34
	8	AB 1109.02	118.62	579.61	53.29	585.00	161.33	923.15	385.55
	12	B 801.96	109.74	979.50	149.88	1249.32	100.39	1087.04	332.58
	16	A 1441.77	92.31	1158.53	393.74	1194.20	381.14	917.41	195.95
	20	A 1543.03	172.01	926.05	223.93	847.19	198.97	783.03	154.90
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	f A a 1220.91	0.00	b 905.21	48.70	b 804.01	85.62	B b 708.11	78.75
	8	f B 642.05	0.05	595.76	175.55	951.99	0.00	B 558.03	145.08
	12	A 1301.61	129.93	1140.74	189.19	778.14	0.00	A 1339.36	168.68
Sabrina	0	811.78	72.88	899.87	173.00	714.28	216.38	717.11	185.34
	8	1307.07	118.39	1129.03	217.32	1090.88	134.59	853.67	345.42

Table 8. Descriptive statistics and comparison of results for Zn.

Cultivars	Storage time (days)	Storage temperature 0 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	33.03	0.33	34.93	3.30	36.16	4.76	32.35	5.17
	8	#39.93	0.30	42.02	0.00	39.94	2.08	41.51	2.55
	12	33.63	1.69	35.72	0.43	31.52	0.43	35.76	1.72
	16	38.48	0.00	36.90	3.35	32.69	5.62	36.68	1.49
	20	42.32	4.65	35.14	1.24	f 39.70	1.76	f34.84	1.60
Sabrina	0	37.92	5.87	C 36.13	2.56	23.90	12.66	39.12	2.12
	8	60.58	6.93	BC 47.25	1.34	46.55	4.97	47.53	0.85
	12	44.06	8.05	BC 42.63	2.32	46.19	4.03	41.53	6.55
	16	47.03	2.31	AB 50.82	1.71	45.81	2.05	39.83	1.27
	20	a 61.60	1.17	b A 55.82	0.47	ab 60.56	1.93	c 50.97	0.79
Cultivars	Storage time (days)	Storage temperature 5 °C							
		Control		UV-C		Hot water		UV-C + hot water	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Rubygem	0	B 33.03	0.33	34.93	3.30	36.16	4.76	32.35	5.17
	8	A 43.01	0.01	33.99	1.68	f 44.70	3.08	46.69	3.99
	12	A 42.58	1.56	38.50	0.58	36.07	4.20	38.80	1.20
Sabrina	0	37.92	5.87	36.13	2.56	23.90	12.66	39.12	2.12
	8	54.14	3.09	57.19	8.16	60.04	1.69	52.01	2.77

Phosphorus is found in the structure of enzymes involved in the metabolism of nutrients essential for the formation of bones and teeth with calcium, and it is necessary for cell functioning. In addition, phosphorus allows the body fluids to resist acid exchange and keep the intracellular and extracellular fluid in balance (Samur, 2008). In our study, the P value increased during storage compared to the baseline, and the highest P value was 9008.04 mg/kg with an increase of 103.24% on the 16th day in control fruits of the cultivar Rubygem stored at 0 °C. On the last day of storage (20th day), the P value was measured as 7765.45 mg/kg in control fruits of Rubygem with an increase of 75.20%. The effects of UV-C, hot water, and UV-C + hot water applications on P content increasing in Rubygem were 30.12%, 62.85%, and 48.16%, respectively. In the cultivar Sabrina stored at 0 °C, the content of P increased by 108.40% in control, 75.19% in UV-C, 165.00% in hot water, and 51.82% in UV-C + hot water treatments. The trend was similar in both fruit cultivars stored at 5 °C. The P contents in mature strawberries varied from 2226 to 3668 mg/kg (Ekholm et al., 2007; Özcan and Hacıseferoğulları, 2007). Similarly, Mahmood et al. (2012) reported that the P content in Korona and Tufts strawberry cultivars at different stages of maturity (immaturity, semimaturity, and full maturity) varied between 2559 and 3021 mg/kg.

Potassium is the main component of fluids in the cells. It provides acid-base balance, regulates blood pressure, acts in the transmission of nerve stimuli, and is effective in muscle contraction. In this study, K value showed an increase throughout storage compared to initial values in both cultivars, except for the UV-C + hot water application in Rubygem fruits. The highest value (31,292.42 mg/kg) was obtained from the fruits of the Sabrina variety in UV-C + hot water treatment on day 20, the last day of storage. K value increments during storage were 59.78% in control, 63.47% in UV-C, 83.91% in hot water, and 4.97% in UV-C + hot water treatments compared to the initial values in the Rubygem variety stored at 0 °C. The K values in the Sabrina variety stored at 0 °C also increased during the storage period at the rates of 46.15% (control), 108.32% (UV-C), 121.38% (hot water), and 73.04% (UV-C + hot water), respectively. The increasing of K content at 5 °C was similar to 0 °C in both cultivars. Selvaraj et al. (1976) studied 20 different strawberry cultivars in terms of mineral composition and found that there was a wide variation among cultivars in terms of K content. The reports showed that the K contents in fresh strawberry fruits ranged from 1551 to 2000 mg/kg (Tahvonen, 1993; Capar and Cunningham, 2000). Özcan and Hacıseferoğulları (2007) and Ekholm et al. (2007) reported that fully ripened strawberries had a K content

varying between 14,909 and 15,500 mg/kg, whereas Mahmood et al. (2012) emphasized that the K content in different stages (immaturity, semimaturity, full maturity) in Korona and Tufts strawberry cultivars varied between 2800 and 3300 mg/kg.

Calcium is an essential element for the construction of bones and teeth, for muscle contraction, for the work of nerves, for the supply of normal blood pressure, for blood clotting, and for keeping cells together (Samur, 2008). The Ca content in this study showed a decrease in all treatments compared to baseline values. The highest content of Ca (5133.01 mg/kg) was obtained at 0 °C in UV-C + hot water treatments on the first day. According to initial values, the decrease of Ca was 36.76% in control, 54.47% in UV-C, 43.12% in hot water, and 38.24% in UV-C + hot water treatments in cultivar Rubygem stored at 0 °C. In Sabrina fruits, the decrease of Ca was 2.51% in control, 20.47% in UV-C, 58.75% in hot water, and 37.31% in UV-C + hot water treatments at 0 °C. At 5 °C, the decrease in Ca in Rubygem and Sabrina cultivars was similar to that at 0 °C. Strawberry fruits show a wide variation in the content of Ca (Selvaraj et al., 1976). It has been reported that the content of Ca changes between 200 mg/kg (Tahvonen, 1993) and 149 mg/kg (Capar and Cunningham, 2000) in fresh strawberries. On the other hand, it was emphasized that strawberry fruit had Ca content ranging from 2000 to 4959 mg/kg during the full postnatal period (Ekholm et al., 2007; Özcan and Hacıseferoğulları, 2007). Similarly, Mahmood et al. (2012) reported that the contents of Ca in the Korona and Tufts strawberry cultivars at different stages of maturity (immaturity, semimaturity, full maturity) varied between 2675 mg/kg (fully mature Tufts) and 3750 mg/kg (immature Korona).

Magnesium regulates energy metabolism in the body and the working of muscle and nervous systems, and helps in the forming of bones and teeth and in the regulation of blood pressure (Samur, 2008). In this study, the Mg value increased during storage compared to the initial value. The highest Mg value was measured as 3591.09 mg/kg with an increase of 76.11% on the 20th day of control fruits in the Sabrina variety stored at 0 °C. Mg content increases in UV-C, hot water, and UV-C + hot water treatments in the Rubygem variety stored at 0 °C were 3.04%, 10.19%, and 11.61%, respectively. The effect of different treatments at the same temperature on the increasing of Mg content in the Sabrina variety was 60.08% in UV-C, 113.88% in hot water, and 37.12% in UV-C + hot water. Also, the increasing of Mg content during the storage of the Rubygem and Sabrina cultivars at 5 °C was similar to that at 0 °C. Selvaraj et al. (1976) studied the mineral composition of 20 different strawberry cultivars and found a wide variation among strawberry cultivars in terms of Mg. Tahvonen (1993) reported that fresh fruits contained 160 mg/kg Mg, whereas Capar and Cunningham (2000) reported the content to be about 123 mg/kg. However, Özcan and Hacıseferoğulları (2007) and Ekholm et al. (2007) determined that mature strawberry juice had Mg content ranging from 1315 to 1400 mg/kg. On the other hand, Mahmood et al. (2012) found that the Mg contents of the Korona and Tufts strawberry cultivars varied from 1600 mg kg^{-1} (immature Tufts) to 2430 mg kg^{-1} (fully ripe Tufts) at different stages of ripening (immaturity, semimaturity, and full maturity).

Copper plays a role with iron in the activity of the cytochrome oxidase enzyme. This activity is transformed into Cu^{+} and Cu^{++} and transports electrons to oxygen. It is present in the active group of the lysyl oxidase enzyme. This enzyme assists in cross-linking between collagen, elastin, and polypeptides. Besides catalase, phenyloxidase, and ascorbic acid oxidase, it is also necessary for iron to be used regularly in the body. Iron does not bind hemoglobin without copper. In this study, different temperatures and treatments resulted in a decrease or increase in Cu content during the storage of the Rubygem and Sabrina cultivars. The Cu content varied between 2.29 mg kg^{-1} (Rubygem, day 12, hot water application) and 4.76 mg kg^{-1} (Rubygem, day 16, control). The Cu content of fresh fruit has been reported as 0.7 mg kg^{-1} (Tahvonen, 1993). Özcan and Hacıseferoğulları (2007) and Ekholm et al. (2007) found Cu contents in mature strawberry as 0.1–1.65 mg/kg. Mahmood et al. (2012) defined Cu contents at 13.6 mg/kg (immature Korona) and at 17.6 mg kg^{-1} (immature Tufts) in strawberry cultivars in different stages of maturity (immaturity, semimaturity, full maturity).

Manganese has an important role in growth and reproductive functions, carbohydrate and lipid metabolism, protein synthesis, mucopolysaccharide production, phosphorylation, and bone formation. The Mn content in this study increased in all treatments, but with a slight decrease (2.61%) on the 20th day of UV-C application in the Rubygem cultivar. The highest increase was measured on the 20th day using UV-C treatment on the Sabrina variety stored at 0 °C at 91.50%. Tahvonen (1993) reported that the content of Mn in fresh strawberry fruit was 4.6 mg/kg, while Capar and Cunningham (2000) reported 3.6 mg/kg. Özcan and Hacıseferoğulları (2007) and Ekholm et al. (2007) reported that the manganese content of ripe strawberries ranged from 4.44 to 42 mg/kg. On the other hand, Mahmood et al. (2012) found that Mn content varied between 27.4 mg/kg (fully mature Tufts) and 57.0 mg/kg (immature Korona) in strawberry cultivars at different stages of ripening (immaturity, semimaturity, and full maturity).

Sodium is very important for the continuation of nerve and muscle functions. Its main task is to provide liquid pumping and to allow food to pass through cell membranes. Excessive amounts of sodium contribute to high blood pressure. It was observed that Na content

increased in some treatments and decreased in others. Özcan and Hacıseferoğulları (2007) and Ekholm et al. (2007) reported that the content of sodium in mature strawberry fruits varied from 701 to 725 mg kg^{-1}. Mahmood et al. (2012) found that the content of Na in the Korona and Tufts strawberry cultivars in different stages of maturity (immaturity, semimaturity, full maturity) was between 2048 mg kg^{-1} (full ripened Korona) and 2645 mg kg^{-1} (immature Tufts).

Zinc is involved in the structure of enzymes that have metabolic functions in the body. In this study, Zn content showed a decrease of 0.25% on the last day of storage in Rubygem fruits at 5 °C using UV-C treatment. Zn contents of strawberries grown at full maturity varied between 8.09 and 10 mg/kg (Ekholm et al., 2007; Özcan and Hacıseferoğulları, 2007). Similarly, Mahmood et al. (2012), found that Zn content was 408 mg/kg (fully ripened Tufts) and 1165 mg/kg (immature Korona) in strawberry cultivars of different stages of maturity (immaturity, semimaturity, full maturity). Hakala et al. (2003) analyzed the contents of Ca, Mg, K, Fe, Zn, Cu, and Mn in frozen Senga Sengana, Jonsok, Korona, Polka, Honeoye, and Bounty strawberry cultivars and found that the strawberries had good potassium (1.55–2.53 g kg^{-1}), magnesium (0.11–0.23 g kg^{-1}), and calcium (0.16–0.29 g kg^{-1}). Researchers have emphasized that the effect of genotype on mineral contents is more effective than cultivation techniques. UV-C applications caused slow ripening by suppressing endogenous ethylene synthesis in fruits (Stevens et al., 2004; Charles et al., 2009) and stimulated resistance to pathogens (Cantos et al., 2001; Shama and Alderson 2005; Keskin et al., 2015). UV-C rays control the storage decay of fruits and vegetables due to inhibitory effects on DNA structure of pathogens as well as the accumulation of antimicrobial compounds, which cause resistance of the fruit shell against pathogens (Stevens et al., 1996; Marquenie et al., 2002; Keskin et al., 2014).

In this study, using different treatments caused an increase in P and Mg contents in both strawberry cultivars during storage at different temperatures. In a study of vegetable amaranth and African nightshade plants, it was observed that UV-C treatment caused an increase in amounts of P, K, and Mg contents in vegetable amaranth and an increase in Zn content in African nightshade as compared to control plants during storage (Gogo et al., 2017). UV-C application causes an increase in nutrient content as a result of stimulating the response of the plant to physiological stress. UV-C applications lead to the establishment of homeostasis in the follicle, which causes an increase in the storage time of some mineral substances (Gogo et al., 2017).

In this study, both cultivars showed a decrease in Ca content during storage at different temperatures using various treatments. It was supposed that after UV-C application the stress-responsive mechanism is an initial stress signal being characterized by a decline in mineral element contents.

The effects of different treatments on Cu and Na contents were different in both cultivars at different temperatures. In addition, K, Mn, and Zn contents increased in all treatments except for one group. Okpalamma et al. (2013) reported the reduction in K, Ca, Mg, and Zn contents in fluted pumpkin as a result of oxidative reactions that occurred due to heat and light exposure during storage.

Increases in weight loss occur during storage of fruits and vegetables. This leads to differences among the cultivars in terms of maturity levels and practices. Weight loss physiology is faster in all products, especially in small fruits, which have a short shelf life. This is because there is no outer shell of the fruit and there is a water vapor outflow from the surface of the fruit by diffusion. In this study, the increase in the amount of macro- and micronutrients can be attributed to the increase in density of the fruit itself as a result of this water loss.

In conclusion, in this study, it was attempted to determine the changes of mineral content in two commercial strawberry cultivars stored at different temperatures in MAP using hot water and UV-C treatments. Results showed that storing both cultivars at different temperatures increased P and Mg contents and decreased Ca contents in all treatments, but had different trends for Cu and Na contents. Moreover, except for one treatment, the K, Mn, and Zn contents were observed to increase in the groups.

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