



Linking Pre-Harvest Management to Storage Quality in Table Grape: A Variety-Based Approach

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ABSTRACT

In this study, the effects of pre-harvest 6 and 9 mM cyanocobalamin (CC), 0.5% and 1% chitosan (C) applications on the storage and grape quality characteristics of Red Globe and Tilki Kuyruğu table grape varieties were tried to be determined. It has been determined that pre-harvest applications of 0.5% and 1% chitosan with modified atmosphere packaging (MAP) and SO₂ generators in the Red Globe variety preserve both physical, biochemical, and sensory properties, delay spoilage, and the variety can be easily stored along 120 days. Among all parameters examined, it can be said that the applications had a negative effect on berry removal force. When the data of the Tilki Kuyruğu variety is evaluated, pre-harvest 0.5% C, and 1% C applications can be recommended due to their positive effects on weight loss (day 120 0.5% C: 1.92 % 2021, 1.40% 2022; 1% C: 1.48 % 2021, 1.84 % 2022, berry removal force (day 120 0.5% C: 394.8 gf 2021, 485.3 gf 2022; 1% C: 380.0 gf 2021, 482.1 gf 2022), and sensory properties. It is believed that conducting more detailed conservation studies on the Tilki Kuyruğu variety in future studies would be beneficial for identifying the variety and assessing its performance. The study yielded positive results, but it is necessary to determine the practical application methods and any potential adverse effects/challenges (phytotoxicity on leaves, etc.) arising from these applications.

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Introduction

Grapes are often treated with SO₂ to prevent post-harvest decays that will occur during storage and transportation. However, SO₂ application can damage grapes and leave behind sulfite residues, which is unacceptable for consumer health (Chervin et al., 2005; Shen and Yang, 2017). Sulfur preparations used to combat diseases during cultivation also cause SO₂ accumulation in grapes. The highest acceptable SO₂ residual amount is 10 ppm (Smilanick et al., 1990; Anonymous, 1997).

Especially in recent years, studies have been focused on methods and chemicals that are more effective, not harmful to human health, and do not create a residue effect for the cold storage of table grapes (Lydakis and Aked, 2003; Mlikota et al., 2005). In this context, plant growth regulators (PGRs), abscisic acid (ABA), auxins, cytokinins, ethylene, and gibberellic acid (GA₃) applications were used pre-harvest and post-harvest in previous studies (Lo'ay, 2017). In addition, in recent years, the effects of pre-harvest and post-harvest use of compounds such as cyanocobalamin (Vitamin B₁₂) (Lo'ay,

2017), chitosan (Lo'ay and El-Khateeb, 2018), chitosan-g-salicylic acid (Shen and Yang, 2017) have been investigated, especially in grapes. Cobalamin, also known as vitamin B₁₂, is a water-soluble vitamin (Asensi-Fabado and Mune'-Bosh, 2010). It has been investigated that use together with ascorbic acid in preventing chilling injury in mango during storage (Samaan et al., 2011), in prolonging the shelf life of persimmon (El-Baz et al., 2011; Lo'ay, 2010), in preserving and increasing the marketability of guava (Samaan et al., 2012), and in the effects on yield and quality of 'Williams' banana variety (El-Baz et al., 2016). In the studies conducted with cyanocobalamin on grapes, only its effect on shelf life was examined.

Chitosan has attracted attention due to its antimicrobial properties against different microorganisms such as bacteria, fungi, and yeast, and many other functional properties and has begun to take its place in the food industry (Shahidi et al., 1999; Bostan et al., 2007; Tarim, 2023). Chitosan is a biopolymer obtained by partial deacetylation from chitin, a natural polysaccharide found

in the exoskeletons of shellfish such as crabs and shrimps, in the wings of butterflies, and in the cell walls of fungi, and has reactive functional amino groups; it is similar to cellulose in chemical structure and is the most common biopolymer in nature after cellulose (Shepherd et al., 1997; Taştan and Baysal, 2013). Covering foods with chitosan film reduces the partial oxygen pressure inside the package, keeps the temperature under control by moisture transfer between the food and its environment, reduces water loss, delays enzymatic browning in fruits, controls respiration, delays ripening in fruits, etc. (El-Ghaouth et al., 1991; Butler et al., 1996).

The Tilki Kuyruğu grape variety is one of the most important varieties of Mersin viticulture. The harvest time is October and November because it is a late grape variety. Another important feature of this variety is that it reaches maturity at a time when there are very few/no grapes on the Türkiye market. The Red Globe table grape variety has become one of the most demanded fruits in the world since its introduction to the grape market in the United States. This variety is widely grown in regions extending from the tropics to the subtropics (Zhao et al., 2018; Jia et al., 2020). It is a variety in demand in world table grape import and export, and is grown intensively in the Mediterranean region in our country.

The countries from which our country imports grapes are Chile (30.2%), Iran (32.5%), South Africa (19.7%), Peru (13.2%), and Uzbekistan (5.7%). The variety we import from Chile and Peru, especially between January and April when there are no fresh grapes on the market in our country, is the Red Globe grape variety.

Grapes are a non-climacteric fruit with low physiological activity. However, despite these positive characteristics, post-harvest decay caused by gray mold (*Botrytis cinerea*), rachis browning, and water loss are important factors limiting storage life (Crisosto et al., 2002; Lo'ay, 2017). Grapes are often treated with SO₂ to prevent postharvest decay during storage and transportation. However, SO₂ application can damage the grapes and leave behind sulfite residues, which is unacceptable for consumer health (Chervin et al., 2005; Shen and Yang, 2017). Especially in recent years, studies have been intensified on methods and chemicals that are more effective, not harmful to human health, and do not create residual effects for the cold storage of table grapes (Lydakis and Aked, 2003; Mlikota et al., 2005). The research results and applications carried out in our country in terms of storing and packaging grapes with different storage techniques are quite few. Although there have been developments in this regard in recent years, the usage rate of grape storage facilities is quite low (Yalav, 2011). In the study, the effects of pre-harvest 6 and 9 mM cyanocobalamin (CC), 0.5% and 1% chitosan (C) applications on the physical and sensory properties of Red Globe and Tilki Kuyruğu table grape varieties during storage were determined.

Material and Method

Material

In the study, Red Globe and Tilki Kuyruğu table grape varieties were used as plant material. Tilki Kuyruğu is a white variety with seeds (1-2) and ripens late (late October-

early November). Average bunch weight is 525 g, bunch shape is large, long, branched-conical, berry color is yellow, berry shape is ellipse, and berry size is medium-large (İnal, 2000). The vineyard where the applications were made is in Sebil neighborhood at 37.13831 latitude, 34.58726 longitude (Çamlıyayla/Mersin) coordinates. The distance between the rows is 3 m and the distance between the rows is 2 m. The other variety used in the study, Red Globe, is a table grape variety and is a colored grape variety. Red Globe is a variety that demand in world table grape import and export. The bunches are large (1000 g), densely packed. The berries are purplish red and very large (12-14 g), round-shaped and have 3-4 seeds. The total soluble solids (TSS) content is between 17-18%. The vineyard where the applications were made is also located in Sebil neighborhood (Çamlıyayla/Mersin) at 37.140438 latitude and 34.637727 longitude degrees.

One of the materials used in the pre-harvest application, cyanocobalamin, is a water-soluble vitamin B₁₂ with a purity of ≥95% and a molecular weight of 1355.4 (Cayman Chemical Company, Michigan, USA). Chitosan (Sigma Aldrich, St. Louis, Missouri, USA) is in powder form and was prepared by dissolving in 1% glacial acetic acid.

Method

Preharvest applications of control, cyanocobalamin (6 and 9 mM) and chitosan (0.5% and 1%) were made by spraying the bunches twice: at veraison-maturity and 10 days before predicted maturity. Applications were made in the early morning hours, before sunrise, because cyanocobalamin is sensitive to sunlight. For each application, all bunches of 25 vines were sprayed.

At harvest, the bunches grouped according to applications were pre-cooled until the internal berry temperature dropped to 2°C. The pre-cooling process was carried out in room-cooled conditions. The pre-cooled grapes were weighed, placed in a 5 kg capacity MAP with SO₂ generators, sealed, and stored at 0°C and 90% relative humidity for four months (120 days). Physical and sensory analyses were conducted every 15 days during storage in the laboratories of the Alata Horticultural Research Institute.

Physical Quality Parameters

Weight Loss (%): To determine the weight loss during storage, the bunches separated for analysis at the beginning and every 15 days were removed from their packages and their weights were weighed using a scale (sensitivity of 0.01), and the difference compared to the initial weight was calculated as a percentage.

Berry Skin Elasticity (gf): Berry skin elasticity (skin + flesh) was measured using a Sundoo brand SH-100 model dynamometer on 10 berries of each bunch, 4 from the upper part, 4 from the middle part, and 2 from the lower part, and recorded as gf.

Berry Removal Force (gf): Berry removal force was measured with a Sundoo brand SH-100 model dynamometer on 10 bunches, 4 from the upper part, 4 from the middle part, and 2 from the lower part of each bunch, and the applied force was recorded as gf.

Rachis Browning Index: This was carried out according to the method of Bahar et al. (2017). Rachis browning was assessed subjectively. The main rachis, lateral extensions,

and berry peduncles were evaluated and scored as their average; completely green parts received a value of 0, while completely brown-dry parts received a value of 1. The relative extent of drying was scored in 0.1 intervals, representing 10% coverage units.

Sensory Analyses

Grapes were evaluated on a scale of 1–9 (1: Very weak, soft, 3: Weak and soft, 5: Medium and limited marketability, 7: Good, 9: Excellent) for physical appearance, taste, and texture (Artes-Hernandez et al., 2004). Six panelists performed sensory evaluations.

Pathogenic and physiological losses were scored visually on a scale of 1–5 (1: Absent, 2: Few, 3: Medium, 4: High, 5: Very high) (Artes-Hernandez et al., 2006; Çakır, 2010).

Statistical Analysis

The study was conducted using a randomized plot design with three replications, with packages containing an average of 5 kg grapes used in each replication. The obtained data were subjected to variance analysis using the JMP 7.0 package program and evaluated using the Tukey comparison test at $p < 0.05$.

Findings and Discussion

In the two-year study, the first year (2021) was planned for a 16-week storage period for both varieties. In the second year (2022), the Tilki Kuyruğu variety was damaged by two hailstorms in Çamlıyayla-Sebil, where the vineyards are located. Considering the amount of grapes harvested, the trial was set up for 12 weeks. No problems were encountered with the Red Globe variety, and the trial was set up for 16 weeks as planned.

Weight Loss (%)

When the weight loss data of the Red Globe variety were examined, storage period, treatments and their interactions were found to be statistically significant in both years. In the first year of the study, the lowest weight loss was determined in the 0.5 C application on the 15th day

(0.21%), and the highest loss was determined in the Control application on the 120th day (1.67%) (Table 1). Considering the 120th day values of the trial, the least loss was determined in the 1 C application with 0.72%. In the second year, the lowest weight loss was measured on the 15th day in the 1 C application (0.37%), and the highest weight loss was measured on the 120th day in the 9 CC application (2.13%). When the values of the last week of the study were examined, the least loss was found in the 0.5 C application with 0.97% (Table 2).

When the effect of storage period was examined in both years, the lowest loss occurred at the beginning and the highest losses occurred at the 120th day, as expected. When evaluated on the base of applications, the highest loss in the first year was found in the Control and the lowest loss in the 0.5 C application; in the second year, the highest loss was found in the 9 CC and the lowest loss was found in the 0.5 C application, the same as the first year.

When the weight loss data of the Tilki Kuyruğu variety at the end of storage were examined, the storage period, treatments and their interactions were found to be statistically significant in both years. In the first year of the study, the lowest weight loss was found in the 9 CC application on the 15th day (0.57%), and the highest weight loss was found in the 6 CC application on the 120th day (10.32%) (Table 3). Considering the 120th day values of the trial, the least loss was determined in the 1 C application with 1.08%. In the second year, the lowest weight loss was measured on day 15 in the 0.5 C application (0.62%), and the highest loss was measured on day 120 in the 9 CC application (4.40%). When the values for the last week of the study were examined, the lowest loss was found in the 0.5 C application with 1.40% (Table 4). When the effect of storage period was considered in both years, as expected, the lowest loss occurred on day 15, and the highest losses occurred on day 120. When evaluated on a per treatment basis, in the first year, the highest loss was found in the 6 CC application, and the lowest loss was found in the 1 C application; in the second year, the highest loss was found in the 9 CC application, and the lowest loss was found in the 0.5 C application, the same as in the first year.

Table 1. Weight loss during storage in the Red Globe (%) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	0.00 k	0.00 k	0.00 k	0.00 k	0.00 k	0.00 F
15	0.33 g-k	0.24 h-k	0.24 h-k	0.21 ijk	0.34 g-k	0.27 E
30	0.40 g-k	0.41 f-k	0.30 g-k	0.22 ijk	0.37 g-k	0.34 E
45	0.47 d-k	0.52 c-k	0.41 f-k	0.45 e-k	0.52 c-k	0.47 DE
60	0.92 a-1	0.55 c-k	0.62 c-k	0.48 c-k	0.53 c-k	0.62 CD
75	0.94 a-h	0.65 c-k	0.63 c-k	0.62 c-k	0.64 c-k	0.70 CD
90	0.95 a-g	1.19 a-d	0.67 c-k	0.63 c-k	0.67 c-k	0.82 BC
105	1.50 ab	1.24 abc	1.13 a-f	0.71 c-j	0.69 c-j	1.05 AB
120	1.67 a	1.31 a-e	1.19 a-d	0.78 b-1	0.72 b-j	1.13 A
Average Applications	0.90 A	0.76 AB	0.65 BC	0.51 C	0.56 BC	
CV: 2.2164						
Prob > F	Storage Period <.0001		Applications <.0001		Storage Period × Application 0.0566	

*Logarithmic transformation was applied to the figures. Statistical analyses were performed on the transformed values and they were assigned letters. The figures in the table are those without logarithmic transformation. Mean values given in different capital letters in the same column and row, and the interaction mean values in lower case letters in the middle of the table, were found to be statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

Table 2. Weight loss during storage in the Red Globe (%) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.48 E
15	0.54 g-l	0.44 h-m	0.65 e-l	0.40 klm	0.37 lm	0.59 DE
30	0.68 e-l	0.44 i-m	0.99 c-l	0.40 klm	0.42 j-m	0.64 DE
45	0.81 d-l	0.47 h-m	0.99 c-j	0.46 h-m	0.47 h-m	0.67 DE
60	0.87 c-l	0.52 g-m	1.01 c-i	0.47 h-m	0.49 g-m	0.76 CD
75	0.93 c-l	0.54 e-m	1.21 b-e	0.52 g-m	0.61 f-l	0.91 BC
90	0.97 c-k	0.74 e-l	1.44 bc	0.59 g-l	0.80 d-l	1.08 B
105	1.02 c-h	0.88 c-l	1.79 ab	0.67 e-l	1.06 c-g	1.35 A
120	1.41 bcd	1.20 b-f	2.13 a	0.97 c-k	1.06 c-g	0.48 E
Average Applications	0.80 B	0.58 C	1.13 A	0.50 C	0.59 C	
CV: 1.7477						
Prob > F	Storage Period <.0001	Applications <.0001		Storage Period × Application 0.0065		

*Logarithmic transformation was applied to the figures. Statistical analyses were performed on the transformed values and they were assigned letters. The figures in the table are those without logarithmic transformation. Mean values given in different capital letters in the same column and row, and the interaction mean values in lower case letters in the middle of the table, were found to be statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

Table 3. Weight loss during storage in the Tilki Kuyruğu (%) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 C
15	0.71 bcd	0.72 bcd	0.57 cd	0.72 bcd	0.67 bcd	0.68 B
30	0.79 bcd	1.01 bcd	0.75 bcd	0.94 bcd	0.78 bcd	0.85 B
45	1.02 bcd	1.12 bcd	1.01 bcd	1.07 bcd	0.83 bcd	1.01 B
60	1.13 bcd	1.40 bcd	1.56 bcd	1.23 bcd	0.84 bcd	1.23 B
75	1.26 bcd	1.43 bcd	1.65 bcd	1.51 bcd	1.25 bcd	1.42 B
90	1.46 bcd	8.34 a	2.40 bc	1.79 bcd	1.34 bcd	3.07 A
105	3.25 b	8.57 a	2.47 bc	1.87 bcd	1.46 bcd	3.52 A
120	3.34 b	10.32 a	2.83 b	1.92 bcd	1.48 bcd	3.98 A
Average Applications	1.62 B	4.11 A	1.66 B	1.38 B	1.08 B	
CV: 5.3179						
Prob > F	Storage Period <.0001	Applications <.0001		Storage Period × Application <.0001		

*Logarithmic transformation was applied to the figures. Statistical analyses were performed on the transformed values and they were assigned letters. The figures in the table are those without logarithmic transformation. Mean values given in different capital letters in the same column and row, and the interaction mean values in lower case letters in the middle of the table, were found to be statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

Table 4. Weight loss during storage in the Tilki Kuyruğu (%) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	0.00 l	0.00 l	0.00 l	0.00 l	0.00 l	0.00 F
15	0.66 jkl	0.81 h-k	0.87 g-k	0.62 kl	0.81 h-k	0.75 E
30	0.67 jk	1.70 d-g	1.36 e-k	0.66 jkl	0.95 g-k	1.07 D
45	0.78 h-k	1.80 c-f	1.52 d-h	0.75 ijk	1.19 f-k	1.21 D
60	1.82 b-f	1.93 b-f	1.87 b-f	0.88 g-k	1.46 d-i	1.59 C
75	2.68 bc	2.16 b-e	2.29 bcd	1.34 e-k	1.48 d-i	1.99 B
90	2.72 b	2.23 b-e	4.40 a	1.40 e-j	1.84 b-f	2.52 A
Average Applications	1.33 BC	1.52 AB	1.76 A	0.81 D	1.10 C	
CV: 2.0952						
Prob > F	Storage Period <.0001	Applications <.0001		Storage Period × Application <.0001		

*Logarithmic transformation was applied to the figures. Statistical analyses were performed on the transformed values and they were assigned letters. The figures in the table are those without logarithmic transformation. Mean values given in different capital letters in the same column and row, and the interaction mean values in lower case letters in the middle of the table, were found to be statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

Yadav et al. (2022b) investigated the effect of pre-harvest and post-harvest chitosan application on berry moisture content. According to the analysis results, the greatest moisture loss occurred in the control treatment, and less moisture loss occurred in the treated grapes compared to the control. Kassem et al. (2022) reported that pre-harvest chitosan application resulted in less weight loss than the control treatment in their study on the Crimson

Seedless variety. Wati and Maharani (2020) applied different chitosan doses to grapes and, according to their results, determined that weight loss decreased as the applied chitosan concentration increased. Liguori et al. (2021) also reported that the use of chitosan and MAP significantly reduced weight loss both at storage and in shelf life trials.

Table 5. Berry skin elasticity changes during storage in the Red Globe (gf) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	279.7 ab	343.7 ab	415.7 a	368.7 ab	428.0 a	367.1 A
15	279.7 ab	294.5 ab	294.2 ab	287.0 ab	318.2 ab	294.7 B
30	308.7 ab	302.5 ab	315.5 ab	311.2 ab	341.7 ab	315.9 B
45	322.7 ab	400.8 ab	307.8 ab	316.0 ab	300.3 ab	329.5 AB
60	312.8 ab	345.5 ab	323.7 ab	340.3 ab	300.2 ab	324.5 AB
75	294.2 ab	318.0 ab	342.0 ab	283.5 ab	303.7 ab	308.3 B
90	311.0 ab	331.8 ab	304.5 ab	282.2 ab	293.0 ab	304.5 B
105	292.8 ab	269.8 b	305.5 ab	279.3 ab	287.8 ab	287.1 B
120	285.0 ab	251.8 b	277.8 ab	350.8 ab	327.7 ab	298.3 B
Average Applications	298.5	317.6	320.7	313.2	329.0	
CV: 13.1763						
Prob > F	Storage Period <.0001		Applications 0.2321		Storage Period × Application 0.0409	

*The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Table 6. Berry skin elasticity changes during storage in the Red Globe (gf) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	334.3 abc	333.5 abc	302.3 abc	336.2 abc	356.7 a	332.6 A
15	323.1 abc	306.9 abc	358.3 a	301.1 abc	292.5 abc	316.4 AB
30	286.2 abc	326.3 abc	309.3 abc	325.7 abc	300.3 abc	309.6 ABC
45	242.2 abc	251.0 abc	317.7 abc	283.7 abc	276.2 abc	274.2 BC
60	235.5 abc	208.3 bc	342.5 ab	281.2 abc	281.2 abc	269.7 BC
75	249.0 abc	378.8 abc	266.0 abc	256.2 abc	292.8 abc	288.6 BC
90	254.0 abc	321.5 abc	352.7 a	241.0 abc	303.0 abc	294.4 ABC
105	237.7 abc	327.5 abc	314.3 abc	262.3 abc	281.5 abc	284.7 BC
120	201.7 c	293.3 abc	253.3 abc	290.8 abc	286.3 abc	265.1 C
Average Applications	262.6 B	305.2 A	312.9 A	286.5 AB	296.7 A	
CV: 13.9346						
Prob > F	Storage Period <.0001		Applications 0.0009		Storage Period × Application 0.0288	

*The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Chitosan can slow down respiration rates and reduce transpiration losses by altering the permeability of the fruit to oxygen, water, and carbon dioxide within the package. It can also act as a physical barrier to delay moisture loss and fruit shriveling by forming an edible film on the fruit surface (Chaiprasart et al., 2006; Ribeiro et al., 2007; Ehtesham Nia et al., 2021).

Samaan et al. (2012) reported that postharvest applications of 3 and 6 mM vitamin B₁₂ to guava reduced weight loss at the end of the storage period (30 days) compared to the control application. Samaan et al. (2011) found that preharvest cyanocobalamin application to mango increased weight loss compared to the control application.

Berry Skin Elasticity (gf)

When the berry skin elasticity values, which are of great importance in terms of berry strength during storage, were examined, it was seen that the applications did not have a statistically significant effect in the first year in the storage output data of the Red Globe variety (Table 5), while the storage period, applications and their interactions were found to be statistically significant in the second year (Table 6).

In the first year, the highest value was 1 C on the 0th day (428.0 gf), the lowest value was 6 CC on the 120th day (251.8 gf); in the second year, 1 C on the 0th day, 9 CC on the 15th and 90th days were in the same group and had the

highest values (356.7, 358.3 and 352.7 gf, respectively), and the lowest value was determined in the Control treatment on the 120th day (201.7 gf).

For the Tilki Kuyruğu variety, only the storage period was statistically significant in both years of the study. In the first year, the highest value was recorded on day 0 (240.3 gf), and the lowest on day 120 (199.3 gf) (Table 7); in the second year, the highest value was recorded on day 0 (290.6 gf), the same as in the first year; the other analysis days were statistically included in the same group (Table 8).

Kassem et al. (2022) stated that pre-harvest chitosan application increased berry firmness. Another research group stated that post-harvest chitosan application delayed berry softening (Elwahas et al., 2014; Plácido et al., 2016; Latif et al., 2022). Samaan et al. (2012) reported in their study on guava fruit that among 3 and 6 mM vitamin B₁₂ applications after harvest, the 3 mM dose gave approximately the same value as the control on the 30th day of the end of the storage period, while the 6 mM application increased fruit flesh firmness. Lo'ay (2010) conducted a post-harvest preservation study on persimmon using the immersion method in different concentrations of cyanocobalamin solution and found that as the applied concentration increased, fruit flesh firmness decreased and approached the values of the control treatment samples. El-Baz et al. (2011) found that pre-harvest cyanocobalamin application in persimmon increased fruit flesh firmness.

Table 7. Berry skin elasticity changes during storage in the Tilki Kuyruğu (gf) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	203.0	249.5	258.5	230.2	260.5	240.3 A
15	218.0	223.8	211.5	202.3	195.8	210.3 B
30	218.3	191.3	251.5	220.2	198.5	216.0 B
45	214.5	202.7	241.2	199.5	218.8	215.3 AB
60	231.5	210.2	195.8	197.8	236.2	214.3 AB
75	232.5	205.5	215.7	209.3	228.5	218.3 B
90	224.5	222.0	199.7	201.2	199.7	209.4 B
105	227.2	233.7	218.2	227.3	208.7	223.0 AB
120	215.0	191.7	193.8	197.3	198.7	199.3 B
Average Applications	220.5	214.5	220.7	209.5	216.2	
CV: 10.4603						
Prob > F	Storage Period 0.0004		Applications 0.4291		Storage Period × Application 0.1033	

* The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Table 8. Berry skin elasticity changes during storage in the Tilki Kuyruğu (gf) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	278.7	313.3	277.5	285.7	297.8	290.6 A
15	233.3	233.8	256.8	201.2	200.2	225.1 B
30	224.8	225.2	222.7	214.2	263.0	230.0 B
45	228.8	183.8	204.5	190.3	247.0	210.9 B
60	196.7	186.7	204.5	180.7	235.8	200.9 B
75	219.0	229.7	201.0	205.0	197.5	210.4 B
90	199.0	227.0	193.5	200.7	195.0	203.0 B
Average Applications	225.8	228.5	222.9	211.1	233.8	
CV: 12.1313						
Prob > F	Storage Period <.0001		Applications 0.1022		Storage Period × Application 0.1096	

*The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Table 9. Berry removal force changes during storage in the Red Globe (gf) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	672.3 a-d	665.0 a-e	649.0 a-f	791.0 a	725.3 a-d	700.5 A
15	662.8 a-e	542.5 a-f	617.8 a-f	635.5 a-f	525.2 b-f	596.8 BCD
30	502.2 b-f	513.3 b-f	554.7 a-f	671.8 a-d	458.2 c-f	540.0 CDE
45	668.0 a-d	409.8 f	441.5 def	489.8 b-f	453.5 c-f	492.5 E
60	605.7 a-f	533.0 b-f	413.0 ef	453.5 c-f	594.2 a-f	519.9 DE
75	644.0 a-f	703.8 abc	578.0 a-f	626.8 a-f	656.8 a-f	641.9 AB
90	702.5 abc	599.7 a-f	527.3 b-f	591.0 a-f	457.0 c-f	575.5 B-E
105	631.5 a-f	715.8 ab	599.7 a-f	617.5 a-f	573.8 a-f	627.7 ABC
120	700.5 abc	458.2 a-f	584.5 a-f	649.3 a-f	657.8 a-f	610.1 AB
Average Applications	643.3 A	571.2 BC	551.7 C	614.0 AB	566.9 BC	
CV: 12.7936						
Prob > F	Storage Period <.0001		Applications 0.0001		Storage Period × Application 0.0015	

* The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Berry Removal Force (gf)

In the Red Globe variety, storage period, treatments and their interactions were found to be statistically significant in the first year of the trial, and storage period in the second year. When the first year was examined based on the treatments, the highest value was given to the Control (643.3 gf), and the lowest value was given to the 9 CC treatment (551.7 gf). Considering the storage period, the tightest removal force was determined on day 0 (700.5 gf), and the lowest removal force was determined on day 45 (492.5 gf) (Table 9). When the interactions of the

treatments were examined, the highest berry removal force was measured in the 0.5 C treatment on day 0 (791.0 gf), and the berry removal force was measured in the 6 CC treatment on day 45 (409.8 gf). Considering the second year, the 105th and 120th days were statistically in the same group and had the highest values (987.7 and 988.2 gf, respectively), while the lowest value was obtained on the 15th day (802.4 gf), as seen in Table 10.

In the first year of the Tilki Kuyruğu variety, only the storage period was statistically significant (Table 11), while in the second year, storage period, treatments and

their interactions were not found to be significant (Table 12). When the effect of the storage period in the first year was examined, the highest removal force was measured on the 75th day (395.7 gf), and the lowest on the 30th day (289.6 gf) (Table 11).

Previous studies have indicated that coating berries with chitosan, before and after harvest, increases berry resistance to rachis split (Elwahab et al., 2014; Kassem et al., 2022). Furthermore, Wu et al. (2021) reported that chitosan coating reduced SO₂-induced berry shedding by 95.6%, making chitosan an edible coating that can be effectively used to protect against postharvest SO₂-induced

shedding. They also reported that it increased berry removal force by 50%.

Bunch Appearance

According to bunch appearance evaluations made on a scale of 1-9, the Red Globe variety maintained its initial appearance until day 60 in both years. However, after this date, appearance deterioration began due to the onset of bleaching caused by SO₂ pads. Despite this, economic quality was maintained until day 120 of analysis. There was no difference in bunch appearance between treatments (Figure 1).

Table 10. Berry removal force changes during storage in the Red Globe (gf) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	819.8	832.0	737.7	960.8	810.8	832.2 BC
15	708.3	803.3	901.4	732.2	866.9	802.4 C
30	787.8	966.8	954.0	915.5	877.2	900.3 ABC
45	874.3	975.8	924.7	898.7	820.2	898.7 ABC
60	1045.8	857.8	1041.0	933.7	877.8	951.2 ABC
75	925.0	972.8	879.5	891.0	977.5	929.2 ABC
90	992.3	867.5	1020.7	942.5	1011.5	966.9 AB
105	934.5	1107.5	975.0	916.3	1005.3	987.7 A
120	877.2	961.7	1003.0	1038.8	1060.3	988.2 A
Average Applications	885.0	927.2	937.4	914.4	923.1	
CV: 14.2190						
Prob > F	Storage Period 0.0003		Applications 0.7660		Storage Period × Application 0.4815	

* The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Table 11. Berry removal force changes during storage in the Tilki Kuyruğu (gf) (2021)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	361.3	303.2	290.7	336.8	302.3	318.9 B
15	243.0	319.8	311.7	295.5	323.2	298.6 B
30	252.0	334.0	313.5	241.5	307.0	289.6 B
45	307.8	309.5	321.0	348.0	333.5	323.9 B
60	310.2	386.0	321.3	314.7	347.8	336.0 AB
75	378.7	409.8	436.5	342.0	411.3	395.7 A
90	364.0	372.5	346.3	347.7	386.0	363.3 AB
105	345.2	359.7	349.5	340.7	313.7	341.8 AB
120	346.8	361.7	359.0	394.8	380.0	368.5 AB
Average Applications	323.2	350.7	338.8	329.1	344.9	
CV: 18.8514						
Prob > F	Storage Period 0.0004		Applications 0.3291		Storage Period × Application 0.8923	

*The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

Table 12. Berry removal force changes during storage in the Tilki Kuyruğu (gf) (2022)*

Storage Period (Day)	Applications					Average Storage Period
	Control	6 CC	9 CC	0.5 C	1 C	
0	517.8	502.7	500.0	410.2	371.3	460.4
15	536.5	509.5	467.8	404.8	491.8	482.1
30	439.2	524.0	465.0	439.5	479.0	469.3
45	422.8	457.3	466.8	456.3	497.8	460.2
60	501.0	469.2	458.8	437.5	421.2	457.5
75	478.0	469.5	492.0	484.5	467.7	478.3
90	488.0	536.2	500.3	485.3	482.1	498.4
Average Applications	483.3	495.5	478.7	445.4	458.7	
CV: CV: 14.3673						
Prob > F	Storage Period 0.8481		Applications 0.2300		Storage Period × Application 0.6936	

*The mean values given with different capital letters in the same column and row and the mean values of the interaction with lower case letters in the middle of the table were found to be statistically significant; those without letters were found to be insignificant (p < 0.05).

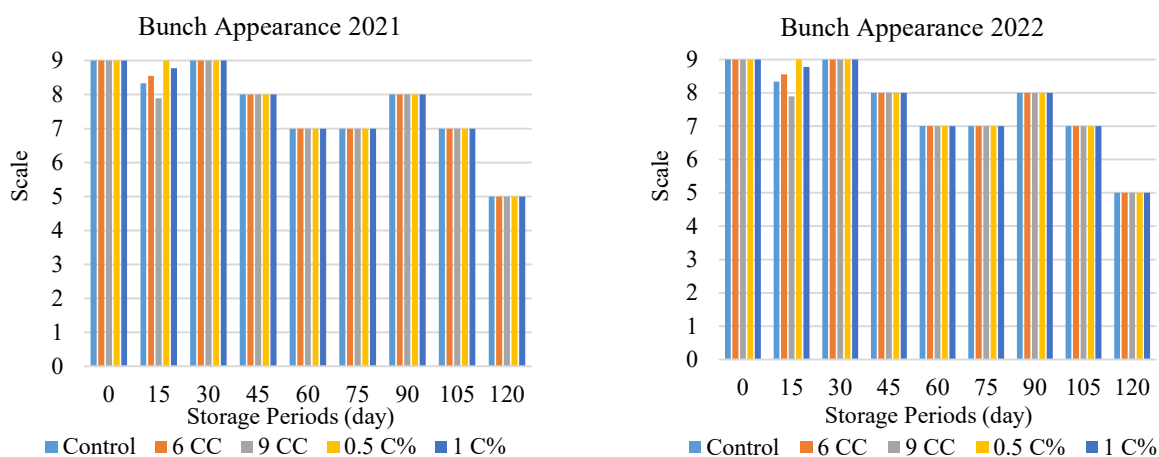


Figure 1. Effect of different pre-harvest treatments on bunch appearance in Red Globe

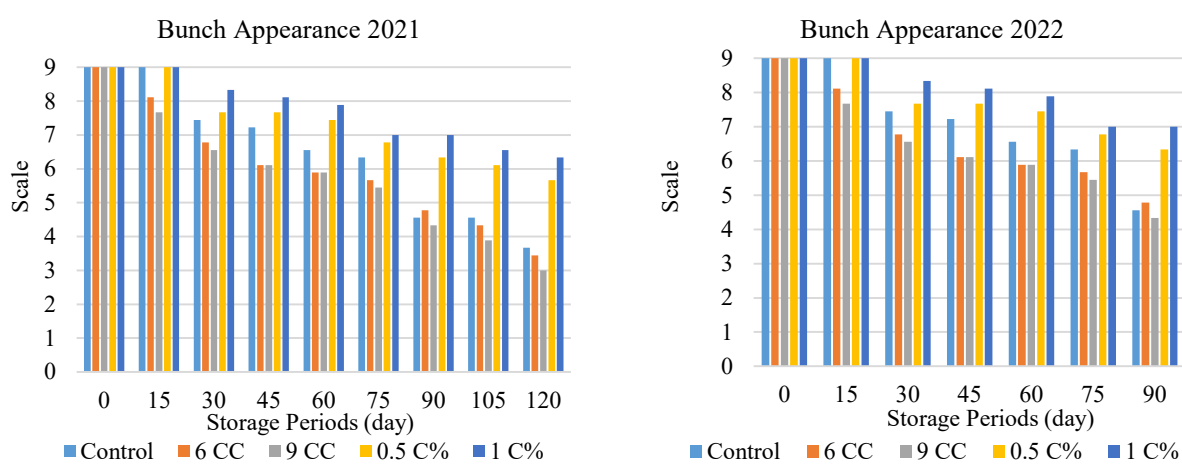


Figure 2. Effect of different pre-harvest treatments on bunch appearance in Tilki Kuyruğu

In the Tilki Kuyruğu variety, when all analysis days were examined in the first year, the 1 C treatment had the best bunch appearance, followed by the 0.5 C and Control treatments. The 6 CC and 9 CC treatments were the treatments that received the lowest scores, generally having equal effects (Figure 2). Considering the second year's figure, unlike the first year, the Control treatment received lower scores than the 6 CC and 9 CC treatments on the 90th day, the end of the trial (Figure 2).

Yadav et al. (2022a) reported that pre-harvest and post-harvest chitosan combinations had a positive effect on grape berry texture scores, with better color as chitosan concentration increased. Liguori et al. (2021) reported that the MAP+Chitosan application received higher scores than the Control (MAP only) application in all sensory scores, including bunch appearance.

Berry Texture

In sensory analyses conducted on the Red Globe variety during both the first year of storage, overall texture quality was maintained until day 120, excluding day 45 (Figure 3). The decrease on day 45 is thought to be related to increases in pathological and physiological losses. In the second year, differences began to emerge among the treatments after day 30. The 0.5% C treatment was prominent in the 30th day scores, followed by the 1% C treatment on the other analysis days. By day 105, the best scores were

obtained from the 0.5% C and 1% C treatments, while the lowest scores were obtained from the 6 CC and 9 CC treatments (Figure 3). By day 120, the final analysis day, a decline was observed in all treatments, with all receiving the same scores.

In the Tilki Kuyruğu variety, the same results were obtained in the storage trials in terms of berry texture in both years, with the berries in the 1 C application having the best texture, followed by the 0.5 C application. The control, 6 CC and 9 CC applications had approximately the same scores (Figure 4).

Yadav et al. (2022a) reported that pre-harvest and post-harvest chitosan combinations had a positive effect on berry texture scores in grapes, with color improving as chitosan concentrations increased. Similarly, Xu et al. (2007), Shiri et al. (2013), and Elwahab et al. (2014) reported that chitosan treatment in grapes preserved texture longer in their studies.

The degree of fruit softening is reported to be directly related to the rate of decay of pectin compounds, as is the activity of pectin methylesterase (PME) and polygalacturonase (PG) enzymes during ripening (Ehtesnam Nia et al., 2021). Chitosan reduces the activity of cell wall-degrading enzymes and fungal spoilage, which may result in coating treatments that preserve berry texture compared to controls.

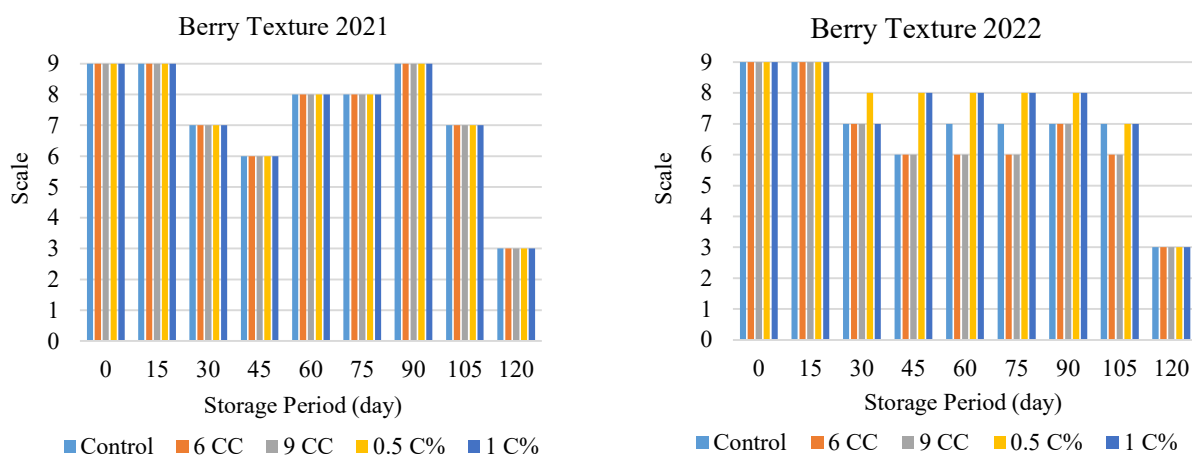


Figure 3. Effect of different pre-harvest treatments on berry texture in Red Globe

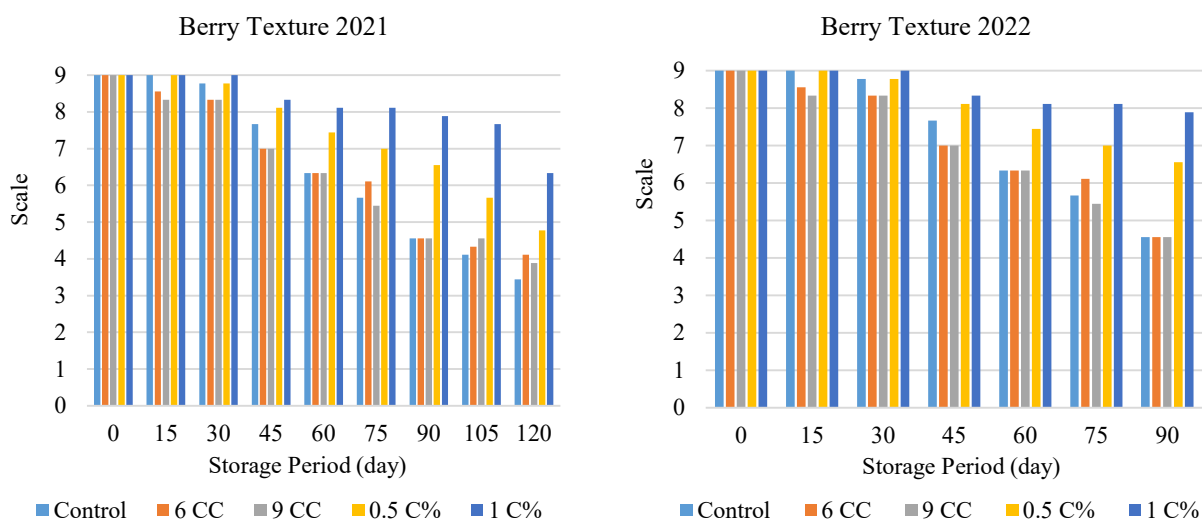


Figure 4. Effect of different pre-harvest applications on berry texture in the Tilki Kuyruğu

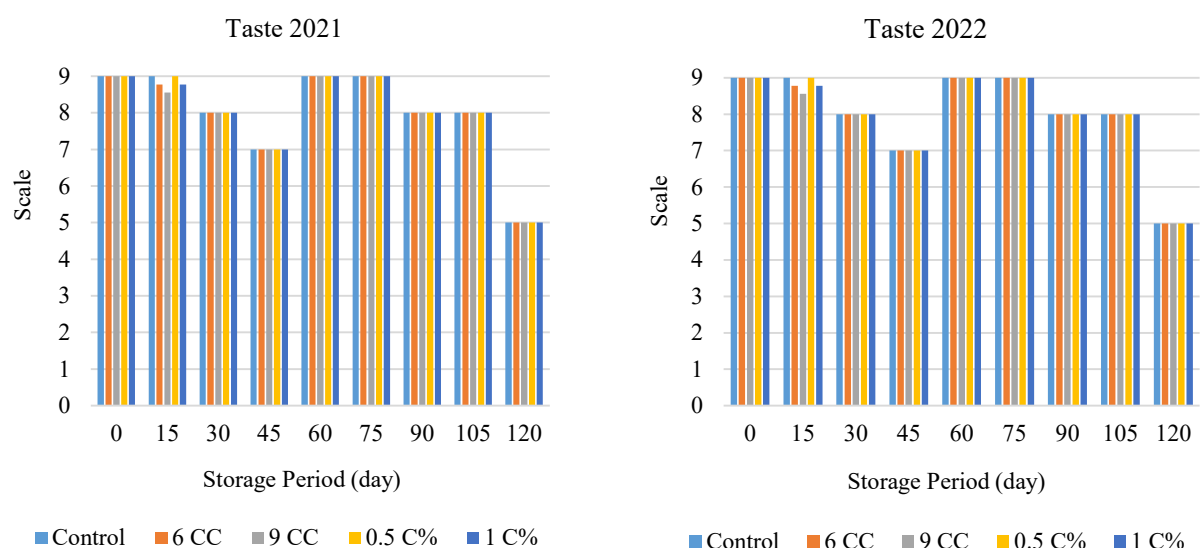


Figure 5. Effect of different pre-harvest treatments on taste in Red Globe

Taste

Although the Red Globe variety experienced decreases in taste scores due to pathological and physiological deterioration on day 45, similar to the berry texture, quality was maintained until the final analysis day of the trial. A

review of both study years reveals that pre-harvest treatments had no significant effect on this parameter (Figure 5). On the final analysis day, all treatments received a score of 5: Moderate and limited marketability.

In the Tilki Kuyruğu variety, the taste remained as good as it was when first harvested until the 45th day of the study, and no difference was observed between the treatments in this respect. From the 45th day until the end of the trial, the 1 C and 0.5 C treatments had the best taste, while the lowest score was determined in the 9 CC treatment (Figure 6).

Yadav et al. (2022a) reported that pre-harvest and post-harvest chitosan combinations had a positive effect on taste scores in grapes, with color improving as chitosan concentrations increased. Similarly, Xu et al. (2007), Shiri et al. (2013), and Elwahab et al. (2014) reported that chitosan application in grapes preserved flavor longer in their studies.

Pathological and Physiological Losses

In the Red Globe variety, in both trial years, except for an additional increase on day 45, no physiological or pathological losses occurred until day 105. The increase began in the analyses on day 105. and 120. No different effects were detected between treatments (Figure 7).

In the Tilki Kuyruğu variety, losses began on the 30th day in both years of the study, with the highest loss occurring in the 9 CC application. The lowest losses

occurred in the Control, 0.5 C, and 1 C applications. At the end of the trial, pathological and physiological losses occurred from low to high in the following order: Control > 9 CC > 0.5 C > 6 CC > 1 C (Figure 8).

Ehtesham Nia et al. (2021) reported that the decay index of chitosan-coated fruits was lower than that of uncoated fruits during storage. Furthermore, the same researchers explain the mechanism of chitosan's bactericidal effect as the amino groups in its molecular structure attaching to the cell membrane via electrostatic force, preventing bacteria from disrupting the outer cell membrane.

Rachis Browning Index

In the first year of the study, differences began to emerge between treatments for the Red Globe variety on day 45 of storage emergence, and on day 60 in the second year. Considering the end of the trial at day 120, no significant differences were observed among treatments in year one (Figure 9). In second year, the best results were obtained from the 6 CC, 0.5% C, and 1% C treatments (Figure 9). Overall, across all analysis days, the best results were obtained from the 0.5% C and 1% C treatments.

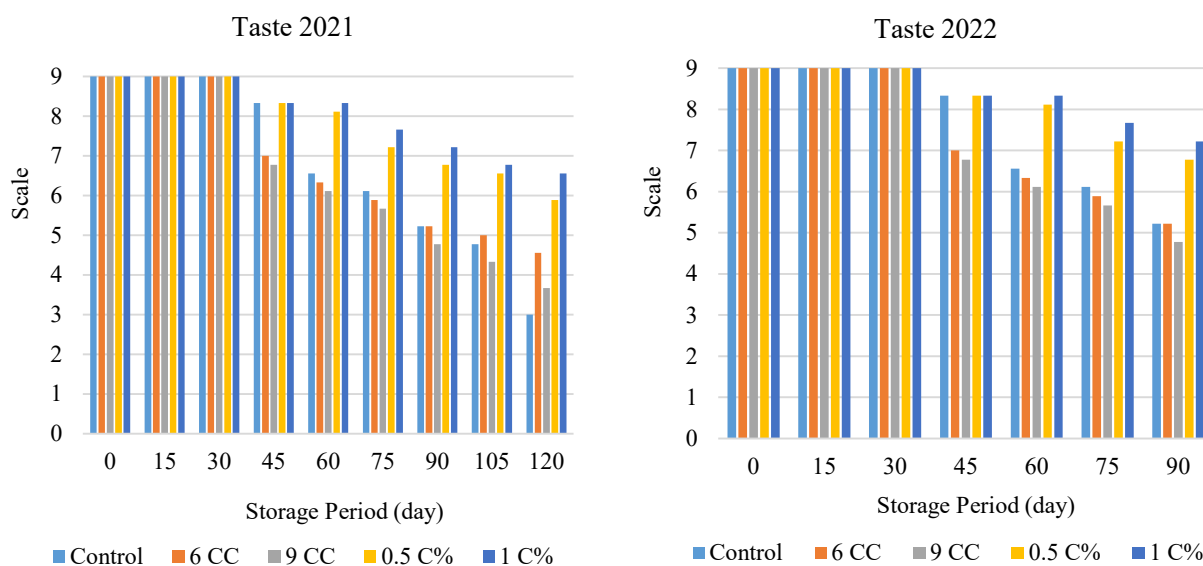


Figure 6. Effect of different pre-harvest treatments on taste in Tilki Kuyruğu

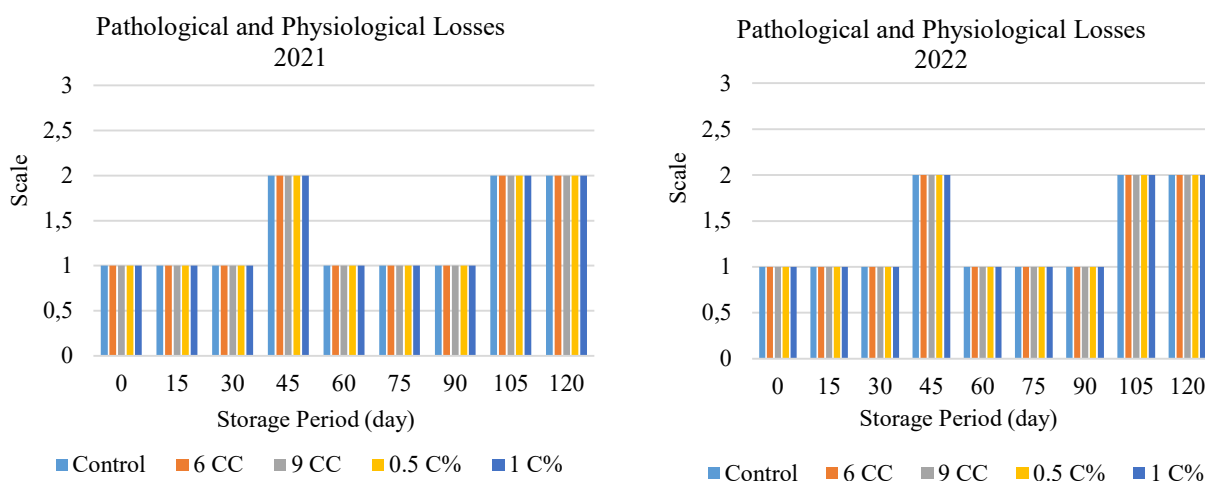


Figure 7. Effect of different pre-harvest treatments on pathological and physiological losses in the Red Globe

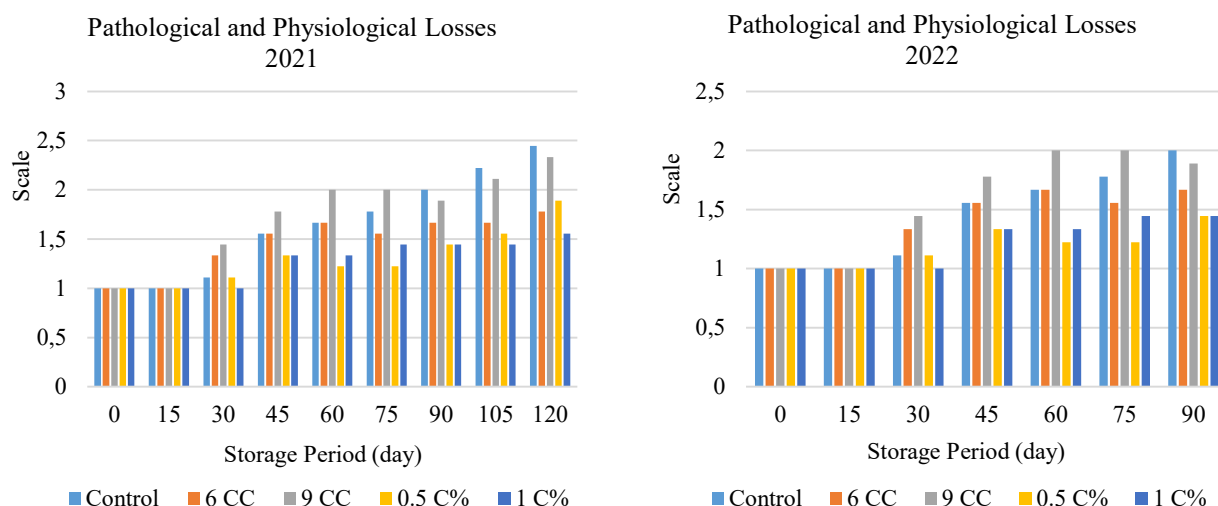


Figure 8. Effect of different pre-harvest treatments on pathological and physiological losses in the Tilki Kuyruğu

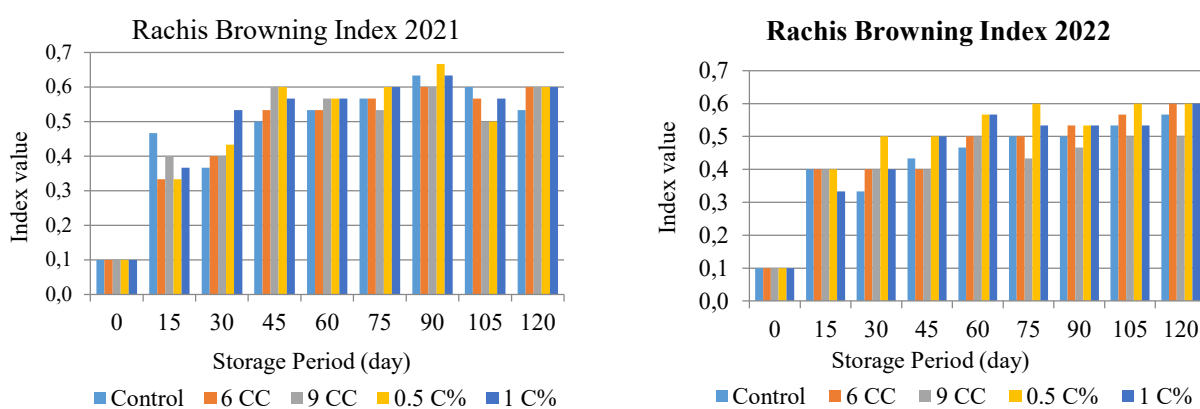


Figure 9. Effect of different pre-harvest treatments on rachis browning index in Red Globe

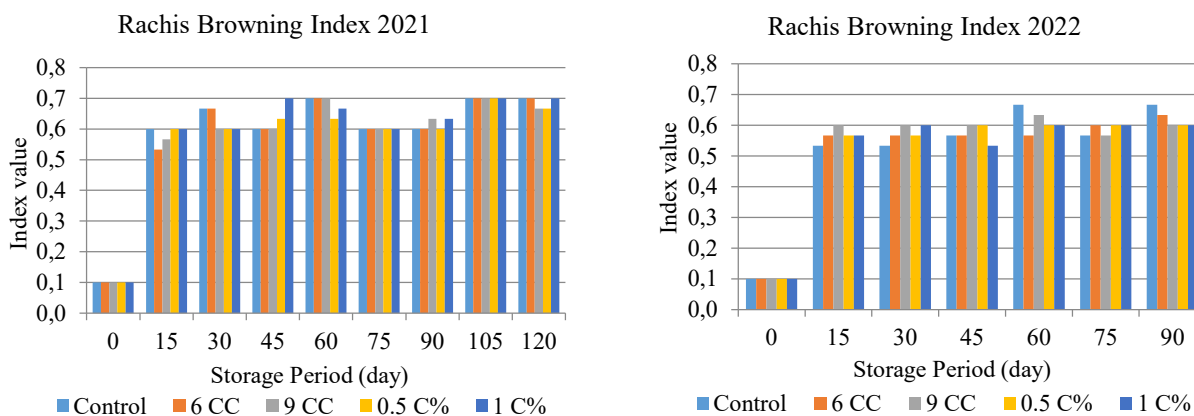


Figure 10. Effect of different pre-harvest treatments on rachis browning index in the Tilki Kuyruğu

In the Tilki Kuyruğu variety, rachis browning index values increased rapidly starting from the 15th day of the first year. While 6 CC and 9 CC treatments yielded similar results to the Control treatment in almost all weeks, the index value was lower in the 0.5 C and 1 C treatments. When examined on the 120th day, the end of the trial, the lowest rachis browning was observed in the 9 CC and 0.5 C treatments (Figure 10).

In the second year, rachis browning index values increased rapidly starting from day 15. At the end of the second year, the highest values were lower than in the first

year, and the least browning occurred in the samples from the 9 CC, 0.5 C and 1 C applications (Figure 10).

Chitosan coating delays weight loss and browning in the rachis and fruits (Xu et al., 2007; Shiri et al., 2013; Elwahab et al., 2014; Yadav et al., 2022a). Rachis browning begins first in the berry peduncle due to polyphenol oxidase activity, then progresses to the intermediate laterals and is finally observed in the central axis (Carvajal-Millan et al., 2001; Yadav et al., 2022a). It has also been reported that the rachis is a physiologically active part with a higher respiratory intensity than the fruit and is of great importance in storage (Crisosto et al., 2022).

Conclusions

An overall evaluation of the results revealed that pre-harvest applications of MAP and SO₂ generators and 0.5% and 1% chitosan on the Red Globe variety preserved both physical and sensory properties, delayed spoilage, and allowed the variety to be easily stored for 120 days. Among all the parameters examined, the applications had a negative effect on berry removal force.

When the results were evaluated for the Tilki Kuluğu variety, pre-harvest applications of 0.5% C and 1% C were recommended due to their positive effects on weight loss, berry removal force, and sensory parameters. The applications had no effect on other parameters.

It is believed that conducting more detailed conservation studies on the Tilki Kuyruğu variety in future studies would be beneficial for identifying the variety and assessing its performance. The study yielded positive results, but it is necessary to determine the practical application methods, and any potential adverse effects/challenges (phytotoxicity on leaves, etc.) arising from these applications. When using cyanocobalamin, red color residues on the berries after application due to the color of the prepared solution. Rainfall in the studied region prior to harvest washed out the red color, and this did not pose a problem. However, this point should be taken into consideration when using cyanocobalamin in future studies.

Declarations

Ethical Approval Certificate

No ethical clearance is required.

Author Contribution Statement

Güzin Tarım: Pre-harvest applications, storage and laboratory studies, data collection, and writing the original draft

Okan Özkaya: Supervision, and editing

Fund Statement

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Conflict of Interest

The authors declare no conflict of interest.

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