Effects of preharvest GA₃, CaCl₂ and modified atmosphere packaging treatments on specific phenolic compounds of sweet cherry

Burhan Ozturk¹*, Erdal Aglar², Orhan Karakaya¹*, Onur Saracoglu³, Sefa Gun¹

¹ Ordu University, Faculty of Agriculture, Department of Horticulture, Ordu-Turkey
² Sivas Cumhuriyet University, Suşehri Timur Karabal Vocational School, Sivas-Turkey
³ Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Horticulture, Tokat-Turkey

ABSTRACT

The fruit of sweet cherry are more sensitive against external factors than many fruit species so the post harvest quality loss on sweet cherry is quite higher. For this reason, it is very significant to reduce the postharvest losses and to extend the storage period in sweet cherry, and this is one of the main objectives for producers and consumers. The aim of the study was to determine the effects of GA₃, CaCl₂ and modified atmosphere packaging (MAP) applications on individual phenolics compounds in postharvest storage on sweet cherry. In the study, GA₃ was applied at 30 mg L⁻¹ concentration when fruit skin was yellow-straw, and CaCl₂ was applied at 0.5% concentration 20 and 10 days before the estimated harvest date. The study consisted of 4 different spray (Control (water only), GA₃, CaCl₂, GA₃+CaCl₂) and 2 packaging applications (without and with MAP). MAP was applied to the fruit after the harvest. In our study, individual phenolics such as catechin, 4-hydroxybenzoic acid, epicatechin, caffeic acid, p-coumaric acid, 4-amino benzoic acid and protocatechuic acid were determined. It has been determined that pre-harvested GA₃, and CaCl₂ applications have increased the content of individual phenolics in fruit. The concentration of individual phenolics generally decreased with increasing cold storage time, whereas epicatechin and 4-hydroxy benzoic acid concentrations increased. 4-hydroxybenzoic acid and caffeic acid concentrations were higher CaCl₂, and GA₃ treatments than in control in all measured period. The MAP application had a positive effect on the losses of other phenolic compounds except catechin during cold storage.

1. Introduction

With the increasing interest in human health in the recent years, the using of the fruits and vegetables in a balanced diet and proper diet is very significant. While there is a positive correlation between the daily use of fruits and vegetables and the reduction of the risk of disease, especially clinical tests and chemical analyses emphasize the role of fruits and vegetables in preventing diseases (cardiovascular disorder, cancer, rheumatoid arthritis, lung emphysema, skin inflammation, cataract, neurological degenerative, endothelial cell disorder) caused by oxidative stress (Kaur and Kapoor, 2001; Benzie, 2003). Fruits are considered a natural source of antioxidants such as anthocyanins and polyphenols, which can reduce the risk of stress-induced degenerative disease such as cancer, heart disease, stroke (Ames et al., 1993; Robards et al., 1999; Kaur and Kapoor, 2001; Ma and Kinner, 2002). It has been reported the polyphenol antioxidants have different positive effects such as anti-inflammatory and anti-carcinogenic on human healthy (Garcia-Closas et al., 1999; Kroon and Williamson, 1999; Mamani-Matsuda et al., 2006), and are significant in human nutrition (Usenik et al., 2008).

Sweet cherry is greatly rich in terms of the bioactive compounds such as anthocyanins, quercetin, hydroxycinnamates (Gao and Mazza, 1995; Chaovanalikit and Wrolstad, 2004; González-Gómez et al., 2009; Gimenez et al., 2016; Aglar et al., 2019). The prominent anthocyanins present in sweet cherry are cyanidin 3-rutinoside and cyanidine 3-glucoside (Mozetic et al., 2002; Gonçalves et al., 2007; Usenik et al., 2008; Gonzalez-Gomez et al., 2010; Liu et al., 2011; Kelebek and Selli, 2011) while hydroxycinnamates, neochlorogenic acid and p-coumarylquinic acid have been found in adequate quantities (Kim, et al., 2005; Usenik et al., 2010; Liu et al., 2011). Matilla et al. (2006) have reported that there are small amounts of chlorogenic acid, hydroxybenzoic acids and ferulic acid on sweet cherry. The polyphenol compounds such as anthocyanins and hydroxycinimmic esters on sweet cherry have a positive effect cancer, cardiovascular disease, diabetes, inflammatory diseases (McCune et al., 2011; Ballistrieri et al., 2013), and these compounds are significant...
due to their potential contribution to the color of sweet cherry fruit (Mazza and Miniatti, 1993; Gao and Mazza, 1995; Mozetic et al., 2002).

However, the amounts of nutrients and bioactive components on sweet cherry can be altered depending on factors such as the ripening of the fruit, postharvest storage conditions, and processing (Serrano et al., 2009; Valero et al., 2011; Díaz-Mula et al., 2012). Sweet cherry is a non-climacteric fruit species with high respiratory rate and susceptible to fungal decay (Alique and Zamarro, 2005), and sweet cherries are by nature more perishable and postharvest quality loss is consequently higher. For this reason, it is very important to reduce the postharvest losses and to extend the storage period in sweet cherry, and this is one of the main objectives for producers and consumers (Meheriuk et al., 1995). In recent years, in order to preserve the quality of fruits after harvest and to reduce the losses at cold storage, the pre-harvest plant growth regulators such as gibberellic acid (Amarante et al., 2005; Steffens et al., 2011; Huang et al., 2014; Souzza et al., 2016; Zaho et al., 2018; Ozturk et al., 2018; Dong et al., 2019), calcium (Martín-Diana et al., 2007; Tsalti et al., 2007; Wójcik et al., 2013; Wójcik and Wawrzyńczak, 2014; Michailidis et al., 2017; Dong et al., 2019), methyl jasmonate (Kucuker and Ozturk, 2015; Venkatachalam and Meenune, 2015; Gomez et al., 2017), methylecyclopropene (Baswal et al., 2020), salicylic acid (Lu et al., 2011; El-Razeek et al., 2013; El-Shazly et al., 2013; Fatemi et al., 2013; Baswal et al., 2020), and the postharvest coating materials such as Aleo vera (Carrillo-Lopez et al., 2000; Martinez-Romero et al., 2006), chitosan (Romanazzi et al., 2003; Valero et al., 2014), modified atmosphere packaging (Guibert et al., 1996; Petracek et al., 2002; Cantin et al., 2008; Kaynas et al., 2010; Díaz-Mula et al., 2012; Giacalone and Chiabrando, 2013; Guillen et al., 2013; Naserzaei et al., 2015; Agrar et al., 2017) and algin ate (Diaz-Mula et al., 2012) were applied.

Gibberellic acid (GA3), which plays significant role in breaking seed dormancy, promoting flower bud differentiation and stem elongation, and delaying the senescence of plant organs (Achard et al., 2009; Sun, 2010; Zaho et al., 2018), has been used in commercial horticultural cultivation as a plant growth regulator to improve fruit size and quality (Khalil and Aly, 2013; Zang et al., 2016; Gundogdu et al., 2017), to delay ripening and to maintain fruit quality of postharvest crops (Steffens et al., 2011; Huang et al., 2014; Souzza et al., 2016; Zaho et al., 2018). Basak et al. (1998), Clayton et al. (2003), Lenahan et al. (2008), Zhang and Whiting (2011) Einhorn et al. (2013) and Canli et al. (2015), have reported that pre-harvest GA3 application has a significant effect on quality of sweet cherry fruit. GA3 have a significant effect on fruit coloration and anthocyanin synthesis capacity, and normal phenolic metabolism on sweet cherry (Li et al., 2019). Dong et al. (2019) have determined that GA3 application significantly reduced phenolic compounds, anthocyanin accumulation and antioxidant capacity on sweet cherry. Pre-harvest GA3 applications in sweet cherry have significant effects on preservation of the quality and chemical composition of the fruit at postharvest cold storage (Kappel and Macdonald, 2002; Einhorn et al., 2013).

Calcium, which is highly effective against fruit’s physiological disorders (Hernandez-Munoz et al., 2006; Korkmaz et al., 2016) and has many significant functions both structurally as a stabilizer of plant cell wall and membrane integrity (Hocking et al., 2016; Hosein-Beige et al., 2019), is used to improve the fruit quality of sweet cherry (Martín-Diana et al., 2007; Tsalti et al., 2007; Wójcik et al., 2013; Wójcik and Wawrzyńczak, 2014; Michailidis et al., 2017). Hosein-Beige et al. (2019) have determined that pre-harvest Ca application has a significant effect on the fruit chemical composition on sweet cherry. Wójcik and Wawrzyńczak (2014) and Michailidis et al. (2017) reported that the pre-harvest Ca applications in sweet cherry have significant effects on the preservation of the quality and chemical composition of the fruit at postharvest cold storage.

It has been reported the storage techniques such as MAP are effective in extending the storage period and on minimizing the losses the fruit quality at cold storage in stone fruits (Zhang et al., 2003; Naserzaeim et al., 2015; Agrar et al., 2017). Petracek et al. (2002), Remon et al. (2000), Spotts et al. (2002) and Tian et al. (2004) have reported that the application of the MAP, which is used to delay the physicochemical changes, to retard microbial spoilage and to retain color by reducing the oxidation, extending the shelf life of the fruit species (Singh et al., 2010), has a significant effect in delaying the physico-chemical changes on sweet cherry. The MAP applications that balance the CO2 concentrations and inhibits enzyme activity favoring stability of color (Rocha and Moreais, 2001; Remon et al., 2004) has slightly increased the total anthocyanin content of sweet cherry during the cold storage (Conte et al., 2009; Padilha-Zakour et al., 2007; Remon et al., 2000). However, Remon et al. (2003) have determined that MAP application has not a significant effect on the total anthocyanin content of sweet cherry at postharvest.

Many studies on the effects of GA3, CaCl2 and MAP applications on the quality and chemical composition of the fruit of sweet cherry at harvest and at postharvest, has been carried out. However, there is no study on the effect of GA3, CaCl2 and MAP applications on individual phenolic in sweet cherry at harvest and at postharvest storage. The aim of the study was to determine the effects of GA3, CaCl2 and modified atmosphere packaging (MAP) applications on the composition and concentration of individual phenolic in postharvest storage on sweet cherry.

2. Materials and methods

2.1. Material

In the research, the trees belonging to Regina cultivar grafted on MaxMa 14 rootstock and were planted in 2008 in Gaziosmanpaşa University Faculty of Agriculture Horticulture Application Orchard, were used as plant material.

2.2. Methods

In the study, GA3 was applied at 30 mg L⁻¹ concentration when fruit skin was yellow-straw, and CaCl2 was applied at 0.5% concentration 20 and 10 days before the estimated harvest date. The research was planned in a randomized block design as 2 trees at per replication with 3 replications.
The study consisted of 4 different applications (Control (water only), \( \text{GA}_3 \), \( \text{CaCl}_2 \), \( \text{GA}_3 + \text{CaCl}_2 \)) for both MAP and non-MAP treatment. The solutions prepared for each application were sprayed to the trees in the morning of a windless and rainless day with a pressure back pump until the trees were completely wet. Tween 20 (0.1%) was used as the spreading adhesive in the applications. The harvest of the fruit was carried out on June 20. The fruit, homogeneously colored, uniformly sized, undamaged healthy and perfect ones, had been selected and stacked in cardboard packages. These fruits were immediately transferred to Ordu University, Faculty of Agriculture, Department of Horticulture, and Fruit Laboratory by means of refrigerated vehicle. Fruit was divided into 8 different groups as control, \( \text{GA}_3 \), \( \text{CaCl}_2 \), \( \text{GA}_3 + \text{CaCl}_2 \), control + MAP, \( \text{GA}_3 + \text{MAP} \), \( \text{CaCl}_2 + \text{MAP} \) and \( \text{GA}_3 + \text{CaCl}_2 + \text{MAP} \). In addition, each application was arranged as 3 replicates (each replicate containing approximately 1 kg of fruit). Analyses were carried out to determine the composition and concentration of individual phenolic in fruit during the harvesting period. After these analyzes, the fruit were stored for 21 days in 0°C and 90 ±5% relative humidity conditions in the cold storage of Ordu University Faculty of Agriculture. On the 7th, 14th and 21st days of the cold storage, measurements and analyses of individual phenolic were carried out in Ordu University Faculty of Agriculture Department of Horticulture. Modified atmosphere packaging (MAP) application: Fruit were transferred to cold storage immediately after the separation and packaging. Subsequently, they were exposed to pre-cooling at about 1°C for 24 hours until the fruit temperature dropped to 3-4°C. After the pre-cooling, the fruit were placed in 22 μm LDPE based 5 kg MAP package (Xtend, Stepac, Israel) and their mouths were closed with plastic clips. In the study, the concentrations of the individual phenolic acids in MAP package were determined with 7 day intervals for 21 days. Individual phenolic acids were analyzed as follows. Homogeneously selected fresh fruit samples were weighed as 1 gram and extracted with methyl alcohol (5 mL) in a test tube for 6 hours. The extract was analyzed by high pressure liquid chromatography (HPLC) (Perkin-Elmer series 200, Norwalk, USA). The HPLC system was equipped with UV detector (Series 200, UV / Vis detector) and quaternary solvent dispensing system (Series 200, analytical pump) and used at 280 nm. Analyses were separated by a Phenomenex Kromasil (Phenomenex, Torrance, USA) 100A C18 (250 mm × 4.60 mm, 5 μm) column. The mobile phase is formed from water and acetonitrile (A) containing 2.5% formic acid (B). The mobile phase flow rate was maintained at 1 mL per minute and 20 μL of the sample was injected and expressed in mg kg⁻¹ in light of the results of the peak areas obtained.

2.13. Statistical analysis
The Kolmogorov-Smirnov test was used to confirm and the homogeneity of variances was tested the Levene’s test. After the data were analyzed by analysis of variance, the significance level between the treatments was determined by Duncan multiple comparison test. Statistical analyzes were performed in SAS program (SAS 9.1 version, USA). The significance level was considered as α = 5% in statistical analysis and interpretation of results.

3. Results
3.1. Catechin
The data relative to the effects of pre-harvest gibberellic acid and calcium chloride and post-harvest modified atmosphere packaging applications on catechin was shown in Table 1.

The highest catechin content during a harvest period was measured in \( \text{GA}_3 \) treated fruit and the lowest in control fruit. Catechin content decreased in all applications during cold storage. When the fruit applied with MAP were examined, the catechin concentration was significantly higher in the fruit treated with \( \text{CaCl}_2 \) + MAP and \( \text{GA}_3 \) + MAP on day 7th than the control, whereas on day 14th and 21th it was determined that \( \text{GA}_3 \) + MAP the application had higher catechin concentration than the other applications. When the averages of application were examined, the catechin content of fruit treated with MAP in all applications was higher than control fruit, whereas in non-MAP treated fruit, the highest concentration was recorded with the application of \( \text{GA}_3 \) while the difference between the applications of \( \text{GA}_3 \) and \( \text{CaCl}_2 \) was not significant at harvest and in 7th of storage. When the measurement periods were compared, it was seen that MAP treated fruit had significantly lower catechin content than fruit without MAP at all periods (Table 1).

3.2. 4-hydroxybenzoic acid
When the effect of pre-harvest \( \text{CaCl}_2 \) and \( \text{GA}_3 \) applications on the 4-hydroxybenzoic acid in fruit was evaluated, the highest amount of 4-hydroxybenzoic acid was recorded with \( \text{GA}_3 \) applied fruit and the lowest hydroxybenzoic acid concentration was obtained with control application in without MAP fruit at harvest, 7th and 14th days. The cold storage period had a significantly effect on hydroxybenzoic acid concentration. Thus, the concentration of hydroxybenzoic acid, which was 14.08 mg kg⁻¹ at the harvest the MAP application, reached 19.17 mg kg⁻¹ at the end of storage the MAP application. In addition to, the increase in MAP application was observed to be higher. When the effect of \( \text{CaCl}_2 \) and \( \text{GA}_3 \) applications during cold storage was evaluated, it was determined that the highest value was obtained with \( \text{GA}_3 + \text{CaCl}_2 \) application at all measurement periods, while the fruit of the control application had the lowest hydroxybenzoic acid concentration. On the 7th day of the cold storage, the significant differences between all applications have occurred. On the 14th day, there was no difference between \( \text{CaCl}_2 \) and control application, and the difference between \( \text{CaCl}_2 \) or \( \text{GA}_3 \) and control applications at the end of the cold storage was not statistically significant. The highest values were obtained with \( \text{GA}_3 + \text{CaCl}_2 \) application while no significant difference between \( \text{CaCl}_2 \) and control application in all measurement periods in MAP treated fruit was observed. On the 7th day of the cold storage, higher hydroxybenzoic acid concentration with application of \( \text{GA}_3 \) were recorded compared to control and \( \text{CaCl}_2 \) applications in fruit not treated with MAP, but there was no significant difference between three applications at the end of the cold storage.
Table 1. Effects of pre-harvest spray treatments (GA<sub>3</sub> and CaCl<sub>2</sub>) and MAP on catechin contents of sweet cherry fruit throughout cold storage

| Treatments               | Harvest | 7    | 14   | 21    |
|--------------------------|---------|------|------|-------|
|                          |         |      |      |       |
| Results by packaging     |         |      |      |       |
| MAP                      | 636     | 285 b| 222 b| 188 b |
| non-MAP                  | 636     | 382 a| 296 a| 231 a |
| **Significance**         | ****    | *    | *    | *     |
| Results by spraying      |         |      |      |       |
| Control                  | 382 c   | 287 c| 225 b| 209 ab|
| CaCl<sub>2</sub>         | 739 a   | 256 c| 205 b| 195 ab|
| GA<sub>3</sub>           | 893 a   | 433 a| 341 a| 266 a |
| GA<sub>3</sub>+CaCl<sub>2</sub> | 530 b | 358 b| 263 b| 168 b |
| **Significance**         | *       | *    | **   | *     |
| MAP                      |         |      |      |       |
| Control                  | 382 c   | 343 b| 271 b| 253 b |
| CaCl<sub>2</sub>         | 739 a   | 205 b| 199 c| 191 c |
| GA<sub>3</sub>           | 893 a   | 502 a| 399 a| 304 a |
| GA<sub>3</sub>+CaCl<sub>2</sub> | 530 b | 480 a| 314 b| 176 c |
| **Significance (interaction)** | *     | *    | **   | *     |

There was no statistically significant difference between CaCl<sub>2</sub>, GA<sub>3</sub> and CaCl<sub>2</sub> + GA<sub>3</sub> applications in fruit not treated with MAP in the 7th, 14th and 21st days of the cold storage. There was no statistically significant difference between CaCl<sub>2</sub>, GA<sub>3</sub> and CaCl<sub>2</sub> + GA<sub>3</sub> applications in fruit without MAP (Table 2).

3.3. Epicatechin

When the effects of pre-harvest CaCl<sub>2</sub> and GA<sub>3</sub> applications on epicatechin content in fruit were evaluated, it was found that CaCl<sub>2</sub> application had no effect on epicatechin in the study, whereas GA<sub>3</sub> application increased epicatechin in fruit. An increase in the rate of epicatechin was observed in proportion to the storage time. When the effects of CaCl<sub>2</sub>, GA<sub>3</sub> and MAP applications at postharvest were evaluated, it was determined that in MAP-treated fruit, the epicatechin concentration of the fruit of CaCl<sub>2</sub> + MAP application was significantly lower than control’s on the 7th day, whereas the epicatechin concentration the fruit treated with GA<sub>3</sub> on 14th day and the fruit of all applications on the 21st day higher epicatechin content than control fruit. In fruit not treated with MAP, the highest amount of epicatechin during cold storage was recorded in GA<sub>3</sub>-treated fruit while there was a significant difference between GA<sub>3</sub> and CaCl<sub>2</sub> applications and control application on the 7th and 14th days of cold storage; however, no difference was found between the epicatechin concentrations of GA<sub>3</sub>, CaCl<sub>2</sub> and control applications at the end of cold storage (Table 3).

3.4. Caffeic acid

When the effect of pre-harvest CaCl<sub>2</sub> and GA<sub>3</sub> applications on fruit caffeic acid content was evaluated, it was determined that the increase in caffeic acid concentration occurred with CaCl<sub>2</sub> and GA<sub>3</sub> applications. However, there was no difference between caffeic acid concentrations of the fruit of CaCl<sub>2</sub> and GA<sub>3</sub> applications. It was determined that caffeic acid concentration decreased with the extended cold storage time and this decrease was lower with MAP application. On the 7th day of the cold storage, there was no significant difference between CaCl<sub>2</sub>, GA<sub>3</sub> and CaCl<sub>2</sub>+GA<sub>3</sub> applications, whereas caffeic acid concentrations of CaCl<sub>2</sub> and GA<sub>3</sub> were similar at 14th day. On the 21st day of the cold storage, the significant differences between the all applications were observed and the highest value was recorded with CaCl<sub>2</sub> application. However, it was found that the fruit of the control were found to have the lowest caffeic acid concentration at all measurement periods (Table 4). The statistically significant differences between CaCl<sub>2</sub> and GA<sub>3</sub> applications in MAP-treated fruit in terms of caffeic acid concentration on the 7th and 21st days of the cold storage occurred. The highest value in 7th day of the cold storage was obtained with GA<sub>3</sub> application, but on the 21st day, the highest value was recorded with CaCl<sub>2</sub> application. On the 14th day of the cold storage, significant differences between the caffeic acid content of the fruit of CaCl<sub>2</sub> and GA<sub>3</sub> applications were found. The statistically significant differences between CaCl<sub>2</sub> and GA<sub>3</sub> applications in caffeic acid concentration in fruit without MAP on the 7th and 21st days of the cold storage were observed. The highest value on 7th day of the cold storage was obtained with GA<sub>3</sub> application, but on 21st day, the highest value was recorded...
with CaCl₂ application. On the 14th day of the cold storage, the difference between the amount of caffeic acid of the fruit of CaCl₂ and GA₃ applications was not significant, the lowest value was recorded with control application (Table 4).

Table 2. Effects of pre-harvest spray treatments (GA₃ and CaCl₂) and MAP on 4-hydroxybenzoic acid contents of sweet cherry fruit throughout cold storage

| Treatments       | Harvest | 7       | 14      | 21       |
|------------------|---------|---------|---------|----------|
| MAP              | 14.08   | 16.95 a | 17.69 a | 19.17 a  |
| non-MAP          | 14.08   | 15.76 b | 16.72 b | 18.08 a  |
| **Significance** |         | *       | *       | **       |

Table 3. Effects of packaging (MAP and non-MAP) on 4-hydroxybenzoic acid contents of sweet cherry fruit throughout cold storage

| Treatments       | Harvest | 7       | 14      | 21       |
|------------------|---------|---------|---------|----------|
| Control          | 11.36 c | 14.21 c | 16.15 b | 17.23 b  |
| CaCl₂            | 13.83 b | 15.85 b | 16.17 b | 17.91 b  |
| GA₃              | 15.73 a | 17.38 a | 17.68 a | 18.25 b  |
| GA₃+CaCl₂        | 15.38 a | 17.97 a | 18.83 a | 21.11 a  |
| **Significance** |         | *       | *       | **       |

Table 4. Effects of pre-harvest spray treatments (GA₃ and CaCl₂) and MAP combinations on hydroxybenzoic acid contents of sweet cherry fruit throughout cold storage

| Treatments       | Harvest | 7       | 14      | 21       |
|------------------|---------|---------|---------|----------|
| Control          | 11.36 c | 15.40 c | 16.80 b | 17.65 b  |
| CaCl₂            | 13.83 b | 15.70 c | 15.81 b | 17.91 b  |
| GA₃              | 15.73 a | 17.38 b | 17.69 b | 18.20 b  |
| GA₃+CaCl₂        | 15.38 a | 19.31 a | 20.46 a | 22.90 a  |
| **Significance** |         | **      | **      | **       |

Table 5. Effects of packaging (MAP and non-MAP) on hydroxybenzoic acid contents of sweet cherry fruit throughout cold storage

| Treatments       | Harvest | 7       | 14      | 21       |
|------------------|---------|---------|---------|----------|
| Control          | 11.36 c | 13.02 b | 15.50 b | 16.80 b  |
| CaCl₂            | 13.83 b | 16.00 a | 16.53 a | 17.91 a  |
| GA₃              | 15.73 a | 17.38 a | 17.67 a | 18.29 a  |
| GA₃+CaCl₂        | 15.38 a | 16.62 a | 17.19 a | 19.31 a  |
| **Significance** |         | *       | *       | *        |

*: p < 0.05, **: p < 0.01. The differences among the means indicated with the same lowercase letter in the same column were not significant.

3.5. p-coumaric acid

When the effect of pre-harvest CaCl₂ and GA₃ applications on p-coumaric acid content in fruit was evaluated, the difference between the applications was significant, the highest amount of 4-hydroxybenzoic acid was obtained from fruit applied with GA₃ + CaCl₂, and the lowest p-coumaric acid concentration was recorded with control application. It was determined that the cold storage period had a positive effect on p-coumaric acid concentration. Such that, the p-coumaric acid concentration, which was 9.30 mg kg⁻¹ at the harvest, decreased to 6.20 mg kg⁻¹ at the end of the cold storage. In addition to, the amount of reduction during the cold storage was lower with MAP application. When the effects of CaCl₂ and GA₃ applications at the end of the cold storage was evaluated, the highest value was obtained with CaCl₂+GA₃ application. At the end of the cold storage, the difference between CaCl₂ and GA₃ applications was not statistically significant. While the highest p-coumaric acid concentration was recorded in all fruit applied with GA₃ + CaCl₂ at all measurement periods in MAP-treated fruit, there was no statistically significant between the other three applications. There was no statistically significant difference between CaCl₂ and GA₃ applications in fruit without MAP. The lowest value was obtained with control application while the highest value was recorded with CaCl₂+GA₃ application (Table 5).

3.6. 4-aminobenzoic acid

The effects of pre-harvest CaCl₂ and GA₃ applications and post-harvest MAP application in 4-aminobenzoic acid content of fruit at post-harvest cold storage was shown in Table 6. When the data were evaluated, CaCl₂ and GA₃ decreased to the 4-aminobenzoic acid concentration while the lowest amount of 4-aminobenzoic acid was recorded in fruit applied with GA₃. It was determined that 4-aminobenzoic acid concentration decreased as the cold storage time increased, but CaCl₂ and GA₃ applications had no effect on this decrease. Considering the data of CaCl₂ and GA₃ and MAP combinations, significant differences between the applications on the 14th and 21st days of the cold storage were not observed while on the 7th day of the cold storage, the lowest value was obtained with the application of GA₃ + CaCl₂. There were no significant differences in terms of 4-aminobenzoic acid concentration after the cold storage in fruit without MAP application (Table 6).
Table 3. Effects of pre-harvest spray treatments (GA$_3$ and CaCl$_2$) and MAP on epicatechin contents of sweet cherry fruit throughout cold storage

| Treatments | Harvest | Epicatechin (mg kg$^{-1}$) |
|------------|---------|---------------------------|
|            | 7       | 14                        | 21                       |
| Results by packaging |         |                           |                          |
| MAP        | 13.54   | 15.47                     | 18.07 a                  | 19.91                   |
| non-MAP    | 13.54   | 15.71                     | 16.93 b                  | 19.59                   |
| Significance | ns.    | *                         | ns.                      |                         |
| Results by spraying |         |                           |                          |
| Control    | 12.26 b | 15.71 a                   | 16.61 b                  | 19.22 b                 |
| CaCl$_2$   | 12.15 b | 14.71 b                   | 17.61 ab                 | 21.29 a                 |
| GA$_3$     | 14.41 a | 16.29 a                   | 18.51 a                  | 20.14 ab                |
| GA$_3$+CaCl$_2$ | 15.33 a | 15.67 a                   | 17.28 ab                 | 18.33 c                 |
| Significance | *      | *                         | *                        | *                       |
| MAP        | 13.54   | 15.47                     | 18.07 a                  | 19.91                   |
| Control    | 12.26 b | 16.25 a                   | 17.21 b                  | 17.86 c                 |
| CaCl$_2$   | 12.15 b | 14.42 c                   | 17.57 b                  | 21.81 a                 |
| GA$_3$     | 14.41 a | 15.63 b                   | 18.88 a                  | 19.51 b                 |
| GA$_3$+CaCl$_2$ | 15.33 a | 15.59 b                   | 18.63 a                  | 20.44 a                 |
| Significance | *      | **                        | *                        | **                      |
| non-MAP    | 13.54   | 15.47                     | 18.07 a                  | 19.91                   |
| Control    | 12.26 b | 15.17 c                   | 16.01 b                  | 20.58 a                 |
| CaCl$_2$   | 12.15 b | 14.99 c                   | 17.64 a                  | 20.77 a                 |
| GA$_3$     | 14.41 a | 16.94 a                   | 18.13 a                  | 20.77 a                 |
| GA$_3$+CaCl$_2$ | 15.33 a | 15.74 b                   | 15.92 b                  | 16.22 b                 |

*: p < 0.05, **: p < 0.01, ns: non-significant. The differences among the means indicated with the same lowercase letter in the same column were not significant.

Table 4. Effects of pre-harvest spray treatments (GA$_3$ and CaCl$_2$) and MAP on caffeic acid contents of sweet cherry fruit throughout cold storage

| Treatments | Harvest | Caffeic acid (mg kg$^{-1}$) |
|------------|---------|-----------------------------|
|            | 7       | 14                          | 21                        |
| Results by packaging |         |                            |                           |
| MAP        | 9.93    | 8.81 a                      | 8.46 a                    | 7.28 a                   |
| non-MAP    | 9.93    | 8.40 b                      | 8.25 b                    | 7.03 b                   |
| Significance | *      | *                          | *                         |                         |
| Results by spraying |         |                            |                           |
| Control    | 7.61 b  | 6.87 b                      | 6.69 c                    | 6.09 c                   |
| CaCl$_2$   | 10.49 a | 9.31 a                      | 8.75 b                    | 8.00 a                   |
| GA$_3$     | 10.82 a | 8.71 a                      | 8.12 b                    | 7.40 b                   |
| GA$_3$+CaCl$_2$ | 10.79 a | 9.54 a                      | 9.86 a                    | 7.13 b                   |
| Significance | **     | *                          | *                         | **                      |
| MAP        | 9.93    | 8.81 a                      | 8.46 a                    | 7.28 a                   |
| Control    | 7.61 b  | 6.95 c                      | 6.78 c                    | 6.49 c                   |
| CaCl$_2$   | 10.49 a | 10.17 a                     | 9.13 ab                   | 7.37 b                   |
| GA$_3$     | 10.82 a | 8.21 b                      | 8.12 b                    | 8.10 a                   |
| GA$_3$+CaCl$_2$ | 10.79 a | 9.90 a                      | 9.80 a                    | 7.14 b                   |
| non-MAP    | 9.93    | 8.81 a                      | 8.46 a                    | 7.28 a                   |
| Control    | 7.61 b  | 6.78 c                      | 6.60 c                    | 5.69 c                   |
| CaCl$_2$   | 10.49 a | 8.44 b                      | 8.36 b                    | 8.62 a                   |
| GA$_3$     | 10.82 a | 9.21 a                      | 8.12 b                    | 6.70 b                   |
| GA$_3$+CaCl$_2$ | 10.79 a | 9.17 a                      | 9.92 a                    | 7.12 b                   |
| Significance | **     | **                         | *                         | **                      |

*: p < 0.05, **: p < 0.01. The differences among the means indicated with the same lowercase letter in the same column were not significant.
acids are the major hydroxycinnamic acids and are the most prevalent phenolic compounds on sweet cherry. Gallic acid (3.77 mg 100 g⁻¹) was the individual phenolic with the lowest concentration (3.77 mg 100 g⁻¹), while the highest concentration (636 mg kg⁻¹) was protocatechuic acid. Catechin (4.77 mg 100 g⁻¹) was the most prevalent phenolic on sweet cherry.

In our study, individual phenolics identified in sweet cherry samples were catechin, 4-hydroxybenzoic acid, epicatechin, caffeic acid, p-coumaric acid, 4-aminobenzoic acid, protocatechuic acid. Catechin was the individual phenolic, which had the highest concentration (636 mg kg⁻¹), while the individual phenolic with the lowest concentration (3.77 mg kg⁻¹) was protocatechuic acid. Jakobek et al. (2009) and Gonçalves et al. (2019) have reported that gallic acid (0.73–10.64 mg 100 g⁻¹ frw), p-hydroxybenzoic (0.73–10.64 mg 100 g⁻¹), and 2,5-dihydroxybenzoic acids (0.46–1.64 mg 100 g⁻¹) are the most prevalent phenolic compounds on sweet cherry. Han et al. (2007) have reported that caffeic, coumaric, ferulic, and sinapic acids are the major hydroxycinnamic acids on sweet cherry. The fact that Hayaloglu and Demir (2016), have determined that the phenolics on sweet cherry are neochlorogenic and p-coumaroylquinoic acids, epicatechin, chlorogenic acid, and rutin on sweet cherry. In addition to Serrano et al. (2005) and Usenik et al. (2008) reported that p-coumaroylquinic acid was principal phenolic on sweet cherry.

Pre-harvest GA3 application has a significant effect on fruit quality of sweet cherry (Basak et al., 1998; Clayton et al., 2003; Lenahan et al., 2008; Zhang and Whiting, 2011; Einhorn et al., 2013; Canli et al., 2015). In the study, it was found that the application of GA3, which is applied before harvest, generally increases the content of individual phenolics in fruit. In accordance with the results of the study, Diaz-Mula et al. (2009) reported that a significant increasing occurred in total phenolic, anthocyanin and antioxidant capacity in fruit by application of GA3, while Ozkan et al. (2016) found that total anthocyanin content and total antioxidant capacity of GA3 application in Regina and Sweetheart sweet cherry cultivar were significantly lower than control. With the application of GA3, anthocyanin accumulation in strawberry (Martinez et al., 1994) and antioxidant capacity in plum (Eroglu and Sen, 2015) occurred. Han et al. (2007) have reported that caffeic, coumaric, ferulic, and sinapic acids are the major hydroxycinnamic acids on sweet cherry. The fact that Hayaloglu and Demir (2016), have determined that the phenolics on sweet cherry are neochlorogenic and p-coumaroylquinic acids, epicatechin, chlorogenic acid, and rutin on sweet cherry. In addition to Serrano et al. (2005) and Usenik et al. (2008) reported that p-coumaroylquinic acid was principal phenolic on sweet cherry.

In the study, it was observed that the concentration of the protocatechuic acid increased with CaCl2 application and there was no significant difference between GA3 and control application. It was determined that a decrease in the amount of protocatechuic acid in proportion to the cold storage time occurred, in this decrease, MAP application had no effect on the 7th and 14th days of the cold storage, but MAP -treated fruit had higher the protocatechuic acid concentration at the end of the cold storage. When the effect of GA3 and CaCl2 applications on protocatechuic acid concentration during the cold storage was evaluated, the highest value was obtained from the fruit of the CaCl2 application and there were no statistically significant differences between GA3 and control applications (Table 7).

### Table 5. Effects of pre-harvest spray treatments (GA3 and CaCl2) and MAP on p-coumaric acid contents of sweet cherry fruit throughout cold storage

| Treatments | Harvest 7 | Harvest 14 | Harvest 21 |
|------------|-----------|------------|-----------|
| **Results by packaging** | **Results by spraying** | **Results by spraying** | **Results by spraying** |
| MAP | 6.18 d | 6.10 c | 6.03 c | 5.42 c |
| non-MAP | 6.31 ab | 6.07 b | 5.96 b | 5.94 b |
| **Significance** | **Significance** | **Significance** | **Significance** |
| Control | 6.18 d | 6.07 b | 5.96 b | 5.94 b |
| CaCl2 | 6.13 b | 6.09 b | 4.77 c |
| GA3 | 6.12 b | 6.65 b | 5.88 b |
| GA3+CaCl2 | 6.63 a | 6.48 a | 6.09 a |
| **Significance** | ns. | * | * | * |

**: p < 0.05, **: p < 0.01, ns: non-significant. The differences among the means indicated with the same lowercase letter in the same column were not significant.

### 3.7. Protocatechuic acid

In the study, it was observed that the concentration of the protocatechuic acid increased with CaCl2 application and there was no significant difference between GA3 and control application. It was determined that a decrease in the amount of protocatechuic acid in proportion to the cold storage time occurred, in this decrease, MAP application had no effect on the 7th and 14th days of the cold storage, but MAP -treated fruit had higher the protocatechuic acid concentration at the end of the cold storage. When the effect of GA3 and CaCl2 applications on protocatechuic acid concentration during the cold storage was evaluated, the highest value was obtained from the fruit of the CaCl2 application and there were no statistically significant differences between GA3 and control applications (Table 7).

### 4. Discussion

In our study, individual phenolics identified in sweet cherry samples were catechin, 4-hydroxybenzoic acid, epicatechin, caffeic acid, p-coumaric acid, 4-aminobenzoic acid, protocatechuic acid. Catechin was the individual phenolic, which had the highest concentration (636 mg kg⁻¹), while the individual phenolic with the lowest concentration (3.77 mg kg⁻¹) was protocatechuic acid. Jakobek et al. (2009) and Gonçalves et al. (2019) have reported that gallic acid (0.73–10.64 mg 100 g⁻¹ frw), p-hydroxybenzoic (0.73–10.64 mg 100 g⁻¹), and 2,5-dihydroxybenzoic acids (0.46–1.64 mg 100 g⁻¹) are the most prevalent phenolic compounds on sweet cherry. Han et al. (2007) have reported that caffeic, coumaric, ferulic, and sinapic acids are the major hydroxycinnamic acids on sweet cherry. The fact that Hayaloglu and Demir (2016), have determined that the phenolics on sweet cherry are neochlorogenic and p-coumaroylquinic acids, epicatechin, chlorogenic acid, and rutin on sweet cherry. In addition to Serrano et al. (2005) and Usenik et al. (2008) reported that p-coumaroylquinic acid was principal phenolic on sweet cherry.

Pre-harvest GA3 application has a significant effect on fruit quality of sweet cherry (Basak et al., 1998; Clayton et al., 2003; Lenahan et al., 2008; Zhang and Whiting, 2011; Einhorn et al., 2013; Canli et al., 2015). In the study, it was found that the application of GA3, which is applied before harvest, generally increases the content of individual phenolics in fruit. In accordance with the results of the study, Diaz-Mula et al. (2009) reported that a significant increasing occurred in total phenolic, anthocyanin and antioxidant capacity in fruit by application of GA3, while Ozkan et al. (2016) found that total anthocyanin content and total antioxidant capacity of GA3 application in Regina and Sweetheart sweet cherry cultivar were significantly lower than control. With the application of GA3, anthocyanin accumulation in strawberry (Martinez et al., 1994) and antioxidant capacity in plum (Eroglu and Sen, 2015) occurred. Han et al. (2007) have reported that caffeic, coumaric, ferulic, and sinapic acids are the major hydroxycinnamic acids on sweet cherry. The fact that Hayaloglu and Demir (2016), have determined that the phenolics on sweet cherry are neochlorogenic and p-coumaroylquinic acids, epicatechin, chlorogenic acid, and rutin on sweet cherry. In addition to Serrano et al. (2005) and Usenik et al. (2008) reported that p-coumaroylquinic acid was principal phenolic on sweet cherry.

Pre-harvest GA3 application has a significant effect on fruit quality of sweet cherry (Basak et al., 1998; Clayton et al., 2003; Lenahan et al., 2008; Zhang and Whiting, 2011; Einhorn et al., 2013; Canli et al., 2015). In the study, it was found that the application of GA3, which is applied before harvest, generally increases the content of individual phenolics in fruit. In accordance with the results of the study, Diaz-Mula et al. (2009) reported that a significant increasing occurred in total phenolic, anthocyanin and antioxidant capacity in fruit by application of GA3, while Ozkan et al. (2016) found that total anthocyanin content and total antioxidant capacity of GA3 application in Regina and Sweetheart sweet cherry cultivar were significantly lower than control. With the application of GA3, anthocyanin accumulation in strawberry (Martinez et al., 1994) and antioxidant capacity in plum (Eroglu and Sen, 2015) decreased. This can be explained by means of delaying the maturity of the fruit with GA3 application (Kappel and Mac Donald, 2002; Amarente et al., 2005; Lenahan et al., 2006; Çetinbaş and Koyuncu, 2013).
Gonçalves et al. (2004) have determined that phenolic concentrations increased with increasing cold storage time. In our study, the concentration of the individual phenolics generally decreased during the cold storage, whereas epicatechin and 4-hydroxybenzoic acid contents decreased at 22°C. In the study, although the percentage of losses in individual phenolic during cold storage was higher in CaCl$_2$ and GA$_3$ applications than in control, it was found that the amount of individual phenolic at the end of the cold storage was higher on CaCl$_2$ and GA$_3$ applications. The increasing of the individual phenolic concentrations of the fruit at harvest by pre-harvest CaCl$_2$ and GA$_3$ applications caused by the occurrence of this result. Calcium treatments represent a safe and potentially effective technology for enhancing the postharvest life and nutritional quality of fruits and vegetables (Martin-Diana et al., 2007; Aghdam et al., 2013). Supapvanich et al. (2012) determined that CaCl$_2$ application maintained to total phenolics, total flavonoids, ascorbic acid content at cold storage (Aghdam et al., 2013). In addition to, Aghdam et al. (2013) have determined that the postharvest CaCl$_2$ application has increased total phenolics, flavonoids, antocyanins and ascorbic acid contents of cornelian cherry fruit, and they have suggested that the CaCl$_2$ enhanced antioxidant potential could be due to the activation of phenypropanoid-flavonoids pathways in the cornelian cherry fruits. Gibberellic acid (GA$_3$), which plays significant role in breaking seed dormancy, promoting flower bud differentiation and stem elongation, and delaying the senescence of plant organs (Achard et al., 2009; Sun, 2010; Calciu et al., 2007; Diana et al., 2007; Beigi et al., 2019) on sweet cherry. Many studies have suggested that the CaCl$_2$ applications in the plant have been obtained (Val et al., 2010). In our study, which was relative to the effect of applications of CaCl$_2$ on the content of individual phenolic in fruit during harvest and post-harvest storage on sweet cherry, it was found that the application of CaCl$_2$ increased the individual phenolic content in fruit. Chen et al. (2011) reported that the using of calcium at low concentration increases the nutritional quality of fruit and vegetables.

The preharvest foliar spray treatments with plant growth regulators such as salicylic acid and GA$_3$ induced also enhancement of phenolic content at harvest in Navel oranges (Huang et al., 2008) and jujube (Cao et al., 2013) fruits (Gimenez et al., 2014). In our study, the concentration of the individual phenolics generally decreased during the cold storage, whereas epicatechin and 4-hydroxybenzoic acid concentrations increased with increasing cold storage time. Gonçalves et al. (2004) have determined that that phenolic acid contents decreased with processing and storage at 1–2°C and increased with storage at 1-5°C, and the epicatechin concentration decreased at 22°C. In the study, although the percentage of losses in individual phenolic during cold storage was higher in CaCl$_2$ and GA$_3$ applications than in control, it was found that the amount of individual phenolic at the end of the cold storage was higher on CaCl$_2$ and GA$_3$ applications. The increasing of the individual phenolic concentrations of the fruit at harvest by pre-harvest CaCl$_2$ and GA$_3$ applications caused by the occurrence of this result. Calcium treatments represent a safe and potentially effective technology for enhancing the postharvest life and nutritional quality of fruits and vegetables (Martin-Diana et al., 2007; Aghdam et al., 2013). Supapvanich et al. (2012) determined that CaCl$_2$ application maintained to total phenolics, total flavonoids, ascorbic acid content at cold storage (Aghdam et al., 2013). In addition to, Aghdam et al. (2013) have determined that the postharvest CaCl$_2$ application has increased total phenolics, flavonoids, antocyanins and ascorbic acid contents of cornelian cherry fruit, and they have suggested that the CaCl$_2$ enhanced antioxidant potential could be due to the activation of phenypropanoid-flavonoids pathways in the cornelian cherry fruits.

Pre-harvest Ca application has a significant effect on fruit quality (Dong et al., 2019). The fruit chemical composition (Hosein-Beigi et al., 2019) on sweet cherry. Many studies were carried out (Lidster et al., 1979; Facteau et al., 1987; Tsantili et al., 2007; Wójcik et al., 2013; Eroglu, 2014; Michailidis et al., 2017) relative to the using of calcium to reduce cracking and improve fruit quality in sweet cherry. However, the inconsistent results relative to the increasing of the calcium content and the improving of the fruit quality of these applications in the plant have been obtained (Val et al., 2008; Sotiropoulos et al., 2010). In our study, which was relative to the effect of applications of CaCl$_2$ on the content of individual phenolic in fruit during harvest and post-harvest storage on sweet cherry, it was found that the application of CaCl$_2$ increased the individual phenolic content in fruit. Chen et al. (2011) reported that the using of calcium at low concentration increases the nutritional quality of fruit and vegetables.

### Table 6. Effects of pre-harvest spray treatments (GA$_3$ and CaCl$_2$) and MAP on 4-aminobenzoic acid contents of sweet cherry fruit throughout cold storage

| Treatments          | 4-aminobenzoic acid (mg kg$^{-1}$) | Harvest | 7  | 14 | 21 |
|---------------------|-----------------------------------|---------|----|----|----|
| **Results by packaging** |                                   |         |    |    |    |
| MAP                 | 4.80                              | 4.36    | 4.25| 4.15|
| non-MAP            | 4.80                              | 4.31    | 4.22| 4.11|
| **Significance**    | ns.                               | ns.     | ns.|    |
| **Results by spraying** |                                 |         |    |    |    |
| Control             | 5.49 a                            | 4.32    | 4.20| 4.15|
| CaCl$_2$            | 4.99 b                            | 4.47    | 4.32| 4.03|
| GA$_3$              | 4.38 c                            | 4.34    | 4.32| 4.21|
| GA$_3$+CaCl$_2$     | 4.32 c                            | 4.21    | 4.19| 4.12|
| **Significance**    | *                                 | ns.     | ns.|    |
| MAP                 | 5.49 a                            | 4.41 ab | 4.22| 4.16 a|
| CaCl$_2$            | 4.99 b                            | 4.56 a  | 4.31| 4.12 a|
| GA$_3$              | 4.38 c                            | 4.30 b  | 4.30| 4.18 a|
| GA$_3$+CaCl$_2$     | 4.32 c                            | 4.16 c  | 4.16| 4.12 a|
| **Significance (interaction)** |                             | *       | *  | ns.|

*: p < 0.05, **: p < 0.01, ns: non-significant. The differences among the means indicated with the same lowercase letter in the same column were not significant.
Zaho et al., 2018), has been used in commercial horticultural cultivation as a plant growth regulator to improve fruit size and quality (Khalil and Aly, 2013; Zang et al., 2016; Gundogdu et al., 2017), to delay ripening and to maintain fruit quality of postharvest crops (Steffens et al., 2011; Huang et al., 2014; Souza et al., 2016; Zaho et al., 2018).

Table 7. Effects of pre-harvest spray treatments (GA3 and CaCl2) and MAP on protocatechuic acid contents of sweet cherry fruit throughout cold storage

| Treatments          | Protocatechuic acid (mg kg⁻¹) | Harvest 7 | Harvest 14 | Harvest 21 |
|---------------------|--------------------------------|-----------|------------|------------|
|                     |                                |           |            |            |
| Results by packaging|                                |           |            |            |
| MAP                 | 3.77                           | 3.63      | 3.53       | 3.37 a     |
| non-MAP             | 3.77                           | 3.55      | 3.46       | 3.19 b     |
| Significance        | ns.                            | ns.       |            | **         |
| Results by spraying |                                |           |            |            |
| Control             | 3.72 b                         | 3.54 b    | 3.37 b     | 3.27 b     |
| CaCl2               | 4.33 a                         | 4.12 a    | 4.06 a     | 3.70 a     |
| GA3                 | 3.57 b                         | 3.35 b    | 3.29 b     | 3.13 b     |
| GA3+CaCl2           | 3.45 b                         | 3.34 b    | 3.27 b     | 3.02 b     |
| Significance        | *                              | *         | **         | *          |
| MAP                 |                                |           |            |            |
| Control             | 3.72 b                         | 3.56 b    | 3.38 b     | 3.17 b     |
| CaCl2               | 4.33 a                         | 4.25 a    | 4.18 a     | 3.99 a     |
| GA3                 | 3.57 b                         | 3.43 b    | 3.32 b     | 3.28 b     |
| GA3+CaCl2           | 3.45 b                         | 3.26 b    | 3.25 b     | 3.02 b     |
| Significance (interaction) | *                              | *         | **         | *          |

*: p < 0.05, **: p < 0.01, ns: non-significant. The differences among the means indicated with the same lowercase letter in the same column were not significant.

Dong et al. (2019) have reported that GA3 combined with Ca application may have high potential for improving storage or shipping quality of commercial sweet cherry. The fact that, in our study, it was observed that CaCl and GA3 combination has occurred to the differences on the effect. Petracek et al. (2002), Remon et al. (2000), Spotts et al. (2002) and Tian et al. (2004) have reported that the application of the MAP, which is used to delay the physicochemical changes, to retard microbial spoilage and to retain color by reducing the oxidation to extend the shelf life of the fruit species (Singh et al., 2010), has a significant effect in delaying of the physico-chemical changes on sweet cherry. The MAP applications that balance the CO2 concentrations and inhibits enzyme activity favoring stability of color (Rocha and Morais, 2001; Remon et al., 2004) has slightly increased the total anthocyanin content of sweet cherry during the cold storage (Conte et al., 2009; Padilla-Zakour et al., 2007; Remon et al., 2000). However, Remon et al. (2003) have determined that MAP application has not a significant effect on the total anthocyanin content of sweet cherry at postharvest. In our study, MAP application had a positive effect on the losses of other phenolic compounds except catechin during cold storage.

The fact that, Serrano et al. (2006) reported decreased losses in antioxidant activity, total phenolics and vitamin C contents of broccoli with MAP treatments. However Aglar et al. (2017) have reported that MAP-treated fruits had significantly lower antioxidant activity than the control fruits in cold storage. In addition to Giacalone and Chiabrando (2013) indicated that MAP treatments did not have any negative impacts on phenolic compounds and antioxidant activity. Khan and Singh (2008) reported that MAP-treated plums had lower antioxidant activity than the control fruit. Similarly, Artes-Hernandez et al. (2006) reported that MAP treatments retarded the formation of carotenoids and anthocyanin-like color pigments.

5. Conclusion

Pre-harvest GA3 and CaCl2 applications caused an increase in the content of individual phenolic in fruit. The concentration of individual phenolic generally decreased with increasing cold storage time. The percentage of losses in individual phenolic during cold storage was proportionally higher in CaCl2 and GA3 applications. However, at the end of the cold storage, the amount of the individual phenolic of CaCl2 and GA3 applications was higher. The increasing of the individual phenolic concentrations of the fruit at harvest by pre-harvest CaCl2 and GA3 applications caused by the occurrence of this result. MAP application had a positive effect on the losses of other phenolic compounds except catechin during cold storage. In conclusion, pre-harvest GA3 and CaCl2 applications are significant applications to
increase the percentage of individual phenolic in fruit. MAP can be used to reduce the losses of individual phenolic in cold storage.

Acknowledgement
This work is supported by the Scientific Research Project Fund of Ordu University under the Project number AR-1658.

References
Achard, P., Gusti, A., Cheminant, S., Alioua, M., Dhoult, S., Coppens, F., & Genschik, P. (2009). Gibberellin signaling controls cell proliferation rate in Arabidopsis. Current biology, 19(14), 1188-1193.

Aghdam, M. S., Dokhanieh, A. Y., Hassanpour, H., & Fard, J. R. (2013). Enhancement of antioxidant capacity of cornelian cherry (Cornus mas) fruit by postharvest calcium treatment. Scientia horticulturae, 161, 160-164.

Agler, E., Ozturk, B., Guler, S. K., Karakaya, O., Uzun, S., & Saracoglu, O. (2017). Effect of modified atmosphere packaging and ‘Parka’treatments on fruit quality characteristics of sweet cherry fruits (Prunus avium L. ’0900 Ziraat’) during cold storage and shelf life. Scientia horticulturae, 222, 162-168.

Agler, E., Saracoglu, O., Karakaya, O., Ozturk, B., & Gun, S. (2019). The relationship between fruit color and fruit quality of sweet cherry (Prunus avium L. cv. ‘0900 Ziraat’). Turkish Journal of Food and Agriculture Sciences, 1(1), 1-5.

Alique, R., Zamorano, J. P., Martinez, M. A., & Alonso, J. (2005). Effect of heat and cold treatments on respiratory metabolism and shelf-life of sweet cherry, type picota cv “Ambrunes”. Postharvest Biology and Technology, 35(2), 153-165.

Amarante, C. V. T. D., Drehmer, A. M. F., Souza, F. D., & Francescato, P. (2005). Preharvest spraying with gibberellic acid (GA₃) and aminoethoxyvinylglycine (AVG) delays fruit maturity and reduces fruit losses on peaches. Revista Brasileira de Fruticultura, 27(1), 1-5.

Ames, B. N., Shigenaga, M. K., & Hagen, T. M. (1993). Oxidants, antioxidants and the generative disease of aging. Proceedings of the National Academy of Sciences of the United States of America, 90, 7915-7922.

Artés-Hernández, F., Tomás-Barberán, F. A., & Artés, F. (2006). Modified atmosphere packaging preserves quality of SO₂-free ‘Superior seedless’ table grapes. Postharvest Biology and technology, 39(2), 146-154.

Ballistreri, G., Continella, A., Gentile, A., Amenta, M., Fabroni, S., & Rapisarda, P. (2013). Fruit quality and bioactive compounds relevant to human health of sweet cherry (Prunus avium L.) cultivars grown in Italy. Food chemistry, 140(4), 630-638.

Basak, A., Rozpara, E., & Grzyb, Z. (1997, July). Use of bioregulators to reduce sweet cherry tree growth and to improve fruit quality. In III International Cherry Symposium 468 (pp. 719-724).

Baswal, A. K., Dhaliwal, H. S., Singh, Z., Mahajan, B. V. C., & Gill, K. S. (2020). Postharvest application of methyl jasmonate, 1-methylcyclopentene and salicylic acid extends the cold storage life and maintain the quality of ‘Kinnow’mandarin (Citrus nobilis L. X C. deliciosa L.) fruit. Postharvest Biology and Technology, 161, 111064.

Benzie, I. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. Analytical biochemistry, 239(1), 70-76.

Canli, F. A., Pektas, M., & Ercisli, S. (2015). Benzyladene and gibberellin applications improve fruit weight and delay maturity of sweet cherry. Erwerbs-Obstbau, 57(2), 71-75.

Cantin, C. M., Crisosto, C. H., & Day, K. R. (2008). Evaluation of the effect of different modified atmosphere packaging box liners on the quality and shelf life of ‘Friar’plums. HortTechnology, 18(2), 261-265.

Cao, J. K., Yan, J. Q., Zhao, Y. M., & Jiang, W. B. (2013). Effects of four pre-harvest foliar sprays with β-amino butyric acid or salicylic acid on the incidence of post-harvest disease and induced defense responses in jujube (Zizyphus jujuba Mill.) fruit after storage. The Journal of Horticultural Science and Biotechnology, 88(3), 338-344.

Carrillo-Lopez, A., Ramirez-Bustamante, F., Valdez-Torres, J., Rojas-Villegas, R., & Yahia, E. (2000). Ripening and quality changes in mango fruit by coating with an edible film. Journal of Food Quality, 23, 479-486.

Cetinbas, M., & Koyuncu, F. (2013). The ripening and fruit quality of ‘Monro’e peaches in response to pre-harvest application gibberellic acid. Journal of Akdeniz University Faculty of Agriculture, 20(2), 73-80.

Cheon, G. H., Shin, Y., Kim, T. G., & Park, J. W. (2001). Antioxidant activity of mulberry leaf extract. The Journal of Medicinal Plants Research, 2(2), 94-97.

Dong, Y., Díaz, M., & Ploegman, A. (2013). Fruit quality assessment of ‘Khalkhal’ (FCT 67) and ‘Khalkhal’ (FCT 72) sweet cherry under different postharvest conditions. Scientia Horticulturae, 145, 373-378.

El-Razek, E. A., Hassan, H. S. A., & El-Din, K. M. G. (2013). Effect of foliar application with salicylic acid, benzyladene and gibberellic acid on flowering, yield and fruit quality of olive trees (Olea europaea L.). Middle-East Journal of Scientific Research, 14(11), 1401-1406.

El- Shazly, S. M., Eisa, A. M., Moatamed, A. M. H., & Kotb, H. R. M. (2013). Effect of some agrochemicals preharvest foliar application on yield and fruit quality of swaying peach trees. Alexandria Journal of Agricultural Research, 58, 219-229.

Erogul, D., & Sen, F. (2015). Effects of gibberellic acid treatments on fruit thinning and fruit quality in Japanese plum (Prunus salicina Lindl.). Scientia Horticuluture, 186, 137-142.
Facteau, T. J., Rowe, K. E., & Chestnut, N. E. (1987). Response of Bing' and Lambert sweet cherry fruit to preharvest calcium chloride applications. HortScience, 22, 271–273.

Fatemi, H., Mohammadi, S., & Aminifar, M. H. (2013). Effect of postharvest salicylic acid treatment on fungal decay and some postharvest quality factors of kiwi fruit. Archives of phytopathology and plant protection, 46(11), 1338-1345.

Gao, L., & Mazza, G. (1995). Characterization, quantitation, and distribution of anthocyanins and colorless phenolics in sweet cherries. Journal of Agricultural and Food Chemistry, 43(2), 343-346.

García-Closas, R., Gonzalez, C. A., Agudo, A., & Riboli, E. (1999). Intake of specific carotenoids and flavonoids and the risk of gastric cancer in Spain. Cancer Causes & Control, 10(1), 71-75.

Giacalone, G., & Chiabrando, V. (2013). Modified atmosphere packaging of sweet cherries with biodegradable films. International Food Research Journal, 20(3), 1263-1268.

Giménez, M. J., Valverde, J. M., Valero, D., Guilén, F., Martínez-Romero, D., Serrano, M., & Castillo, S. (2014). Quality and antioxidant properties on sweet cherries as affected by preharvest salicylic and acetylsalicylic acids treatments. Food chemistry, 160, 226-232.

Giménez, M. J., Valverde, J. M., Valero, D., Zapata, P. J., Castillo, S., & Serrano, M. (2016). Postharvest methyl salicylate treatments delay ripening and maintain quality attributes and antioxidant compounds of ‘Early Lory’ sweet cherry. Postharvest Biology and Technology, 117, 102-109.

Gómez, C. A., Herrera, A. O., Flórez, V. J., & Balaguera-López, H. Methyl jasmonate, a degreening alternative for mandarin (Citrus reticulata) var. arrayana fruits. International Journal of Engineering Research and Applications, 7, 22-29.

González, B., Landbo, A. K., Let, M., Silva, A. P., Rosa, E., & Meyer, A. S. (2004). Storage affects the phenolic profiles and antioxidant activities of cherries (Prunus avium L.) on human low-density lipoproteins. Journal of the Science of Food and Agriculture, 84(9), 1013-1020.

González, B., Silva, A. P., Moutinho-Pereira, J., Bacelar, E., Rosa, E., & Meyer, A. S. (2007). Effect of ripeness and postharvest storage on the evolution of colour and anthocyanins in cherries (Prunus avium L.). Food Chemistry, 103(3), 976-984.

González, A. C., Bento, C., Jesus, F., Alves, G., & Silva, L. R. (2018). Sweet Cherry Phenolic Compounds: Identification, Characterization, and Health Benefits. In Studies in Natural Products Chemistry (Vol. 59, pp. 31-78). Elsevier.

González-Gómez, D., Lozano, M., Fernández-León, M. F., Ayuso, M. C., Bernalte, M. J., & Rodríguez, A. B. (2009). Detection and quantification of melatonin and serotonin in eight sweet cherry cultivars (Prunus avium L). European Food Research and Technology, 229(2), 223-229.

González-Gómez, D., Lozano, M., Fernández-León, M. F., Bernalte, M. J., Ayuso, M. C., & Rodríguez, A. B. (2010). Sweet cherry phytochemicals: Identification and characterization by HPLC-DAD/ESI-MS in six sweet-cherry cultivars grown in Valle del Jerte (Spain). Journal of Food Composition and Analysis, 23(6), 533-539.

Guilbert, S., Gontard, N., & Gorris, L. G. (1996). Prolongation of the shelf-life of perishable food products using biodegradable films and coatings. LWT-food science and technology, 29(1-2), 10-17.

Guillén, F., Diaz-Mula, H. M., Zapata, P. J., Valero, D., Serrano, M., Castillo, S., & Martinez-Romero, D. (2013). Aloe arborescens and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest biology and technology, 83, 54-57.

Gundogdu, M., Berk, S., Canan, I., Tuna, S., Kocoglu, F. C., & Akkul, T. A. S. (2017). Determination of Effect of Gibberellic Acid Treatments on The Fruit Quality of Strawberry cv. Seaescape. Yuzuncu Yil University Journal of Agriculture Science, 27 (4), 608–612.

Han, X., Shen, T., & Lou, H. (2007). Dietary polyphenols and their biological significance. International Journal of Molecular Sciences, 8(9), 950-988.

Hayaloglu, A. A., & Demir, N. (2016). Phenolic compounds, volatiles, and sensory characteristics of twelve sweet cherry (Prunus avium L.) cultivars grown in Turkey. Journal of food science, 81(1), 7-18.

Hernández-Muñoz, P., Almenar, E., Ocio, M. J., & Gavara, R. (2006). Effect of calcium dips and chitosan coatings on postharvest life of strawberries (Fragaria x ananassa). Postharvest Biology and Technology, 39(3), 247-253.

Hocking, B., Tyerman, S. D., Burton, R. A., & Gillilham, M. (2016). Fruit calcium: transport and physiology. Frontiers in plant science, 7, 1-17.

Hoscin-Beigi, M., Zarei, A., Rostaminia, M., & Efrangi-Moghadam, J. (2019). Positive effects of foliar application of Ca, Ba and Ga3 on the qualitative and quantitative traits of pomegranate (Punica granatum L.) cv. ‘Malase-Torshe-Saveh’. Scientia Horticulturae, 254, 40-47.

Huang, R., Xia, R., Lu, Y., Hu, L., & Xu, Y. (2008). Effect of pre-harvest salicylic acid spray treatment on post-harvest antioxidant in the pulp and peel of ‘Cara cara’ navel orange (Citrus sinensis L. Osbeck). Journal of the Science of Food and Agriculture, 88(2), 229-236.

Huang, H., Jing, G., Wang, H., Duan, X., Qu, H., & Jiang, Y. (2014). The combined effects of phenylurea and gibberellins on quality maintenance and shelf life extension of banana fruit during storage. Scientia horticulturae, 167, 36-42.

Jakobek, L., Šeruga, M., Šeruga, B., Novak, I., & Medvidović-Kosanović, M. (2009). Phenolic compound composition and antioxidant activity of fruits of Rubus and Prunus species from Croatia. International journal of food science & technology, 44(4), 860-868.

Kappel, F., & MacDonald, R. A. (2002). Gibberellic acid increases fruit firmness, fruit size, and delays maturity of‘Sweetheart’ sweet cherry. Journal of the American Pomological Society, 56(4), 219.

Kaur, C., & Kapoor, H. C. (2001). Antioxidants in fruits and vegetables—the millennium’s health. International journal of food science & technology, 36(7), 703-725.

Kayaş, K., Sakaldas, M., & Yurt, U. (2009, April). The Effects of Different Postharvest Applications and Different Modified Atmosphere Packaging Types on Fruit Quality of‘Angeleno’Plums. In X International Controlled and Modified Atmosphere Research Conference 876 (pp. 209-216).

Kelebek, H., & Selli, S. (2011). Evaluation of chemical constituents and antioxidant activity of sweet cherry (Prunus avium L.) cultivars. International Journal of Food Science and Technology, 46, 2530–2537.

Kim, D. O., Heo, H. J., Kim, Y. J., Yang, H. S., & Lee, C. Y. (2005). Sweet and sour cherry phenolics and their protective effects on neuronal cells. Journal of agricultural and food chemistry, 53(26), 9921-9927.

Khalil, H. A., & Aly, H. S. (2013). Cracking and fruit quality of pomegranate (Punica granatum L.) as affected by pre-
harvest sprays of some growth regulators and mineral nutrients. J. Hortic. Sci. Ornam. Plants, 5(2), 71-76.

Khan, A. S., & Singh, Z. (2008). 1-Methylecyclopentene application and modified atmosphere packaging affect ethylene biosynthesis, fruit softening, and quality of ‘Tegan Blue’ Japanese plum during cold storage. Journal of the American Society for Horticultural Science, 133(2), 290-299.

Korkmaz, N., Askin, M. A., Ercisl, S., & Okatan, V. (2016). Foliar application of calcium nitrate, boric acid and gibberellic acid affects yield and quality of pomegranate (Punica granatum L.). Acta Scientiarum Polonorum-Hortorum Cultus, 15(3), 105-112.

Kucuk, E., & Ozturk, B. (2015). The effects of aminoethoxyvinylglycine and methyl jasmonate on bioactive compounds and fruit quality of ‘North Wonder’ sweet cherry. African Journal of Traditional, Complementary and Alternative Medicines, 12(2), 114-119.

Kroon, P. A., & Williamson, G. (1999). Hydroxycinnamates in plants and food: current and future perspectives. Journal of the Science of Food and Agriculture, 79(3), 355-361.

Lenahan, O. M., Whiting, M. D., & Elving, D. C. (2006). Gibberellic acid inhibits floral bud induction and improves ‘Sweet cherry’ fruit quality. HortScience, 41(3), 654-659.

Lenahan, O. M., Whiting, M. D., & Elving, D. C. (2005, June). Gibberellic acid is a potential sweet cherry crop load management tool. In V International Cherry Symposium 795 (pp. 513-516).

Li, M., Cheng, S., Wang, Y., & Dong, Y. (2019). Improving fruit coloration, quality attributes, and phenolics content in ‘Rainier’ and ‘Bing’ cherries by gibberellic acid combined with homobrassinolide. Journal of Plant Growth Regulation, (unpublished).

Lidster, P. D., Porritt, S. W., & Tung, M. A. (1979). Effects of a delay in storage and calcium chloride dip on surface disorder incidence in ‘Van’ cherry. Journal of the American Society for Horticultural Science, 104, 298–300.

Liu, Y., Liu, X., Zhong, F., Tian, R., Zhang, K., Zhang, X., & Li, T. (2011). Comparative study of phenolic compounds and antioxidant activity in different species of cherries. Journal of food science, 76(4), 633-638.

Lu, X., Sun, D., Li, Y., Shi, W., & Sun, G. (2011). Pre-and post-harvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit. Scientia Horticulturae, 130(1), 97-101.

Ma, Q., & Kinneer, K. (2002). Chemoprotection by Phenolic Antioxidants Inhibition of Tumor Necrosis Factor A Induction In Macrophages. Journal of Biological Chemistry, 277(4), 2477-2484.

Mamani-Matsuda, M., Kauss, T., Al-Kharrat, A., Rambert, J., Fawaz, F., Thiolat, D., Moynet, D., Caves, S., Malvy, D., & Mosaalayi, M. D. (2006). Therapeutic and preventive properties of quercetin in experimental arthritis correlate with decrease macrophage inflammatory mediators. Biochemical pharmacology, 72, 1304–1310.

Martin-Diana, A. B., Rico, D., Frias, J. M., Barat, J. M., Henehan, G. T. M., & Barry-Ryan, C. (2007). Calcium for extending the shelf life of fresh whole and minimally processed fruits and vegetables: a review. Trends in Food Science & Technology, 18(4), 210-218.

Martinez, G. A., Chaves, A. R., & Anon, M. C. (1994). Effect of gibberellic acid on ripening of strawberry fruits (Fragaria ananassa Duch.). Journal of Plant Growth Regulation, 13(2), 87.

Martinez-Romero, D., Alburquerque, N., Valverde, J. M., Guillén, F., Castillo, S., Valero, D., & Serrano, M. (2006). Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. Postharvest Biology and Technology, 39(1), 93-100.

Mattila, P., Hellström, J., & Törnroen, R. (2006). Phenolic acids in berries, fruits, and beverages. Journal of agricultural and food chemistry, 54(19), 7193-7199.

Mazza, G., & Miniatti, E. (1993). Types of anthocyanins, anthocyanins in fruits, vegetables and grains. USA: CRC Press, 57–60.

McCune, L. M., Kubota, C., Stendell-Hollis, N. R., & Thomson, C. A. (2011). Cherries and health: a review. Critical Reviews in Food Science and Nutrition, 51, 1–12.

Meheriuk, M., Girard, B., Moys, L., Beveridge, H. J. T., McKenzie, D. L., & Harrison, J. (1995). Modified atmosphere packaging of ‘Lapins’ sweet cherry. Food Research International, 28, 239-244.

Michalidis, M., Karagiannis, E., Tanou, G., Karamanoli, K., Lazaridou, A., Matsi, T., & Molassiotis, A. (2017). Metabolomic and physico-chemical approach unravel dynamic regulation of calcium in sweet cherry fruit physiology. Plant physiology and biochemistry, 116, 68-79.

Mozečić, B., Trebše, P., & Hribar, J. (2002). Determination and quantitation of anthocyanins and hydroxycinnamic acids in different cultivars of sweet cherries (Prunus avium L.) from Nova Gorica region (Slovenia). Food Technology and Biotechnology, 40(3), 207-212.

Naserzaeim, F., Radishi, M., & Sayfzadeh, S. (2015). Wrapping materials and cold storage durations effect on dry matter content of plum. Agricultural Engineering Research Journal, 5(1), 07-10.

Ozkan, Y., Ucar, M., Yildiz, K., & Ozturk, B. (2016). Pre-harvest gibberellic acid (GA3) treatments play an important role on bioactive compounds and fruit quality of sweet cherry cultivars. Scientia Horticulturae, 211, 358-362.

Ozturk, B., Bektas, E., Aglar, E., Karakaya, O., & Gun, S. (2018). Cracking and quality attributes of jujube fruits as affected by covering and pre-harvest Parka and GA3 treatments. Scientia horticulturae, 240, 65-71.

Padilla-Zakour, O. I., Ryona, I., Cooley, H. J., Robinson, T. L., Osborne, J., & Freer, J. (2007). Shelf-life extension of sweet cherries by field management, post-harvest treatments and modified atmosphere packaging. New York Fruit Quarterly, 15, 3–6.

Petracek, P. D., Joles, D. W., Shirazi, A., & Cameron, A. C. (2002). Modified atmosphere packaging of sweet cherry (Prunus avium L., ev. ‘Sams’) fruit: metabolic responses to oxygen, carbon dioxide, and temperature. Postharvest Biology and Technology, 24(3), 259-270.

Remón, S., Ferrer, A., Marquina, P., Burgos, J., & Oria, R. (2000). Use of modified atmospheres to prolong the postharvest life of Burlat cherries at two different degrees of ripeness. Journal of the Science of Food and Agriculture, 80(10), 1545-1552.

Remón, S., Venturini, M. E., Lopez-Buesa, P., & Oria, R. (2003). Burlat cherry quality after long range transport: optimisation of packaging conditions. Innovative Food Science & Emerging Technologies, 4(4), 425-434.

Remón, S., Ferrer, A., López-Buesa, P., & Oria, R. (2004). Atmosphere composition effects on Burlat cherry colour during cold storage. Journal of the Science of Food and Agriculture, 84(2), 140-146.
Robards, K., Prenzler, P. D., Tucker, G., Swatitsiang, P., & Glover, W. (1999). Phenolic compounds and their role in oxidative processes in fruits. Food chemistry, 66(4), 401-436.

Rocha, A. M. C. N., & De Morais, A. M. M. B. (2005). Polyphenoloxidase activity of minimally processed 'Jonagold' apples (Malus domestica). Journal of food processing and preservation, 29(1), 8-19.

Romanazzi, G., Nigro, F., & Ippolito, A. (2003). Short hypobaric treatments potentiate the effect of chitosan in reducing storage decay of sweet cherries. Postharvest Biology and Technology, 29(1), 73-80.

Serrano, M., Díaz-Mula, H. M., Zapata, P. J., Castillo, S., Guilién, F., Martínez-Romero, D., ... & Valero, D. (2009). Maturity stage at harvest determines the fruit quality and antioxidant potential after storage of sweet cherry cultivars. Journal of Agricultural and Food Chemistry, 57(8), 3240-3246.

Serrano, M., Guilién, F., Martínez-Romero, D., Castillo, S., & Valero, D. (2005). Chemical constituents and antioxidant activity of sweet cherry at different ripening stages. Journal of Agricultural and Food Chemistry, 53(7), 2741-2745.

Serrano, M., Martínez-Romero, D., Guilién, F., Castillo, S., & Valero, D. (2006). Maintenance of broccoli quality and functional properties during cold storage as affected by modified atmosphere packaging. Postharvest Biology and Technology, 39(1), 61-68.

Singh, P., Langowski, H. C., Wani, A. A., & Saengleraub, S. (2010). Recent advances in extending the shelf life of fresh Agaricus mushrooms: a review. Journal of the Science of Food and Agriculture, 90(9), 1393-1402.

Sotiropoulos, T., Petridis, A., Koukourikou-Koutritou, M., Koundouras, S., ... & Pappa, M. (2014). Efficacy of using rain protective plastic films against cracking of four sweet cherry (Prunus avium L.) cultivars in Greece. International Journal of Agriculture Innovations and Research, 2(6), 1035-1040.

Souza, K. O., Viana, R. M., de Siqueira Oliveira, L., Moura, C. F. H., & Miranda, M. R. A. (2016). Preharvest treatment of growth regulators influences postharvest quality and storage life of cashew apples. Scientia Horticulturae, 209, 53-68.

Spotts, R. A., Cervantes, L. A., & Facteau, T. J. (2002). Effect of preharvest calcium treatments on physiological and quality parameters in ’Vogue’ cherries during storage. The Journal of Horticultural Science and Biotechnology, 82(4), 657-663.

Tian, S. P., Jiang, A. L., Xu, Y., & Wang, Y. S. (2004). Responses of physiology and quality of sweet cherry fruit to different atmospheres in storage. Food Chemistry, 87(1), 43-49.

Tsantili, E., Rouskas, D., Christopoulos, M. V., Stanidis, V., Akrivos, J., & Papanikolaou, D. (2007). Effects of two preharvest calcium treatments on physiological and quality parameters in ‘Vogue’ cherries during storage. The Journal of Horticultural Science and Biotechnology, 82(4), 657-663.

Usenik, V., Fabčič, J., & Stampar, F. (2008). Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry (Prunus avium L.). Food Chemistry, 107(1), 185-192.

Usenik, V., Fajt, N., Mikulik-Petkovsek, M., Sltnar, A., Stampar, F., & Veberic, R. (2010). Sweet cherry pomological and biochemical characteristics influenced by rootstock. Journal of agricultural and food chemistry, 58(8), 4928-4933.

Val, J., Monge, E., Risco, D., & Blanco, A. (2008). Effect of pre-harvest calcium sprays on calcium concentrations in the skin and flesh of apples. Journal of plant nutrition, 31(11), 1889-1905.

Valero, D., Díaz-Mula, H. M., Zapata, P. J., Castillo, S., Guilién, F., Martínez-Romero, D., ... & Serrano, M. (2011). Postharvest treatments with salicylic acid, acetylsalicylic acid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. Journal of agricultural and food chemistry, 59(10), 5483-5489.

Wójcik, P., Akgül, H., Demirtaş, İ., Sarsu, C., Aksu, M., & Gubhuk, H. (2013). Effect of preharvest sprays of calcium chloride and sucrose on cracking and quality of ‘Burlat’ sweet cherry fruit. Journal of plant nutrition, 36(9), 1453-1465.

Wójcik, P., & Wawrzyńczak, P. (2014). Effect of preharvest sprays of calcium on cracking and 'Schattenmorelle'sour cherry fruit quality harvested mechanically. Journal of plant nutrition, 37(9), 1487-1497.

Zhao, H., Shu, C., Fan, X., Cao, J., & Jiang, W. (2018). Near-freezing temperature storage prolongs storage period and improves quality and antioxidant capacity of nectarines. Scientia Horticulturae, 228, 196-203.

Zhang, Y., Chen, K., Zhang, S., & Ferguson, I. (2003). The role of salicylic acid in postharvest ripening of kiwifruit. Postharvest Biology and Technology, 28(1), 67-74.

Zhang, C., & Whiting, M. D. (2011). Improving ‘Bing’sweet cherry fruit quality with plant growth regulators. Scientia Horticulturae, 127(3), 341-346.