# Application of Postharvest Treatments to Alleviates Chilling Injury and Maintains Quality of Cherry Tomatoes during Cold Storage

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## ABSTRACT

This study was carried out during 2022 and 2023 seasons on cherry tomatoes cv. Katalina-522 to study the effect of dipping fruits in a solution of arginine (AG) at 0.5 mM for 10 min, glycine betaine (GB) at 30 mM for 10 min, salicylic acid (SA) at 2 mM for 5 min, and sodium nitroprusside (SNP – a nitric oxide (NO) donor) at 2 mM for 30 min and then sealed in polypropylene film,active modified atmosphere packaging (MAP) at 5% $O_2$ + 5% $CO_2$ or 5% $O_2$ + 8% $CO_2$ and passive MAP in addition to untreated fruits (control) during storage at 5°C for 20 days plus 2 days at 20°C (shelf life) on alleviating chilling injury and maintaining fruit quality attributes. Results indicated that cherry tomato fruits treated with all postharvest treatments were effective in reducing weight loss, loss of firmness, chilling injury, color change and modifying the atmosphere inside the package, as well as maintaining ascorbic acid, total phenolic content, antioxidant activity and the overall appearance of fruits during all storage periods plus shelf life as compared with untreated control. Samples treated with SA, SNP and GB appeared without any symptoms of chilling injury till the end of storage, while active MAP at 5% $O_2$ + 5% $CO_2$ and arginine treatments delayed the beginning of chilling injury and recorded a slight score at the end of storage. Furthermore, SA was the most effective treatment in preserving all the quality attributes of fruits and gave an excellent appearance of fruits for 20 days at 5°C plus 2 days at 20°C, while SNP and GB treatments gave a good appearance at the same period.

**Keywords:** Chilling injury-Glycine betaine- Salicylic acid- Sodium nitroprusside- Modified atmosphere packaging.

## INTRODUCTION

Cherry tomato is a climacteric and perishable fruit with a short shelf life and high susceptibility to fungal diseases, quality degradation and rapid senescence (Nitin et al., 2020). Thus, storage at low temperatures has been considered the most efficient method to maintain the quality of fruits by reducing metabolic processes (Aghdam and Bodbodak, 2013).However, cherry tomatoes, being of tropical origin, are susceptible to chilling injury (CI) if held at 10°C for two weeks or at 5°C for more than 6-8 days (El Assi, 2004). Therefore, an optimum storage temperature of approximately 12 °C is recommended for tomatoes during postharvest to avoid chilling injury (Maul et al., 2000).

The most common chilling injury symptoms in tomatoes include irregular ripening, pitting, water-soaked areas, shriveling, inhibition of color development and increased susceptibility of the fruit to fungal infection, which leads to substantial degradation of fruit quality. These symptoms often develop after the transfer of the chilled tomato fruit to non-chilling temperatures (Sharom et al., 1994). Therefore, it is necessary to use some techniques to alleviate chilling injury and maintain the quality of fruits during storage.

Postharvest application of arginine has shown a positive response in reducing chilling injury and maintaining the quality of cherry tomato fruits (Zhang et al., 2010). Moreover, arginine treatment significantly decreased weight loss and decay, maintained firmness and ascorbic acid and tolerance to chilling injury in sweet pepper (Akram et al., 2021).

The application of exogenous glycine betaine treatment would be a promising strategy for attenuating postharvest senescence and enhancing the tolerance of tomato fruits against chilling stress (Karabudak et al., 2014) and improving postharvest quality in peaches (Wang et al., 2019).

Salicylic acid has potential postharvest applications by alleviating chilling injury, maintaining quality, reducing decay and improving the health benefits of tomato fruit consumption by inducing the antioxidant system (Aghdam et al., 2014), increasing resistance to postharvest diseases in cherry tomatoes (Abou-Zaid et al., 2020) and delaying the ripening and softening of cantaloupe fruit (Minh, 2022).

Application of sodium nitroprusside treatment, an exogenous nitric oxide donor, has been proven to have a significant effect on alleviating the chilling injury of fruits (Jiménez-Muñoz et al., 2021), reducing the ethylene production, increasing the antioxidant activity, delaying fruit ripening and prolonging the shelf life of tomato fruit (Lai et al., 2011) and having the potential to preserve quality by enhancing firmness, delaying the development of undesirable color and decreasing electrolyte leakage and malondialdehyde accumulation (Dai et al., 2023).

Modified atmosphere packaging can effectively alleviate chilling injury and extend the postharvest life of tomatoes, retard the ripening process, delay color development, reduce pitting scores and decay rates, extend the shelf life of tomato fruit stored at 4°C and increase gene expression of protease inhibitors II and catalase (Park et al., 2018).

Therefore, the aims of this work were to study the effects of postharvest treatments of cherry tomatoes with arginine, glycine betaine, salicylic acids, sodium nitroprusside and modified atmosphere packaging on reducing chilling injury and maintaining the overall quality attributes of fruits during cold storage at 5°C plus 2 days at 20 °C (shelf life).

## MATERIALS AND METHODS

Cherry tomatoes (*Solanum lycopersicum* var. cerasiforme) cv. Katalina-522 were harvested at the pink stage (red color covering between 50 and 60% of the fruit surface) on 6th and 8th of February in 2022 and 2023 seasons, respectively, from a private farm in Wadi El-Natrun, El-Beheira Governorate and then the fruits were transported to the laboratory of Vegetable Handling Research Department, Horticultural Research Institute, Agricultural Research Center, Giza, Egypt. Fruits free from any visual damage or defects and uniform in size (20-25 mm in diameter) and color were selected for the storage experiment.

The treatments were applied as follows: cherry tomato fruits were dipped in arginine (AG) at 0.5 mM for 10 min, glycine betaine (GB) at 30 mM for 10 min, salicylic acid (SA) at 2 mM for 5 min and sodium nitroprusside (SNP – a nitric oxide (NO) donor) at 2 mM for 30 min. All the previous treatments were air dried and packed in transparent plastic punnets, then sealed with polypropylene film (30 µm thickness, 15 × 25 cm size). As for the other treatments, fruits were packed in transparent plastic punnets, then sealed with the same film and flushed with different gas mixtures at 5% $O_2$ + 5% $CO_2$ and 5% $O_2$ + 8% $CO_2$ (active modified atmosphere packaging (MAP) and without flushing (passive MAP) and additionally untreated fruits were packed in transparent plastic punnets as a control treatment.

Each punnet contains about 250 g of cherry tomato fruits, represented as one replicate. Eighteen replicates were prepared for each treatment and stored at 5ºC and 90-95% relative humidity (RH) plus 2 days at 20ºC (shelf life). All samples were arranged in a complete randomized design. Three replicates from each treatment were taken at random and examined immediately after harvest and after 4, 8, 12, 16 and 20 days of storage at 5ºC in addition to 2 days at 20ºC to determine the following properties:

**1. Weight loss (%):** It was calculated according to the equation = [(Wi –Ws)/ Wi] x100.

Where, Wi = fruit weight at initial period, Ws = fruit weight at sampling period.

**2. General appearance** was measured using a scale from 9 to 1, with 9 = excellent, 7 = good, 5 = fair, 3 = poor and 1 = unsalable; fruits rated 5 or lower were considered unmarketable, according toKader et al. (2002).

**3. External surface color** was evaluated by using a Minolta CR-400 Chroma Meter (Minolta Co., Ltd., Osaka, Japan) to measure the L* describes lightness (L*=0 for black, L*=100 for white) and a* describes intensity in red-green (a*>0 for red, a*<0 for green), according to McGuire (1992).

**4. Chilling injury** was determined based on a five scale: 0 = no injury; 1 = <10%; 2 = 11 to 25%; 3 = 26–40% and 4 = >40%. The severity of the symptoms was assessed visually according to 5 parameters: surface pitting, shriveling, water-soaked areas, uneven ripening and color development and decay (Vega-García et al., 2010).

**5. Fruit firmness** was determined by a hand pressure tester (Italian model) with an 8 mm plunger expressed in kg/cm$^2$ (Abbott, 1999).

**6. Ascorbic acid content** (mg/100g fresh weight) was determined by titration method using 2,6dichloro-phenol-indo-phenol the dye as described in AOAC (1990).

**7. Total phenolic content** (mg/100g fresh weight) was measured by the Folin-Ciocalteu method, according to Singleton et al. (1999).

**8. Antioxidant activity** (%)was measured by determining of the free radical scavenging activity evaluated by 2.2-diphenyl-1-picrylhydrazyl (DPPH), according to Sánchez-Moreno et al. (2003).

**9. Gas composition in package:** $O_2$ and $CO_2$ concentrations in the package were monitored with a Dual Trak Model 902 D gas analyzer. Insert the test probe into the rubber seal attached to the outside of the package.

**Statistical analysis**

Using MSTATC software, statistical analysis of the data was performed to calculate the means, variance and standard error. The LSD value at the 5% level was calculated to estimate mean separations (Snedecor and Cochran, 1980).

## RESULTS AND DISCUSSION

**1. Weight loss percentage:-**

Data in Fig. (1) show that the weight loss percentage of cherry tomatoes increased considerably and consistently with the prolongation of the storage period in the two seasons, and these are in agreement with Abdullah and Ibrahim (2018). This may be attributed to respiration and other senescence-related metabolic processes during storage (Amarante et al., 2001). However, all postharvest treatments retained their weight during storage as compared with the untreated control. After 20 days of storage at 5°C plus 2 days at 20 °C, data show that salicylic acid (SA) was the most effective treatment in reducing weight loss, followed by sodium nitroprusside (SNP) and glycine betaine (GB) treatments with no significant differences between them. The highest value was recorded with untreated control in the two seasons, and these are in agreement with Mandal et al. (2016), Jiménez-Muñoz et al. (2021) and Habibi et al. (2022).

The lower weight loss in treated fruits by SA, SNP and GB treatments may be due to reducing membrane permeability and increasing membrane stability and integrity, which ultimately leads to less water loss and shriveling. In addition, the suppressing effect of these treatments on respiration rate and ethylene production slows down the metabolic processes, which diminishes the weight loss during storage (Zaharah and Singh, 2011, Koyuncu et al., 2019andElmenofy and Ketta, 2021). Also, SA minimized fruit weight loss by shutting stomata (Zheng and Zhang, 2004).

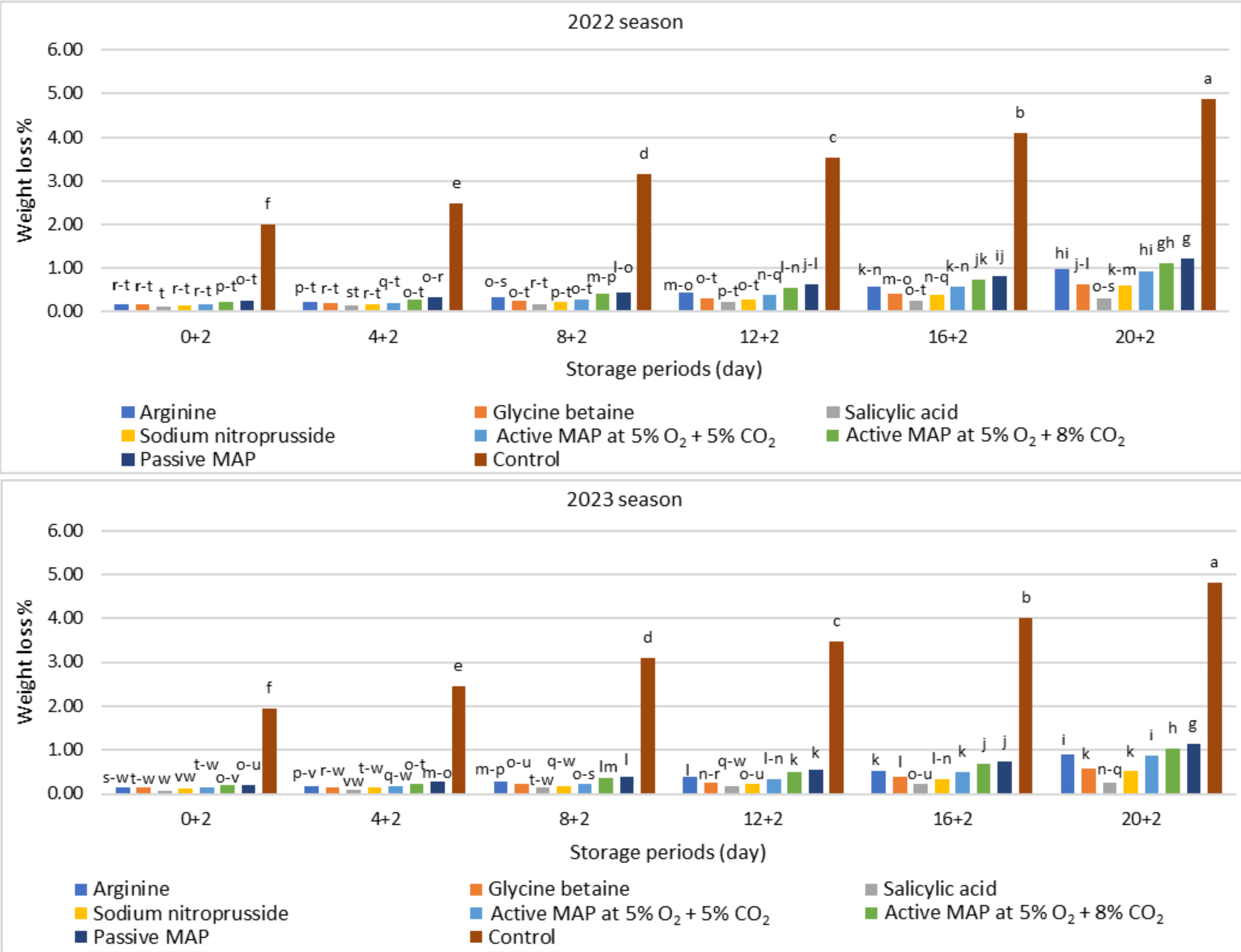


**Fig. (1).** Effect of some postharvest treatments and storage periods on weight loss percentage of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

**2. General appearance:-**

Data in Fig. (2) indicate that there was a significant reduction in the general appearance of cherry tomato fruits with the prolongation of the storage period in both seasons, and these are in agreement with Abdullah and Ibrahim (2018). This may be due to a slight dryness of the surface instead of the translucency of macroscopic decay and change of color (Qiu et al., 2013). However, cherry tomato fruits treated with all postharvest treatments had significantly higher score of appearance as compared with untreated fruits. After 20 days of storage at 5°C and 2 days at 20°C, fruits dipped in SA treatment showed the best appearance and did not exhibit any changes in this appearance, while SNP and GB treatments rated good appearance. On the other hand, the untreated fruits had an unsalable appearance at the same period in the two seasons, and these are in agreement with Mandal et al. (2016) andDai et al.(2023).

SA treatment mainly functions by maintaining the ability to inhibit $O_2$ accumulation, delaying $H_2O_2$ decrease and enhancing antioxidant enzyme activities with an increase in the expression of senescence-related proteins or defense proteins to keep the fruit in good quality during storage (Tareen et al., 2012).Also, SNP has been shown to prolong the postharvest shelf life of tomato fruits by delaying senescence and ripening, reducing respiration rate, ethylene production, the climacteric phase, disease incidence, peel color change and enzyme activity (Eum et al., 2009).

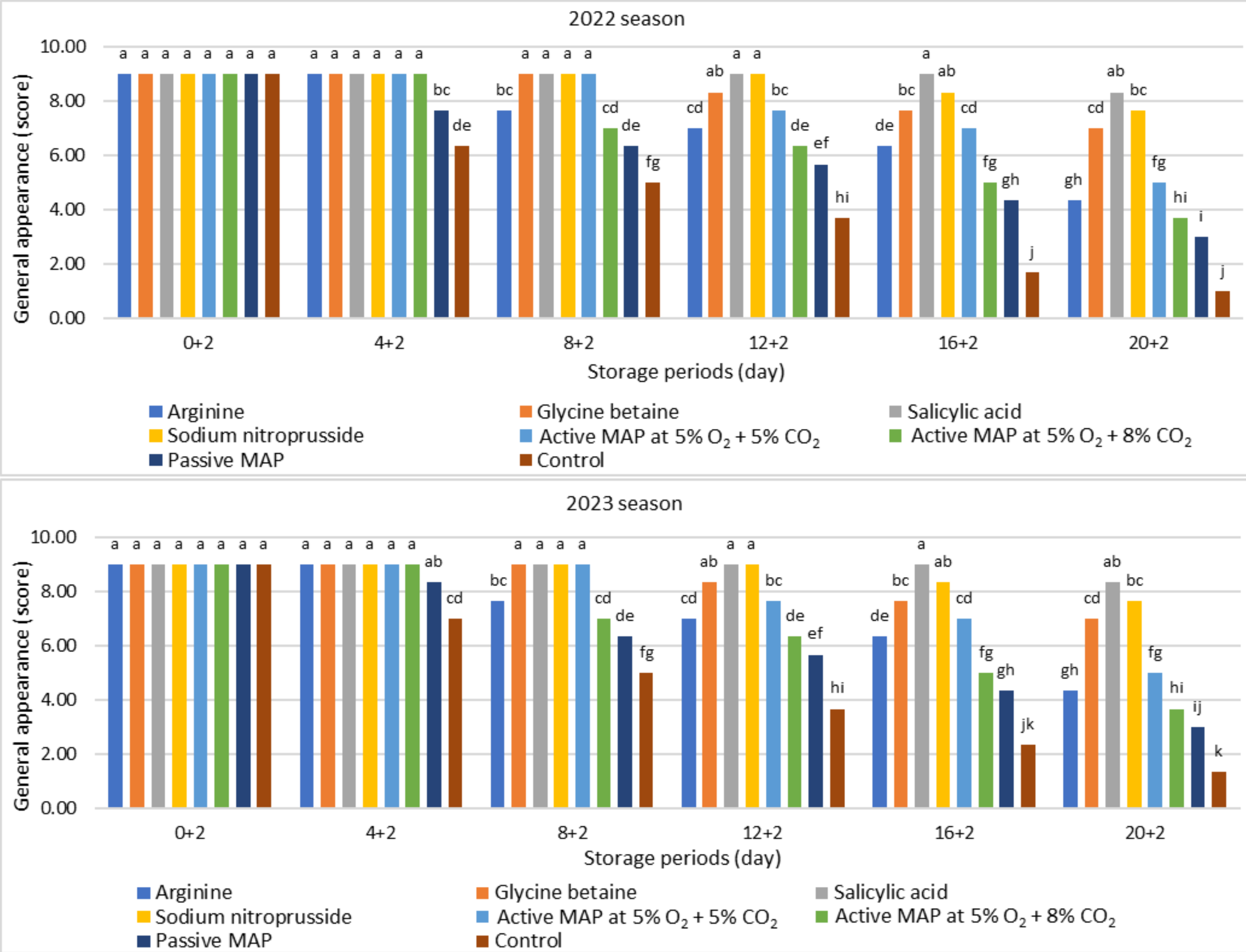


**Fig. (2).** Effect of some postharvest treatments and storage periods on general appearance (score) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

**3. Color (L* value):**

Data in Fig. (3) indicate that there was a significant decrease in L* value with increasing storage period of cherry tomato fruits showing darker fruits in the two seasons, and these are in agreement with Abou-Zaid et al. (2020). This may be relating to water loss in fruit (Ardakani and Mostofi, 2019).However, all postharvest treatments significantly maintained L* values compared with untreated fruits. At the end of the storage period, cherry tomato fruits dipped in SA had a significantly higher L* value (indicating lighter fruits), followed by SNP treatment. While the untreated control had the lowest L* value (indicating dark fruits) in the two seasons, and these are in agreement with Tareen et al. (2012) and Dai et al. (2023).

The higher loss of peel luminosity in control groups was possibly related to the higher water loss of control fruit, while SA treatment had higher L* values (less dark peel) and maintained the skin brightness of pomegranate compared to control samples. (Koyuncu et al., 2019).

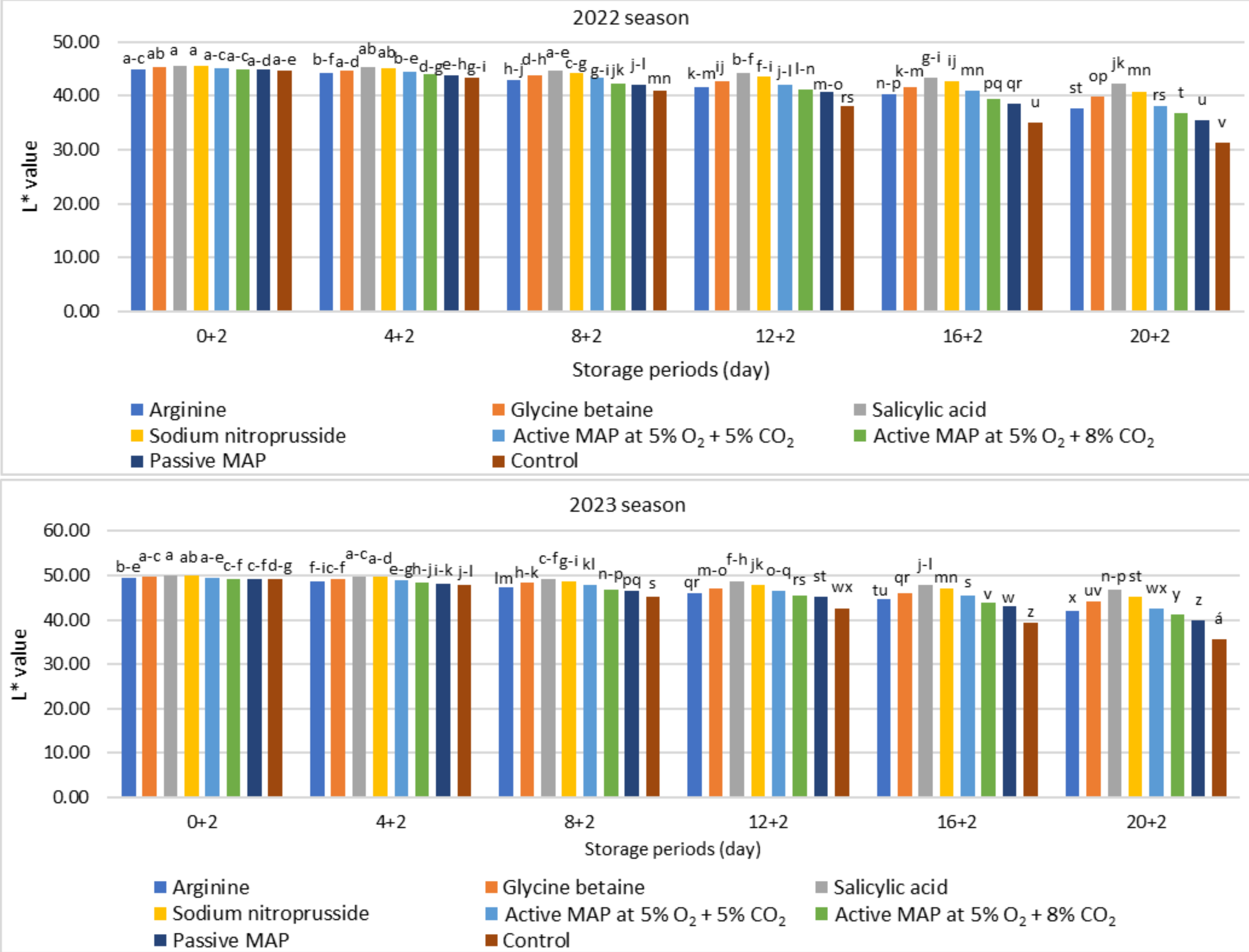


**Fig. (3).** Effect of some postharvest treatments and storage periods on color (L* value) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

### 4. Color (a* value):

Data in Fig. (4) indicate that there was a significant increase in the a* value with increasing storage periods in the two seasons, and these are in agreement with Abou-Zaid et al. (2020). The change in color is mainly due to the conversion of chloroplasts into chromoplasts, which leads to lycopene accumulation and chlorophyll degradation (Tadesse et al., 2015). Salicylic acid was the most effective treatment for reducing changes in color during storage and shelf life. At the end of the storage period, the surface color of fruits treated with SA had a lower a* value (less redness), followed by SNP treatment. While untreated fruits had a higher a* value (high redness) in the two seasons, and these are in agreement with Tareen et al. (2012) and Dai et al. (2023). The highest a* (high redness) value recorded in control fruits may be correlated with the physiological status of the fruits, which was advancing towards deterioration and quality loss (Dai et al., 2023).

The reduction of color development in tomato fruits treated with SA and SNP could be attributed to the low rate of respiration and reduced ethylene production, which resulted in lower activity of chlorophylls and chlorophyll degradation, reducing the color change of the fruit during storage (Manjunatha et al., 2010 and Mandal et al., 2016). Promoted antioxidant enzyme activities in banana fruits treated with nitric oxide, contributed to enhancing antioxidant capacity and reactive oxygen species (ROS) scavenging ability and thus delayed chlorophyll degradation and reduced the color development of fruit during storage (Wang et al., 2015).

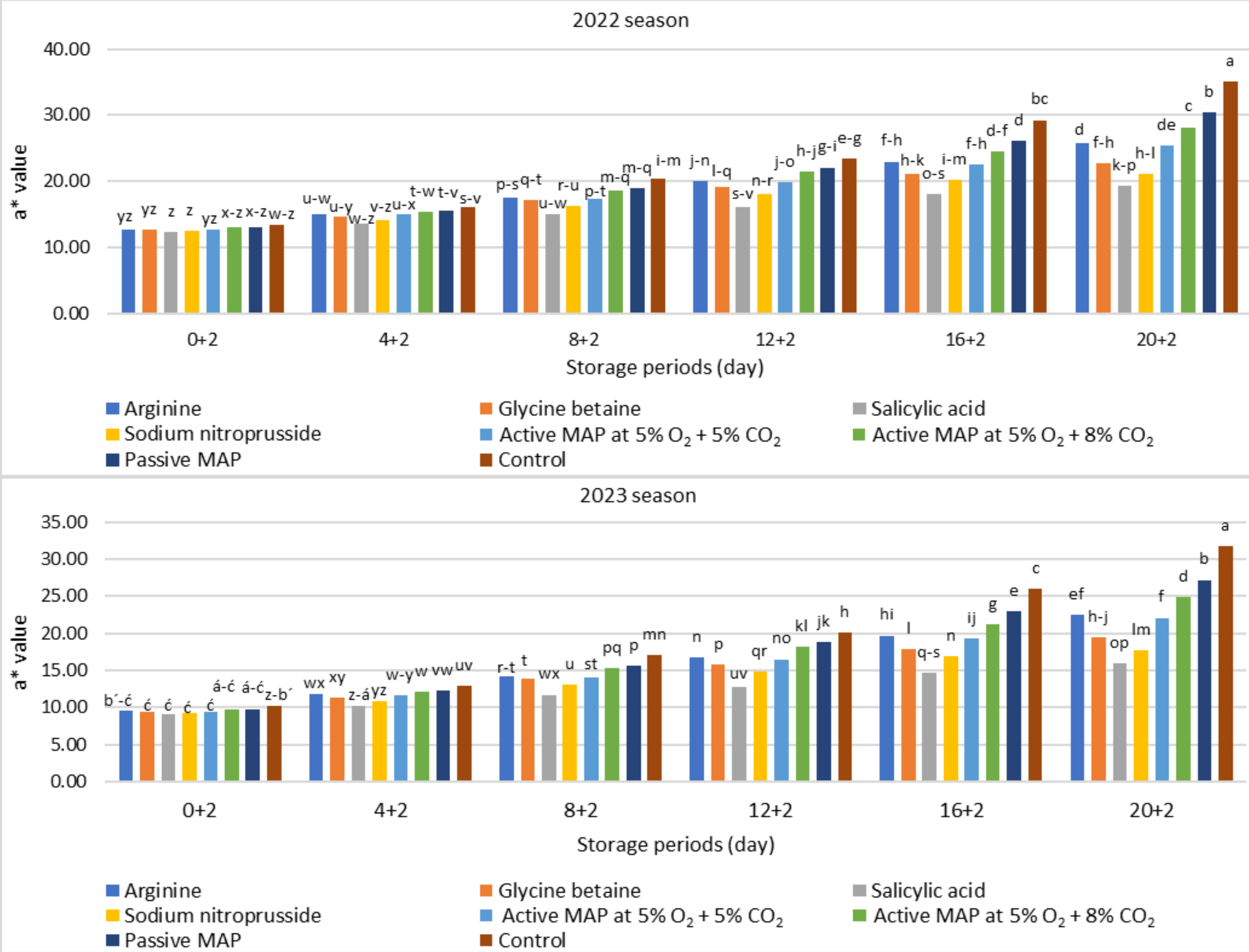


**Fig. (4).** Effect of some postharvest treatments and storage periods on color (a* value) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

**5. Chilling injury:**

Data in Fig. (5) show that chilling injury severity increased gradually with the prolongation of storage duration in the two seasons, and these are in agreement with Albornoz et al. (2019). This may be due to the fact that when horticultural crops are exposed to severe abiotic stresses, including cold stress, large amounts of intracellular ROS are generated, which are responsible for oxidative damage (Gualanduzzi et al., 2009). The accumulation of ROS would induce lipid peroxidation, damage membrane structure, breakdown of cell membrane integrity and a change in membrane permeability represented by higher electrolyte leakage and malondialdehyde(MDA) accumulation in conjunction with increased membrane degrading enzymes phospholipase (PLD) and lipoxygenase (LOX) (Jannatizadeh, 2019).

However, all treatments were effective in reducing chilling injury severity as compared with the control treatment. Moreover, cherry tomato fruits dipped in SA, SNP and GB appeared without any symptoms of chilling injury until the end of the storage duration and showed a more regular ripening of the fruits. The onset of CI symptoms in fruits was delayed by active MAP at 5% $O_2$ + 5% $CO_2$ and arginine treatments and recorded a slight score after 20 days of cold storage plus 2 days of shelf life with no significant differences between them, while active MAP at 5% $O_2$ + 8% $CO_2$ treatment recorded a moderate score at the same period. Passive MAP treatment was less effective in this regard and recorded a high score at the end of the storage period. On the other hand, trace

CI symptoms initially occurred in the control treatment after 4 days of cold storage plus 2 days of shelf life and the symptoms of CI became more apparent in fruits after 12 days of cold storage plus 2 days of shelf life and reached their extreme stage at the end of storage duration and showed irregular ripening and color development. These results were similar to those obtained by Aghdam et al. (2014), Park et al. (2018), Akram et al. (2021), Jiménez-Muñoz et al. (2021)and Molaei et al. (2021).

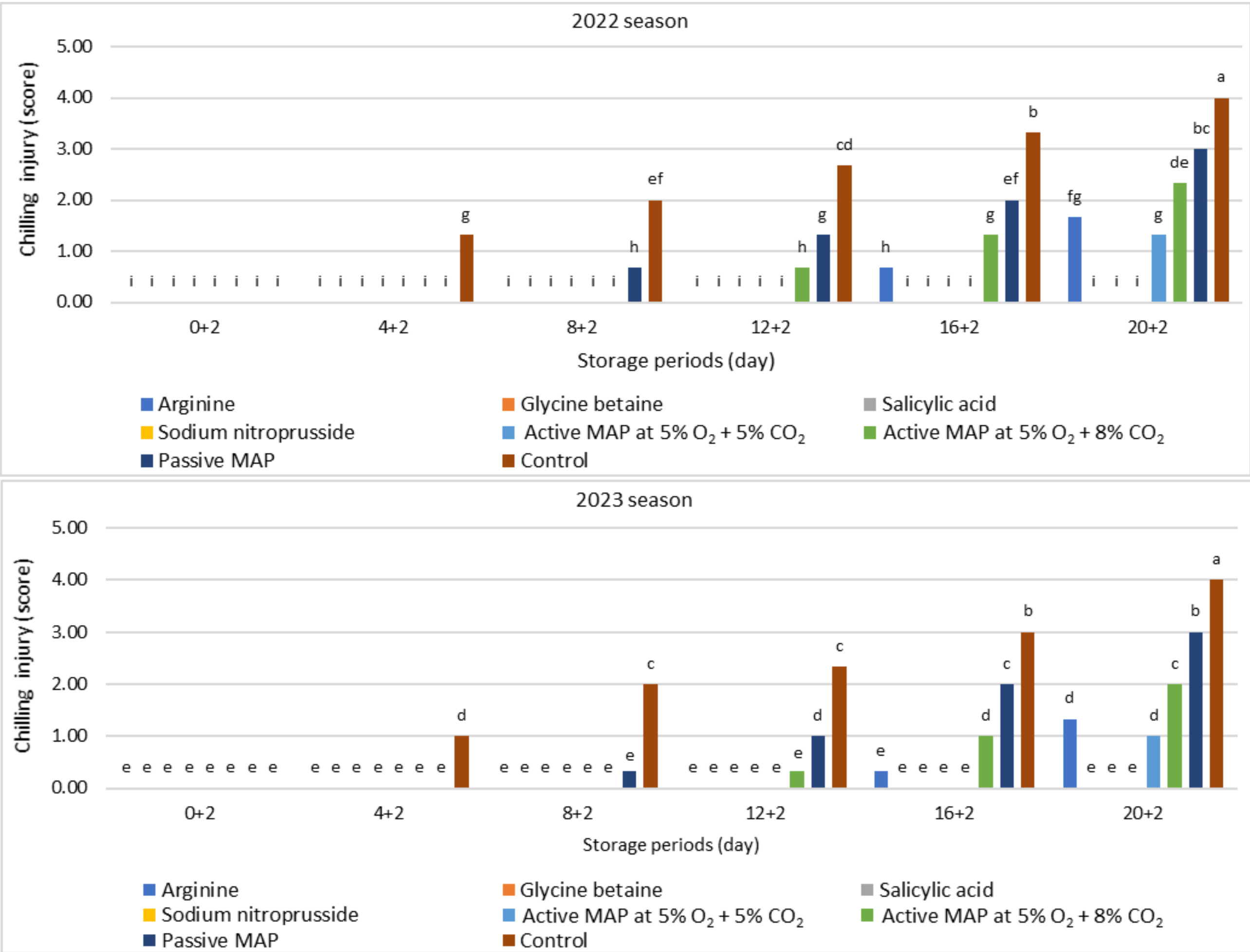


**Fig. (5).** Effect of some postharvest treatments and storage periods on chilling injury (score) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

The mechanisms of SA, SNP and GB treatments in alleviating CI could be attributed to enhancing membrane integrity and antioxidant system activity, inhibiting the lipid peroxidation and this increased antioxidant activity due to significantly inhibited the activities of LOX and PLD and decreased electrolyte leakage and MDA content, suppressing generation of ROS and alleviating oxidative damage, improving antioxidant enzyme activity ((peroxidase (POD), ascorbate peroxidase (APX), superoxide dismutase (SOD) and catalase (CAT)) may be a key factor in lowering the oxidative damage caused by cold stress, detoxifying ROS such as $H_2O_2$ and $O_2•^-$ and inducing the expression of chilling injury-related genes (Asghari and Aghdam, 2010, Ghorbani et al., 2018, Razavi et al., 2018 and Rasouli et al., 2019). Also, these treatments significantly increase phenylalanine ammonia-lyase (PAL) and decrease polyphenol oxidase (PPO) enzyme activities, thus increasing the antioxidant capacity of the cells against ROS (Aghdam and Bodbodak, 2013, Wang et al., 2015 and Razavi et al., 2018).

Furthermore, SA treatment increases arginine pathways, proline content, heat shock proteins (HSPs) gene expression and the activation of C-repeat binding factor (CBF) pathway, inducing the expression of ROS avoidance genes and ROS scavenging genes (Aghdam and Bodbodak, 2013 andAghdam et al., 2014). Also, GB treatment reduces CI by suppressing membrane phase transitions from liquid crystal to solid gel under cold stress, increasing endogenous GB and proline accumulation, increasing energy content, improving fruit sugar metabolism, attenuating oxidative stress, preserving the integrity of cell membranes and inhibiting cell death to prevent cold stress (Shan et al., 2016 and Wang et al., 2019).

**6. Fruit firmness:-**

Data in Fig. (6) indicate that there was a significant reduction in fruit firmness due to the prolongation of storage period and shelf life in the two seasons, and these are in agreement with Abou-Zaid et al. (2020). This may be due to the loss of cell wall hydrolase activity and intracellular turgor pressure, which results in fruit softening (Tokala et al., 2021). However, all postharvest treatments had a significant effect on decreased fruit firmness loss as compared with the untreated fruits during storage and shelf life. At the end of the storage period, cherry tomatoes dipped in SA gave the highest value of fruit firmness, followed by SNP treatment. The lowest value of fruit firmness was obtained from untreated control in the two seasons, and these are in agreement with Awad(2013)and Dai et al.(2023).

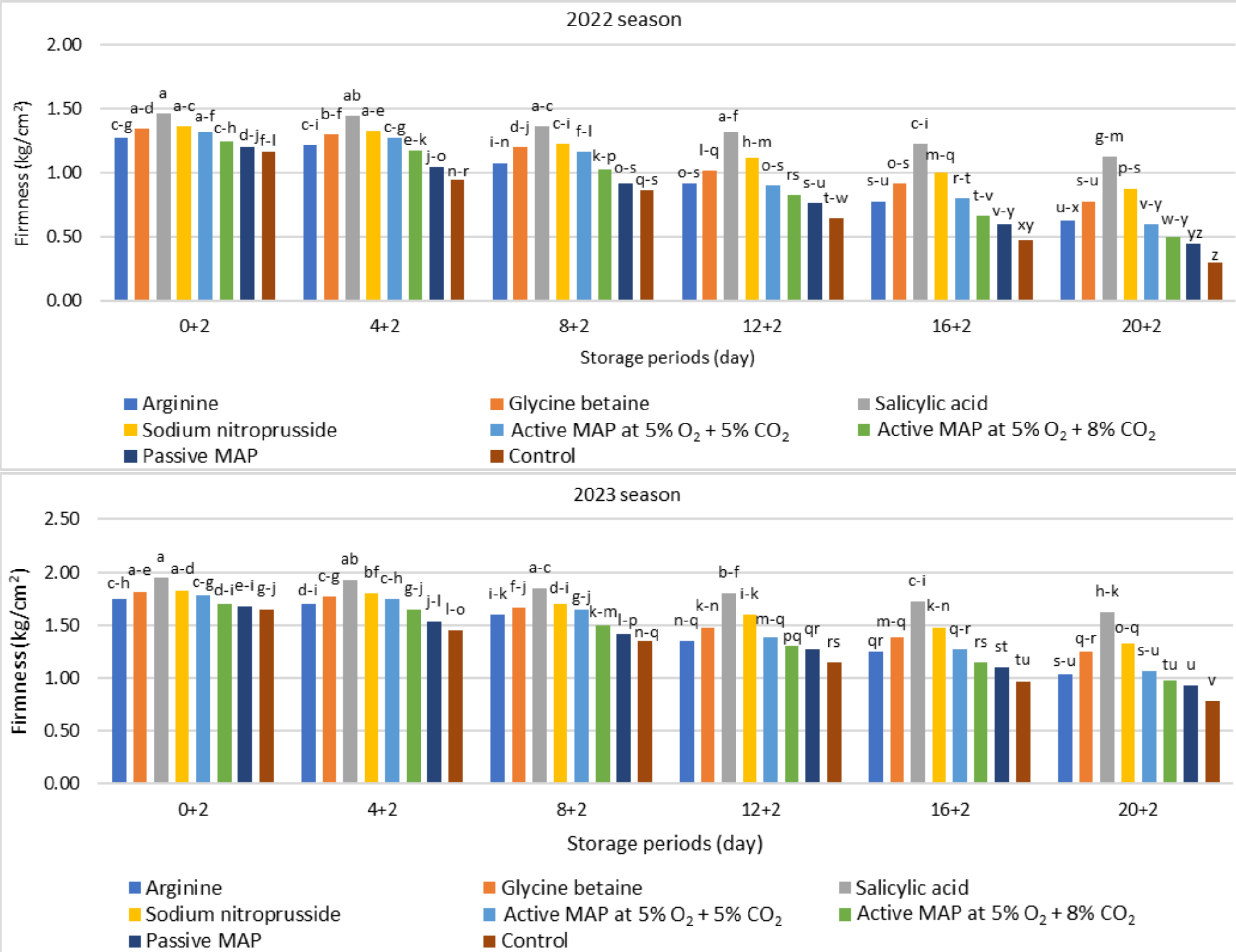


**Fig. (6).** Effect of some postharvest treatments and storage periods on firmness (kg/cm$^2$) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

The favorable effect of SA and SNP on maintaining fruit firmness could be due to lower activity of fruit softening enzymes like pectin methylesterase, polygalacturonase, lipoxygenase and cellulose, resulting in retaining the fruit firmness by inhibiting ethylene biosynthesis and reducing the degradation of the cell wall (Kannaujia et al., 2019)

**7. Ascorbic acid:-**

Data in Fig. (7) indicate that the ascorbic acid content significantly decreased as the storage progressed in the two seasons, and these are in agreement with Mandal et al. (2016). Ascorbic acid is a part of the non-enzymatic antioxidant system, which participates in ROS scavenging (Aghdam et al., 2018). The decline of ascorbic acid was associated with its consumption to neutralize free radicals under stress conditions (Naser et al., 2018). Also, by the activity of ascorbic acid oxidase (Hosseini et al., 2018). However, all postharvest treatments were significantly effective in preventing ascorbic acid content degradation during storage and shelf life as compared with control treatment. At the end of the storage period, SA and SNP treatments recorded the highest values of ascorbic acid content with no significant differences between them, followed by GB treatment. On the other hand, the lowest values of ascorbic acid recorded in untreated fruits in the two seasons, and these are in conformity with Mandal et al. (2016), Jiménez-Muñoz et al. (2021) andMolaei et al. (2021).

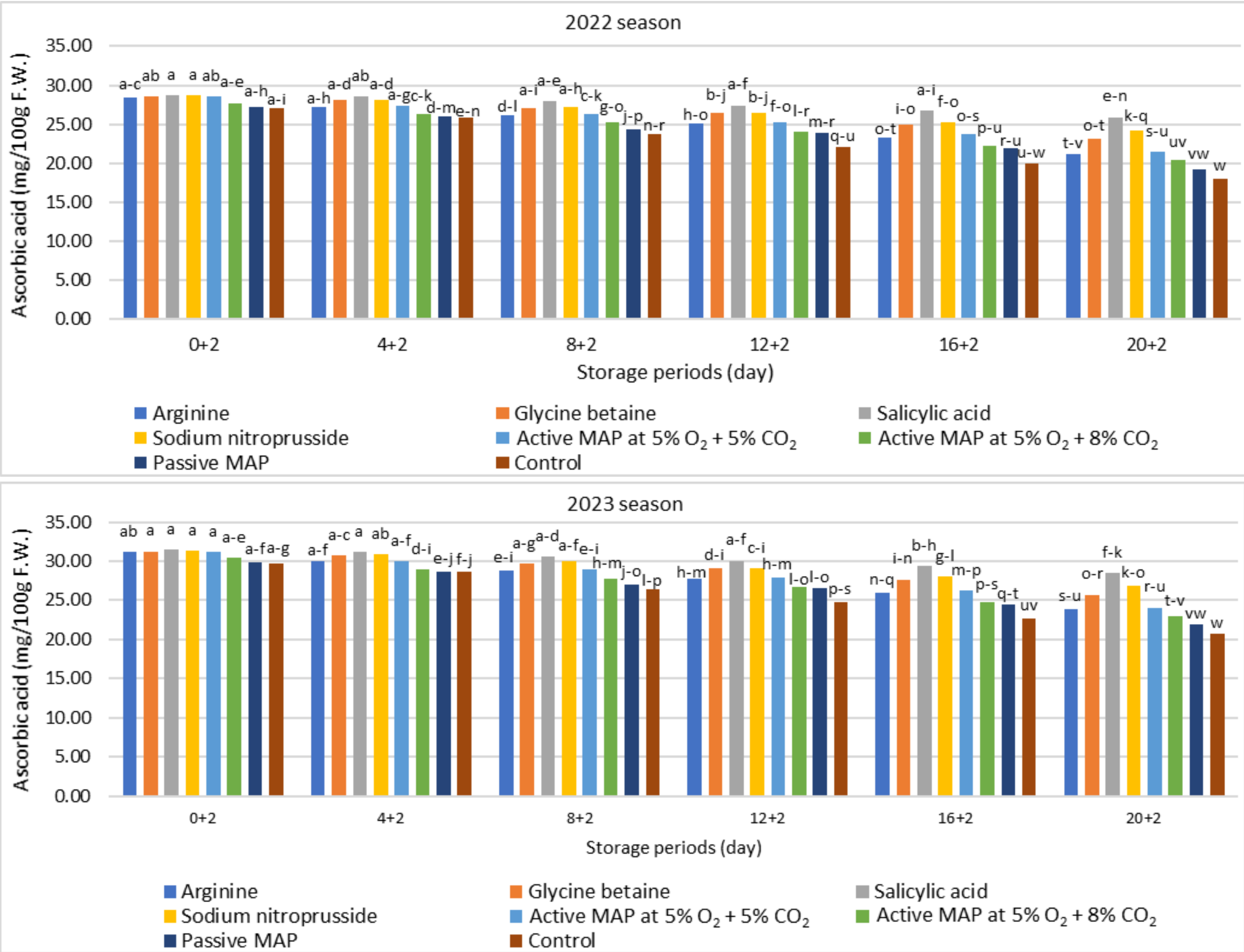


**Fig. (7).** Effect of some postharvest treatments and storage periods on ascorbic acid (mg/100g F.W.) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

Ascorbic acid content observed to be retained in fruit treated with SA, SNP and GB might be due to enhanced antioxidant enzymes activity and a reduction in the oxidation process (Yang et al., 2011, Razaviet al., 2018 andRasouli et al., 2019). Also, by inducing the activity of ascorbate peroxidase as well as motivation of the ascorbate-glutathione pathway, inhibition of the ascorbic acid oxidase (AAO) enzyme and higher GR/APX system activity, it might have led to the maintenance of ascorbic acid during storage (Rao et al., 2011).

**8- Total phenolic content:-**

As shown in Fig. (8), the total phenolic content (TPC) significantly decreased until the end of the storage duration in both seasons, and these are in agreement with Singh et al. (2020). Phenols are one of the most effective non-enzymatic antioxidants in scavenging ROS (Rastegar et al., 2020). The decline in total phenolics during storage was associated with their consumption to inhibit free radicals under cold-stress conditions (Naser et al., 2018). Also, this could be attributed to the senescence caused by the disintegration of cell construction and phenolic oxidation by enzymatic activities such as PPO (Razzaq et al., 2014). However, all postharvest treatments significantly reduced the loss in total phenolic content during storage durations and shelf life as compared with untreated fruits. At the end of the storage period, SA treatment recorded the highest values of total phenolic, followed by SNP treatment. While untreated fruits recorded the lowest values of total phenolic content in the two seasons, and these are in conformity with Jiménez-Muñoz et al. (2021) and Minh (2022).

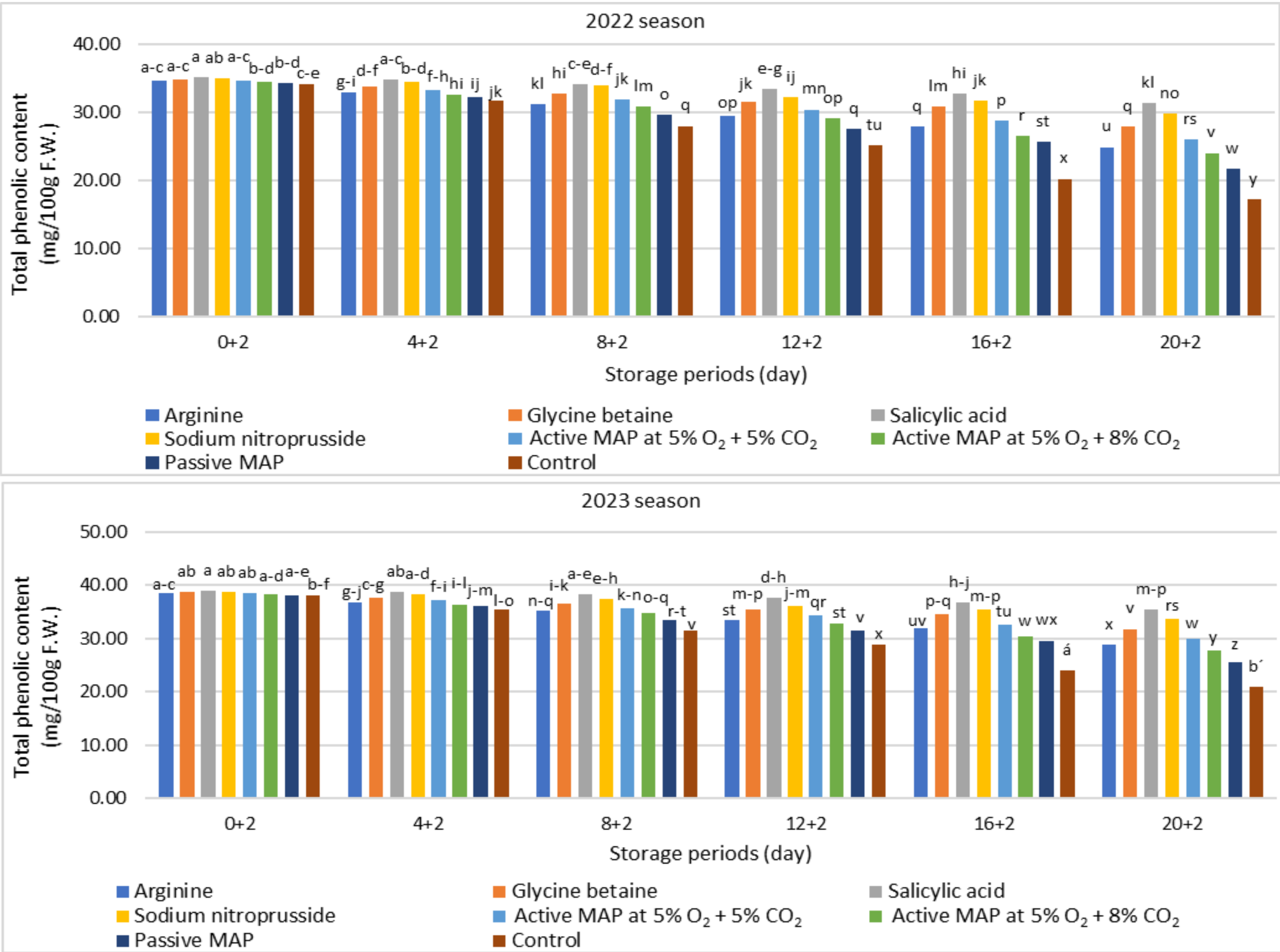


**Fig. (8).** Effect of some postharvest treatments and storage periods on total phenolic content (mg/100g F.W.) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

The accumulation of higher phenolic contents in SA and SNP-treated fruits might be due to these materials inhibiting PPO activity as well as increasing PAL activity, which is involved in phenolic biosynthesis. Therefore, these materials enhanced the total phenolic content of cold-stored fruits (Siboza et al., 2014 and Wang et al., 2015).

**9- Antioxidant activity:-**

The antioxidant activity helps the fruits overcome oxidative stress and prevent damage to the membranes through their antioxidant activity against ROS (Rastegar et al., 2020). The DPPH radical scavenging capacity percentage is commonly used to evaluate the antioxidant activity in fruits (Zhang et al., 2018). As shown in Fig. (9), the antioxidant activity (%) of fruits decreased significantly with prolongation of storage duration plus shelf life in both seasons, and these are in agreement with Singh et al. (2020). This may be attributed to the oxidation of polyphenols (Razzaq et al., 2014) and ascorbic acid (Hosseini et al., 2018) during storage, which decreased DPPH scavenging activities (Lecholocholo et al., 2022). Also, antioxidants are involved in scavenging ROS produced during stressful conditions and therefore their levels decrease during the early days of storage (Hounsome et al., 2009). All postharvest treatments significantly reduced the loss in antioxidant activity as compared with untreated fruits. At the end of the storage period, SA treatment significantly contributed to preserving the antioxidant activity of fruits, followed by SNP treatment. While the untreated fruits had the lowest values of antioxidant activity in both seasons, and these are in agreement with Hadian-Deljou et al. (2017) and Jiménez-Muñoz et al. (2021).

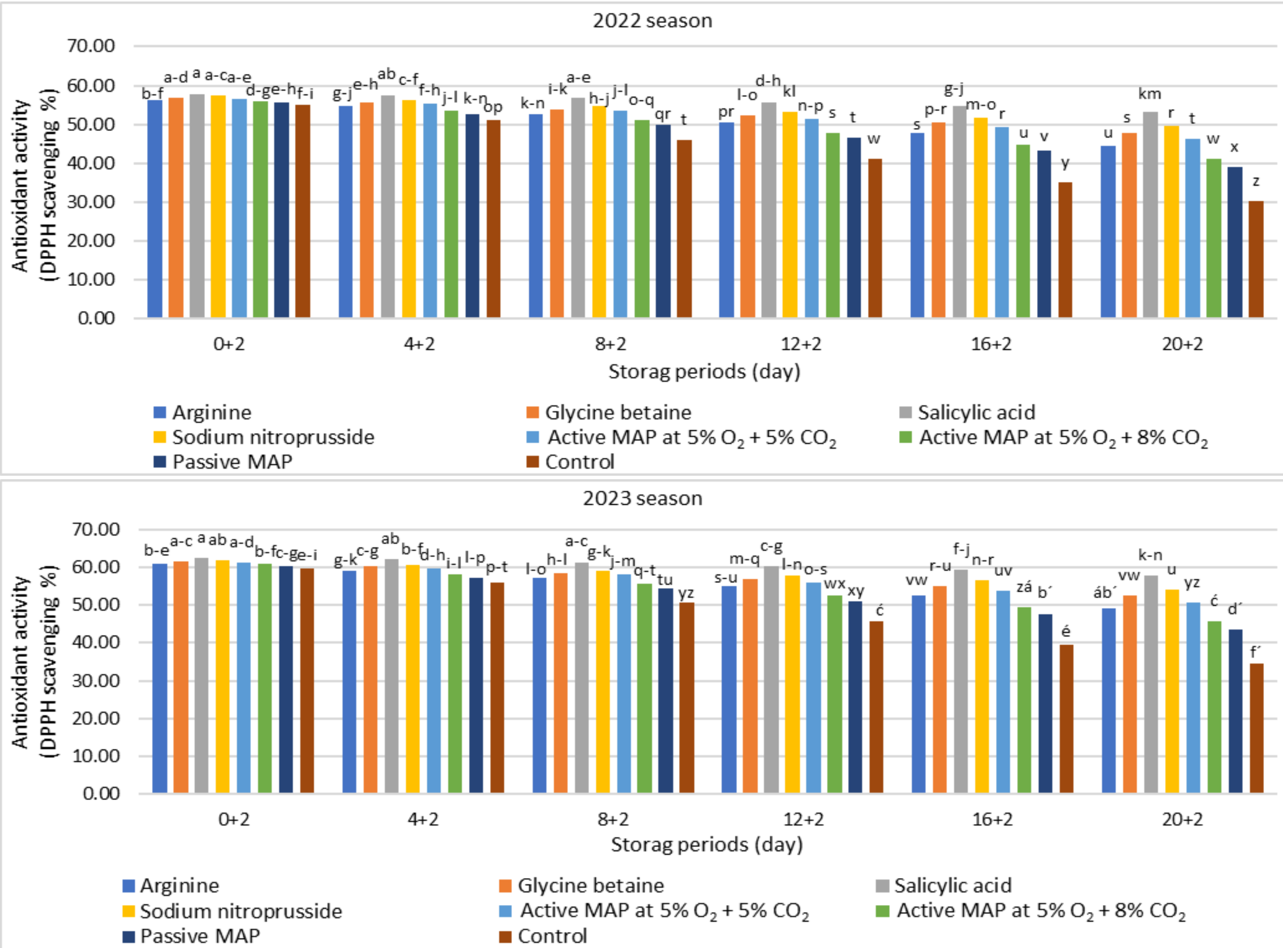


**Fig. (9).** Effect of some postharvest treatments and storage periods on antioxidant activity (DPPH scavenging %) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

SA and SNP treatments are possibly effective in maintaining antioxidant activity and recording higher DPPH% scavenging capacity in fruit through the activation of responsible genes for producing antioxidant compounds and increasing activity of the antioxidant enzymes such as SOD, POD, CAT and APX (Asghari and Aghdam, 2010 andGhorbani et al., 2018). These enzymes are important in the antioxidant system and also help in the scavenging of ROS (Duan et al., 2011). Also, the previous study showed that there was a significant positive correlation between total phenolic, ascorbic acid contents and DPPH scavenging capacity (Safariet al., 2021).

**10- Gas composition in package:-**

The data in Figs. (10 and 11) show that there was a significant decrease in $O_2$ % and increase in $CO_2$ % in the packages during the storage period plus shelf life in the two seasons, and these are in agreement with Albornoz et al. (2019) who reported that this may be due to the consumption of $O_2$ and production of $CO_2$ during the respiration process of fruit.

However, the gas composition inside the packages treated with SA and SNP had high $O_2$ and low $CO_2$ concentrations compared with passive MAP treatment. At the end of the storage period, the highest $O_2$ and lowest $CO_2$ concentrations were recorded with SA treatment, followed by SNP treatment. Also, samples under active MAP at 5% $O_2$ + 5% $CO_2$ showed decreased $O_2$ and relatively increased $CO_2$. This was also confirmed by the variations in $O_2$ and $CO_2$ concentrations over the storage period compared to the initial concentrations of $O_2$ and $CO_2$. As expected, the unpacked fruits (control) showed no changes in $O_2$ and $CO_2$ concentration during the storage period plus shelf life in the two seasons, and these are in agreement with Asghari and Aghdam (2010), Tran et al. (2015) and Park et al. (2018).

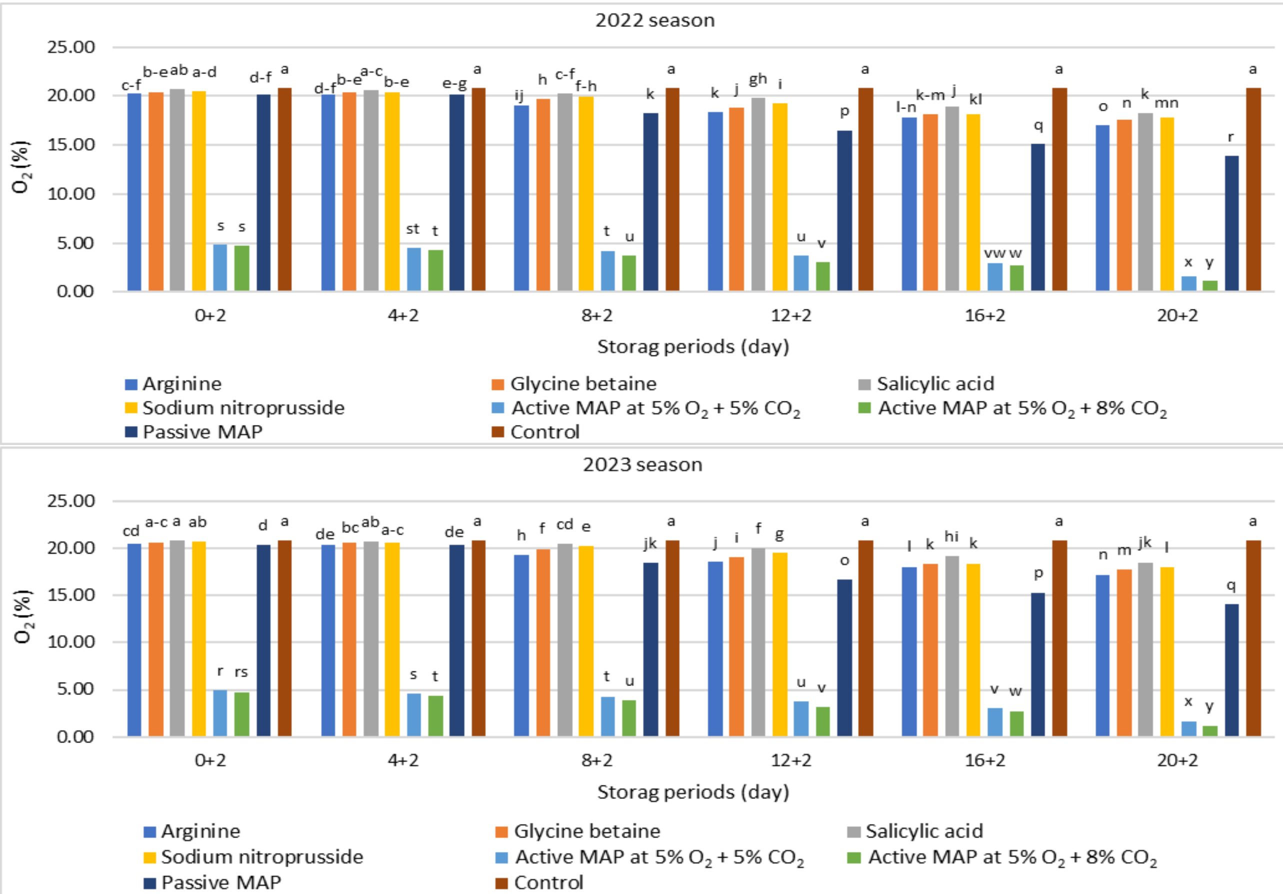


**Fig. (10).** Effect of some postharvest treatments and storage periods on $O_2$ (%) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

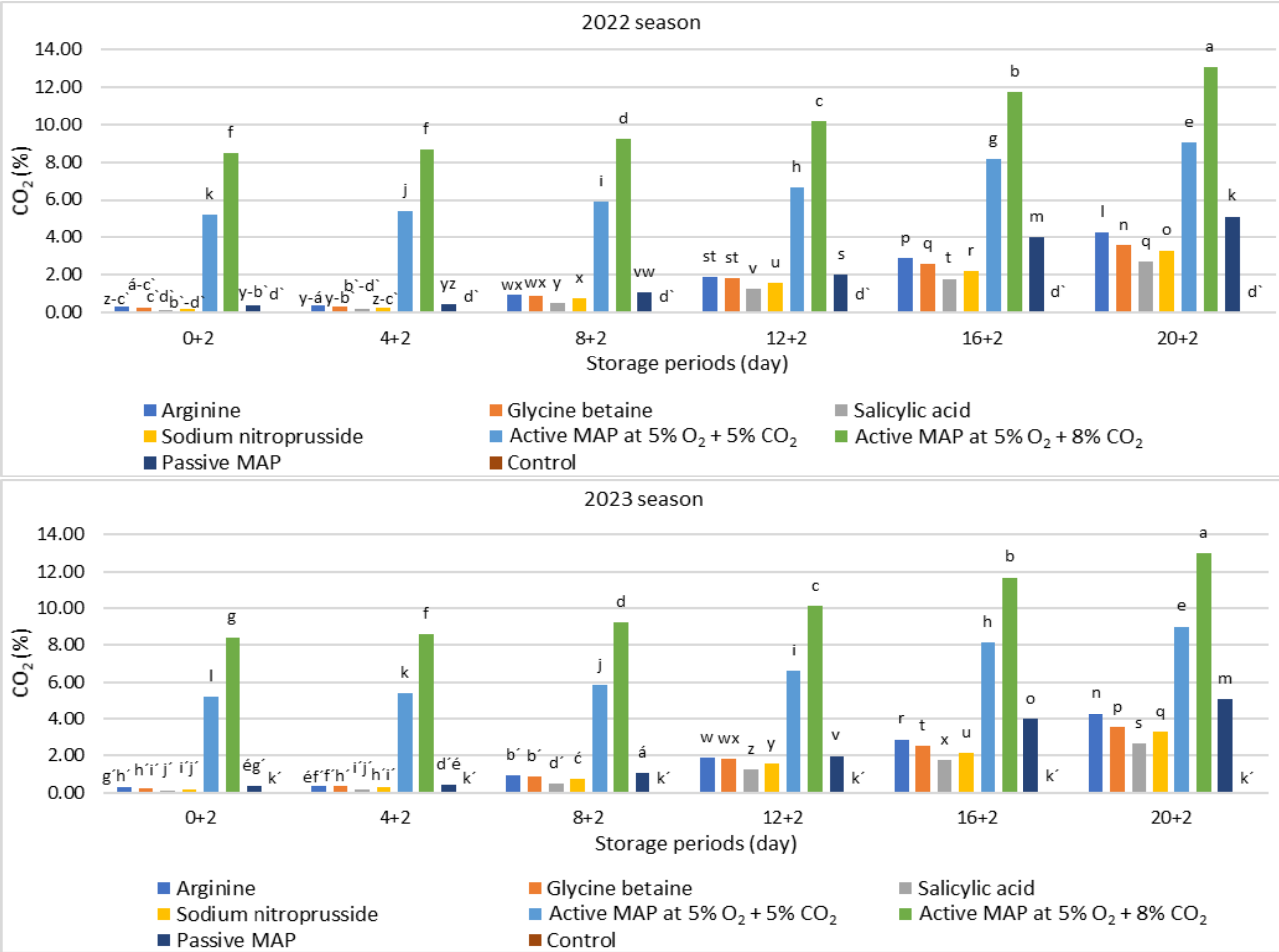


**Fig. (11).** Effect of some postharvest treatments and storage periods on $CO_2$ (%) of cherry tomatoes during storage at 5°C plus 2 days at 20°C in 2022 and 2023 seasons. The different letters show there are significant differences in the interaction between treatments and storage periods at level 5%.

The high $O_2$ and low $CO_2$ concentrations inside the package treated with SA or SNP treatments may be due to these materials ability to prevent ethylene production and action, which slows down the respiration rate and consequently reduces the consumption of $O_2$ and the accumulation of $CO_2$ concentrations inside the packages (Renhua et al., 2008 and Eum et al., 2009).

## CONCLUSION

Cherry tomato fruits dipped in solution of salicylic acid at 2mM for 5 min were a promising technique in preserving all the qualityattributes of fruitsand showed the excellent appearance of fruits without any chilling injury symptoms until 20 days of storage at 5°C plus 2 days at 20°C.

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## الملخص العربى

## تطبيق معاملات ما بعد الحصاد للتخفيف من أضرار البرودة والحفاظ على جودة ثمار الطماطم الشيرى أثناء التخزين المبرد

**محسن السيد محمد سعد- شيرين عطا عطاالله - نوره على جاد الرب أحمد**

**قسم بحوث تداول الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة – مصر**

أجريت هذه الدراسة خلال موسمي 2022 و 2023 على الطماطم الشيرى صنف كتالينا 522 لدراسة تأثير معاملات ما بعد الحصاد باستخدام الأرجينين بتركيز 0.5 ملي مولار لمدة 10 دقائق، جلايسين بيتين بتركيز 30 ملي مولار لمدة 10 دقائق، وحمض الساليسيليك بتركيز 2 ملى مولار لمدة 5 دقائق، ونتروبروسيد الصوديوم (مانح لأكسيد النيتريك) بتركيز 2 ملى مولار لمدة 30 دقيقة ثم التغليف باكياس بولى بروبلين، والتعبئة فى الجو الهوائى المعدل الموجب بتركيز 5 % اكسجين + 5 % ثانى اكسيد الكربون أو بتركيز 5 % اكسجين+ 8 % ثانى اكسيد الكربون، و التعبئة فى الجو الهوائى المعدل السالب بالاضافة الى المعاملة الكنترول خلال التخزين المبرد على درجة 5°م لمدة 20 يوم بالإضافة إلى يومين على درجة 20°م (فترة العرض) على تخفيف أضرار البرودة والحفاظ على خصائص جودة الثمار. أشارت النتائج إلى أن ثمار طماطم الشيرى المعاملة بجميع معاملات ما بعد الحصاد كانت فعالة في تقليل الفقد فى الوزن، الفقد فى الصلابة، أضرار البرودة، التغير فى اللون، وتعديل الجو الهوائى داخل العبوة، وكذلك الحفاظ على حمض الأسكوربيك، محتوى الفينولات الكلية، نشاط مضادات الأكسدة، والمظهر العام للثمار خلال جميع فترات التخزين بالإضافة إلى فترة العرض مقارنة بالمعاملة الكنترول. كما لوحظ عدم ظهور أي أعراض لأضرار البرودة فى الثمار المعاملة بحمض الساليسيليك، نتروبروسيد الصوديوم و جلايسين بيتين حتى نهاية التخزين، بينما الثمار المعبأة فى الجو الهوائى المعدل الموجب عند 5 % اكسجين + 5 % ثانى اكسيد الكربون و المعاملة بالأرجينين أدت الي تأخير بداية ظهور أعراض أضرار البرودة وسجلت أعراض بسيطة بعد 20 يوم من التخزين على درجة 5°م بالإضافة إلى يومين على درجة 20°م. علاوة على ذلك، كانت المعاملة بحمض الساليسيليك هي الأكثر فاعلية في الحفاظ على جميع صفات جودة الثمار وأعطت مظهرًا ممتازًا للثمار لمدة 20 يوم من التخزين على درجة 5°م بالإضافة إلى يومين على درجة 20°م، بينما أعطت المعاملة بنتروبروسيد الصوديوم و جلايسين بيتين مظهرًا جيدًا للثمار خلال نفس الفترة.