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Improving Fruit Quality and Prolonging Postharvest Life of Superior Grapevine during Cold Storage

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ABSTRACT

The present work was done at privet lab., in the two seasons of 2022 and2023 to examine the post-harvest effect of SO2 (1g/kg), Salicylic acid (2ml/L), ethanol (20%), modified atmosphere package, chitosan (5%), and calcium chloride (1%) on grape berries fruits physicochemical parameters during cold storage. The obtained results confirmed that berries' physical and chemical properties were significantly affected by post-harvest application, cold storage periods, and their interaction in both seasons. The lowest reduction in weight, respiration rate, berries shatter fungi decay as well as berries contents of TSS and total acidity while the highest berries firmness and maturity index were recorded in berries fruits that were treated with Chitosan in both seasons. the largest berries contents of total sugars and reducing sugars were recorded under the control treatment followed by CaCl2 and SO2 in the two seasons. According to the findings about the effects of cold storage periods, weight loss, berry shattering, and fungal decay along with TSS, maturity index, total reducing and non-reducing sugars rose gradually with the lengthening of the cold storage period in both seasons. While berries' firmness and respiration rate reduced when the cold storage period was extended over both seasons.

KEYWORDS: Table grapes, postharvest, Sulfur dioxide, Modified Atmosphere, Chitosan

1. INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the most favorable fruit crops in the whole world (USDA, 2021). Table grape is a non-climacteric fruit with a relatively low rate of physiological activity (Robinson and Davies, 2000). Grapes are an important source of antioxidants (Baiano and Terracone, 2011) and have many active biological compounds, which play a vital role against cardiovascular disease, arteries, infections, cancers, eye disorders, diabetes, obesity, and nervous system functions References (Bucić-kojić et al., 2009). In the 2022 season the world total production was 79034332 tons produced from harvested area reached 7.15 million hectares while, the total harvested area in Egypt was 76837 hectares and produced 1715342 tons (FAO, 2022)).

Due to high enzyme activity and pathogenic infection, grape berries lose a large part of their weight during transportation and shelf life (Feliziani et al., 2013). The total losses due to fungal decay are estimated at 10-40% of total grape production around the whole world (Sonker et al., 2015). Grapes have a high water content, pH, and nutrient composition, they are easily affected by fungi and produce mycotoxins, which are toxic to both humans and animals (Gatto et al., 2011 Zain, 2011). Grape berries are subjected to cinerea fungi which is the common cause of postharvest disease in table grapes (Sonker et al., 2016). To avoid the bad effects of fungal diseases, synthetic fungicides are used. These fungicides caused environmental pollution, and human health impacts (Tripathi and Dubey, 2004).Recently, several methods were developed to use as safe alternatives to synthetic fungicides such as modified atmosphere packages and edible coating. Modified atmosphere packaging (MAP) is a preservation technique where the in-package atmosphere is modified by using polymeric films with or without perforations and the air surrounding the fruit in the package is changed to another composition (lowered level of O2 and a heightened level of CO2). This kind of package delays the natural deterioration of the fruit by slowing down respiration activity, the ripening process, and the incidence of various physiological disorders and pathogenic infestations (Kader, 1986). Modified

diseases (Beaudry, 1999).in grape berries that were stored at 0±1ºC for 4 weeks and assessed weekly intervals MAP was superior in most cases such as restriction of weight loss, and maintenance of berry appearance in comparison with ethanol. On the other hand, the use of MAP together with ethanol exhibited the best results in the maintenance of overall quality parameters (Sabir et al., 2010).

One of the secure plant hormones employed in the preparation of fruits after harvest is salicylic acid (SA). When plants are exposed to biotic and abiotic challenges, it stimulates their defence mechanisms (Asghari and Aghdam, 2010). Salicylic acid is only used post-harvest at non-phytotoxic amounts, though (Babalar et al., 2007). Salicylic acid delays fruit ripening and maintains post-harvest quality and reduces fruit decay (Supapvanich and Promyou, 2013). Post-harvest treatments increased the shelf life of various fruits and vegetables, such as dill (Koyuncu et al., 2018) and strawberries. (Kumar and Kaur 2019). By reducing the rate of ethylene generation and respiration, SA can preserve the post-harvest quality of fresh horticulture crops (Koyuncu et al. 2018).

Calcium salts are used to increase the Ca content of the cell wall fruits. Pre-harvest and postharvest calcium application have been effective in controlling several physiological disorders in various fruits like strawberries, peaches, nectarines, and apples (Dunn and Able, 2006), reduced the incidence of fungal pathogens and maintaining fruit firmness, reduced the respiration rate at harvest stage, delaying senescence, ripening and resulting in higher quality fruit (Raese and Drake, 2006). Calcium significantly improved the maintenance of fruit firmness decreased weight loss, showed higher levels of TA and lowered contents of SSC %, and slightly maintained the loss of ascorbic acid in papaya fruits (Mahmud et al., 2008).).

Sulfur dioxide SO2 preservatives provide effective pathogen control with minimal effect on beneficial organisms (Zhou et al., 2019; Youssef et al., 2020). Sulphur dioxide is a synthetic fungicide used in the conventional management of decay brought on by the fungus Botrytis cinerea, but overuse or an increase in its concentration causes wounds to appear in berries and clusters, which is a significant problem for the consumer. To address this issue, excessive use of sulphur dioxide or an increase in its concentration must be avoided. Harvested clusters are usually stored in the presence of sulfur dioxide, which is harmful to table grapes and is harmful to human health (Crisosto et al., 2002). Sulphur dioxide gas from table grapes causes phytotoxic symptoms such as browning of rakes, sulphur taste, hairline fractures on the skin of berries, bleaching, discoloration and sulphide residues that may cause hypersensitivity reactions in some persons. This gas is not allowed to be used on organic grapes (Zoffoli et al., 2008). As a result, this study attempts to evaluate the role of some post-harvest treatments such as sulfur dioxide, salicylic acid, ethanol, modified atmosphere package, chitosan and calcium chloride in maintaining the physical and chemical properties of grape berries during cold storage.

2. MATERIALS AND METHODS

The present study was carried out in privet lab during two successive seasons 2022 and 2023 to examined the post-harvest treatments of SO_2 (1g/kg), Salicylic acid (2ml/L), ethanol (20%), modified atmosphere package, chitosan (5%), and calcium chloride (1%) on grape berries fruits physical and chemical properties during cold storage.

To achieve the previous fresh berries clusters were picked from 4 year-old vines from a privet orchard in Beni-Mazar district–Minia Governorate. The picked clusters were placed in plastic boxes (5 kg capacity) and transferred in refrigerated car (15°C) to the horticulture lab - Faculty of Agriculture Cairo University. Upon arrival, the clusters sorting and the exclusion of damaged and injured berries and non-homogenous in maturity. After that, clean sound clusters were select to use each treatment was divided into six storage periods (0, 10, 20, 30, 40, and 50 days), each storage period consisted of Seven Treatments, and each treatment contained 6 replicate each replicate 2 boxs and contained on 10 clusters. All clusters were put in polyethylene terephthalate (PET) lid bags boxes (one cluster/ bags) with dimensions of 19×12×8.5 cm and the bags were placed in one layer inside corrugated boxes with dimensions of 40×30×13 cm. All experimental boxes were covered by polyethylene sheets with a thickness of 0.04 mm and the boxes were subjected to precooling by put them into a forced air-cooling room (pressures 0.6 to 7.5 m bar and air flows 0.001 to 0.003 m3/second/kg) at 2°C for four hours. After that, the boxes were stored at 0±1°C and 90±5% RH for 50 days. Fruit physical and chemical characteristics were measured at harvest time and then every 10 days from the beginning of cold storage until the end of the cold storage.

2.1. Data recorded

2.1.1. Fruit physical properties:

Fruit weight loss (%)

Using a bench-top digital scale, fruit weight loss during cold storage was determined every 15 days. Version PC-500 (Doran scales, Batavia, IL, USA) and calculated by the following formula: Fruit weight loss (%) = [(Fruit weight before storage - fruit weight after each cold storage period)/ (Fruit weight before storage)] x100.

Berry firmness

Berry firmness was measured using Effegi penetrometer supplemented with a plunger 2 mm diameter penetrator (FT-02, Italy) at two equatorial opposite sites (Watkins and Harman, 1981). Two readings were taken of each berry. The firmness value was determined as a Newton (N) value and given as a gramme force.

Berry shattering (%)

The formula used to determine berry shattering is shown below:

Berry shattering (%) = [(weight of shattering berries after each cold storage period)/ (bunch weight before storage)] x100.

Gray mold decay incidence

Fruit decay naturally occurring rot caused by gray mold was recorded as every 15 days of cold storage by the following equation:

Berry decay (%) = [(number of decayed berries at specified storage period)/ (number of stored branches) x100] according to (Junior et al. 2019).

2.1.2. Fruit chemical attributes:

The observation of berry characters was recorded based on fifty berries taken from 10 bunches.

Total Soluble solids (TSS)

TSS was determined using a digital hand-held refractometer with a range of 0 to 53% Brix (Atago Co., Ltd., Tokyo, Japan) at 20°C. A few drops of the juice were placed on the prism of the refractometer to obtain a direct reading, and the results were expressed in °Brix in accordance with the formula: AOAC (2005).

Titratable acidity (TA%)

TA% was measured using the approach outlined in the AOAC (2005) protocol.

Maturity index (TSS/TA ratio).

The numbers indicated for fruit juice SSC and TA percentages were calculated to arrive at TSSC/TA.

2.1.3. Determination of sugars:

Using the picric acid method as per Thomas and Dutcher's (1924) description, total and reducing sugars were colorimetrically assessed. On the basis of the glucose standard curve, the sugar content was determined as mg. The total soluble and reducing sugars were calculated using two solutions:

i- Sodium carbonate solution: 100 ml of distilled water were used to dissolve 20 grammes of sodium carbonate. ii- Picrate-picric sodium solution was created by mixing 36 grammes of picric acid with 500 ml of 1.0% sodium hydroxide in a one-liter flask. Next, 400 ml of hot water was added, and the mixture was occasionally shaken to help the picric acid dissolve. Finally, the mixture was cooled and diluted to one litre.

For the measurement of total soluble sugars, 0.5 ml of each sample was transferred to a 70 cc test tube containing 5 ml of distilled water and 4 ml of picrate-picric solution. The mixture was then boiled for 10 minutes in a water bath, after which one ml of sodium carbonate was added, and the mixture was again boiled for 10 minutes. The liquid was then chilled and diluted to a final volume of 50 cc using distilled water. Using the "Spekol" spectro-colorimeter (Carl Zeiss Jena), the optical density of the produced colour was assessed at 540 nm. The aforementioned method was also used to determine reducing sugars, with the exception that sodium carbonate and picrate-picric were added simultaneously and heated for just 10 minutes. Non-reducing sugars were calculated using the difference between the total soluble and reducing sugars. All these determinations were expressed as milligrams of glucose per gram fresh weight of fruits.

2.2. Statistical analysis

According to Gomez and Gomez (1984), all data were subjected to the analyses of variance (Two-way ANOVA) split in randomized block design (RCBD) design, followed by compared means with LSD at level probability 5% using computer software.

3. RESULTS

3.1. Effect post-harvest applications of sulfur dioxide 1 gm/kg (SO2) , salicylic acid 2ml/l (SA) , ethanol 20%, modified atmosphere package (MAP) , chitosan 5%, and calcium chloride 1%(CaCl) on physical properties of 'Superior' grapevines cv. during different cold storage periods.

The presented data in Tables 1 to 8 confirmed that berries weight loss, discarded fruits, adherence strength, fruit firmness, respiration rate, berries Shattering, fungi decay, and total fruit losses were significantly affected by post-harvest treatments, cold storage periods and their interaction in both seasons.

3.1.1. Weight loss (%).

Concerning the effect of post-harvest treatments, the results in Table 1 indicated that all post-harvest treatments led to a significant decrease in weight loss of berries compared with the control in both seasons. The lowest weight loss was recorded in berries treated with Chitosan (1.01 and 1.28%) without any significant differences with berries that were stored in a modified atmosphere package (1.02 and 1.26%) in both seasons respectively. Also, berries dipped in salicylic acid post-harvest showed low desirable weight loss (2.22 and 2.04%) in both seasons, respectively.

Table 1. The effect of postharvest dipping treatments on weight loss (%) in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons.

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
2022							
Control	0.00p	1.47i-m	2.30hi	5.33e	8.00d	14.00a	5.18A
SO2 (1gm/kg)	0.00p	0.40n-p	1.87i-k	3.50fg	5.33e	9.00c	3.35B
SA (2 ml/L)	0.00p	1.00k-o	1.00k-o	2.30hi	3.33g	5.67e	2.22D
Ethanol 20 %	0.00p	1.23j-n	1.60i-l	3.00gh	4.17f	11.00b	3.50B
MAP	0.00p	0.30op	0.833l-p	1.37j-m	1.60i-l	2.00ij	1.02E
Chitosan (5 %)	0.00p	0.30op	0.63m-p	1.37j-m	1.47i-m	2.30hi	1.01E
CaCl2 (1%)	0.00p	1.13j-o	1.53i-m	2.33hi	3.77fg	7.83d	2.77C
Storage periods Mean	0.00F	0.83E	1.40D	2.74C	3.95B	7.40A	
2023							
Control	0.00s	1.87l-n	2.23k-m	4.20gh	7.30d	11.67a	4.54A
SO2 (1gm/kg)	0.00s	1.63m-o	1.90l-n	2.20k-m	3.97h	7.87c	2.93C
SA (2 ml/L)	0.00s	1.37n-p	1.67m-o	2.00lm	2.70jk	4.50fg	2.04D
Ethanol 20 %	0.00s	1.97l-n	2.47j-l	3.30i	4.83ef	8.63b	3.53B
MAP	0.00s	0.60r	1.20o-q	1.63m-o	1.90l-n	2.20k-m	1.26E
Chitosan (5 %)	0.00s	0.50rs	1.03p-r	1.67m-o	1.90l-n	2.60jk	1.28E
CaCl2 (1%)	0.00s	0.70qr	1.67m-o	1.97l-n	2.80ij	5.10e	2.04D
Storage periods Mean	0.00F	1.23E	1.74D	2.42C	3.63B	6.08A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

However, the untreated berries experienced the greatest weight reduction (5.18% and 4.54in the first and second seasons, respectively.

The findings in Table 1 regarding the impact of cold storage periods showed that weight loss increased steadily when the cold storage period is extended in both seasons. The lowest loss in berries weight was found at the beginning of the cold storage period (0.00 and 0.00%), then it increased to (0.83 and 1.23%) after ten days of cold storage in both seasons, respectively. After 50 days of cold storage in each of the two seasons, the weight loss of the berries peaked (7.04 and 6.08%, respectively).

The findings in Table 1 for the interaction between treatments and storage periods on weight loss in berries showed that all treatments were significantly less effective than controls in both seasons throughout all cold storage durations. Modified atmosphere package treatment of chitosan exceeded all used treatments and the control in reducing the loss of berries weight across all cold storage periods in both seasons. The lowest weight loss after 50 days of cold storage was recorded in berries fruits that store in a modified atmosphere package (2.00 and 2.20%) followed by chitosan (2.30 and 2.60%) then the post-harvest application of SA (5.67 and 4.50%) in both seasons, respectively.

3.1.2. berries firmness (Ib/inch2).

Concerning the effect of post-harvest treatments on berries' firmness, the results presented in Table 2 revealed that berries' firmness differed significantly under all post-harvest treatments where all treatments resulted in a significant increase in berries' firmness more than the control in both seasons. The highest berries firmness was recorded in the berries fruits that were storage in a modified atmosphere package (761.70 and 738.90 Ib/inch2) followed by Chitosan (743.30 and 724.40 Ib/inch2) in both seasons respectively. In the same way, dipped berries fruit in salicylic acid post-harvest showed high desirable berries firmness (712.80 and 672.20 Ib/inch2) in both seasons, respectively. However, in the first and second seasons, respectively, the untreated berries had the lowest

Table 2. The effect of postharvest dipping treatments on firmness (lb./inch2) in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons.

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	863.3a	743.3f	633.3m	510.0s	413.3u	380.0v	590.6G
SO2 (1gm/kg)	863.3a	740.0fg	666.7k	613.3n	556.7q	473.3t	652.2F
SA (2 ml/L)	863.3a	783.3cd	740.0fg	696.7j	623.3mn	570.0p	712.8C
Ethanol 20 %	863.3a	766.7e	723.3h	646.7l	573.3p	473.3t	674.4E
MAP	863.3a	813.3b	773.3de	746.7f	710.0i	663.3k	761.7A
Chitosan (5 %)	863.3a	790.0c	763.3e	730.0gh	690.0gh	623.3mn	743.3B
CaCl2 (1%)	863.3a	766.7e	726.7h	656.7kl	590.0o	543.3r	691.1D
Storage periods Mean	863.3A	771.9B	718.1C	657.1D	593.8E	532.4F	
				2023			
Control	816.7a	720.0g	630.0l	556.7n	396.7r	270.0t	565.0G
SO2 (1gm/kg)	816.7a	740.0ef	640.0kl	553.3n	453.3q	400.0r	600.6F
SA (2 ml/L)	816.7a	756.7cd	703.3h	650.0k	580.0m	526.7o	672.2C
Ethanol 20 %	816.7a	730.0fg	663.3j	556.7n	490.0p	376.7s	605.6E
MAP	816.7a	776.7b	750.0de	723.3g	700.0h	666.7j	738.9A
Chitosan (5 %)	816.7a	766.7bc	736.7f	703.3h	686.7i	636.7l	724.4B
CaCl2 (1%)	816.7a	730.0fg	696.7hi	650.0k	573.3m	523.3o	665.0D
Storage periods Mean	816.7A	745.7B	688.6C	627.6D	554.3E	485.7F	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

unwanted berry hardness measurements (590.60 and 565.00 Ib/inch2).

Table 2's findings on the relationship between cold storage intervals and berry firmness revealed that, in both seasons, fruit firmness steadily declined as cold storage intervals grew longer. The firmness of the berries was maximum at the start of the cold storage period (863.30 and 816.70 Ib/inch2), and it gradually dropped to (718.10 and 688.60 Ib/inch2) after 20 days of cold storage in each season.

After 50 days of cold storage in the two seasons, the firmness of the berries reached its lowest levels (532.40 and 485.70 Ib/inch2, respectively).

The results in Table 2 showed that there was a substantial increase in berry firmness across all cold storage periods when compared to the control in both seasons for the interaction between treatment and storage period effects on berry firmness. Chitosan and the changed environment package outperformed all other treatments used, and the control delayed the loss of berry firmness during all cold storage intervals during both seasons. Fruits stored in modified atmosphere packages had the highest berry firmness after 50 days of cold storage (663.30 and 666.70 Ib/inch2), followed by chitosan (623.30 and 636.71 Ib/inch2) and SA applied post-harvest (570.00 and 526.70 Ib/inch2) in both seasons, respectively.

3.1.3. Respiration rate.

Concerning the effect of post-harvest treatments on berries' fruit respiration rate, the results in Table 3 indicated that all post-harvest treatments led to a significant decrease in berries' respiration rate compared with the control in both seasons. The lowest respiration rate was recorded in berries fruits that were stored in the Modified atmosphere package (4.21 and 3.69) followed by berries that were treated with Chitosan (4.33 and 3.91) in both seasons respectively. In a similar vein, post-harvest respiration rates for salicylic acid-dipped berries and fruit were lowly desirable (4.50 and 3.81, respectively) in both seasons. On the other hand, the untreated berries had the

Table 3. The effect of postharvest dipping treatments on respiration rate in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	12.67a	3.90d-f	3.33g-l	3.67e-h	3.97de	5.50b	5.51A
SO2 (1gm/kg)	12.67a	3.73e-h	3.03j-o	3.30g-l	3.63e-i	4.67c	5.14B
SA (2 ml/L)	12.67a	3.50e-j	2.23r-t	2.57o-s	2.77m-q	3.27h-m	4.50C
Ethanol 20 %	12.67a	3.77e-h	2.97k-p	3.37g-l	3.80e-g	4.43c	5.17B
MAP	12.67a	3.43f-k	1.97t	2.17r-t	2.37q-t	2.67n-r	4.21D
Chitosan (5 %)	12.67a	3.52e-j	2.07st	2.37q-t	2.50p-s	2.87l-q	4.33CD
CaCl2 (1%)	12.67a	3.67e-h	2.87l-q	3.13i-n	3.37g-l	4.30cd	5.00B
Storage periods Mean	12.67A	3.65C	2.64F	2.94E	3.20D	3.93B	
				2023			
Control	13.40a	2.90ef	2.67e-j	2.33h-m	3.73c	4.30b	4.89A
SO2 (1gm/kg)	13.40a	2.73e-i	2.30i-m	2.03l-o	2.93e	3.60cd	4.50B
SA (2 ml/L)	13.40a	2.50e-k	1.37pq	1.13q	2.03l-o	2.40g-l	3.81DE
Ethanol 20 %	13.40a	2.77e-h	2.37g-m	1.97m-o	2.80e-g	3.50cd	4.47BC
MAP	13.40a	2.47f--k	1.27q	1.13q	1.67op	2.23j-n	3.69E
Chitosan (5 %)	13.40a	2.52e-k	1.43pq	1.23q	2.10k-n	2.80e-g	3.91D
CaCl2 (1%)	13.40a	2.67e-j	2.13k-n	1.87no	2.57e-j	3.30d	4.32C
Storage periods Mean	13.40A	2.65C	1.93D	1.67E	2.55C	3.16B	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

highest respiration rates in the first and second seasons, respectively (5.81 and 4.89).

For the effect of cold storage periods on respiration rate the results in Table 3 indicated that respiration rate was significantly affected by cold storage periods in both seasons. The highest respiration rate was found at the beginning of the cold storage period (12.67 and 13.40), then sharply decreased to (2.64 and 1.93) after 20 days of cold storage in both seasons, respectively. respiration rate increased at the end of the cold storage period until reached (3.93 and 3.16) in the two seasons, respectively.

Regarding the effect of the interaction between treatments and storage periods on respiration rate, the results in Table 3 showed that all used treatments significantly affect respiration rate across all cold storage periods compared with the control in both seasons. Modified atmosphere package chitosan exceeded all used treatments and the control in reducing respiration rate across all cold storage periods in both seasons. The lowest respiration rate after 50 days of cold storage was recorded in berries fruits that store in a modified atmosphere package (2.67 and 2.23) followed by chitosan (2.87 and 2.80) then the post-harvest application of SA (3.27 and 2.40) in both seasons, respectively.

3.1.4. Berries Shatter (%).

According to the results of post-harvest treatments on the percentage of berries that shatter, all treatments significantly reduced the percentage of berries that shatter more than the control in both seasons, as shown in Table 4. The fruits of berries stored in modified atmosphere packages had the lowest proportion of berries that shatter (1.26 and 1.63%), followed by Chitosan (1.43 and 1.77%) in both seasons, with no discernible variations between the two treatments. Additionally, after harvest, berries that had been salicylate-dipped showed low-desirable rates of berries shatter (1.67 and 2.11%) for the two seasons. However, the untreated berries had the most unfavourable percentages of berries shattering in the first and second seasons, respectively (4.06 and 4.30%).

The findings in Table 4 regarding the relationship between cold storage times and the percentage of berries that shatter indicated that, in

Table 4. The effect of postharvest dipping treatments on Shatter in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments Mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	0.00k	0.00k	1.80i	3.73f	6.30c	12.50a	4.06A
SO2 (1gm/kg)	0.00k	0.00k	0.77j	2.73gh	4.23f	8.70b	2.74C
SA (2 ml/L)	0.00k	0.00k	0.60j	0.97j	2.97g	5.50d	1.67E
Ethanol 20 %	0.00k	0.00k	0.97j	3.00g	5.20de	8.93b	3.02B
MAP	0.00k	0.00k	0.63j	0.77j	2.30h	3.83f	1.26F
Chitosan (5 %)	0.00k	0.00k	0.50j	0.77j	2.50gh	4.83e	1.43F
CaCl2 (1%)	0.00k	0.00k	0.67j	0.97j	4.00f	6.27c	1.98D
Storage periods Mean	0.00E	0.00E	0.85D	1.95C	3.93B	7.22A	
				2023			
Control	0.00k	0.00k	1.80l	3.80h	6.60d	13.60a	4.30A
SO2 (1gm/kg)	0.00k	0.00k	0.83m	3.07j	4.27g	8.27c	2.74C
SA (2 ml/L)	0.00k	0.00k	0.73m	2.60k	3.27ij	6.03e	2.11E
Ethanol 20 %	0.00k	0.00k	1.13m	3.30ij	5.27f	9.13b	3.14B
MAP	0.00k	0.00k	0.73m	0.83m	3.60hi	4.63g	1.63F
Chitosan (5 %)	0.00k	0.00k	0.63m	0.73m	3.63hi	5.60ef	1.77F
CaCl2 (1%)	0.00k	0.00k	1.00m	1.13m	5.60ef	6.83d	2.43D
Storage periods Mean	0.00E	0.00E	0.98D	2.21C	4.61B	7.73A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

both seasons, the percentage of berries that shatter steadily increases when cold storage times are extended. The average percentage of berries that shatter was 0.00 at the start of the cold storage period and 0.00 at ten days. After 30 days of cold storage in both seasons, the percentages increased to 1.95 and 2.21, respectively. After 50 days of cold storage in each of the two seasons, the percentage of berries that shatter peaked at 7.22 and 7.73%, respectively.

The information in Table 4 demonstrated that all applied treatments significantly reduced the proportion of berries that shatter during the course of all cold storage intervals when compared to the control in both seasons. This came from the interaction between treatments and storage periods. Chitosan and the modified environment package outperformed all other treatments and the control in lowering the proportion of berries that broke during all cold storage times during both seasons. The fruits that are stored in modified atmosphere packages (3.89 and 4.63%), chitosan (4.83 and 5.60%), and post-harvest application of SA (5.50 and 6.03%), respectively, had the lowest percentage of berries breaking after 50 days of cold storage.

3.1.5. Fungi decay (%).

For the effect of post-harvest treatments on fungi decay the results in Table 5 revealed that all used post-harvest treatments resulted in a significant decrease in fungi decay more than the control in both seasons. The lowest fungi decay was recorded in berries fruits that were stored in modified atmosphere package (1.82 and 2.11%) followed by fruits that were treated with Chitosan (2.39 and 2.39 %) in both seasons respectively. Also, dipped berries fruit in salicylic acid post-harvest showed low desirable fungi decay percentages (2.56 and 3.03 %) in both seasons, respectively. On the other hand, in the first and second seasons, the untreated berries had among the highest fungus decay percentages (9.32 and 11.47%).

The results in Table 5 for the impact of cold storage periods on fungal decay infections showed that fungi decay steadily increased when cold storage periods were prolonged in both

Table 5. The effect of postharvest dipping treatments on fungi decay in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	0.00q	1.20m-p	2.70l	8.33f	17.00c	26.67a	9.32A
SO2 (1gm/kg)	0.00q	0.33q	0.60nq	1.33mn	7.00h	15.00d	4.04C
SA (2 ml/L)	0.00q	0.30q	0.43pq	1.30m-o	4.67j	8.67f	2.56E
Ethanol 20 %	0.00q	0.47o-q	1.73m	3.83k	7.33gh	20.00b	5.56B
MAP	0.00q	0.17q	0.43pq	1.30m-o	3.00l	6.00i	1.82F
Chitosan (5 %)	0.00q	0.27q	0.43pq	1.30m-o	4.33jk	8.00fg	2.39E
CaCl2 (1%)	0.00q	0.30q	0.60nq	1.87m	6.67hi	12.00e	3.57D
Storage periods Mean	0.00F	0.43E	0.99D	2.75C	7.14B	13.76A	
				2023			
Control	0.00q	2.20m-o	3.93k	15.67d	21.00b	26.00a	11.47A
SO2 (1gm/kg)	0.00q	0.60qr	1.33pq	2.80lm	13.00f	15.00d	5.46C
SA (2 ml/L)	0.00q	0.43r	1.30pq	2.43mn	6.00j	8.00h	3.03E
Ethanol 20 %	0.00q	1.60op	3.47kl	6.33ij	14.00e	20.00c	7.57B
MAP	0.00q	0.43r	0.70qr	1.77n-p	3.77k	6.00j	2.11F
Chitosan (5 %)	0.00q	0.47r	0.70qr	2.33m-o	3.87k	7.00i	2.39F
CaCl2 (1%)	0.00q	0.60qr	1.33pq	2.53mn	6.67ij	11.00g	3.69D
Storage periods Mean	0.00F	0.90E	1.82D	4.84C	9.76B	13.29A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

seasons. The lowest fungi decay was found at the beginning of the cold storage period (0.00 and 0.00%), then increased to (0.99 and 1.82 %) after 20 days of cold storage in both seasons, respectively. Fungi decay reached their peak (13.76 and 13.29%) after 50 days of cold storage in the two seasons, respectively.

The findings shown in Table 5 clearly show that all employed treatments resulted in significantly lower fungal decay % across all cold storage periods when compared to the control in both seasons. This is because of the interaction between treatments and storage periods' effects on fungi decay. Chitosan and the modified atmosphere package outperformed all other treatments, while the control resulted in less fungal decomposition after both seasons' worth of cold storage. Berry and fruit stored in modified atmosphere packages had the lowest fungal decay after 50 days of cold storage (6.00 and 6.00%), followed by chitosan (8.00 and 7.00%) and then SA applied after harvest (8.67 and 8.00%) in both seasons, respectively.

3.2. Effect post-harvest applications of sulfur dioxide, salicylic acid, ethanol, modified atmosphere package, chitosan, and calcium chloride on chemical properties of ‘Superior’ grapevines cv. during different cold storage periods.

The information in tables 6 to 14 demonstrated how post-harvest treatments, cold storage intervals, and their interactions in both seasons considerably impacted the contents of berries and fruits in terms of total soluble solids, total acidity, maturity index, total sugars, reducing sugars, and non-reducing sugars.

3.2.1. Total soluble solids (%).

Concerning the effect of post-harvest treatments, the results in Table 6 indicated that total soluble solids significantly differ under the different post-harvest treatments in both seasons. The lowest TSS levels were found in berries stored in modified atmosphere packages (16.87 and 16.30%), followed by berries treated with chitosan (16.97 and 16.45%) in both seasons, with

Table 6. The effect of postharvest dipping treatments on TSS (%) in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	15.90op	17.03i-l	17.13h-l	17.23h-k	18.33c	19.33a	17.49A
SO2 (1gm/kg)	16.03n-p	17.17h-l	17.33g-i	17.40gh	17.90ef	18.77b	17.43A
SA (2 ml/L)	16.13no	16.93kl	17.40gh	17.45gh	17.77ef	18.23cd	17.31B
Ethanol 20 %	16.03n-p	17.13h-l	17.30h-j	17.33g-i	17.90ef	18.93b	17.44A
MAP	15.90op	16.27n	16.60m	17.00j-l	17.43gh	18.00de	16.87C
Chitosan (5 %)	15.83p	16.20n	16.87l	17.27h-j	17.63fg	18.03de	16.97C
CaCl2 (1%)	16.17no	17.17h-l	17.40gh	17.40gh	17.87ef	18.40c	17.40AB
Storage periods Mean	16.00F	16.74E	17.15D	17.29C	17.83B	18.53A	
				2023			
Control	15.57p-r	16.13mn	17.20j	17.97e-g	18.37cd	19.30a	17.42A
SO2 (1gm/kg)	15.20s-u	15.80op	16.27lm	17.33ij	17.93fg	18.77b	16.88BC
SA (2 ml/L)	15.07tu	15.53qr	15.97no	16.73k	17.87fg	18.20de	16.56D
Ethanol 20 %	15.27st	15.73o-q	16.40l	17.57hi	18.13d-f	18.77b	16.98B
MAP	15.00u	15.33rs	15.83o	16.33lm	17.40ij	17.90fg	16.30F
Chitosan (5 %)	15.07tu	15.43rs	15.97no	16.47l	17.77gh	18.00e-g	16.45E
CaCl2 (1%)	15.27st	15.73o-q	16.23lm	17.33ij	17.90fg	18.47c	16.82C
Storage periods Mean	15.21F	15.67E	16.27C	17.10C	17.91B	18.49A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

no appreciable differences between the two treatments in the first. Additionally, after harvest, fruits that had been soaked in salicylic acid revealed low acceptable TSS (17.31 and 16.56%, respectively) in both seasons. However, untreated berries had the highest total soluble solids (17.49 and 17.42%) in the first and second seasons, respectively. However, these values were not substantially different from those of SO2, ethanol, and CaCl2 in the first season.

Total soluble solids gradually rise with an expansion of the cold storage duration in both seasons, according to the findings in Table 6 about the impact of cold storage periods. Berry and fruit TSS peaked at 16.00 and 15.21% at the start of the cold storage period, respectively, and then increased to 17.15 and 16.27% after 20 days of cold storage in both seasons. In the two seasons, after 50 days of cold storage, the total soluble solids peaked (18.53 and 18.49%).

The findings in Table 6 for the interaction between treatments and storage periods on the total soluble solids (TSS) content of berries showed that all used treatments significantly reduced TSS during all cold storage periods when compared to the control in both seasons. Chitosan and the modified environment package outperformed all other treatments and the control in terms of reducing TSS in berries and fruits during all cold storage times during both seasons. The berries and fruits stored in modified environment packages had the lowest total soluble solids after 50 days of cold storage (18.00 and 17.90%), followed by chitosan (18.03 and 18.00%), and then SA applied post-harvest (18.23 and 18.20%) in both seasons, respectively.

3.2.2. Total acidity (%).

According to the findings in Table 7, post-harvest treatments had a substantial impact on berry total acidity. All treatments resulted in a considerable decrease in berry total acidity more than the control in both seasons. The lowest percentage of berries content of total acidity was recorded in that berries fruits that were storage in a modified atmosphere package (0.842 and 0.839%) followed by Chitosan (0.856 and 0.839%) in both seasons respectively without any significant differences between the two treatments

Table 7. The effect of postharvest dipping treatments on total acidity (%) in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
2022							
Control	1.257a	1.33de	1.033gh	0.933i-k	0.850l-n	0.800n-p	1.001A
SO2 (1gm/kg)	1.217a-c	1.100ef	0.983hi	0.883k-m	0.817no	0.700r-t	0.950B
SA (2 ml/L)	1.200bc	1.033gh	0.950ij	0.850l-n	0.767o-q	0.633u	0.906C
Ethanol 20 %	1.250ab	1.067fg	0.983hi	0.900j-l	0.833mn	0.717q-s	0.958B
MAP	1.200bc	1.033gh	0.900j-l	0.750p-r	0.650tu	0.517v	0.842D
Chitosan (5 %)	1.200bc	1.033gh	0.917jk	0.767o-q	0.667s-u	0.550v	0.856D
CaCl2 (1%)	1.167cd	1.067fg	0.950ij	0.817no	0.767o-q	0.667s-u	0.906C
Storage periods Mean	1.213A	1.067B	0.959C	0.843D	0.764E	0.655F	
2023							
Control	1.233ab	1.200bc	1.100d	1.00e	0.933e-g	0.900f-h	1.061A
SO2 (1gm/kg)	1.250ab	1.100d	1.000e	0.933e-g	0.800i-k	0.767j-l	0.975B
SA (2 ml/L)	1.267ab	1.133cd	1.000e	0.900f-h	0.733kl	0.700lm	0.956B
Ethanol 20 %	1.300a	1.200bc	1.100d	1.000e	0.900f-h	0.850hi	1.058A
MAP	1.217b	1.000e	0.867g-i	0.750l	0.650mn	0.550o	0.839C
Chitosan (5 %)	1.200bc	1.000e	0.850hi	0.733kl	0.650mn	0.600no	0.839C
CaCl2 (1%)	1.267ab	1.100d	1.000e	0.950ef	0.833h-j	0.733kl	0.981B
Storage periods Mean	1.248A	1.105B	0.988C	0.895D	0.786E	0.729F	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

in the two seasons. Also, dipped berries fruit in salicylic acid post-harvest showed a low percentage of berries content of total acidity (0.906 and 0.956%) in both seasons, respectively. However, the untreated berries showed the highest percentages of total acidity in the first and second seasons, respectively (1.001 and 1.061%).

The results in Table 7 showed that, in accordance with the influence of cold storage periods on the berries' total acidity content, the total acidity of the berries steadily reduced with the lengthened cold storage duration in both seasons. Beginning with the cold storage phase, the berries' greatest total acidity level (1.213 and 1.248%) was discovered, then decreased to (0.959 and 0.988%) after 20 days of cold storage in both seasons, respectively. After 50 days of cold storage in the two seasons, the total acidity of the berries had decreased to its lowest levels (0.655 and 0.729%).

According to the findings in Table 7, all used treatments led to a significant reduction in berry total acidity across all cold storage periods when compared to the control in both seasons. This was true regardless of the interaction between treatments and storage periods. Chitosan and the modified environment package outperformed all other treatments and the control in lowering the level of total acidity in the berries during all cold storage times during both seasons. The fruits that were stored in modified atmosphere packages for 50 days had the lowest percentage of total acidity in their berries, followed by chitosan (0.550 and 0.600%) and SA applied after harvest (0.633 and 0.700%) in both seasons, respectively.

3.2.3. Maturity index (TSS/TA).

Concerning the effect of post-harvest treatments on maturity index, the results in Table 8 revealed that all used post-harvest treatments except ethanol resulted in a significant increase in berries maturity index more than the control in both seasons. The highest maturity index was recorded in berries fruits that were stored in a modified atmosphere package (21.96 and 21.17) followed by fruits that were treated with Chitosan (21.50 and 21.10) in both seasons respectively without any significant differences between both treatments. Additionally, fruits that had been post-harvested dipped in salicylic acid showed high

Table 8. The effect of postharvest dipping treatments on TSS/acid ratio in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	12.65p	15.03no	16.58lm	18.47jk	21.56gh	24.16e	18.08D
SO2 (1gm/kg)	13.17p	15.61mn	17.63kl	19.71ij	21.91f-h	26.81d	19.14C
SA (2 ml/L)	13.44p	16.39l-n	18.32jk	20.52hi	23.17ef	28.80c	20.10B
Ethanol 20 %	12.82p	16.05mn	17.60kl	19.26ij	21.49gh	26.40d	18.94C
MAP	13.25p	15.75mn	18.44jk	22.67fg	26.82d	34.82a	21.96A
Chitosan (5 %)	13.19p	15.68mn	18.40jk	22.52fg	26.43d	32.78b	21.50A
CaCl2 (1%)	13.86op	16.09mn	18.32jk	21.30gh	23.30ef	27.59d	20.07B
Storage periods Mean	13.23F	15.80E	17.90D	20.63C	23.53B	28.77A	
				2023			
Control	12.63o-q	13.44n-p	15.64kl	17.97j	19.69hi	21.44fg	16.80C
SO2 (1gm/kg)	12.16pq	14.36l-n	16.27k	18.57ij	22.41f	24.47e	18.04B
SA (2 ml/L)	11.89q	13.71m-o	15.97k	18.59ij	24.38e	26.00f	18.42B
Ethanol 20 %	11.75q	13.11n-q	14.91k-m	17.57j	20.14gh	22.08f	16.59C
MAP	12.33o-q	15.33kl	18.26ij	21.77f	26.77c	32.55a	21.17A
Chitosan (5 %)	12.56o-q	15.43kl	18.79h-j	22.47f	27.34c	30.00b	21.10A
CaCl2 (1%)	12.05pq	14.30l-n	16.23k	18.24ij	21.49f	25.20de	17.92B
Storage periods Mean	12.19F	14.24E	16.58D	19.31C	23.17B	25.96A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

maturity indexes (20.10 and 18.04, respectively), depending on the season . In contrast, the untreated berries in the first and second seasons had the lowest maturity index values (18.08 and 16.80, respectively).According to Table 8's findings regarding the influence of cold storage durations, the maturity index steadily increased as the length of the cold storage time in both seasons increased. The beginning of the cold storage period yielded the lowest maturity index values (13.23 and 12.19), which increased to (17.90 and 16.58) after 20 days of cold storage in each season, respectively. After 50 days of cold storage in each of the two seasons, the maturity index peaked (28.77 and 25.96, respectively).

The findings shown in Table 8 clearly show that all utilised treatments led to a significant rise in maturity index values across all cold storage durations compared with the control in both seasons. This is based on the effect of the interaction between treatments and storage periods on the maturity index. In terms of increased maturity index over all cold storage periods in both seasons, modified atmosphere package and chitosan outperformed all other treatments and the control. Berry fruits stored in modified environment packages had the highest maturity index after 50 days of cold storage (34.82 and 32.55), followed by chitosan (32.78 and 30.00), and then SA applied after harvest (28.80 and 26.00 in both seasons, respectively).

3.2.4. Total sugars (%).

As for how post-harvest treatments affected the total sugar content of the berries, the results shown in Table 9 showed that there was a significant difference between the total sugar content of the berries under each post-harvest treatment, with each treatment significantly lowering the total sugar content of the berries more than the control in both seasons.

The control treatment produced the highest total sugar level in berries (15.45 and 15.36%), which was followed by CaCl2 (15.27 and 14.77%) in both seasons. In the same way, dipped berries fruit in SO2 post-harvest showed highly desirable berries contents of total sugars (14.49 and 14.60%) in both seasons, respectively. On the other hand, berries fruits that were treated with chitosan recorded the lowest berries contents of

Table 9. The effect of postharvest dipping treatments on Total sugars in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
2022							
Control	13.54z	14.54r	15.19l	15.73g	16.40c	17.28a	15.45A
SO2 (1gm/kg)	13.61y	13.93w	14.29tu	14.65q	16.13e	16.96b	14.93C
SA (2 ml/L)	13.58yz	13.75x	14.73p	15.20l	15.94f	16.38c	14.93C
Ethanol 20 %	13.52z	13.93w	14.42s	14.93n	15.48i	16.17e	14.74D
MAP	13.58yz	13.79x	14.10v	14.32t	15.03m	15.35j	14.36E
Chitosan (5 %)	13.58yz	13.78x	13.96w	14.33t	14.75p	15.26k	14.28F
CaCl2 (1%)	13.62y	14.24u	14.86o	15.62h	16.31d	16.99b	15.27B
Storage periods mean	13.58F	14.00E	14.51D	14.97C	15.72B	16.34A	
2023							
Control	13.27t	14.09pq	15.26k	15.87h	16.35d	17.30a	15.36A
SO2 (1gm/kg)	13.12u	13.39s	14.24o	14.73m	16.04g	16.55c	14.6C
SA (2 ml/L)	12.97vw	12.98vw	14.08pq	14.39n	15.64i	16.21ef	14.38E
Ethanol 20 %	12.97vw	13.12u	14.08pq	14.98l	15.93h	16.26e	14.56D
MAP	12.91w	13.04uv	13.96r	14.26o	15.03l	15.26k	14.08G
Chitosan (5 %)	12.95w	13.07u	14.02qr	14.13p	15.23k	15.57i	14.16F
CaCl2 (1%)	12.96vw	13.12u	13.99r	15.36j	16.14f	17.03b	14.77B
Storage periods mean	13.02F	13.26E	14.23D	14.82C	15.77B	16.31A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

total sugars (14.28 and 14.16 %) in the first and second seasons, respectively.The results in Table 9 for the impact of cold storage periods on berries' total sugar contents show that berries' total sugar contents steadily rose with the prolonged cold storage duration in both seasons. The lowest berries contents of total sugars were recorded at the beginning of the cold storage period (13.58 and 13.02 %), then increased to (14.51 and 14.23 %) after 20 days of cold storage in both seasons, respectively. Berries' contents of total sugars reached their peak (16.34 and 16.31 %) after 50 days of cold storage in the two seasons, respectively.

The results in Table 9 clearly show that all used treatments caused a significant decrease in berry contents of total sugars across all cold storage periods compared to the control in both seasons. This is true for the interaction between treatments and storage periods in berry contents of total sugars. In terms of total sugar content for all cold storage times during both seasons, the control treatment outperformed all other treatments that were employed. The control treatment's berries had the highest level of firmness after 50 days of cold storage (17.28 and 17.30%), followed by CaCl2 (16.99 and 17.03%) and SO2 (16.96 and 16.55%) applied after harvest in both seasons.

3.2.5. Reducing sugars (%).

Regarding the effect of post-harvest treatments on berries contents of reducing-sugars, the results presented in Table 10 confirmed that berries contents of reducing sugars were significantly affected by different post-harvest treatments where all treatments resulted in significantly decreased berries contents of reducing-sugars more than the control in both seasons. The highest berries contents of reducing-sugars were recorded under the control treatment (14.16 and 13.99 %) followed by SO2 (13.84 and 13.67 %) in both seasons respectively. In the same way, dipped berries fruit in SA as post-harvest application recorded high berries contents of reducing-sugars (13.62 and 13.35%) in both seasons, respectively.

Table 10. The effect of postharvest dipping treatments on reducing sugars in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods***						Treatments Mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
2022							
Control	12.35w	12.99r	13.73k	14.02h	15.66c	16.20a	14.16A
SO2 (1gm/kg)	12.46v	12.75t	13.54n	13.71kl	15.05e	15.50d	13.84C
SA (2 ml/L)	12.52v	12.93s	13.39o	13.66lm	14.16g	15.04e	13.62D
Ethanol 20 %	12.59u	13.03r	13.14q	13.41o	13.85j	14.42f	13.41E
MAP	12.63u	12.72t	13.04r	13.21p	13.42o	13.61m	13.10G
Chitosan (5 %)	12.50v	12.72t	12.93s	13.1pq	13.64m	13.93i	13.15F
CaCl2 (1%)	12.59u	12.93s	13.65lm	14.01h	15.54d	15.87b	14.10B
Storage periods mean	12.52F	12.87E	13.35D	13.60C	14.47B	14.94A	
2023							
Control	12.32no	13.09j	13.68h	14.15f	14.75d	15.94a	13.99A
SO2 (1gm/kg)	12.17pq	12.50m	13.61h	13.77g	14.81d	15.18c	13.67B
SA (2 ml/L)	12.02rs	12.35n	12.97k	13.08j	14.52e	15.17c	13.35C
Ethanol 20 %	11.97st	11.96st	13.06j	13.40i	14.06f	15.45b	13.32C
MAP	11.96st	12.09qr	11.99st	12.35n	12.48m	12.47m	12.22F
Chitosan (5 %)	11.95st	12.03rs	12.00r-t	12.33no	12.69l	12.69l	12.28E
CaCl2 (1%)	11.92t	12.14q	12.25op	13.11j	13.39i	13.80g	12.77D
Storage periods mean	12.04F	12.31E	12.79D	13.17C	13.81B	14.39A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

On the other hand, berries fruits that were stored in MAP recorded the lowest berries contents of total sugars (13.01 and 12.22 %) in the first and second seasons, respectively.

According to the results from Table 10 for the impact of cold storage durations on berries' reducing-sugar contents, berries' reducing-sugar contents steadily increased during both seasons of lengthy cold storage. The lowest berry reducing sugar concentrations were found at the beginning of the cold storage period (12.52 and 12.04%), rising to (13.35 and 12.79%) after 20 days of cold storage in each season, respectively. After 50 days of cold storage in the two seasons, respectively, the berries' maximal levels of reducing sugars (14.94 and 14.39%) were reached.

The data in Table 10 showed that all used treatments caused a significant decrease in berries contents of reducing-sugars across all cold storage periods compared to the control in both seasons. This effect was due to the interaction between treatments and storage periods. The control treatment exceeded all used treatments' berries contents of reducing sugars across all cold storage periods in both seasons. After 50 days of cold storage, the control treatment's berries had the highest reducing-sugar content (16.20 and 15.94%), followed by SiO2 (15.50 and 15.18%) and the post-harvest application of SA (15.04 and 15.17%) in both seasons, respectively.

3.2.6. Non-reducing sugars (%).

According to the findings in Table 11, all post-harvest treatments in both seasons considerably affected the amount of non-reducing sugars contained in berries. This difference was seen across all post-harvest treatments. The berries with the highest non-reducing sugar contents were treated with ethanol (1.327%) in the first season and CaCl2 (1.998%) in the second one. In the same way, dipped berries fruit in SA as post-harvest showed high berries contents of non-reducing sugars (1.312%) in the first season. Also, chitosan recorded high berries content non-reducing in the second season (1.881%) without any significant difference with MAP (1.855%). On the other side, berries fruits treated with SO2 recorded the lowest berries contents of total sugars (1.092.28 and 1.003 %) in the first and second seasons, respectively.

The results in Table 11 for the impact of cold storage durations on the amount of non-reducing sugars in berries showed that the amount of non-reducing sugars in berries steadily increased with the lengthened cold storage period in both seasons. When the cold storage period began (1.054% and 0.978%), the lowest berry non-reducing sugar levels were observed. These values climbed to (1.161 and 1.438%) after 20 days of cold storage in both seasons, respectively. After 50 days of cold storage in each of the two seasons, berries' non-reducing sugar content peaked (1.404 and 1.923%).

The results shown in Table 11 clearly show that all used treatments caused significant differences in berry non-reducing sugar contents across all cold storage periods in both seasons. This is due to the interaction between treatments and storage periods. The berry fruits treated with ethanol (1.750%) in the first season and CaCl2 (3.223%) in the second season had the highest non-reducing sugar levels after 50 days of cold storage.

4. DISCUSSIONS

4.1. Effect post-harvest applications of sulfur dioxide, salicylic acid, ethanol, modified atmosphere package, chitosan, and calcium chloride on physical properties of 'Superior' grapevines cv. during different cold storage periods.

The presented results confirmed that berries' weight loss, fruit firmness, respiration rate, berries Shattering, and fungi decay were significantly affected by post-harvest treatments, cold storage periods, and their interaction in both seasons. The lowest loss in weight, respiration rate, berries shatter and fungi decay as well as the highest berries firmness were recorded in berries fruits that were treated with Chitosan in both seasons.

Table 11. The effect of postharvest dipping treatments on Non-Reducing sugars in Superior grapevine fruits under cold storage during the 2022 and 2023 seasons .

Treatments	Storage periods						Treatments mean
	0.0 days	10 days	20 days	30 days	40 days	50 days	
				2022			
Control	1.190kl	1.543d-f	1.463gh	1.703ab	0.737t	1.087n-q	1.287B
SO2 (1gm/kg)	1.147k-n	1.183k-m	0.747t	0.940r	1.080n-q	1.453h	1.092F
SA (2 ml/L)	1.053o-q	0.823s	1.343i	1.637e-g	1.773a	1.340i	1.312AB
Ethanol 20 %	0.933r	0.903r	1.277ij	1.527f-h	1.633bc	1.750a	1.327A
MAP	0..950r	1.077n-q	1.060o-q	1.107m-q	1.610c-e	1.743a	1.258C
Chitosan (5 %)	1.080n-q	1.053o-q	1.033pq	1.150k-n	1.113l-p	1.333i	1.127E
CaCl2 (1%)	1.027q	1.313i	1.207jk	1.613cd	0.763st	1.123l-o	1.174D
Storage periods Mean	1.054F	1.12E	1.161D	1.368B	1.244C	1.404A	
				2023			
Control	0.953qr	0.993p-r	1.587j	1.717i	1.587j	1.353k	1.367C
SO2 (1gm/kg)	0.953qr	0.883rs	0.623t	0.960qr	1.230lm	1.370k	1.003E
SA (2 ml/L)	0.947qr	0.630t	1.110n-p	1.317kl	1.123m-o	1.037o-q	1.027E
Ethanol 20 %	1.003p-r	1.157mn	1.017o-q	1.583j	1.870gh	0.807s	1.239D
MAP	0.947qr	0.953qr	1.973fg	1.913fg	2.553d	2.790bc	1.855B
Chitosan (5 %)	1.000p-r	1.040o-q	2.017f	1.803hi	2.540d	2.883b	1.881B
CaCl2 (1%)	1.043o-q	0.980qr	1.740i	2.247e	2.753c	3.223a	1.998A
Storage periods Mean	0.978D	0.948D	1.438C	1.649B	1.952A	1.923A	

Means followed by the same letters within each column are not significantly different from each other at 1% level.

The main objective of Modified Atmospheric Packaging (MAP) is to modify the components of the atmosphere surrounding the fruits in order to extend the shelf life of the product and reduce the change in the quality characteristics of the fruits (weight loss, fruit hardness, breakage, fungal decay and respiration rate). The majority of fruits and vegetables take longer to ripen when the oxygen content of the air diminishes. This is due to the fact that low oxygen levels decrease product respiration and metabolism, which in turn slows down the natural ageing process (Jobling 2001). According to Varoquaux et al., (2002), breathing by living plant tissues and gas diffusion through packing materials alter the atmospheric makeup of fresh product packaging. For the storage of fruit tissues, this modified atmosphere (MA) can be helpful, but if the films' permeability is not correctly optimised, the MA can be ineffectual or even dangerous. Mir and Baudry (2000) also reported that modified atmosphere packaging can be used to extend the shelf life of many fruits and vegetables. According to the Fresh Fruits and Vegetables Map, breathable fruit is actively sealed in polymeric film packaging in order to control the atmosphere's levels of oxygen and carbon dioxide. In order to affect the metabolism of the product being packaged or the activity of decomposers to improve storageability and/or shelf life, it is frequently desirable to create an environment that is low in O2 and high in CO2. Adjusting both O2 and CO2 may be advantageous for some products. Along with modifying the atmosphere, MAP also makes substantial advancements in moisture retention, which may have a bigger impact on quality preservation than O2 and CO2 levels. Additionally, the packaging protects the product from the outside environment and contributes to maintaining circumstances that, if not sterile, at least minimise exposure to pollutants and pathogens.

Application of chitosan improved the activity of several antioxidant enzymes, decreased water loss, and minimised membrane damage. among addition, among the three cultivars examined, fruits covered with chitosan showed a slower rate of degradation than fruits that were not treated (Petriccione et al., 2015). Our findings are consistent with those of Ghasemnezhad et al., (2010), who found that mulberry with chitosan coating (0.5%) was preferable for regulating weight loss decrease. Canino apricots were dipped in 0.0, 1., and 2% chitosan to prevent weight loss, rot, and fruit hardness while being stored in the cold, according to El-Badawy and El-Salhy (2011). Despite the fact that found that treating apple fruits with 2g/L chitosan reduced respiration rate and prevented the growth of mould on the surface of apple pieces. In the same way, Shiri et al., (2013) reported that treatment of shrouds with chitosan at any concentrations used was effective in reducing caries, weight loss, breakage, browning, and cracking. Lopes et al., (2014) found that post-harvest strawberry fruits dipped in chitosan had 84% less infection with gray rot than un-dipped fruits. Also, Bal (2018) found that the use of chitosan after harvesting and storage at low temperatures affects the respiration rate, weight loss, decomposition, and firmness of plum fruits. Ararkani and Mostofi (2019) agreed that coating the “shroud” of table grapes with chitosan and thymus essential oil is effective in reducing respiration rate, glycolysis, weight loss, and acidity. Finally, Sabir et al., (2019) reported that the value of berry weight loss in control berries was consistently significantly higher than that of chitosan coating treatments.

According to research on the effects of cold storage periods, weight loss, fruit breaking, and microbial decomposition rapidly rose as the cold storage period in both seasons grew longer. While the fruits' respiration rate and hardness significantly decreased when the cold storage period in both seasons was extended. Grapes lose a lot of water when in storage, which affects their firmness and causes them to somewhat wither (Lydakis and Aked 2003). An increase in water-soluble pectin accompanied by a loss of proto-pectin (soluble Na2CO3 pectin) during storage may be the reason for the decrease in grape firmness (Deng et al., 2005). During the storage period, reduction of grape fruit decay and disease accumulation is very important under refrigerated storage conditions. In grapes, browning/discoloration and gray mold disease Botrytis are important factors determining the shelf life and quality of table grapes (Lichter et al., 2006). According to Pessu et al., (2011), the quality of the fruits degrades with storage, leading to unexpected odours, a softer outer surface, browning, a loss of water, and a breakdown in surface texture. Additionally, storage conditions make it easier for plants to become infected with fungus, which lowers the nutritional value of the fruits. While Palou et al. (2014) indicated that factors that result in considerable financial losses to the grape industry can limit table grape storage and the preservation of their shelf life. These include bunch desiccation, which results in the grape fruit losing water and the stem turning brown, skin discoloration, quick softening, and microbiological harm, particularly grey rot decay brought on by B. cinerea. After 30 days of cold storage, Youssef and Roberto (2014) revealed grey mould infection rates of about 15 and 25%, respectively. demonstrated that storing seedless table grapes from Thompson in Greece for two and three weeks at -1.5 and -0.5°C is preferable to storing them for those times at 3.5°C. On average, two weeks of storage yields grapes of higher quality than three weeks of storage. Even when the grapes were inoculated, Colombo et al., (2018) reported that cold storage significantly reduced grey mould in seedless grapes 'BRS Isis' for 50 days; nonetheless, no difference was noticed between the treatments. In both untreated control treatments, more water was lost.

4.2. Effect post-harvest applications of sulfur dioxide, salicylic acid, ethanol, modified atmosphere package, chitosan, and calcium chloride on chemical properties of ‘Superior’ grapevines cv. during different cold storage periods.

The data showed that cold storage times, post-harvest treatments, and their interactions in both seasons had a substantial impact on the total soluble solids, total acidity, maturity index, total sugars, reducing sugars, and non-reducing sugars contents of berries and fruits. The lowest berries' contents of TSS and total acidity in addition to the highest maturity index were recorded in berries that were stored in a modified atmosphere package and Chitosan in both seasons. Before enclosing the product in vapor-barrier materials, modified atmosphere packaging (MAP) involves removing and/or replacing the atmosphere around it (McMillin, 2008) Berry quality loss was mitigated to variable degrees by modified environment packing, whereas untreated berries started to lose their marketable quality after the third week. Applications made while the berries were being stored did not change their flavour. In compared to ethanol, MAP performed better in the majority of cases, including limiting weight loss and maintaining the look of berries (Sabir et al., 2010). A reduced rate of respiration, which slows the pace of substrate depletion, is one of the main impacts of MAP, according to Escalona et al., (2006). Natural plant hormone ethylene (C2H4) is physiologically active in trace amounts (0.1 ppm) and is essential for the start of ripening. At O2 concentrations of about 2.5%, the generation of C2H4 is reduced by nearly half. These low oxygen levels prevent ripening by preventing C2H4 synthesis and activity. Kohlrabi stem packaging under modified environment also demonstrated quality enhancement.

Ghasemnezhad et al., (2010) and El-Badawy and El-Salhy (2011) approved that coated apricot fruits chitosan at a concentration of 0.5% was superior to the control treatment in delaying the change in TSS, TA, TSS/TA, PH, and total sugars during cold storage. Moreover, Shiri et al (2013) stated that coated grapes fruits with chitosan at 0.5 and 1% increased TSS/TA ratio and decreased TSS and titratable acidity. In the same trend, Petriccione et al (2015) showed that the application of chitosan had a positive effect in reducing water loss, delaying the qualitative changes in color, titratable acidity, and ascorbic acid of strawberries. Also, Bal (2018) indicated that "Stanely and Giant" Cv. plum fruits were coated with chitosan at 1% delaying the change in titratable acidity and sugar percentage during cold storage. Ararkani and Mostofi (2019) approved that coating table grape "shroud" with chitosan and thymus essential oil is effective in increasing total soluble solids. Also, The highest berries contents of total sugars and reducing sugars were recorded under the control treatment followed by CaCl2 and SiO2 in both seasons.

According to Table 9's findings about the impact of cold storage periods, total soluble solids, maturity index, total sugars, reducing sugars, and non-reducing sugars all gradually rise when the cold storage term is extended in both seasons. Imlak et al. (2017) confirmed that the higher temperature increased the starch conversion in a similar manner. The quick transformation of intricate starch molecules into more straightforward sugars was blamed for the increase in total sugars. It is also possible to attribute this increase to excessive moisture loss from fruiting tissues and vacuoles. Additionally, TSS of the fruits rose during storage, primarily as a result of glycogenesis and metabolism of fruiting tissues that became partially inactive as a result of changes in glucose and fructose levels. According to Colombo et al. (2018), the carton boxes were kept for five days at room temperature (22 oC) after a 50-day period of cold storage. Water loss and the occurrence of grey mould were evaluated at both periods, along with soluble solids (SS), pH, titratable acidity (TA), SS/TA ratio, and colour traits.

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الملخص العربي

تحسين صفات الجودة واطالة العمر التخزيني لثمار العنب السوبيريور تحت ظروف التخزين المبرد

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قسم البساتين – كليه الزراعه – جامعه بنها

تم إجراء هذا العمل في معمل خاص خلال الموسمين المتتاليين ٢٠٢٢ و٢٠٢٣ لاختبار تأثير معاملات ما بعد الحصاد (ثانى أكسيد الكبريت (١جم/كجم) وحمض الساليسيليك (٢ مل / لتر) والإيثانول (٢٠٪).، التعبئة بعبوات الغلاف الجوي المعدل، الشيتوزان (٥٪)، وكلوريد الكالسيوم (١٪) على الخواص الفيزيائية والكيميائية لثمار العنب السوبريور خلال التخزين البارد. أكدت النتائج أن جميع الخواص الفيزيائية والكيميائية لثمار العنب تأثرت معنوياً بمعاملات ما بعد الحصاد والتخزين البارد والتفاعل بينهما في كلا الموسمين. تم الحصول على أقل نسب الفقد في الوزن ، معدل التنفس ، فرط الثمار ، التلف الفطرى وكذلك محتوى الثمار من المواد الصلبة الذائبة الكلية والحموضة الكلية بالإضافة إلى أعلى قيم الصلابة والنضج فى الثمار المعاملة بالشيتوزان وكذلك المخزنة فى العبوات المعدلة للغلاف الجوى. تم تسجيل أعلى محتويات العنب من السكريات الكلية والسكريات المختزلة تحت معاملة الكنترول تليها الكالسيوم كلورايد وثانى أكسيد الكبريت في كلا الموسمين. فيما يتعلق بتأثير فترات التخزين البارد ، أوضحت النتائج أن الفقد فى وزن الثمار ، الفرط ، التلف الفطرى بالإضافة إلى المواد الصلبة الذائبة ، دليل النضج ، والسكريات الكلية ، والسكريات المختزلة والسكريات غير المختزلة زادت تدريجياً مع مد فترة التخزين البارد في كلا الموسمين. بينما انخفض معدل التنفس وصلابة الثمار تدريجياً مع مد فترة التخزين البارد في كلا الموسمين