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Effects of UV-C and salicylic acid on quality of 'Muskule' table grapes during cold storage

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Abstract

Muskule grape variety which has table and late maturing attributes, was used for this study. Storage of table grapes requires stringent control of gray mold, which is caused by *Botrytis cinerea* Pers. In spite of the fact that the use of sulfur dioxide (SO_2) in controlling gray mould is common practice, it has some advantages and disadvantages. Thus, physical, natural organic elicitors and biological methods have been used for delaying decays. In this study, UV-C (0.25kJ m^{-2}), salicylic acid (1, 2, 3mM) and $Na_2S_2O_5$ (0.4g powdered sodium metabisulfate pads) treatments were used to reduce quality losses during the cold storage of Muskule grape. Treated clusters were placed into polyethylene container and packaged with polyethylene bags having 10.5 µ thicknesses and stored at 0±1 °C and 90±5% relative humidity throughout 100 day. At the end of 100 day, weight loss (%), soluble solids content (%), titratable acidity (g 100 mL^{-1}), pH of fruit juice, sensory evaluation, view of cluster skeleton and decay rate (%) were determined at 20 days interval. SA (3mM) + UV-C combined treatment and SA (3mM) treatment were found to be effective depending on examined criterion.

Key words: Grape, UV-C treatment, salicylic acid, storage, sensory evaluation

Introduction

Grape is a non-climacteric fruit with low physiological activity and is sensitive to water loss and fungal infection that is mainly caused by *Botrytis cinerea* Pers. during postharvest handling. Sulfur dioxide is highly corrosive to metals, injurious to most of the fresh fruits and causes injury to rachis and berries if used excessively (Nelson, 1985). Fumigation with SO_2 is the most common method to control decay during cold storage of table grape clusters (Luvisi *et al.,* 1992; Crisosto *et al.*, 1994).

In recent years, there has been increasing consumer pressure to eliminate or decrease the use of synthetic fungicides on fresh products. As table grape consumers are becoming increasingly cautious about SO_2 residues, alternative methods to control decay on grapes are of increasing interest to the fresh produce sector. One approach has been the use of controlled atmosphere to suppress the development of *Botrytis cinerea* Pers. on table grapes (Yahia *et al.,* 1983). An alternative method is the use of heat and in recent years, there has been renewed interest in the potential of heat treatments (Lurie, 1998) although its commercial application is still limited.

Salicylic acid is not only a well known natural inducer of disease resistance in plants (Sticher *et al.,* 1997), but also a simple phenolic compound involved in the regulation of many processes in plant growth and development, including stomatal movement, seed germination, ion absorption, sex polarization. It can also interfere with the biosynthesis and action of ethylene in plants (Raskin, 1992). Yalpani *et al.* (1994) and Kang *et al.* (2003) observed that application of salicylic acid could significantly induce resistance against a variety of biotic and abiotic stress.

Some researchers reported that exogenous application of salicylic acid or methyl-salicylic acid could also induce the expression of many defense genes in tobacco (Fraissinet-Tachet *et al.,* 1998), tomatoes (Ding *et al.,* 2002) and parsley (Thulke and Conrath, 1998). Zainuri Joyce *et al.* (2001) reported that preharvest and postharvest applications of 2.0 mg salicylic acid mL^{-1} tended to suppress postharvest anthracnose disease severity caused by *Colletotrichum gloeosporioides* in fruits of mango cv. Kensington Pride.

Studies about effects of salicylic acid treatments on fruits of different species such as *Actinidia deliciosa* (kiwifruit) (Poole and McLeod, 1994), *Citrus paradisi* (grapefruit) (Droby *et al.*, 1999), *Cucumis melo* (rock and hami melon) (Huang *et al.,* 2000), *Passiflora edulis* (passionfruit) (Willingham *et al.,* 2002), *Mangifera indica* (mango) (Zainuri Joyce *et al.*, 2001), *Prunus persica* (peach) (Han *et al.*, 2003) and *Prunus avium* (sweet cherry) (Yao and Tian, 2005) have been performed until recent times.

Induction of natural disease resistance in horticultural crops using physical elicitors has received increasing attention over recent years (Wilson *et al.*, 1994; 1997). In spite of the fact that fungal spores and mycelia infections on and in the outer cell layers of fruit or vegetables are removed or destroyed by using physical treatments like low temperature storage, wounding (Ismail and Brown, 1979), CO_2 treatment (Prusky *et al.*, 1993), heat treatment (Schirra *et al.*, 2000), ionizing irradiation (McDonald *et al.,* 2000) and UV-C irradiation (Wilson *et al.*, 1997), they also enhance natural disease resistance.

Wilson *et al.* (1997) reported that non-ionizing radiation had considerable potential amongst physical methods for controlling postharvest diseases. Terry and Joyce (2004) reported that low doses of short-wave ultraviolet light (UV-C) (190–280 nm wavelengths) can control many storage rots of fruit and vegetables by targeting the DNA of micro-organisms. In addition to being a

germicidal or mutagenic agent, UV-C irradiation can modulate induced defense in plants.

Using appropriate wavelength and dose, UV-C irradiation can stimulate accumulation of stress-induced phenylpropanoids, many of which have been associated with induced disease resistance (Ben-Yehoshua *et al.,* 1998) and pathogenesis-related proteins (Porat *et al.,* 2000).

Liu *et al.* (1993) reported that the responsiveness of harvested horticultural product to UV-C treatment reduced with ripening process and was also influenced by harvest time (D'hallewin *et al.*, 1999). The aim of present work was to determine effects of salicylic acid and UV-C treatments, which are accepted as new methods against conventional SO_2 application during storage of Muskule grape by using modified atmosphere packaging.

Materials and methods

This study was conducted under the laboratory conditions of the Horticulture Department, Agricultural Faculty, Namik Kemal University, Turkey in 2005.

Muskule grape, which is known as late-maturing table variety in Turkey was used in the study. Some average values of the quality characteristics in this variety were as follows: Soluble solids content: 16.4%, titratable acidity: 0.4 g 100mL^{-1} and pH: 3.69.

After discarding decayed and badly viewed grapes from harvested clusters, following treatments were performed

Code	Treatments
$Na_2S_2O_5$	Treatment of 0.4 g powdered sodium metabisulfate pads
UV-C	According to Akbudak and Karabulut (2002), UV-C treatment from 100 cm distance (0.25 kJm^{-2}) for 4 min on clusters which were put in a special cabin designed by Nigro *et al.* (1998)
SA	Dipping of clusters into 1, 2 and 3 mM of salicylic acid solutions for 2 min, drying with an electric fan and packaging (Sigma-Aldrich, Germany)
SA+UV-C	1, 2 and 3 mM of salicylic acid treatment plus UV-C treatment

During UV-C treatments, radiation was provided with fluorescent germicidal lamps (Osram12 HNS OFR, GE 30 W) with a peak emission at 254 nm.

After all treatments were performed, clusters were put into polyethylene containers carrying paper towels at their bases to absorb moisture and these polyethylene containers were placed in polyethylene bags of 10.5 µ thicknesses. Afterwards, all these packages were stored in cool air store (at 0±1^{0}C, 90±5% relative humidity) throughout 100 days.

Analyses and measurements such as weight loss (%), soluble solids content (%), titratable acidity (as tartaric acid) (g 100mL^{-1}), pH of fruit juice, sensorial evaluation performed by 5 panelist according to 1-9 scale (1: extremely poor or soft in texture; 3: poor or soft; 5: moderate; 7: good; 9: excellent) based on Kader *et al.* (1973) and Lipton (1980), view of cluster skeleton according to 0-5 scale (0: bright green; 1: green; 2: matt green. 3: green-light brown; 4: brown; 5: dried grey brown) based on Harvey *et al.* (1988), decay rate (%) were carried out at 20 day intervals throughout 100 days.

In the study, split parcels in randomized complete blocks design were used as experimental model with three replicates (Turan, 1995) and each replicate was consisted of 3 polyethylene containers. LSD (P=0.05) values were used to indicate the differences among mean values.

Results and discussion

Weight loss is most important factor limiting storage and increase in weight losses are related with treatments which were especially found out towards storage period in this study. Results on different species about UV-C radiation performed by Taira *et al.* (1997), Maharaj *et al.* (1999), Akbudak and Karabulut (2002) and SA treatments carried out by Zheng and Zhang (2004) showed that weight losses were lower in treated fruits than control. In a similar way, in our study weight losses were found to be lower in SA and UV-C treatments than control. As regards weight loss, the highest value was 4.32 g for control on 100th day. On the 20th day there was no significant difference in weight loss among the treatments (Table 1).

Soylemezoglu and Agaoglu (1992) and Turkben and Eris (1990) stated difference in soluble solids content depending on weight loss in grapes. Fluctuations in soluble solids content of grapes were apparent during storage period. While the lowest value of soluble solids content was 17.91% for $Na_2S_2O_5$ treatment at the end of 100th day, the highest value was 18.64% for SA 3mM +UV-C combined treatment (Table 2).

Increase in acidity of grapes during storage period was explained by respiration (Turkben and Eris, 1990). There are some studies about effects of UV-C radiation on decreasing of titratable acidity in literatures such as Ozer and Akbudak (2003) on grape and Kim (1997) on apple. When the values of titratable acidity were examined, it was seen that averages generally declined with storage period. Among the treatments, the lowest value was 0.35 g 100 mL^{-1} for control, the highest value was 0.40 g 100 mL^{-1} for SA 3mM treatment (Table 3).

Table 1. Effect of different treatments on weight loss (%) in Muskule grape throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	0.50a-d	0.44a-c	0.34a	0.35a	0.39ab	0.36a	0.48a-d	0.43abc	0.38a	0.41a
40th day	1.37g-k	0.90b-g	0.87b-f	0.90c-g	0.71a-e	0.95d-h	1.16e-ı	0.87b-f	1.21f-j	0.99b
60th day	2.70o	1.82klm	1.64jkl	1.58ı-k	1.42h-k	1.22f-j	1.27f-j	1.44ıjk	1.37g-k	1.61c
80th day	3.29p	2.05lmn	2.28mno	2.28mno	2.15mn	2.38no	2.41no	2.39no	2.13mn	2.37d
100th day	4.32r	3.59pq	3.27p	3.55pq	3.85qr	3.59pq	3.34p	3.36p	3.34p	3.58e
Treatment effect	2.44b	1.76a	1.68a	1.73a	1.70a	1.70a	1.73a	1.70a	1.69a	
LSD (P=0.05)	Treatment x Storage period : 0.481;			Treatment :0.215;		Storage period :0.160				

Table 2. Effect of different treatments on soluble solids content (%) in Muskule grape throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	16.73h-q	16.97f-q	15.90q	16.84g-q	17.12e-p	17.62a-j	16.63ı-q	17.64a-ı	17.11f-p	16.95c
40th day	16.09opq	17.15e-p	17.63a-j	16.18n-q	16.17n-q	17.75a-ı	16.31l-q	16.67h-q	16.47j-q	16.71c
60th day	17.02f-q	16.04pq	17.23d-o	17.49a-k	16.27m-q	16.88g-q	16.33k-q	16.93f-q	17.29c-n	16.83c
80th day	17.69a-ı	17.46b-l	17.80a-h	18.08a-f	17.56a-j	17.41b-m	17.67a-ı	18.08a-f	17.95a-g	17.74b
100th day	18.52ab	17.91a-g	18.49ab	18.28a-e	18.09a-f	18.36a-d	18.49ab	18.42abc	18.64a	18.35a
Treatment effect	17.21	17.10	17.41	17.37	17.04	17.60	17.09	17.55	17.49	
LSD (P=0.05)	Treatment x Storage period: 1.164;			Storage period: 0.387						

Table 3. Effect of different treatments on titratable acidity (g 100 mL^{-1}) in Muskule grape throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	0.39	0.40	0.38	0.40	0.41	0.42	0.42	0.41	0.41	0.41c
40th day	0.36	0.43	0.39	0.41	0.41	0.42	0.39	0.43	0.41	0.41c
60th day	0.38	0.40	0.39	0.39	0.42	0.42	0.40	0.39	0.40	0.40c
80th day	0.32	0.39	0.36	0.37	0.39	0.39	0.37	0.37	0.38	0.37b
100th day	0.30	0.34	0.32	0.33	0.33	0.34	0.31	0.31	0.34	0.32a
Treatment effect	0.35a	0.39d	0.37b	0.38c	0.39d	0.40e	0.38c	0.39d	0.39d	
LSD (P=0.05)	Treatment :0.014	Storage period: 0.01								

Table 4. Effect of different treatments on pH of grape juice in Muskule grape throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	3.71m-q	3.68o-q	3.81d-j	3.71k-q	3.67q	3.67q	3.70n-q	3.74ı-q	3.68o-q	3.71c
40th day	3.87c-f	3.77g-o	3.87c-f	3.73j-q	3.72k-q	3.67q	3.80e-l	3.73j-q	3.75h-q	3.77b
60th day	3.97ab	3.80e-k	3.85c-g	3.76h-p	3.72k-q	3.70n-q	3.75h-q	3.78f-n	3.79f-m	3.79b
80th day	4.01a	3.80e-k	3.92abc	3.82d-ı	3.85c-g	3.82d-ı	3.87c-f	3.88cde	3.89bcd	3.88a
100th day	3.99a	3.88cde	3.88cde	3.88cde	3.82d-ı	3.82d-ı	3.87c-f	3.84c-h	3.84c-h	3.87a
Treatment effect	3.91a	3.79bc	3.87a	3.78bc	3.75cd	3.73d	3.80b	3.79bc	3.79bc	
LSD (P=0.05)	Treatment x Storage period: 8.887			Treatment: 0.042		Storage period: 0.031				

Table 5. Effect of different treatments on sensory evaluation scores in Muskule grape throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	7.80c-f	8.60abc	8.60abc	8.46abc	8.73ab	8.46abc	9.00a	8.46abc	8.20a-d	8.48a
40th day	8.33a-d	8.46abc	8.33a-d	8.86ab	8.60abc	7.80c-f	8.60abc	8.60abc	9.00a	8.51a
60th day	6.73g-j	7.53d-g	7.26e-h	7.53d-g	7.26e-h	7.80c-f	8.06b-e	8.20a-d	8.06b-e	7.60b
80th day	5.53lm	6.73g-j	6.20ı-l	6.46h-k	6.86ghı	7.13fgh	6.60hıj	6.73g-j	7.13fgh	6.60c
100th day	3.40n	5.40lm	5.10m	5.26m	5.13m	5.66klm	5.46lm	5.66klm	5.86j-m	5.21d
Treatment effect	6.36c	7.34ab	7.10b	7.32ab	7.32ab	7.37ab	7.54a	7.53a	7.65a	
LSD (P=0.05)	Treatment x Storage period: 0.879;			Treatment :0.389;		Storage period: 0.290				

Data showed that treatments had different effects on pH of grape juice and values increased depending on the storage period. As shown in Table 4, the highest pH values were 4.01 in 80th day, 3.99 in 100th day and 3.97 in 60th day for control.

Studies on UV-C treated grape (Akbudak and Karabulut, 2002) and SA treated cherry (Yao and Tian, 2005) have demonstrated that better fruit quality was obtained in UV-C treated grapes and SA treated fruits than control. It was seen that scores of sensory evaluation given by sensory evaluation panelists were low towards the end of storage period. At the end of 100th day, only control grapes were unmarketable (3.40). While the highest scores of sensory evaluation was 9.00 for SA 1mM + UV-C combined treatment in 20th day and for SA 3mM + UV-C combined treatment in 40th day; towards the end of 100th day, the highest values became 5.66 for SA 3mM and SA 2mM + UV-C combined treatment and 5.86 for SA 3mM + UV-C combined treatment (Table 5). The present study indicated that UV-C treatments had positive effect on preserving flavour and there were no negative effect of SA on grape.

Variations derived from withering on cluster skeleton of stored grapes were examined and it was observed that treatments slowed down color variation of cluster skeleton at different rates. The best score among the treatments about scale of cluster skeleton was 0.40 for $Na_2S_2O_5$ treatment (20th day) and SA 3mM treatment followed it as 0.80 (20th day). At the end of 100th day, excessive color variation on cluster skeleton was observed in control (Table 6).

It is thought that salicylic acid has direct toxicity to different fungi species responsible for decay and it also prevents spore germination of pathogens (Yao and Tian, 2005). Throughout the storage period of Muskule grape, decays were observed first in control (3.36%) and UV-C treatment (1.24%) at the end of 60th

Table 6. Effect of different treatments on view of cluster skeleton of Muskule grape variety throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	1.40def	0.40a	0.93bc	0.93bc	1.06bcd	0.80ab	0.86bc	0.93bc	1.13bcd	0.94a
40th day	1.40def	0.93bc	1.00bcd	0.93bc	1.13bcd	0.83b	1.00bcd	1.26cde	1.13bcd	1.07ab
60th day	1.80fg	1.00bcd	0.86bc	0.93bc	1.06bcd	1.00bcd	1.20b-e	1.60efg	1.26cde	1.19b
80th day	2.86j	1.60efg	1.80fg	1.93gh	1.93gh	2.00gh	1.93gh	2.26hı	2.00gh	2.03c
100th day	3.33k	2.66ıj	2.66ıj	2.53ıj	2.46ıj	2.46ıj	2.60ıj	2.60ıj	2.60ıj	2.65d
Treatment effect	2.16e	1.32a	1.45abc	1.45abc	1.53bc	1.42ab	1.52bc	1.73d	1.62cd	
LSD (P=0.05)	Treatment x Storage period : 0.432; Treatment :0.192; Storage period: 0.143									

Table 7. Effect of different treatments on decay rates (%) in berry of Muskule grape variety throughout storage period

Storage period	Control	$Na_2S_2O_5$	UV-C	SA 1mM	SA 2mM	SA 3mM	SA 1mM +UV-C	SA 2mM +UV-C	SA 3mM +UV-C	Time effect
20th day	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
40th day	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
60th day	3.36c-g	0.00a	1.24abc	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.52a
80th day	11.46k	1.60a-d	2.43b-e	2.70b-e	0.57ab	0.00a	3.53d-g	1.44a-d	0.00a	2.64b
100th day	17.33l	7.03hıj	8.23j	7.63ıj	4.50efg	2.97c-f	5.50ghı	5.16fgh	4.43efg	6.97c
Treatment effect	6.43e	1.73bcd	2.38d	2.07cd	1.02ab	0.60a	1.81bcd	1.32abc	0.89ab	
LSD (P=0.05)	Treatment x Storage period: 2.221; Treatment: 0.987; Storage period: 0.735									

day. While no decay symptom was detected for SA 3mM and SA 3mM + UV-C combined treatment at the end of 80th day; the highest decay rate was 17.33% for control and the lowest value was obtained from SA 3mM treatment (2.97%). Hence, SA treatment and SA + UV-C combined treatments were effectively protective as $Na_2S_2O_5$ treatment (Table 7).

Akbudak and Karabulut (2002) suggested that UV-C treatments could be used for prevention of decays caused by *B. cinerea* during the cold storage of grapes. Besides, Nigro *et al.* (1998) also stated that UV-C treatment stimulated resistance to *B. cinera* in grapes. Findings of our study were also consistent with these results.

In conclusion, UV-C treatment, which is one of the physical controls and different doses of salicylic acid, which is natural organic elicitor were found to be effective in maintaining quality attributes of Muskule grape during cold storage. In the course of storage, while titratable acidity was slightly decreased, soluble solids content and pH values generally increased. It was determined that weight loss remained to be lower in all the treatments than control. As far as view of cluster skeleton, sensory evaluation and prevention of decay, which are some of the important quality attributes in grapes, were concerned, SA 3mM + UV-C combined treatment and SA 3mM treatment gave best results and these may be used as alternative to $Na_2S_2O_5$ during the cold storage of Muskule grape.

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