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Alternative postharvest treatments to control decay of table grapes during storage

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Summary

The aim of this study is to determine efficacy of some alternative postharvest treatments to sulfur dioxide (SO_2) in maintaining quality and reducing fungal decay during cold storage of table grapes. The table grapes cv. Pafi was subjected to the following treatments after harvest: (1) Hot water dips at 24 °C, 45 °C, 50 °C or 55 °C for 3 min followed by packaging in perforated polyethylene (PPE) bags; (2) Packaging with ethanol vapor generating sachets of Antimold®30 or Antimold®60 in PPE bags; (3) Packaging with SO_2 generating pad in PPE bags; (4) Packaging in PPE bags. Berries were stored at 0 °C for 3 months. Antimold®60 sachet was more effective in reducing fungal decay than control and the SO_2 generating pad treatment without adverse effect on quality parameters during 3 months of cold storage. Stem browning occurred at slightly higher level in grapes dipped in hot water or packaged with Antimold®30 sachet and might limit their use, despite providing effective control of fungal decay.

Introduction

Table grapes are subject to water loss and decay during postharvest handling. Gray mold caused by the fungus *Botrytis cinerea* and stem browning from desiccation are the two main factors reducing table grape postharvest quality (CRISOSTO et al., 1994). The standard practice to control postharvest decay of grapes worldwide is to fumigate the fruit after harvest with sulfur dioxide (SO_2) gas, either by repeated application of gas in storage rooms, or to fumigate packed fruit in polyethylene-lined boxes with a continuous-release SO_2 generating pad (KARABULUT et al., 2004). Despite its efficacy, the SO_2 treatment may compromise fruit taste, cause damage to the berry (cracks and bleaching) and leave excessive sulfite residues (LICHTER et al., 2006). Because some people are dangerously allergic to sulfites, the maximal residual sulfite level allowed for table grapes has been reduced (CRISOSTO et al., 1994). Some countries in Europe are prohibiting its use for grapes imported to the country (LURIE et al., 2006). The environmental and health concerns resulted in a search for alternative treatments to SO_2 generating pads in table grapes.

Postharvest hot water treatments have been tested to control postharvest decay in grapes (KARABULUT et al., 2004; MLIKOTA GABLER et al., 2005). Studies indicate water temperatures must be higher than 50 °C to be effective (KARABULUT et al., 2004; MLIKOTA GABLER et al., 2005). Ethanol is a common food component with potent antimicrobial activity (LARSON and MORTON, 1991). In vitro studies showed that 30% ethanol was lethal to conidia of *B. cinerea*, and was confirmed by the postharvest treatments of grapes (LICHTER et al., 2006). Previous studies performed on several cultivars suggests that dipping grapes in 30-50% ethanol prior to packaging with perforated polyethylene (PPE) or modified atmosphere box liners inhibited berry decay as well as or better than SO_2 generating pads (LICHTER et al., 2002, 2005; KARABULUT et al., 2004; MLIKOTA GABLER et al., 2005). Ethanol dips might lose effectiveness after one- or two- month storage due to latent or secondary infections. Ethanol vapor treatments have an advantage over ethanol dips in that they conferred longer protection, similar to that of the SO_2 generating pad (LURIE et al., 2006). The feasibility of using ethanol vapor for storage was demonstrated on grapes packaged in box liners with ethanol delivered from pre-soaked paper sheets or wick (CHERVIN et al., 2005; LURIE et al., 2006). However, a more practical and safe method of generating ethanol vapor is the use of ethanol vapor generating sachets which are commercially available (SMITH et al., 2004) and have been shown to inhibit mold growth on bakery products (SMITH et al., 1987; DAIFAS et al., 2000). They have not been tested for controlling decay on any fresh produce including grapes. Our objectives were to evaluate the efficacy of hot water dip treatments and ethanol vapor generating sachets on the incidence of decay and determine the effects of these treatments on postharvest quality of table grapes.

Materials and methods

Plant material and treatments

'Pafi' table grapes were harvested at commercial maturity during the 2007 and 2008 seasons from vineyard located in Hassa, Turkey. 'Pafi' is a mid-season, white, seeded table grape cultivar with a very large, round berries (CELIK, 2006). After harvest, the grapes were immediately transported via ventilated truck to cold storage facilities at the Department of Horticulture of Mustafa Kemal University, Antakya, Hatay. After sorting and removing small and decaying berries, grapes were divided into four groups and subjected to one of the following treatments: (1) Grapes were dipped in hot water at 24 °C, 45 °C, 50 °C or 55 °C for 3 min. Hot water treatments were carried out in a 375 L tank fitted with heating elements (0-90 °C, 2 x 2000 watt), an electronic recirculation pump (400 watt). Even water circulation, and temperature, within the baths was achieved by pumping water through perforated PVC tubing (25.4 mm i.d.). During each treatment, bath temperature was constantly maintained within ±0.5 °C of the required temperature by means of an electronic thermostat. Following the treatment, grapes were allowed to dry for about 1 h at room temperature, and placed in PPE box liners (6 mm holes at 7.6 to 10.2 cm center) containing about 3 kg of grapes each. (2) Grapes were packaged with ethanol vapor generating sachets of Antimold®30 or Antimold®60 (Freund Industrial Co., Ltd., Tokyo, Japan) in PPE box liner. The sachets are heat-sealed and constructed of a laminated sheet designed for the slow release of ethanol vapor. They are made of a copolymer of paper/ethyl vinyl acetate copolymer and contain microencapsulated food grade ethanol (55% by weight) absorbed on to silicon dioxide powder (35%). The encapsulated ethanol is released when in contact with water vapor. (3) Grapes were packaged into PPE box liner with a dual release SO_2 generating pad containing 7 g sodium metabisulfite (Fresca UVAS, Santiago, Chile) on the top of grapes. Paper pads were placed on the top of bunches and beneath the SO_2 pads in each bags. (4) Control grapes were packaged into PPE box liner. Three kg of grapes of each replication per treatment were then placed in plastic boxes and kept at 0 °C and 85-90% relative humidity for 3 months.

Quality evaluation

Postharvest quality of grapes was evaluated during cold storage at a month intervals. Weight loss was calculated as percent loss of initial weight. Total soluble solids (TSS) content and titratable acidity (TA) were assessed in juice obtained from 50 berries per replicate. TSS content was determined with a refractometer (Atago Model ATC-1E) and TA by titration of 5 ml of juice with 0.1 N NaOH to pH 8.1 and expressed as g tartaric acid 100 ml^{-1} juice. Berry color was determined with a Minolta Chroma Meter CR-300 (Osaka, Japan). Color measurements were recorded using the CIE L*a*b* color space. From these values, hue angle was calculated as, $h°=\tan^{-1}(b^*/a^*)$. Color values were obtained from 50 berries of each replication. Two measurements were taken from opposite sides at the equatorial region of the each berry. All infected berries were removed and weighed; decay was expressed as a percent of cluster weight on the day removal from storage. Stem browning symptoms were evaluated according to CRISOSTO et al. (1994) on a scale of 1 to 4, where 1=healthy (cap stem healthy); 2=slight (cap stem slightly brown); 3= moderate (cap stem and secondary stem moderately brown); and 4=severe (cap stem, secondary, and primary stem fully brown).

Statistical analysis

The data were analyzed as a completely randomized block design by ANOVA using SAS software (SAS, 1999). Each treatment was repeated three times using 3 kg grapes per replication. Mean separation was performed by Duncan's multiple range test at $P<0.05$ level using SAS's Proc GLM procedure.

Results

The effects of postharvest treatments on the incidence of fungal decay are presented in Tab. 1, 2, and 3. Control and 24 °C-hot water dipped berries developed extensive decay, while SO_2 generating pad prevented, on average, 62% of the decay during storage. The ethanol vapor generating sachets Antimold®30 and Antimold®60 reduced incidence of fungal decay by an average of 87% compared control treatment during three months of storage. Hot water treatments prior to packaging had decay ranging between 0.4 to 24%. Temperatures of 45 °C, 50 °C and 55 °C controlled 34%, 79% and 79% of the decay organisms, respectively.

After one month of storage, the 55 °C hot water treated grapes showed moderate stem browning while grapes from other treatments maintained green stems (Tab. 1). There was no statistical difference in stem browning among treatments after two and three months of storage (Tab. 2 and 3). However, stem browning of grapes treated with hot water and Antimold®30 sachets was rated severe after three months of storage. With the Antimold®60 sachets, we observed only moderate stem browning. Slight to severe stem browning was detected when weight loss reached to 1% to 4.5%, depending on treatment and storage time (Tab. 2 and 3). Grapes packaged with Antimold®60 sachets showed significantly lower weight loss. Antimold®30 sachets resulted in similar weight loss with hot water, SO_2 and control treatments.

Grapes used in this study were harvested at commercial maturity with TSS (±S.D.) of 14.20% (±0.48%), TA of 0.41% (±0.02%) and berry weight of 5.02g (±0.31g), L* value of 41.5 (±0.19) and $h°$ value of 116.6 (±0.34). TSS content and TA decreased significantly in all treatments during storage (Tab. 1, 2, and 3). TSS content was not affected by the treatments during storage. Hot water treated grapes maintained a higher TA during two months of storage although this effect was disappeared after three months of storage (Tab. 2). Grapes become darker (lower L*value) and more yellow (lower $h°$ value) after three months of storage in all treatments. Packaging grapes with Antimold®60 or Antimold®30 sachets resulted in slightly brighter (higher L*value) berries after one month storage. After two or three months of storage, the effects of the treatments on L* and $h°$ value were not significant. In this study, hot water treated and control grapes had similar berry color in terms of L* and $h°$ values during storage (Tab. 1, 2, 3).

Discussion

Packaging 'Pafi' grapes with ethanol vapor generating sachets of Antimold®30 and Antimold®60 effectively reduced incidence of fungal decay, compared to SO_2 generating pad and control treatment during three months of storage. In previous studies, ethanol vapor treatments controlled decay as well as or better than a SO_2 generating pad in grapes. In those studies, ethanol impregnated paper sheets or wicks were used to generate ethanol vapor. Ethanol vapor at doses equal or higher than 3.75 ml kg^{-1} grapes resulted in lower incidence of decay in 'Chasselas' table grapes similar to a commercial SO_2 treatment after four weeks of storage (CHERVIN et al., 2005). LURIE et al. (2006) reported that treatment with 8 ml ethanol kg^{-1} on impregnated paper controlled 98% of the decay in 'Thompson Seedless' table grapes stored at 0 °C for 8 weeks. Ethanol vapor generating sachets have been shown to inhibit mold

Tab. 1: Effects of treatments on quality attributes of 'Pafi' table grapes stored at 0 °C for one month.

Treatments	Decay (%)	Stem browning [X]	Weight loss (%)	TSS (%)	TA (%)	Berry color	
						L*	h°
Untreated	10.7 b[Y]	1.3 b	1.4 b	12.0 a	0.32 bc	42.3 bc	119.1 a
SO_2	2.2 d	1.3 b	1.2 b	12.7 a	0.31 c	41.8 c	117.2 a
24 °C HWT	17.2 a	1.3 b	1.9 a	13.0 a	0.36 ab	41.4 c	116.6 a
45 °C HWT	3.5 c	1.0 b	1.1 b	11.7 a	0.32 bc	42.2 bc	117.7 a
50 °C HWT	1.8 d	1.7 b	1.4 b	12.3 a	0.30 c	42.2 bc	114.6 a
55 °C HWT	0.4 e	2.7 a	1.3 b	12.0 a	0.41 a	41.6 c	115.4 a
Antimold®30	0.0 e	1.5 b	1.2 b	12.3 a	0.34 bc	43.8 ab	117.5 a
Antimold®60	0.6 e	1.0 b	0.4 c	12.9 a	0.34 bc	44.7 a	116.2 a

HWT represents hot water treatment.
Antimold®30 and Antimold®60 are ethanol vapor generating sachets
[X]Stem browning was assessed on a scale of 1 to 4 where 1 = healthy, 2 = slight, 3 = moderate, 4 = severe.
[Y]Mean separation was performed by Duncan's multiple range test. Treatment means (n=3) followed by same letter are not significantly different at $P<0.05$.

Tab. 2: Effects of treatments on quality attributes of 'Pafi' table grapes stored at 0 °C for two months.

Treatments	Decay (%)	Stem browning [X]	Weight loss (%)	TSS (%)	TA (%)	Berry color	
						L*	h°
Untreated	20.5 a [Y]	2.0 a	2.5 b	11.3 a	0.30 c	12.6 a	46.9 a
SO_2	6.0 c	2.0 a	2.0 b	10.7 a	0.32 bc	12.1 a	47.0 a
24 °C HWT	17.2 b	2.3 a	3.4 a	10.3 a	0.30 c	13.6 a	46.9 a
45 °C HWT	14.7 b	2.3 a	2.2 b	11.5 a	0.31 bc	12.5 a	47.0 a
50 °C HWT	2.8 de	2.3 a	2.8 ab	10.7 a	0.34 ab	13.2 a	46.9 a
55 °C HWT	3.9 cd	2.3 a	2.7 b	10.9 a			
0.36 a	12.3 a	46.9 a					
Antimold®30	1.3 de	2.3 a	2.7 ab	11.9 a	0.32 bc	12.0 a	46.1 a
Antimold®60	0.6e	2.0a	1.1c	12.0a	0.29 c	12.9 a	46.8 a

HWT represents hot water treatment.
Antimold®30 and Antimold®60 are ethanol vapor generating sachets
[X]Stem browning was assessed on a scale of 1 to 4 where 1 = healthy, 2 = slight, 3 = moderate, 4 = severe.
[Y]Mean separation was performed by Duncan's multiple range test. Treatment means (n=3) followed by same letter are not significantly different at P<0.05.

Tab. 3: Effects of treatments on quality attributes of 'Pafi' table grapes stored at 0 °C for three months.

Treatments	Decay (%)	Stem browning [X]	Weight loss (%)	TSS (%)	TA (%)	Berry color	
						L*	h°
Untreated	26.3 a [Y]	3.3 a	3.4 b	11.6 a	0.26 c	12.8 a	46.8 a
SO_2	16.5 c	3.3 a	3.2 b	12.4 a	0.29 bc	12.6 a	46.7 a
24 °C HWT	20.1 bc	4.0 a	4.5 a	11.7 a	0.29 bc	11.1 a	46.7 a
45 °C HWT	23.9 ab	3.5 a	2.9 b	11.7 a	0.31 ab	11.3 a	46.9 a
50 °C HWT	8.6 d	3.5 a	3.1 b	11.6 a	0.29 bc	11.8 a	46.8 a
55 °C HWT	10. 6d	3.8 a	3.4 b	11.9 a	0.34 a	11.2 a	46.9 a
Antimold®30	9.0 d	3.7 a	3.8 ab	11.5 a	0.29 bc	11.0 a	46.8 a
Antimold®60	7.9 d	3.0 a	1.9 c	12.5 a	0.28 bc	11.5 a	45.9 a

HWT represents hot water treatment.
Antimold®30 and Antimold®60 are ethanol vapor generating sachets
[X]Stem browning was assessed on a scale of 1 to 4 where 1 = healthy, 2 = slight, 3 = moderate, 4 = severe.
[Y]Mean separation was performed by Duncan's multiple range test. Treatment means (n=3) followed by same letter are not significantly different at P<0.05.

growth on bakery products (SMITH et al., 1987; DAIFAS et al., 2000). This is the first report where the use of ethanol vapor generating sachets for decay control in fresh produce was evaluated.

Hot water treatments of 50 °C and 55 °C prior to packaging also reduced incidence of fungal decay as effectively as ethanol vapor generating sachets and their effects lasted throughout three months of storage. In agreement with our findings, KARABULUT et al. (2004) reported that hot water dips at 50 °C, 55 °C, or 60 °C for 30 or 60 s significantly reduced the number of decayed berries during storage at 1 °C for 30 days. Similarly, MLIKOTA GABLER et al. (2005) reported that hot water treatment of table grapes significantly reduced the incidence of gray mold. The authors suggested that for better control, temperatures higher than 50 °C would be needed but it could injure the berries. They observed objectionable berry darkening after hot water treatment at 60 °C of 'Crimson Seedless' grape. In our study, berry darkening was not observed in any of the treatments.

We did not observe significant increase in stem browning due to ethanol vapor. In contrast to our findings, CHERVIN et al. (2005) reported that ethanol vapor treatment at the high dose tended to increase stem browning in 'Chasselas' grapes during storage at 0 °C. LURIE et al. (2006) observed visible stem and pedicel browning in 'Thompson Seedless' grapes treated with ethanol vapor generated from paper or wick impregnated with ethanol, but not in 'Superior' grapes. The adverse effects of the ethanol treatment in increasing stem browning may be cultivar dependent. Stem browning in 'Pafi' probably occurred as a consequence of water loss as reported previously by (CRISOSTO et al., 2001).

KARABULUT et al. (2004) reported small differences in weight loss between heated water/ethanol and control treatment in 'Crimson Seedless' grapes during storage. In our study, Antimold®60 sachet reduced weight loss while Antimold®30 sachets resulted in similar weight loss to hot water, SO_2 and control treatments. We recommend the use of modified atmosphere packaging for 'Pafi' grapes to limit water loss instead of PPE box liner as suggested previously for other table grape cultivars (LICHTER et al., 2005).

The effect of hot water treatments on the TSS content of Pafi grapes was not significant during storage, in agreement with previous reports on grapes (LYDAKIS and AKED, 2003) and strawberries (VICENTE et al., 2002). Hot water treated grapes maintained a higher TA during two months of storage. Similarly, hot water treatments resulted in a higher TA than control treatments in 'Big Top' nectarines during 45 days of storage (ERTURK CANDIR et al., 2009). In contrast to our

findings, previous studies showed that hot air/hot water treatments had either no significant effect on TA in grapes (LYDAKIS and AKED, 2003), peaches and nectarines (MALAKOU and NANOS, 2005) or reduced TA in nectarines (LAY-YEE and ROSE, 1994) and strawberries (GARCIA et al., 1995; VICENTE et al., 2002) during the storage. MLIKOTA GABLER et al. (2005) observed darker and more intense the color in heat treated 'Crimson Seedless' grapes. In this study, hot water treated and control grapes had similar berry color in terms of L* and $h°$ values during storage (Tab. 1, 2, 3). Consistent with our results, KARABULUT et al. (2004) and LYDAKIS and AKED (2003) found no effect of hot water/heat treatments on berry color.

In conclusion, packaging 'Pafi' grapes with ethanol vapor generating sachets of Antimold®30 and Antimold®60 and hot water dips at 50 °C and 55 °C prior to packaging were more effective in reducing fungal decay than SO_2 generating pads during three months of storage. Stem browning occurred at slightly higher levels in grapes dipped in hot water or packaged with Antimold®30 sachet, which might limit their use. Antimold®60 sachet resulted in lower weight loss and had no adverse effect on stem and berry color, TSS and TA. Although we did not observed any phytotoxicity or unpleasant taste with 'Pafi' grapes packaged with Antimold®60 sachets, ethanol residue levels in grapes needs further investigation. The Antimold®60 sachet seems to be good candidate as an alternative to SO_2 generating pads to prevent decay of grapes during storage.

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