Maintaining Table Grape Post-Harvest Quality for Long Distant Markets

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Stem browning due to water loss and botrytis infection are the two main factors which reduce table grape post-harvest quality. Low critical threshold values for water loss resulting in stem browning were found for Flame Seedless (2.1%) and Thompson Seedless (3.1%). Our survey of water loss during post-harvest operations under California conditions showed that a long cooling delay during mild temperatures, or a short cooling delay during hot temperatures, can contribute to stem browning on Flame Seedless and other cultivars during storage. Cluster bagging and/or a box liner were more important factors than box material for the reduction of water loss during storage. The low critical threshold values, in combination with the high level of water loss during commercial post-harvest operations, pointed out the importance of developing a technique to reduce water loss during post-harvest handling. After evaluation under different conditions, the use of a box liner in combination with an SO_2 pad appears to be a promising technique to reduce water loss and botrytis incidence of field packed table grapes during storage without causing SO_2 phytotoxicity. Additional studies evaluating the perforated liner + SO_2 pad combination should be conducted with the goal of reducing table grape stem browning and botrytis infection during post-harvest handling in California.

Table grapes are a non-climacteric fruit with a low rate of physiological activity (7,8), but are subject to serious water loss and botrytis infection during post-harvest handling (1,2). Stem browning and gray mold infection, caused by the fungus *Botrytis cinerea,* are the two main factors which reduce table grape post-harvest quality (5,7). Flame Seedless is the second most important table grape California; however, this cultivar appears to be very susceptible to stem browning. Gentle handling, careful cluster cleaning, fast hauling and cooling, low temperature, and weekly SO_2 application during storage are recommended to reduce the incidence of these two problems (2,3,5,6,7).

One problem associated with the use of SO_2 to control botrytis infection is the constant potential for injury to the berries and stems (5). Injured tissue first shows bleaching of color, followed by sunken areas where accelerated water loss has occurred. These symptoms first appear on the berry where some other injury has occurred, such as a harvest wound, transit injury, or breakage at the cap stem attachment. Symptoms may also be seen around the cap stem and slowly spread over the berry. Another problem with SO_2 fumigation of grapes is the level of sulfite residue remaining at the time of final sale (5,7). Because some people are dangerously allergic to sulfites, a tolerance of 10 ppm sulfite residue has been established by the U.S. Food and Drug Administration.

During long term storage and shipment to distant markets (over 10 days), in which SO_2 cannot be applied and the fruit is exposed to temperatures exceeding 3°C, stem browning and botrytis infection develop quickly (5,7). During marketing, due to the cumulative water loss, loss of quality due to stem browning, berry shatter, and even wilting and shriveling of berries occurs (9). This research study in progress has the following objectives: *(1)* to determine the water loss threshold for stem browning of different table grape cultivars; *(2)* to survey the amount of water loss occurring during commercial table grape operations in California; and *(3)* to evaluate the post-harvest performance of table grapes under the box liner and SO_2 pad packing technique.

Materials and Methods

A series of experiments to achieve the above objectives are being carried out in the F. Gordon Mitchell Postharvest Center at the Kearney Agricultural Center. Several table grape cultivars, grown using standard commercial practices, were used in the study.

Water loss threshold value determination: During the 1993 season, several table grape cultivars grown at the same location were harvested at commercial maturity to determine their water loss threshold for stem browning. Clusters were exposed to cooling delay periods of 3, 6, 9, 12, and 15 hours at 26°C, 30%RH and an air velocity of near 7.6 m per minute prior to being placed in cold storage (0°C/90% RH). Twenty clusters from each cultivar were weighed and used for each combination of cultivar × delay period. Cluster weight, stem color, stem texture, and berry appearance were measured daily for each sample during the cold storage period. A scoring system for stem browning was used to determine stem condition (1 = cap stem healthy; 2 = cap stem slightly brown; 3 = cap stem and secondary stem moderately brown; and 4 = cap stem, secondary, and

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primary stem fully brown). Stem and berry water content was determined at the end of each experiment and related to stem browning and berry shrivelling symptoms, respectively.

Water loss survey: Water loss from grapes packed in various box (17.5 × 14 × 7.5") materials was measured after different cooling delay periods. Grapes were harvested and packed with and without poly bags in corrugated, TKV, and foam boxes. After grapes were packed, boxes were exposed to different periods in the full sun. Water loss was calculated by weighing the fruit at harvest and reweighing at the end of the sun exposure period. Weight loss percentage was calculated in relation to initial fresh weight. Fruit temperature within the different boxes was monitored every 30 minutes during the sun light exposure period using a 21-X Campbell data logger. Five thermocouples per box were placed in the top and bottom layers of the fruit.

Box liner and SO_2 pad evaluation: The rate of water loss and incidence of botrytis was evaluated on Ruby and Thompson Seedless with different box liner and SO_2 pad combinations under California handling conditions. For each treatment, 10 boxes (10 kilograms) picked at commercial maturity were field -packed according to the following treatments: 1 = control (standard commercial packing management); 2 = solid liner + two-phase SO_2 pad (NOVATEX); 3 = solid liner + two-phase SO_2 sheet (NOVASYS) ; 4 = solid liner + slow phase SO_2 pad (UVAS Quality); 5 = solid liner + no SO_2 pad; and 6 = no liner + no SO_2 pad

Table grapes were placed in cold storage (0°C - 1°C and 85% - 90% RH, with a moderate air flow) and examined after six and 12 weeks. Table grapes were inoculated with a botrytis solution before packing. Grape visual appearance, weight loss, stem condition (stem color and flexibility), incidence of decay, phytotoxicity symptoms, and sulfite residues were determined for each quality evaluation date.

To compare the performance of different box liner and SO_2 pad combinations under commercial shipping postharvest conditions, four boxes (10 kilograms) of Ribier and Thompson Seedless field-packed without initial SO_2 fumigation were used for each of the following six treatments: 1 = solid liner + two-phase SO_2 pad (NOVATEX); 2 = solid liner + two phase SO_2 pad (NOVASYS); 3 = solid liner + two phase SO_2 pad (NOVATEX); 4 = solid liner + two phase SO_2 pad (NOVASYS); 5 = solid liner + no SO_2 pad; and 6 = no liner + no SO_2 pad

Grapes were field-packed at commercial maturity and placed in cold storage for about one week prior to shipment to Los Angeles, California, from Valparaiso, Chile. Table grape quality evaluation was done upon arrival, inspection point (4 weeks after harvest), retail point (4 weeks after harvest + 3 days at 20°C) and after 12 weeks after harvest + 3 days at 20°C).

Table 1. Relationship between water loss and stem browning symptom development for Flame Seedless and Thompson Seedless table grapes.

Flame Seedless		Thompson Seedless	
% Water loss	Stem browning score[z]	% Water loss	Stem browning score[z]
1.0	N	1.4	N
2.1	SL	2.4	N
2.8	M	3.1	SL
3.7	SE	3.6	SL

[z]Stem browning score: N = none, SL = slight, M = moderate and SE = severe.

Table 2. Influence of cooling delay following harvest on water loss of Flame Seedless table grapes in three types of boxes.

	Period of Delay			
	Trial #1	Trial #2		Trial #3
Box type	Full Day 8 hours	Morning 4 hours	Afternoon 4 hours	Afternoon 4 hours
	% Water loss			
Corrugated	1.38	0.23	0.92	0.81
Wooden	0.99	0.20	0.70	0.63
Foam	0.81	0.19	0.47	0.59
LSD 0.05	0.28	0.08	0.20	0.15

Results

Water loss threshold value determination: First visible symptoms of stem browning were observed on Flame Seedless and Thompson Seedless when cluster water loss reached 2.1% and 3.1%, respectively. Flame Seedless showed moderate and severe symptoms when water loss reached 2.8% and 3.7%, respectively. Only slight stem browning symptoms was observed on Thompson Seedless, even when water loss reached 3.6% (Table 1). A much higher water loss than 3.6% was necessary

Table 3. Influence of three container types, with and without bags, on the water loss of Flame Seedless table grapes measured at two steps during a standard commercial post-harvest operation.

Box type	Field delay (4-h delay)	Cold storage (32F/80%RH/ 600CFM)	Final (cumulative)	Stem browning (score[z])
	% Water loss			
Corrugated	0.96	1.44	2.40	SL
Corrugated + Bag	0.87	0.92	1.79	SL
TKV	0.82	1.39	2.21	SL
TKV + Bag	0.57	1.24	1.81	SL
Foam	0.46	1.40	1.86	SL
Foam + Bag	0.48	0.88	1.35	N
LSD 0.05	0.12	0.10	0.35	--

[z]Stem browning score N = none, SL = slight, M = moderate and SE = severe.

Table 4. Quality evaluation of Thompson Seedless and Ribier table grapes after 12 weeks of cold storage and three days at 20°C.

	Thompson Seedless				
	Water loss (%)	Free of decay (%)	Water content (%)	Stem browning (score[z])	SO_2 residues (ppm[y])
Control no liner	7.6	51	54	4.0	-
Commercial	3.5	99	60	2.1	18.1
UVAS	0.1	94	69	1.9	3.0
Novasys	0.1	98	69	1.0	2.5
Novatex	0.1	99	68	1.0	3.0
Control with liner	0.5	2	74	4.0	-
LSD 0.05	0.40	2.0	8	0.6	-

	Ribier					
	Water loss (%)	Free of decay (%)	Stem browning (score[z])	Water content (%)	Phyto-toxicity (%[x])	SO_2 residues (ppm[y])
Control no liner	6.8	90	4.0	47	-	-
Commercial	3.0	98	3.0	55	20.3	7.3
UVAS	0.0	94	3.0	74	7.0	2.1
Novasys	0.0	99	2.0	63	12.3	3.3
Novatex	0.0	98	2.0	61	18.0	4.8
Control with liner	0.3	5	4.0	70	-	-
LSD 0.05	0.10	3.0	0.6	9.0	3.6	

[z]Stem browning score 1 = none, 2 = slight, 3 = moderate and 4 = severe.
[y]A composite sample was pooled from replications.
[x]Percent of fruit showing moderate to severe SO_2 damage.

to induce berry shrivelling symptoms in both cultivars.

Water loss survey: Post-harvest water loss from Flame Seedless table grapes was influenced by the length of sunlight exposure and temperature before cooling. A minimum of 0.19% and a maximum of 0.90% water loss were measured after a four hour cooling delay. After an eight-hour field delay, Flame Seedless grape water loss can reach up to 1.40%. (Table 2). Since we used a one box tier placed directly in the sun during the cooling delay period, these values represent the highest potential for water loss under these environmental conditions. Temperature measurements in the top and bottom of the boxes during the sunlight exposure period did not show any differences among types of box materials.

Box material influenced the amount of water loss occurring during the cooling delay period. In general, grapes packed in corrugated boxes lost more water than grapes packed in TKV boxes, while grapes packed in TKV boxes lost more water than grapes packed in foam. Water loss measured after SO_2 fumigation and cold storage was also affected by the type of box material (Table 2). Grapes in corrugated boxes lost more water than grapes in TKV and foam boxes, while grapes in TKV boxes more than fruit in foam boxes. Larger differences occurred between corrugated and foam boxes than between TKV and foam boxes.

Cluster bagging was a more important factor than box material in the reduction of water loss after cooling delays, SO_2 applications, and cold storage period (Table 3). The greatest water loss (0.98%) during a cooling delay was measured on grapes from the corrugated, non-bagged package combination after four hours of exposure to temperatures of 21°C to 32°C. Water loss in the TKV and foam boxes, for both non-bagged and bagged fruit, reached an average of 0.7% to 0.8%. Bagged grapes packed in foam boxes, lost the least amount of water (0.4%). The protective effect of the cluster bagging to reduce water loss became more evident after the SO_2 initial fumigation and cold storage period than during cooling delays (Table 3).

Box liner and SO_2 pad evaluation: After a 12-week storage period, higher quality was obtained in Ruby and Thompson Seedless grapes by using the liner + SO_2-pad package combination than under the conventional California post-harvest management system. Field-packed grapes with a liner + SO_2-generating pad had low water loss and stems that remained bright green and flexible after 12 weeks of storage. In contrast, the conventionally handled grapes exhibited stem browning and brittle stems (Table 4) during this same period. Water loss of near 2.0% and 3.5% were measured after six and 12 weeks of commercial cold storage (without box liner) (0°C/90% RH), respectively. Only 0.3% water loss was detected in the box liner treatments after six and 12 weeks of storage with both cultivars (Table 4).

Botrytis incidence was lower in all of the treatments with SO_2 application (weekly fumigation or pad) than with no SO_2 application. Botrytis destroyed the grapes in all of the treatments without SO_2 applications. In spite of low phytotoxicity symptoms observed among treatments, SO_2 damage was more clearly observed in Ruby than in Thompson Seedless. Sulfite residue levels analyzed in a commercial laboratory did not exceed 10 ppm on grapes from the SO_2 pad treatments (Table 4, 5).

Reduction of fruit water loss, stem browning, and botrytis incidence without induced phytotoxicity was attained on field packed grapes by using the box liner + SO_2 pad packaging combination (Table 5). Following a 28-day overseas shipment, and a three-day simulated display at 20°C, water loss reached near 0.40% in the treatments with a perforated liner while almost no water loss was recorded in the treatments using a solid liner. Clusters exhibited slight stem browning, but there were no differences in stem browning between treatments using the perforated or solid liner in combination with the SO_2 pad treatments. Field-packed grapes without initial SO_2 application and SO_2 pads had the highest level of botrytis incidence, followed by grapes receiving initial fumigation and packaged without SO_2 pads. Grapes packed without initial fumigation, but using SO_2 pads with the perforated liner, exhibited an intermediate level of botrytis incidence. The lowest level of botrytis incidence was attained with the solid liner combined with the SO_2 pad without initial SO_2 fumigation (Table 5). However, in Thompson Seedless,

Table 5. Quality of Thompson Seedless and Ribier table grapes at the retail point one month after harvest and three days at 20°C.

Initial fumigation	Treatments Pad type	Wrap type	Water loss (%)	Decay intensity % Wt.	Stem condition (score[z])	Phytotoxicity (score[y])
Thompson Seedless						
Without	NOVASYS	Solid	0	1.1	2.4	1
Without	NOVATEX	Solid	0	2.3	2.3	1
Without	NOVASYS	Perforated	.9	4.5	2.8	1
Without	NOVATEX	Perforated	0	3.5	2.4	1
With	NONE	Perforated	.4	6.1	2.3	1
Without	NONE	Perforated	.4	32.0	2.1	1
	LSD 0.05		.3	8.1	0.5	0
Ribier						
Without	NOVASYS	Solid	0	.2	2.6	1
Without	NOVATEX	Solid	0	.2	2.9	1
Without	NOVASYS	Perforated	.6	.2	3.1	1
Without	NOVATEX	Perforated	.6	.2	3.1	1
With	NONE	Perforated	.5	6.7	2.0	1
Without	NONE	Perforated	.7	16.0	2.0	1
	LSD 0.05		.7	3.5	0.4	0

[z]Stem browning score: 1= none, 2= slight, 3= moderate, 4= severe. [y]Phytotoxicity score: 1= healthy, 2= slight, 3= moderate, 4= severe.

under high botrytis inoculum pressure, a higher level of botrytis was found in grapes not receiving an initial fumigation and packed with a liner + SO_2 pad than in grapes receiving an initial fumigation and packed with a liner + $SO_2$2 pad (Table 6). In Ribier, under the same conditions, initial SO_2 fumigation did not show any additional benefits.

Discussion

The low critical threshold for stem browning development found for Flame Seedless pointed out the high susceptibility of this cultivar to stem browning in relation to other cultivars. Thompson Seedless had only slight stem browning symptoms even when subjected to higher water loss levels. This suggests that other factors besides water loss and the rate of respiration may be involved in the expression of stem browning symptoms.

Table 6. Influence of initial SO_2 fumigation on the decay of table grapes after four weeks of cold storage and three days at 20°C.

Initial fumigation	% Wt. decay	Stem condition (score)[z]
Thompson Seedless		
With	0.6	2.5
Without	1.2	2.4
LSD 0.05	0.4	ns
Ribier		
With	2.0	2.5
Without	4.9	2.1
LSD 0.05	ns	0.2

[z]Stem browning score: 1= none, 2= slight, 3= moderate, 4= severe.

Water loss values found during cooling delays and storage were dependent on the length of cooling delay and environmental conditions. Under California conditions, a long cooling delay during mild temperatures, or a short delay during hot temperatures, can contribute to stem browning development on Flame Seedless and other cultivars during subsequent storage. The low critical thresholds for stem browning, in combination with the high water loss values occurring during our commercial post-harvest operations, point out the importance of developing a technique to reduce water loss and, therefore, stem browning of table grapes.

The use of a box liner in combination with the SO_2 pad appears to be a successful technique to reduce water loss during field packed table grape postharvest handling without causing SO_2 phytotoxicity. Our preliminary work also demonstrated the benefit of initial SO_2 grape fumigation for the reduction of botrytis infections. Unfortunately, our proposed box liner + SO_2 liner technique will interfere with the initial SO_2 fumigation practice. However, use of a perforated liner may reduce water loss from field packed grapes without a significant reduction SO_2 penetration during initial fumigation. Additional work evaluating the perforated liner + SO_2 pad packaging technique, as well as studies focusing on stem browning physiology, should be pursued in the future.

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