Developing Optimal Controlled Atmosphere Conditions for 'Thompson Seedless' Table Grapes

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Abstract

Efficacy of controlled atmosphere (CA) conditions for decay control in 'Thompson Seedless' table grapes was evaluated. Early (16.5% soluble solids content = SSC) and late harvested (19% SSC) grapes were exposed to 5, 10, 15, 20 and 25% CO_2 combined with 3, 6 and 12% O_2. Grapes were initially SO_2 fumigated and air stored grapes were used as controls. Storage atmospheres did not affect SSC, TA, SSC:TA, or berry shatter. The main storage limitations for early harvested 'Thompson Seedless' table grapes were rachis and berry browning development, which resulted from exposure to >10% CO_2. However, $\geq$15% CO_2 was needed to control total decay and nesting development independent of O_2 concentrations. CA was more effective in decay control without detrimental effects on quality when late harvested grapes were used. The combination of 15% CO_2 with 3, 6 or 12% O_2 is suggested for up to 12 weeks storage only for late harvested 'Thompson Seedless' table grapes; CA should not be used for early commercially harvested grapes.

INTRODUCTION

The most important table grape cultivar worldwide is 'Thompson Seedless' and it is marketed nearly year around throughout the world. For example, in 2000, California produced approximately 224 metric tons, and in 2001, Chile produced approximately 176 metric tons. Controlled atmospheres (CA) including elevated CO_2 concentrations have been shown to control decay development on some commodities without affecting quality attributes during transport and/or storage. Few studies have been done on 'Thompson Seedless' (Berry and Aked, 1997; Nelson, 1969; Yahia et al., 1983). Nelson (1969) found that berry internal browning incidence overcame the potential benefits of CA in his early trials with 'Thompson Seedless' table grapes from the Coachella Valley. Yahia et al. (1983) using 5% CO_2 + 2% O_2, reported that decay and berry internal browning development were the main deterioration symptoms noted beyond eight weeks storage. In research carried out in England with 'Thompson Seedless' table grapes from Egypt, Berry and Aked (1997) observed an inhibition of *Botrytis cinerea* by exposure to a CA of 15% CO_2 + 5% O_2.

Our objective was to determine optimal CO_2 and O_2 levels to control gray mold (*Botrytis cinerea*) without affecting quality attributes of 'Thompson Seedless' table grapes.

MATERIALS AND METHODS

During the 1998 season, 'Thompson Seedless' table grapes were harvested according to their soluble solids content (SSC) at early (16.5%) and late (19%) commercial maturity. Grape samples were stored under 16 CA combinations for up to 12 weeks at 0ºC. The 16 CA combinations were 5, 10, 15, 20, and 25% CO_2 combined with 3, 6, and 12% O_2. Air storage was used as a control for all of the treatments. Flow rates and gas mixtures were established using a mixing board with micro-metering valves. Supply and exhaust gas O_2 and CO_2 composition was monitored using an Ametek paramagnetic oxygen analyzer (S-3A/II) and a Horiba infrared gas analyzer (VIA-510 for

CO_2).

Five clusters (replications) per treatment were removed every four weeks for quality evaluations, including soluble solids concentration (SSC), titratable acidity (TA), SSC:TA, rachis browning, berry shatter, skin and berry browning, and botrytis development. Rachis browning (stem browning) development was evaluated using the following subjective scoring system as described by Crisosto et al., 2001. All brown berries were removed and weighed, and berry browning was expressed as a percentage of cluster weight. Botrytis decay was evaluated as nesting formation and total decay. Number of nests was then counted for each cluster. Total decay was calculated by weighing healthy berries. Then, decayed berry weight was calculated by subtracting total cluster weight minus the weight of the healthy berries. Thus, total decay was expressed as a percentage of decayed berries based on the original cluster weight.

We used a factorial design, using CO_2 and O_2 levels as factors, with three replications. The data were subjected to analysis of variance (ANOVA) prior to a Least Significant Differences (LSD) means separation using the SAS program. The SAS statistical software (SAS Institute, Cary, NC) was used for these analyses.

RESULTS AND DISCUSSION

High CO_2 treatment suppressed gray mold growth on early (16.5% SSC) and late (18.0% SSC) harvested 'Thompson Seedless' table grapes. Natural quiescent botrytis infection ranged from none to 5.5% in the first month for air stored early harvested grapes. For late harvested grapes, natural botrytis infection varied from 1.0 to 32.8%. In all cases, decay incidence was not related to O_2 or the O_2-CO_2 interaction. Since botrytis was only affected by CO_2 concentrations, ANOVA and LSD analysis were carried out including air treatment and CO_2 treatments. For both early and late maturity grapes, botrytis development was not visible until the second month of storage, when it was significantly higher on the air stored grapes than any of the CO_2 storage treatments. In all of the cases, botrytis incidence was significantly reduced when CO_2 concentrations were $\geq$15% during storage (Fig. 1). There were no significant differences in decay control between the 10% to 25% CO_2 treatments, except under high Botrytis pressure that occurred in the late harvested grapes. Similar results were reported for *Monilinia fructicola* on sweet cherries (Tian et al., 2001).

For early and late harvested grapes, the CO_2 and O_2 combinations tested did not significantly affect berry shatter, SSC, TA or SSC:TA (data not shown). Air stored early and late harvested grapes did not develop commercially important berry browning even after 90 days storage. However, berry browning always increased on early harvested grapes under any of the CA treatments (Fig. 2). Berry browning was accelerated by $\geq$15% CO_2 after 60 days in storage. No or very slight berry browning was observed on late harvested (19% SSC) grapes, except those exposed to 25% CO_2, which exhibited about 11% berry browning after 60 days in storage.

In both maturity stages, the O_2 and CO_2 interaction was not related to the onset of rachis browning. Rachis browning development was significantly lower on the air-stored grapes than on grapes from any of the CO_2 storage treatments (data not shown). For early harvested grapes, rachis browning became commercially important (score $\geq$2.0) by the first month. Late harvested grapes tolerated high CO_2 very well. Only late harvested grapes stored under $\geq$20% CO_2 started to show the first signs of rachis browning. After two months storage, the $\leq$15% CO_2 treatment did not affect rachis browning of late harvested grapes during two months storage (data not shown). For early harvested grapes, the use of >10% CO_2 significantly increased rachis browning within one month in storage (Table 1). On grapes stored under >10% CO_2 the rachises had slight browning after two months storage. After three months, $\geq$10% CO_2 significantly accelerated rachis browning turning the rachis completely brown.

CONCLUSIONS

Based on our work, ≥15% CO_2 is necessary to control Botrytis decay on 'Thompson Seedless' table grapes. However, grape quality losses such as rachis and berry browning development were induced on early harvested grapes. Because of these potential quality problems we do not recommend the use of CA for early harvested 'Thompson Seedless' table grapes. For our work, we defined early harvested grapes as those with about 16% SSC and late harvested grapes as those nearing 20% SSC. Since late harvested 'Thompson Seedless' table grapes tolerate 15% CO_2 very well, we suggest a CA of 15% CO_2 combined with 3, 6 or 12% O_2 to limit Botrytis development without adversely affecting quality attributes.

Literature Cited

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Tables

Table 1. Effect of CO_2 and O_2 concentrations on rachis browning of early harvested (16.5% SSC) 'Thompson Seedless' table grapes during cold storage, 1998.

	Rachis browning score (1-4)		
	Storage time		
Treatment	1 month	2 months	3 months
CO_2 concentration (%)			
5	1.3a	1.4a	2.0a
10	1.2a	2.0b	3.1b
15	2.2b	2.2b	3.7bc
20	2.7bc	3.9c	4.0c
25	2.9c	4.0c	4.0c
P value	0.0001	0.0001	0.0001
LSD 0.05%	0.6	0.5	0.6
O_2 concentration (%)			
3	2.1	2.7	3.3
6	2.4	2.7	3.5
12	1.7	2.7	3.3
P value	0.035	0.93	0.63
LSD 0.05%	0.5	NS	NS
CO_2 x O_2			
P value	NS (0.50)	0.029	NS (0.48)

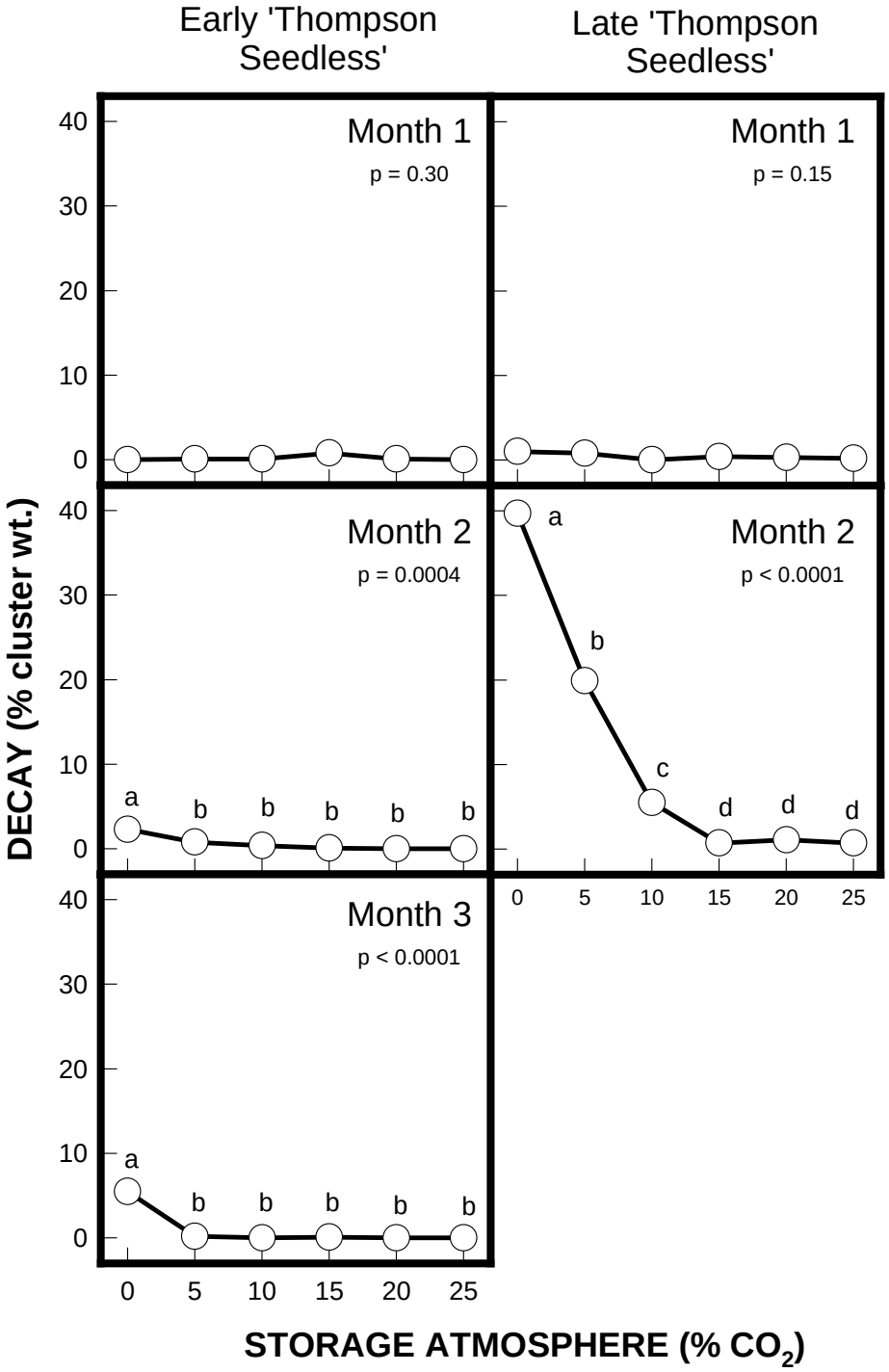

Fig. 1. Decayed berries, expressed as a percentage of cluster fresh weight, of early (16.5% SSC) and late (19% SSC) harvested 'Thompson Seedless' table grapes after 1, 2, and 3 months storage in different CO_2-enriched atmospheres. Different letters indicate a significant difference between storage atmospheres by LSD 0.05.

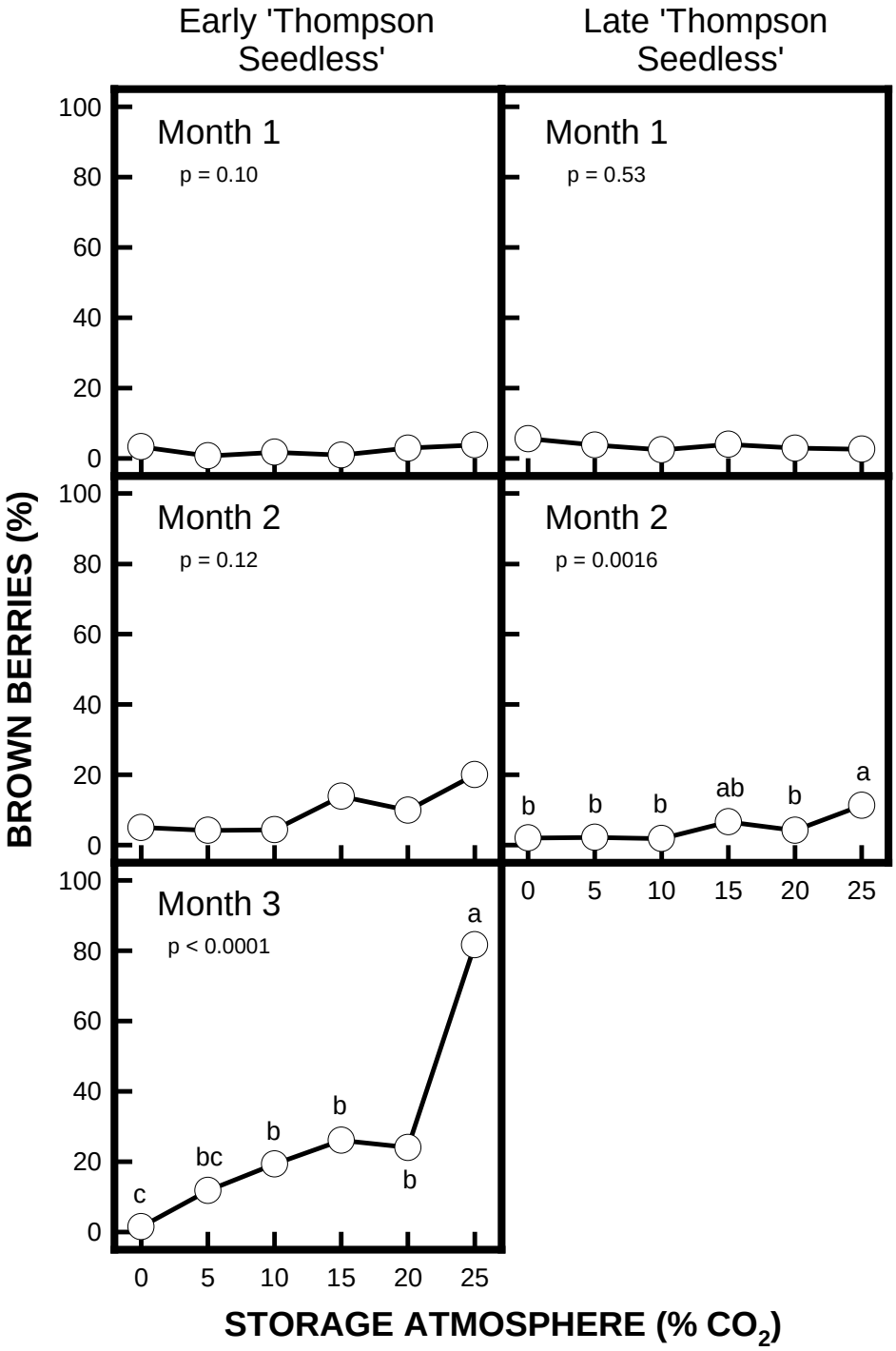

Fig. 2. Brown berries, expressed as a percentage of cluster fresh weight, of early (16.5% SSC) and late (19% SSC) 'Thompson Seedless' table grapes after 1, 2, and 3 months storage in different CO_2-enriched atmospheres. Different letters indicate a significant difference between storage atmospheres by LSD 0.05.