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Evaluation of Sulphur Dioxide-Releasing Pad Usage to Extend Postharvest Storage of Ontario-Grown *Vitis labruscana* 'Sovereign Coronation' Table Grapes

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Introduction

In order to compete with local produce as well as imported grapes, the fresh grape industry in Ontario is interested in developing methods to extend the postharvest storage of *Vitis labruscana* 'Sovereign Coronation' table grapes. The goal of this research project was to benefit the fresh grape industry in Ontario by potentially increasing the storage life of table grapes through the use of sulphur dioxide-generating pads, thus giving them more time to sell the crop. The ability to extend the postharvest storage life of 'Sovereign Coronation' grapes would reduce losses and also maintain the crop value.

In a good production year like 2011, where over 1,800 tons of 'Sovereign Coronation' grapes were marketed in Ontario, there was a loss of 115 tons of fruit that had already been harvested, sorted and packed. During the 'Sovereign Coronation' harvest window, the market is saturated with a wealth of produce. The 115 ton loss occurred due to a combination of the level of market demand at harvest, and the limited ability to store the grapes longer term postharvest; this loss is predicted to be an ongoing problem.

Grapes have a relatively low respiration rate as compared to other fruits, and if they are protected from injury, water loss and decay they are able to live a long time after harvest (Nelson, 1985). The two primary factors which contribute to a reduction in the postharvest quality and storage life of table grapes are stem browning due to water loss and gray mould infection by the fungus *Botrytis cinerea* (Nelson, 1985). Gentle handling, through cluster cleaning of decayed and damaged berries, quick transport, rapid cooling and the use of SO_2 treatment during storage is recommended as the best practice to reduce these two factors (Crisosto et al., 1994). Prior to the use of SO_2 to control gray mould, long-term storage of table grapes was essentially impossible to achieve (Nelson, 1985).

If successful, extending postharvest storage for 'Sovereign Coronation' in Ontario could provide the presence of local produce on store shelves into October or November and could increase sales and the profit margin for 'Sovereign Coronation' table grapes.

Rapid Cooling

After harvest the rate of deterioration of grapes is directly related to temperature (Nelson, 1978). Cooling minimizes harmful water loss which can produce stem browning, stem shriveling, berry shatter (loss of berries from the cap stem) and flabby berries (Soylemezoglu, 2001). In addition, *Botrytis* grows at temperatures $\geq$ – 0.5°C and rapidly colonizes fruits via aerial mycelia (Crisosto and Mitchell, 2002).

Rapid cooling of grapes to 0.5°C and maintaining storage at low temperatures (-1°C to 0°C and 90-95% RH) serves to minimize mould growth, respiration rate and water loss.

Use of Sulphur Dioxide

Adequate controls of *Botrytis* cannot be accomplished with rapid cooling alone (Crisosto and Smilanick). Efficient control of *Botrytis* is achieved through the use of sulphur dioxide (SO_2) and if grapes are not treated, gray mould can lead to substantial losses (Teles et al., 2014). Prior to the use of SO_2 to control gray mould, long-term storage of table grapes was essentially impossible to achieve (Nelson, 1985). Effective control of *Botrytis* is accomplished through standard practices involving weekly application of SO_2 gas through fumigation in chambers, following an initial harvest fumigation treatment (Luvisi et al. 1992), as well as through continuous release SO_2-generating pads placed in the packaging boxes, or through a combination of both methods (Crisosto and Smilanick; Maldonado, 2013). Sulphur pads contain sodium metabisulfite which generates and releases SO_2 gas during storage (Lichter et al., 2008).

Grapes which are intended for domestic market in the U.S.A. do not use SO_2-generating pads and rely on SO_2 fumigation as standard practice (Crisosto and Smilanick; Maldonado, 2013). There is typically a fumigation event directly after harvest (typically 2,500 to 3,000 ppm for 20 mins), followed by a weekly fumigation, which continues until the grapes are shipped to their domestic destination (Maldonado, 2013). The rate of SO_2 required to kill *Botrytis* spores and mycelium is calculated as a cumulative concentration, which is a function of the concentration and length of exposure, and is called a "CT product" (Crisosto and Smilanick). A minimum CT of 100 ppm-hour is required to kill *Botrytis* mycelium and spores at 0°C (Crisosto and Smilanick) and there are also formulas available to calculate the initial and weekly fumigation concentration requirements (Nelson, 1985; Luvisi et al., 1992).

Those grapes in Chile and the U.S.A. which are intended for export will employ the use of SO_2-generating pads, and in many cases this will be used in addition to a fumigation protocol. SO_2-generating pads are placed into the containers as the grapes are being packed. Use of these pads is recommended in combination with a box liner (Crisosto and Smilanick). There are two types of SO_2-generating pads: a single release, in which there is a low concentration and slow release of SO_2 for up to 150 days (concentration in the box up to 10 ppm); and a dual release, in which there is an initial fast and high concentration release of SO_2 which lasts 18 to 24 hours (concentration in the box up to 120 ppm), followed by a slow release stage (Maldonado, 2013).

In the U.S.A., typically single release SO_2-generating pads are used and pad placement occurs in the field during harvest as the grapes are packaged into boxes. Fumigation then occurs and follows the same weekly protocol as is used for domestic grapes (Maldonado, 2013). In Chile, dual release pads are typically used. Grapes are first picked in bulk followed by a single fumigation, after which they are packaged along with the insertion of the SO_2-generating pad (Maldonado, 2013). The use of SO_2-generating pads, in combination with an initial SO_2 application as well as a perforated box liner, has been demonstrated to be highly successful in reducing water loss and in controlling gray mould infection caused by the fungus *Botrytis* in table grapes during storage (Crisosto et al., 1994).

The limiting factor to the concentration of SO_2 is that of phytotoxicity to the grapes, which typically manifests in the form of hairline cracks, bleaching of berries, sunken areas

(Crisosto et al., 1994; Teles et al., 2014) and rachis damage (Baiano et al., 2007). In particular, *Vitis labruscana* varieties can be highly sensitive to symptoms of phytotoxicity upon exposure to high levels of SO_2 (Carlos Crisosto, personal communication, September 26, 2013). As such, sulphur pads are an optimal preliminary approach to judge the potential for the successful postharvest use of SO_2 in Ontario-grown Sovereign Coronation.

Postharvest Management

Preparation for postharvest storage begins in the field. In order to obtain the best fruit quality and longest duration of storage, there are several foundational best practices that must be observed.

At present, the only acceptable harvest method for table grapes is hand harvest. The reason for this is that quality is a critical element in successful storage and marketing for table grapes. Hand harvesting ensures that the clusters are handled with care, in order to avoid mechanical damage, and also allows for selection based on maturity and appearance (Mencarelli and Bellincontro, 2005). The picker is usually also responsible for the removal of decayed and mouldy berries, alternatively this step can be preformed in a packing house. It is imperative that bunches are treated with care when placed into the packaging, without pressing or squeezing (Fig 1). Containers must not be overfilled, in order to avoid bruising or bursting of berries due to compression of bottom layers (Mencarelli and Bellincontro, 2005).

Figure 1. 'Sovereign Coronation' grapes from this experiment showing mechanical damage.

Inaccurate picking and packing procedures, such as overfilling containers and neglecting the removal of damaged or mouldy berries, will dramatically reduce the length of postharvest storage life and the final product quality (Mencarelli and Bellincontro, 2005).

Objective

The primary objective of this project was to investigate the potential of using SO_2-generating pads in the storage of 'Sovereign Coronation' grapes in Ontario. The duration of this project was a one year time span, encompassing the 2014 season harvest.

Materials and Methods

Experimental Setup

Experiments were conducted in 2014 using Ontario-grown 'Sovereign Coronation' table grapes from the Niagara area. 'Sovereign Coronation' table grapes destined for the storage market, rather than fresh market, were commercially harvested. Grapes were harvested September 16, 2014 at an average total soluble solids value of 17.2 °Brix, followed by passive room cooling. The harvest date was selected by the grower based on total soluble solids concentration and commercial maturity. Transport to Vineland Research and Innovation Centre's Postharvest Laboratory (Vineland) occurred on September 17, 2014. Grapes were held in postharvest storage at their recommended optimal temperature and relative humidity (-1°C to 0°C and 90-95% RH).

For commercial packing, a cardboard master container holds eight plastic clamshells, and each clamshell contains several clusters (Fig. 2). Since cardboard will absorb SO_2 (Lichter et al., 2008), the clamshells from each master were transferred out of the cardboard and into plastic SmartCrate containers upon arrival at Vineland. The same commercial configuration of four by two clamshells was maintained. The external dimensions of the SmartCrates were 60 cm (24") long x 40 cm (16") wide x 10 cm (4") high, and these containers are designed to allow for optimum airflow (Fig 3).

Figure 2.

The experiment was designed with SO_2-generating pad type (no pad/control, single release pad-3 grams of active ingredient, and dual release pad-6 grams of active ingredient) as the main factor, replicated three times, and weeks in postharvest storage (3 weeks, 5 weeks and 7 weeks), as the sub factor. Each main factor consisted of five stacked SmartCrates of grapes, termed a "mini-pallet" (MP) (Lichter et al., 2008), with each SmartCrate containing a corresponding pad for the dual (D) and single (S) release SO_2-generating pad treatments, or no pad for the control (C); data were collected from the center three SmartCrates of each MP and the other two SmartCrates served as guards. The SO_2-generating pads were laminated pads kindly provided by Infruta S.A. (Santiago, Chile).

Figure 3.

The SO_2 gas must remain in contact with the grapes and thus the MPs were wrapped using low-density polyethylene bags; the bottom was left open and was raised off of the floor using an empty SmartCrate (Fig. 4). Small blocks of wood were placed at each corner between SmartCrates in the MP, in order to alleviate any possible compression of clamshells and/or grape bunches (Fig. 3). Three replications of each main factor were evaluated at each of the sub factor storage dates.

Figure 4.

Thus, for this experiment a total of 135 masters were used, for a total of 1,080 clamshells:

$$3\left(\begin{matrix}Main\ Factor\\ Treatments\end{matrix}\right)\times 3\ (Replications)\times 3\left(\begin{matrix}Sub\ Factor\\ Storage\\ Times\end{matrix}\right)\times 5\ (Masters/Treatment)\times 8\ (Clamshells/Master)=1{,}080\ Clamshells$$

Quality Analysis of Fruit

Upon arrival at Vineland, replicated initial harvest samples of approximately 100 berries were collected from the top, middle and bottom portions of 33 randomly selected clusters. The samples were weighed, and average berry weight (g) calculated. Then the berries of each sample were homogenized in a blender, the juice filtered, and total soluble solids (°Brix) were measured with a hand-held, temperature-compensating, digital refractometer (PAL-1; ATAGO™-USA, Bellevue, WA). The pH and titratable acidity (g/L tartaric acid) of two ml of the filtered juice diluted in 50 ml Milli-Q® water was determined with an automatic titrator (Titrino™ 848; Metrohm, Switzerland) and titration was accomplished with 0.1 N NaOH to a pH 8.2 endpoint.

Figure 5. 'Sovereign Coronation' received at harvest.

Before the initiation of storage, harvest weights were recorded from a random SmartCrate in each MP, and this SmartCrate was labeled for identification. These same SmartCrates were re-weighed at their subsequent removal from postharvest storage at either 3, 5 or 7 weeks. Weights were measured using a scale accurate to 0.0005 kg with a 30 kg capacity (Ranger OHAU-RC30LS; Ohaus™, USA) and weight loss was expressed as a percentage of original weight.

Quality analysis including average berry weight, total soluble solids, pH, titratable acidity and berry firmness was performed on grapes before and after being submitted to the SO_2 treatments. Grapes from three replications of each main factor MP SO_2-generating pad treatment were evaluated after 3 weeks, 5 weeks and 7 weeks of storage at -1°C to 0°C and 90-95% RH. Approximately 18 berries were collected from each of the nine MPs removed at each storage time point. Berries were detached from the top, middle and bottom portions of six randomly selected clusters and used for determination of average berry weight, total soluble solids, pH and titratable acidity using the methods described earlier.

An additional 18 berries were collected from each of the nine MPs removed at each storage time point by clipping the pedicel and leaving a portion of the cap stem attached to the berry. These berries were removed from the shoulder potion of 18 different clusters, each from a different clamshell, and used to measure berry firmness with a texture analyzer (TA.XT *plus*, Stable Micro Systems Ltd., UK) that was fitted with a 2.5 mm flat probe to compress to a depth of 2 mm at a speed of 5 mm/sec. The maximum compression force (N) that was developed during the run was recorded.

An evaluation of visible presence of mould in 16 clamshells was also performed at the 5 and 7 week storage removal time point. Clamshells were opened without disturbing clusters and scored yes or no for visible mould the percentage of clamshells with visible mould was calculated.

At each removal from storage at 3, 5 and 7 weeks, the SmartCrates were subsequently transferred to room temperature conditions of approximately 20°C, 80% RH for three days to simulate shelf-life. Following the three days at room temperature, 10 clusters from each MP were randomly selected for quality analysis including desiccation, SO_2 damage and decay ratings following established methods (Lichter et al., 2008). An index rating of 1 to 5 was used to score desiccation and SO_2 damage. Desiccation ratings were 1 = rachis and pedicels green and full as at harvest; 2 = slight browning; 3 = browning of rachis and pedicels but no shriveling; 4 = browning and some shriveling; and 5 = both rachis and pedicels dry and brown (Lichter et al., 2008). Clusters with a rating above 3 were considered unmarketable. SO_2 ratings were based on the total number of berries per MP which exhibited bleaching: 1 = no apparent bleaching; 2 = two to five berries; 3 =six to 10 berries; 4 = 11 to 20 berries; and 5 = over 20 bleached berries per 10 bunches (Lichter et al., 2008). Decay was rated by scoring the percent of healthy bunches out of the 10 bunches selected per MP. Healthy bunches were defined as having only one or no decayed berries (Lichter et al., 2008).

Statistical Analysis

An ANOVA analysis was performed on mean values of each quality parameter using XL STAT, version 2013: Microsoft Corporation. Treatment effects reported were significant according to a *t*-test. Significant differences between results were compared using the Least Significant Difference (LSD) with an interval of confidence of 95% ($t<0.05$).

Results and Discussion

Weight Loss and Berry Weight

Weight loss in crops during cold storage is mainly the result of loss of water. Grape berries are covered with a thick wax coating called a cuticle, which aids in prevention of water loss. The rachis (the stem axis bearing the berries) does not have the same level of cuticle protection. In addition, stem or rachis respiration rate is about 15 times higher than the rate of berry respiration (Crisosto and Smilanick). As such, water loss occurs first from the rachis and subsequently from the berries. Grape berries do not show water loss symptoms until after damage to the rachis is substantial (Soylemezoglu, 2001). In general, a weight loss of over 5-6 % is required before shrinkage is evident in berries (Nelson, 1985; Soylemezoglu, 2001), although berries may begin to lose noticeable turgor at around 3% weight loss (Soylemezoglu, 2001). The low critical threshold value for water loss resulting in rachis browning varies depending on the variety of table grape. Previous studies have shown values from 2.0%-2.5% for the low critical threshold and up to 3.3%-4.1% for the appearance of severe stem browning, dependant on the variety tested (Crisosto et al., 2001).

There were no significant differences in total weight loss or changes in berry weight over time found in this experiment (Fig. 6 and Fig. 7). There were also no significant effects between the single release, dual release or control treatments at any of the storage time points.

As expected, the average weight loss shows an increasing trend over time, however the overall weight loss at the end of the seven weeks of storage was very low for all treatments; the control had a weight loss of 1.2%, the single release treatment lost 0.6% and the dual release lost 0.8% of the original weight at harvest.

Berry Firmness

Firmness or turgor is one of the main quality indicators for table grapes (Bernstein and Lustig, 1981), however, there is a large difference in firmness of berries between *Vitis vinifera* and *Vitis labruscana* (Galet, 1979). *V. labruscana* grapes have been described as "tough" or "tender", in comparison with the flesh of *V. vinifera*, which has been described as "crisp" or "non-crisp" (Sato et al., 1997).

Grapes lose firmness through water loss or due to structural changes (Bernstein and Lustig, 1981). A significant reduction in berry firmness or turgor was observed in 'Sovereign Coronation' berries after 5 and 7 weeks of postharvest storage, as compared to the firmness at harvest; however there was no significant decrease in firmness from week 5 to week 7 (Fig. 8). Data from week 3 was lost due to equipment error. As there was no observation of any significant decrease in berry weight over storage time (Fig. 7), this loss of firmness in the berries is likely due to structural changes related to senescence. Due to the fact that *V. labruscana* does not have a crisp texture (Sato et al., 1997), minor changes in firmness may not have a strong negative impact on quality.

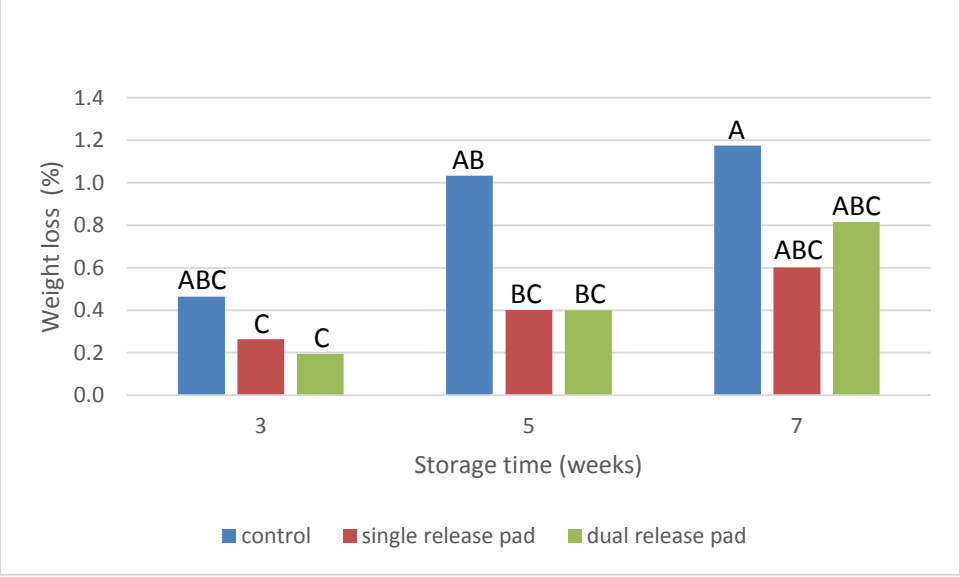

Figure 6. Cluster weight loss (%) measured in 'Sovereign Coronation' over storage time.

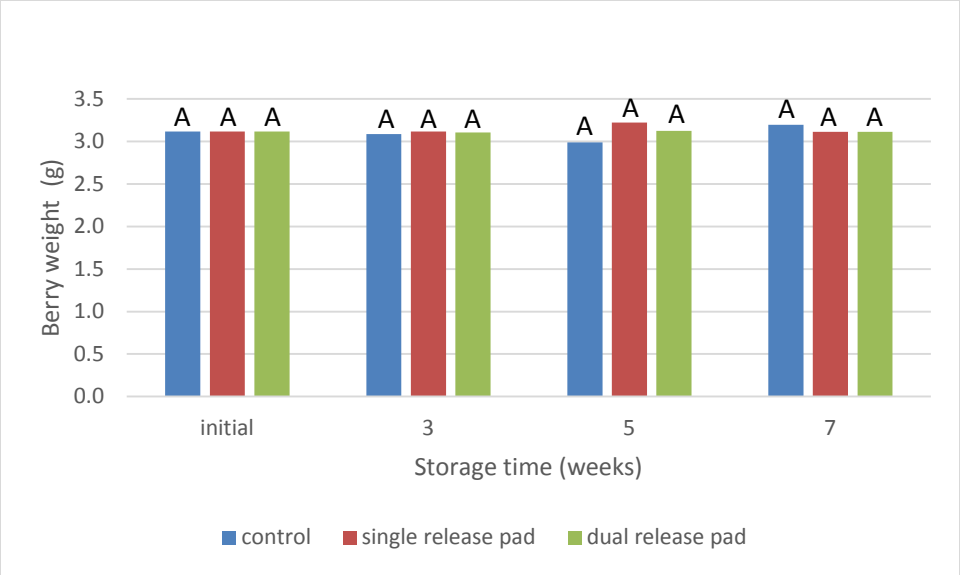

Figure 7. Berry weight (g) measured in 'Sovereign Coronation' over storage time.

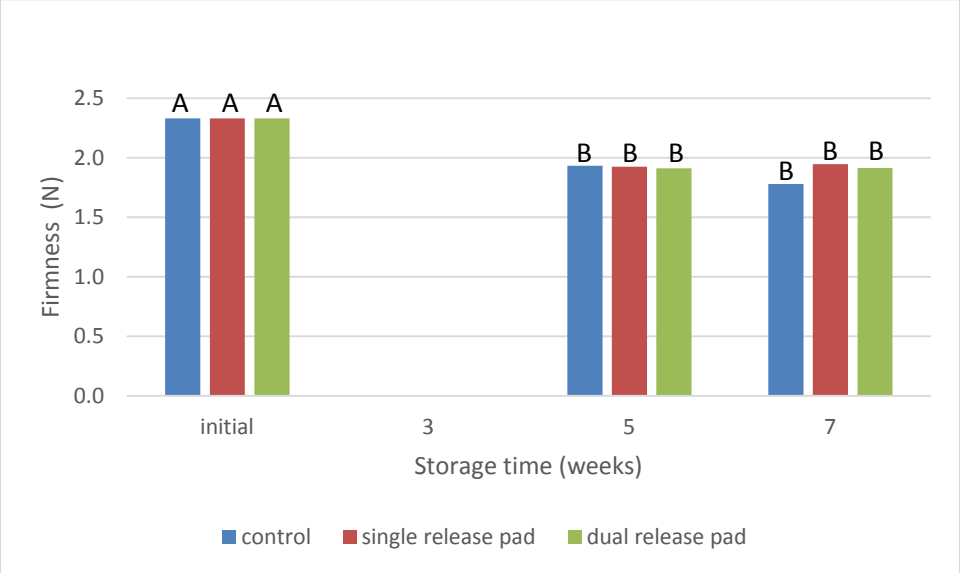

Figure 8. Berry firmness (N) measured in 'Sovereign Coronation' over storage time.

Rachis Browning and Desiccation

Stem condition with respect to colour and turgor is an important quality indicator in table grapes (Mencarelli and Bellincontro, 2005). Whether or not a cluster is marketable is determined by the green colour and freshness of the rachis (Lichter et al., 2008; Mencarelli

and Bellincontro, 2005). SO_2 has been shown to retard the browning of the rachis in table grapes (Nelson, 1983).

For this experiment, a standard desiccation index rating of 1 to 5 was used to score rachis condition after each storage period, followed by three days at room temperature conditions, and a rating above 3 was considered unmarketable (Lichter et al., 2008). After 3 and 5 weeks of postharvest storage, plus 3 days at room temperature conditions, there was no significant loss of marketability of the clusters, regardless of the treatment (Fig. 9). At 7 weeks storage, plus 3 days at room temperature conditions, there was a significant drop in the percentage of marketable clusters in both the control and dual release treatments, in both cases from 100% to 66.7%. At 7 weeks, the highest amount of marketable clusters based on rachis condition was 90%, which was found in the single release treatment.

It is not clear as to why the single release treatment outperformed the dual release treatment at seven weeks with respect to rachis browning and the resulting percentage of marketable clusters. Phytotoxicity to SO_2 can manifest as rachis damage (Baiano et al., 2007), so it is possible that this could explain the lower rachis scores for the higher level of SO_2 exposure in the dual treatment. Further study into this observation would be required to provide a greater understanding of these results.

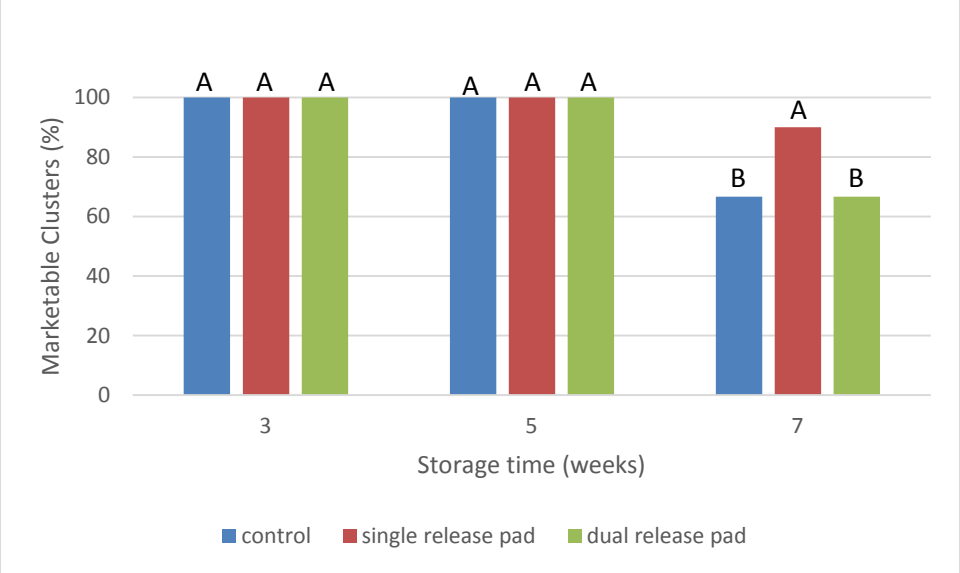

Figure 9. Marketable clusters (%) as determined by rachis desiccation in 'Sovereign Coronation' over time in cold storage, plus three days at room temperature conditions.

Decay

For this experiment decay was measured by scoring the percent of healthy clusters after each storage period, plus three days at room temperature conditions. Healthy bunches were defined as having only one or no decayed berries (Lichter et al., 2008).

The amount of decay was most pronounced in the control treatment, with a drop by 3 weeks to an average of 13.3% healthy clusters and by 7 weeks to only 6.7% healthy clusters remaining (Fig. 10 and 16). At 3 weeks this level was significantly lower than both the single and dual release treatments.

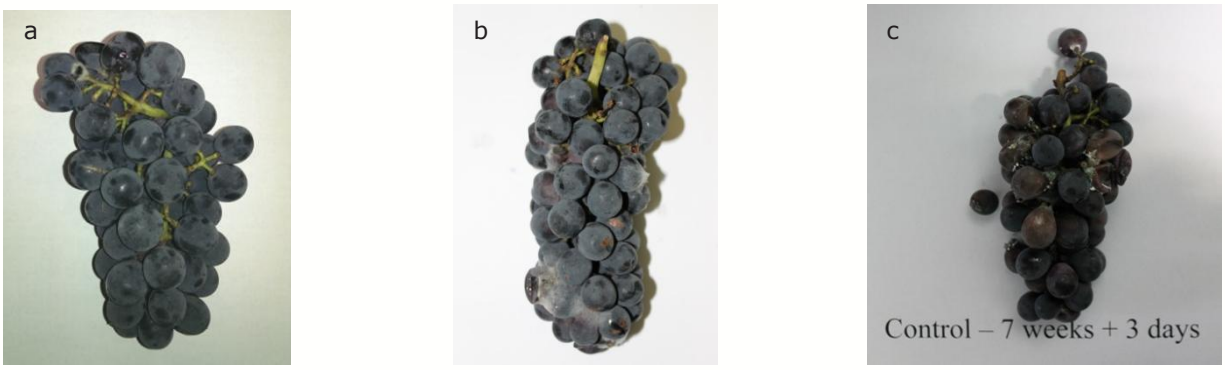

Figure 10. 'Sovereign Coronation' Control treatment: a) unhealthy cluster at 3 weeks storage plus 3 days room temperature; b) unhealthy cluster at 5 weeks storage plus 3 days room temperature; c) unhealthy cluster at 7 weeks storage plus 3 days room temperature.

At 5 and 7 weeks the single release treatment had a similar level of decay as the control and there was no significant difference in the amount of healthy clusters between the two treatments (Fig. 11 and 16).

Figure 11. 'Sovereign Coronation' Single release treatment: a) healthy cluster at 3 weeks storage plus 3 days room temperature; b) unhealthy cluster at 5 weeks storage plus 3 days room temperature; c) unhealthy cluster at 7 weeks storage plus 3 days room temperature.

At all storage time points the dual release treatment significantly reduced decay incidence over the control and single release treatments. The levels of healthy clusters for the dual release treatment at three, five and seven weeks were 86.7%, 73.3% and 56.7% respectively (Fig. 12 and 16).

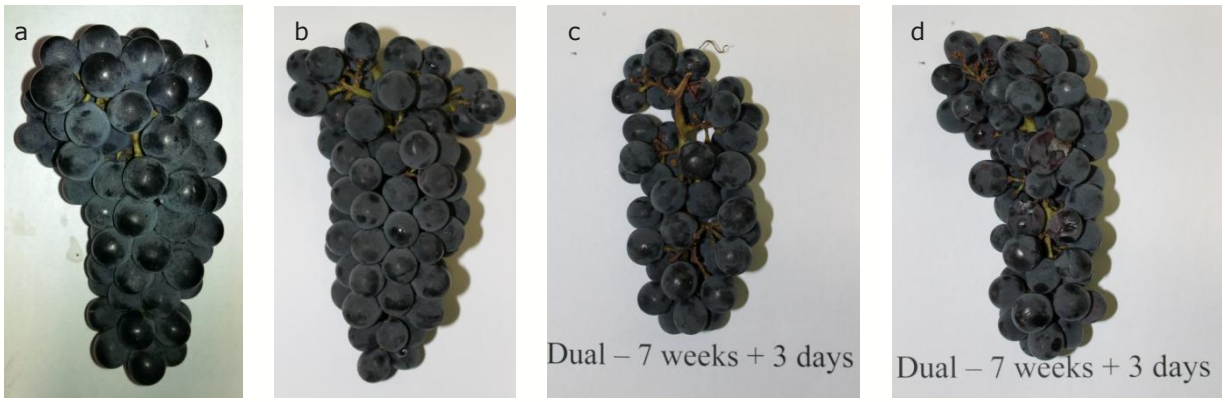

Figure 12. 'Sovereign Coronation' Dual release treatment: a) healthy cluster at 3 weeks storage plus 3 days room temperature; b) healthy cluster at 5 weeks storage plus 3 days room temperature; c) healthy cluster at 7 weeks storage plus 3 days room temperature; d) unhealthy cluster at 7 weeks storage plus 3 days room temperature.

Observational notes were made during the quality analysis on the visual condition of the clusters. These observations serve to provide additional insight into the differences between treatments that was not captured through the percentage of healthy clusters scoring process. In general, all clusters with mechanical damage (split, crushed, broken berries) were prone to decay, as open wounds are an entry point for infection. The SO_2 treatments slowed the infection process in damaged berries as compared to the control treatment (Fig. 13). Those clusters which were scored as unhealthy varied widely in their level of decay and mould presence. Control clusters exhibited nesting (where mould is present across numerous adjacent berries) which was visible as early as week 3 (Fig. 14), however single and dual release treatments tended to only show one or two isolated berries with infection. By week 5, nests in the control clusters had in many cases taken over the entire cluster, while unhealthy scoring SO_2 treated clusters showed only one or a few berries with mould, with the dual release demonstrating a superior control of decay. By week 7 there was a much clearer distinction between the single and dual release treatments with respect to the level of decay. Dual release clusters which were unhealthy still had mould contained to a small number of berries; however single release unhealthy

Figure 13. Split berry in 'Sovereign Coronation' with delayed infection in dual release treatment at 5 weeks storage plus 3 days room temperature.

Figure 14. Example of mould nesting in 'Sovereign Coronation' berries.

clusters were overcome with mould.

Figure 15. Visible mould evaluation in 'Sovereign Coronation' berries.

An additional evaluation of visible presence of mould was also performed at the 5 and 7 week storage time points shortly after removal from cold storage. Clamshells were opened without disturbing clusters and scored yes or no for presence of visible mould and the percentage of containers with visible mould was calculated (Fig. 15). At five weeks 16 clamshells were examined: 87.5% of the control clamshells had visible mould; 62.5% of the single release clamshells had visible mould; and 6.3% of the dual release clamshells had visible mould. At seven weeks 24 clamshells were examined: 100% of the control clamshells had visible mould; 83.3% of the single release clamshells had visible mould; and 8.3% of the dual release clamshells had visible mould.

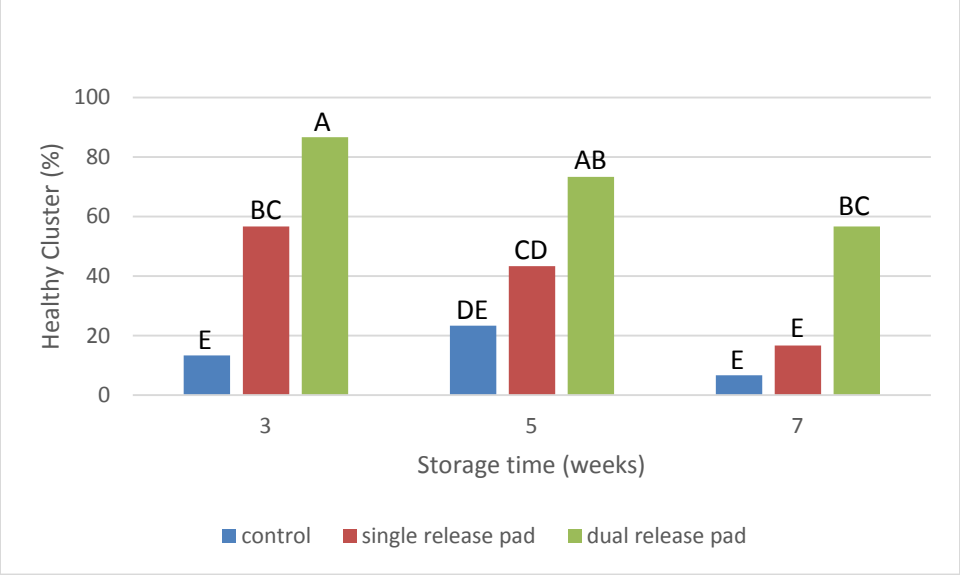

Figure 16. Healthy clusters (%) as determined by decay incidence in 'Sovereign Coronation' over time in cold storage, plus three days at room temperature conditions.

SO_2 Damage

SO_2 damage ratings were based on the total number of berries per MP which exhibited bleaching. No significant levels of bleaching were observed in either of the SO_2 treatments at any of the storage time points.

pH and Titratable Acidity

The predominant organic acids in grape berries are tartaric acid and malic acid and the ratio between the two vary greatly by variety (Kliewer et al., 1967). Tartaric acid is present in the larger quantity (Paliyath, et al., 2008).

During storage there was a significant increase in titratable acidity (TA) at 5 weeks in the control and single release treatments, corresponding to a significant decrease in pH (Fig. 17 and 18). The pH dropped significantly in the dual release treatment at 5 weeks, but there was no significant increase in titratable acidity.

At 7 weeks storage the pH in all treatments increased back to levels which were not significantly different from that seen at harvest. However the titratable acidity in the control remained at a significantly higher level; TA increased in the dual release to levels significantly higher than at harvest; and TA decreased in the single release treatment back to a level not significantly different from harvest.

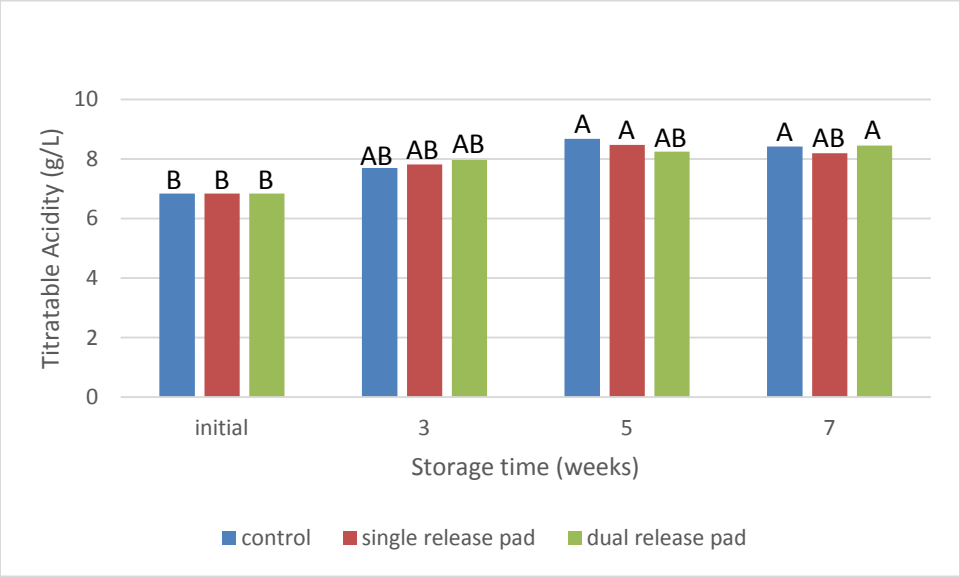

Figure 17. Titratable Acidicy (g/L tartaric acid) measured in 'Sovereign Coronation' over storage time.

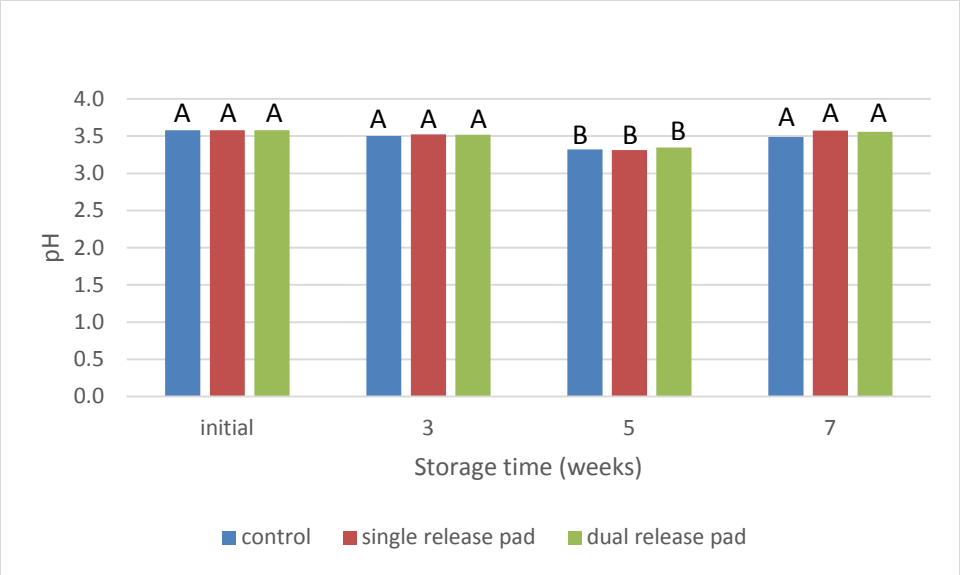

Figure 18. pH measured in 'Sovereign Coronation' over storage time.

Total Soluble Solids

Total soluble solids measured in °Brix was maintained at the same level across all storage time points and was unaffected by treatment (Fig. 19).

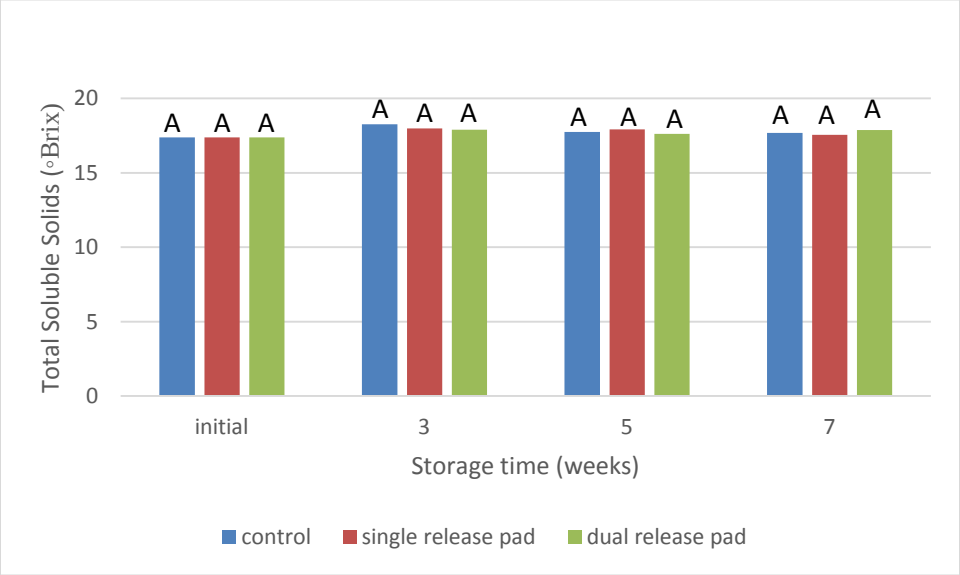

Figure 19. Total Soluble Solids (°Brix) measured in 'Sovereign Coronation' over storage time.

Conclusion

The use of sulphur dioxide-generating pads with Ontario-grown 'Sovereign Coronation' grapes is an effective method to extend postharvest storage life. Results showed that with the grapes used in this experiment, the greatest recommended length of storage was obtained with the dual release pads for 5 weeks, producing 100% of clusters with marketable rachis appearance and 73.3% healthy clusters with respect to decay incidence. Although, 56.7% of the clusters were still healthy at 7 weeks in the dual release treatment, only 66.7% of these clusters had a quality of rachis that would be considered marketable by most standards.

Treatments did not show any berry bleaching due to SO_2 phytotoxicity. There was no effect on the level of total soluble solids or berry weight in the grapes. Weight loss was not significant in any of the treatments and there was a similar decrease in firmness in all treatments. At 5 weeks the titratable acidity of the dual treatment did not change significantly from harvest although there was a decrease in pH level.

Overall, the level of mechanical damage observed in the grapes used in this experiment was unsuitable for successful postharvest storage (Fig. 20). The use of SO_2 with table grapes aids in maintaining postharvest quality and extending storage life, however it is a tool that must be combined with standard recommendations for picking and packing grapes destined for postharvest storage. Inaccurate picking and packing procedures, such as overfilling containers and neglecting the removal of damaged or mouldy berries, will dramatically reduce the length of postharvest storage life and the final product quality (Mencarelli and Bellincontro, 2005). Thus it is quite possible that a higher percent of healthy clusters and/or

Figure 20. Examples of mechanical damage observed in berries of 'Sovereign Coronation'.

a storage period of longer than 5 weeks for Ontario-grown 'Sovereign Coronation' could be achieved using the same dual release treatment by following recommended guidelines for cluster and berry quality, as well as employing the use of forced-air cooling.

Future research should concentrate on exploring the use of SO_2 fumigation methods and determination of SO_2 phytotoxicity concentration thresholds for 'Sovereign Coronation'. Additional research could include the evaluation of bulk harvesting into reusable plastic containers, combined with SO_2 fumigation during storage, as well as packaging and sorting occurring at the time of shipping.

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