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Hairline, a postharvest cracking disorder in table grapes induced by sulfur dioxide

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Abstract

Hairline cracks, which developed after harvest among SO_2-treated table grapes, were characterized by small, fine, longitudinal, cracking lines, almost undetectable with the naked eye. Juice exudation from the cracks resulted in a wet and sticky berry skin. Hairline cracks, which we propose to term 'hairline', were distinctively different from splitting observed before harvest. Hairline was only induced when table grapes were treated with gaseous SO_2, commonly used to prevent decay of table grapes during cold storage in Chile. In practice, conditions that favored higher concentrations of SO_2, such as the use of two SO_2 generating pads (one on top and one on the bottom of the packaged table grapes), promoted hairline cracking. Hairline incidence increased linearly when the concentration and time product (CT) of SO_2 exceeded 3 (mL L^{-1}) h, and no hairline cracking was observed with CT below 0.8 (mL L^{-1}) h. Hairline symptoms were greatly induced on Thompson Seedless table grapes that were immersed in acidic solutions (citric acid and disodium phosphate) at pH 2 or 4. To reduce this disorder, it is essential to use a minimal dose of SO_2 that allows adequate protection from decay without reducing the berry quality. Postharvest practices of table grapes, packaged with a SO_2 generating pad, such as extended delay cooling periods and those practices that involve a raise in temperature, considerably enhance this disorder. Hairline cracking is another expression of phytotoxicity due to overexposure of table grapes to SO_2.

Keywords: Gray mold; Generating pads; Sodium metabisulfite; Grape disorder; *Botrytis cinerea*; SO_2 phytotoxicity

1. Introduction

Fruit splitting is a common disorder in grapes (*Vitis vinifera* L.) (Swift et al., 1974; Considine and Kriedemann, 1972) and other soft fruits, including sweet cherries (Christensen, 1996) and tomatoes (Hankinson and Rao, 1979). Damage develops during cell enlargement (stage III) coinciding with a high internal hydrostatic pressure. This can be promoted by irrigation practices, rain, and has also occurs during storage (Nelson, 1985). Skin extensibility remains relatively constant during stages I and II of the grape berry development. It increases at the beginning of stage III but decreases at the end of this period, 2–3 weeks before harvest (Matthews et al., 1987).

Considine and Kriedemann (1972) demonstrated that susceptible cultivars had about 50% of their berries split with a turgor pressure of 15 atm; however, 40 atm were required for splitting to occur in resistant grape cultivars. Fruit splitting symptoms consist of circumferential and longitudinal injuries, or both, on the grape berry surface. For instance, in Thompson Seedless table grapes, circumferential ring fractures usually appear around the pedicel and longitudinal fractures down the side of the berry (Considine, 1982). These types of fractures have been associated with changes in the magnitude of mechanical stress on the skin of actively growing fruits. The fruit shape changes from spherical to ovoid, which promotes longitudinal cracking. Furthermore, the presence of a core tissue increases cracking near the insertion of the pedicel (Considine and Brown, 1981).

Rain during harvest is the main factor that induces fruit splitting in grapes and sweet cherries. Rains increase the turgor pressure by root water uptake and destroy bearing structures present on fruit surfaces. These are the main factors that support the model for rain-induced cracking of fruit (Sekse, 1998).

Cuticular fractures in the surface of the sweet cherry skin have been described by electron microscopy (Glenn and Poovaiah, 1989), low power observations with a stereo magnifier (Sekse, 1995), and fluorescence microscopy (Peschel and Knoche, 2005). Micro-crack frequency increases during fruit development and with an increase in fruit mass (Knoche et al., 2001).

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The micro-cracks concentrate in the pedicel cavity and stylar end region of sweet cherries (Christensen, 1996; Peschel and Knoche, 2005). Water uptake increased in fruit with micro-cracks (Glenn and Poovaiah, 1989) and cuticular fractures when excessive irrigation increased water content compared to a prior harvest with a more modest water supply (Sekse, 1995).

Grape splitting can also develop during storage, where it appears as fine and long superficial cracks. These symptoms, which we term hairline, have no consistent pattern of distribution, but are seen more frequently on relatively immature green fruit cultivars harvested from over-cropped vines. Hairline is not related to the rate of cooling or to conditions of high humidity during storage (Nelson, 1985). Concentric fine cracking has been described to develop on the base of the pedicel in the berry skin of Sultana table grape and it differs from splitting (Swift et al., 1974).

It has been postulated that overexposure of grapes to sulfur dioxide (SO_2), a commercial practice applied for decay control purposes, induces hairline (Santiago and Hanke, 2000; Zoffoli et al., 2000); however, this remains to be validated. SO_2 injury can result in bleaching, discoloration, and fruit pitting (Nelson and Tomlinson, 1958; Harvey and Pentzer, 1960; Gao et al., 2003). Postharvest decay can be enhanced by hairline, particularly during long-term storage. Uncontrolled and excessive SO_2 concentrations from an in-package SO_2 generating pad increases the risk of SO_2 injuries on grape berries, compared with the more precise practice of fumigation with the gas inside cold storage rooms. The objective of the research reported here was to determine the relationship between SO_2 exposure and the hairline disorder.

2. Materials and methods

2.1. Evolution of hairline cracking during postharvest management

2.1.1. Fruit and packaging materials

Table grapes, cv. Thompson Seedless, harvested at commercial maturity (total soluble solid (TSS) were 18.3–18.8% and titratable acidity (TA) was 0.93–0.98%) were obtained from three commercial vineyards in Colchagua Valley, Chile. Eight clusters were enclosed individually in a 5% perforated polyethylene bag, placed inside a 0.3% vented polyethylene bag, and packaged in 8.2 kg wooden boxes. One SO_2 generator pad per box (Uvas Quality, Imal, Chile) was placed on top of packaged grapes. The SO_2 generating pad was composed of 1.1 g kg^{-1} sodium metabisulfite ($Na_2S_2O_5$) with 0.18 and 0.91 g kg^{-1} $Na_2S_2O_5$ of fast and slow SO_2 release phases, respectively.

2.1.2. Postharvest management

Packaged grapes were subjected to: (1) delayed cooling (12 h at 20 ± 5 °C); (2) commercial force air cooling for 12 h to lower pulp temperature to 0 to 4 °C; (3) storage for 5 days at 0 °C; (4) warming for 4 h at 10 °C to simulate loading process; or (5) storage for another 25 days at 0 °C. With the exception of storage for 5 days at 0 °C, three boxes were randomly selected and evaluated at the end of each process.

2.2. Effect of sulfur dioxide and pH on hairline induction under controlled conditions

2.2.1. Exposure to sulfur dioxide

A system that simulated SO_2 emission from SO_2 generating pads, commercially used to control fungal decays during transportation, was implemented (Zoffoli, 2002; Franck et al., 2005). Thompson Seedless table grapes, harvested at similar maturity (17.8–18.3% TSS, 0.71–0.75% TA) were used, and 50 berries, detached with their pedicels from vineyard 1 (Aconcagua Valley, Chile), were distributed on plastic grids inside a 3.6 L polypropylene box (Tupperware, USA). The boxes were sealed and gaseous SO_2 concentrations generated using 0, 2, 4, 6 and 8 g kg^{-1} of sodium metabisulfite (Merck, Darmstadt, Germany) packaged inside a 32 cm^2 paper kraft envelope. A humid atmosphere (>95% relative humidity) was produced with a water impregnated paper towel placed at the bottom of each chamber. The SO_2 concentration inside the box was determined in a closed system every 6 h with the aid of a pump (3.33 mL s^{-1}) driven through silicon tube inserted in the middle of the box and an infrared analyzer (Horiba PIR 200, Kyoto, Japan) at the other end, previously calibrated with 1883 μL L^{-1} of SO_2. Berries were exposed to the SO_2 atmosphere for 12, 18 and 24 h at 20 °C. One box per treatment was evaluated. This experiment was repeated twice with grapes obtained from vineyards 2 and 3, located in Aconcagua Valley and Colchagua Valley, Chile, respectively.

An additional experiment to study the effect of low SO_2 concentrations on hairline development was conducted with Thompson Seedless table grapes obtained from vineyard 4 (Colchagua Valley, Chile). SO_2 concentrations were generated using 0, 1, 2, and 4 g kg^{-1} sodium metabisulfite and the grapes were exposed for 6, 8, and 10 h. Four 3.6 L polypropylene boxes per treatment were used.

2.2.2. pH solutions

The effect of pH conditions on the berry surface and hairline development was studied using 0.1 M citric acid and 0.2 M disodium phosphate solutions. These solutions were prepared using the following citric acid:disodium phosphate ratios 2:98, 62:38, 37:63, or 1:99, to obtain a final pH of 2, 4, 6, or 8, respectively (Lichter et al., 2002). Four groups of 25 berries with pedicels attached were selected from vineyard 4 and immersed for 3, 4, or 8 h in each pH solution. The effect of the pH solutions was determined after storage in a humid atmosphere for 24 h at 0 and 20 °C. An equal number of dry berries and berries immersed in distilled water, pH 7, were controls.

2.3. Incidence of hairline under commercial conditions using different systems of sulfur dioxide generating pads

2.3.1. Fruit material

Table grapes, cv. Thompson Seedless, were harvested at maturity (16–17% TTS, 0.75–0.8% TA) in commercial vineyards located in Buin (Maipo Valley, Chile). Clusters were individually packaged in perforated bags with 5% vented area.