EFFECTS OF PACKAGING AND POSTHARVEST COOLING ON QUALITY OF TABLE GRAPES (*Vitis vinifera L.*)

BY

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

SUMMARY

The table grape industry uses rapid cooling and packaging to protect grapes from desiccation and decay. Numerous packaging methods and combinations are used in the industry with each having their own advantages and disadvantages.

Inferior postharvest grape quality can usually be ascribed to either deficient or excessive moisture in the carton. Berry split, decay and SO_2 damage are all disorders that are either caused or aggravated by wet berries in conjunction with elevated temperature. On the other hand, grapes that are exposed to desiccating conditions will develop brown stems and cause ineffective control by SO_2 gas generators. Moisture management is governed by perforated or non-perforated liners and/or by placing moisture absorbing materials inside the liners. To find the optimum liner perforation or moisture sheet combination, 'Thompson Seedless' and 'Red Globe' (*Vitis vinifera Linnaeus)* table grape quality was evaluated in various trials.

The investigation of non-perforated liners compared to liners with different degrees of perforation concluded the following: Perforated liners benefit grape quality by decreasing SO_2 damage and berry split due to less moisture in the carton. These benefits, however, also lead to loss in quality due to increased stem desiccation and a lower SO_2 concentration in the packaging. The lower moisture content in the carton compensates for the lower SO_2 concentration, creating an environment less favourable for decay development. SO_2 damage and berry split decreased with an increase in degree of liner perforation, irrespective of the cultivars sensitivity to the disorder. Optimum level of perforation depends on the specific sensitivity of a cultivar to certain quality disorders and the characteristics of the quality disorders associated with a cultivar. Additionally, packing conditions such as product temperature and humidity should be considered. The specific costs associated with the advantages and disadvantages influenced by the degree of liner perforation will be the deciding factor in liner selection.

The investigation of a clay-containing, moisture absorbing sheet emphasized the benefits and risks of absorbing large amounts of water within the packaging. Irrespective of using a perforated or non-perforated liner the influence of the desiccant sheet was evident throughout the trials. It benefited grape quality by lowering the incidence of berry split and SO_2 damage.

However, decay control was impaired by the desiccant sheet, and stem desiccation was aggravated.

The comparison of non-perforated liners with liners of various degrees of perforation showed the benefit of faster cooling rates of perforated liners. The various perforated liners showed little variation in airflow and cooling times.

Morphological studies of various cultivars could not ascribe differences in stem condition to anatomical dissimilarities between various cultivars. It was found that 'Red Globe' had a much larger berry volume to stem weight ratio contributing to a high rate of water loss and stem dehydration. Stem visibility is high in 'Red Globe' due to the straggly, loose nature of the bunches. This heightens the perception of dry, brown stems and overemphasizes the actual severity of the disorder.

OPSOMMING

Die tafeldruifbedryf gebruik versnelde verkoeling en verpakking om druiwe te beskerm teen uitdroging en bederf. Verskeie verpakkingsmetodes word gebruik in die industrie waarvan elkeen sy eie voor- en nadele het.

Ondergeskikte na-oes kwaliteit kan gewoonlik toegeskryf word aan óf te min óf te veel vog in die karton. Korrelbars, SO_2 skade en bederf is almal kwaliteitsdefekte wat óf veroorsaak word, óf vererger word deur nat korrels, saam met 'n verhoging in temperatuur. In teenstelling hiermee sal druiwe wat blootgestel word aan droë toestande, bruin stingels ontwikkel en SO_2 beheer sal ook ondoeltreffend wees. Vog in verpakking word beheer deur geperforeerde of nie-geperforeerde binnesakke en/of deur vogabsorberende materiaal binne die binnesak te plaas. Om die optimum binnesak perforasie of vogabsorberende vel kombinasie te vind is 'Thompson Seedless' en 'Red Globe' (*Vitis vinifera Linnaeus)* tafeldruif kwaliteit ge-evalueer in verskeie proewe.

Die bestudering van nie-geperforeerde binnesakke teenoor binnesakke met verskillende grade van perforasies het die volgende resultate gelewer: Geperforeerde binnesakke bevoordeel druif kwaliteit deur die vermindering van SO_2 skade en korrelbars weens minder vog in die karton. Hierdie voordele sal egter lei tot verlies in kwaliteit weens die vinniger uitdroging van stingels en die verlaging van SO_2 konsentrasie in die verpakking. Die laer vog inhoud in die karton vergoed vir die vermindering van SO_2 konsentrasie, omdat minder gunstige toestande vir die ontwikkeling van bederf geskep word. SO_2 skade en korrelbars het verminder met 'n vermeerdering van perforasies, ongeag die kultivar se sensitiwiteit vir die defekte. Optimum vlakke van perforasie is afhanklik van die spesifieke sensititiwiteit van 'n kultivar tot sekere kwaliteitsdefekte, en eienskappe van die kwaliteitsdefekte wat geassosieer word met die kultivar. Boonop moet verpakkingsomstandighede soos produktemperatuur en humiditeit ook in gedagte gehou word. Die spesifieke koste verbonde aan die voor- en nadele wat beïnvloed word deur die graad van perforasie sal die bepalende faktor wees wanneer 'n binnesak gekies word.

Die bestudering van 'n klei-bevattende, vogabsorberende vel het bewys dat dit voordele en risiko's inhou om groot hoeveelhede vog te absorbeer. Ongeag die gebruik van 'n

geperforeerde of nie-geperforeerde binnesak, was die invloed van die desikkante vel duidelik in al die proewe. Dit was voordelig vir druif kwaliteit deurdat dit korrelbars en SO_2 skade verminder het. Bederfbeheer is egter verswak deur die desikkante vel, en stingel uitdroging is vererger.

Die vergelyking van nie-geperforeerde binnesakke met verskillende grade van geperforeerde binnesakke het die voordeel bewys van vinniger verkoelinstempo's van die geperforeerde binnesak. Verskille in die graad van perforasie het 'n klein invloed gehad op die lugvloei en verkoelingstempo's.

Bestudering van verskeie kultivars kon geen morfologiese verskille uitwys wat variasie in stingelkwaliteit tussen kultivars kan verklaar nie. Dit is bevind dat 'Red Globe' 'n baie groter korrelvolume tot stingelgewig verhouding het. Stingels is meer sigbaar by 'Red Globe' weens die yl, los aard van die trosse. Dit verhoog die persepsie van droë, bruin stingels en dit oorbeklemtoon die voorkoms van die defek.

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1.1 INTRODUCTION

1.1.1 Overview

The great distance that South African fruit has to travel to export destinations, necessitates storage of fruit for longer than one month. This includes large numbers of table grape cartons being shipped mainly to Europe and the United States. The inherently low respiration rate of harvested grapes is being slowed down further by packing grapes with low pulp temperature in polyethylene liners and then cooling it down as soon as possible to a temperature of –0.5 °C. The use of polyethylene liners creates a high relative humidity inside the liner and restricts moisture loss of the grape bunches. This creates an ideal environment for the growth and development of fungi. The biggest cause of decay in export grapes is the fungus *Botrytis cinerea* (Nelson, 1969), also known as grey mould.

Cold chain maintenance throughout the transport of table grapes is necessary to keep grapes at optimum quality. The *B. cinerea* pathogen infects the flowering part in the field and then lies latent in the developing fruits until conditions are favourable for further growth (Williamson, 1997). Fruits that appear to be healthy are often packed and shipped, later undergoing severe postharvest decay (Snowdon, 1990). In an attempt to prevent berry decay, resulting from fungal growth within export grape cartons, sulphur dioxide (SO_2) gas is applied. This is effectively used in the industry by fumigating the grapes with SO_2 gas or by placing a SO_2 generating sheet in contact with the grapes, inside the liner. In most instances the sheet contains sodium metabisulphite, which generates SO_2 gas (Gentry and Nelson, 1968).

1.1.2 Physiology of the grape berry

The berry develops after the ovary has been fertilized. The berries develop in clusters and are attached to the rachis through short pedicels containing vascular bundles. Water and nutrients move through these bundles to the berries (Coombe, 1976). In seedless cultivars, either the cultivar is not fertilized and the seeds do not develop at all, or seed development stops at an early stage of grape development (Coombe, 1973). Development of grapes on the vine can be divided into two phases. After flowering, cell division takes place and the berries grow rapidly. A high metabolic rate and accumulation of acids are measured in this phase,

lasting for one to two months. The second phase follows where maturation and ripening take place. This phase is characterised by softening of berries. Other changes that occur are a lower respiration rate, an increase in glucose and fructose concentrations, colour changes taking place and acidity being diluted by the inflow of water into berries (Kanellis and Roubelakis-Angelakis, 1993).

Growth regulators have been shown to be involved in all of these stages (Kanellis and Roubelakis-Angelakis, 1993). Gibberellin-like substances appear to be important in cell expansion and the attainment of full berry size. The gibberellic acid content correlates with the number of seeds, and exogenous application of gibberellic acid to seedless cultivars is common practice to control bunch shape and berry size (Lynn and Jensen, 1996). A peak of ethylene production occurs at flowering, generally followed by a decrease until harvest. There is no dramatic increase in respiration or ethylene production coincident with ripening, therefore grapes are classified as non-climacteric (Salisbury and Ross, 1992).

In order to achieve produce with maximum sweetness, grapes are picked from the vine when they reach the required predetermined soluble solids concentration. These concentrations are minimum requirements to be achieved for export standards. The concentrations vary between cultivar and growing area. Titratable acidity and sugar to acid ratio are also used as maturity indicators (Crisosto and Mitchell, 2002). After harvest, berries produce almost no ethylene and respiration stays at a steady rate (Snowdon, 1990). Respiration is in a range of 5-10 mg $CO_2.kg^{-1}.h^{-1}$ at 5 °C (Kader, 1992). At the stage when grapes are harvested, they are also starting to senesce. Senescence is retarded by rapid cooling and by storing grapes at -0.5 °C.

1.2 FACTORS INFLUENCING THE POSTHARVEST QUALITY OF TABLE GRAPES

1.2.1 Temperature

Grape berry temperatures are manipulated by cooling grapes down and then storing at certain temperatures. Grapes should be cooled down as quickly as possible. Effective cooling will minimise water loss from berries and stems (Nelson, 1978). The meaning of effectiveness in this case, is to get the surrounding air temperature of grape bunches down to -0.5 °C as

quickly as possible. As long as there is a temperature difference between the grape bunch and the surrounding air, a vapour pressure gradient is maintained and grapes will lose moisture.

Low temperatures slow down the metabolic processes in cells which continue during postharvest handling. Compounds such as sugars and organic acids are oxidized to carbon dioxide (CO_2), and the oxygen (O_2) absorbed is reduced to form water. Energy is released to be used by cells, but heat is also generated as a by-product. The rates at which products deteriorate are proportional to their respiration rates. Respiration can be slowed down dramatically by cooling. The Van't Hoff rule states that the velocity of a biological reaction increases two to three fold for every 10 °C rise in temperature (Salisbury and Ross, 1992). Low temperature protects the non-appearance quality attributes such as aroma, texture, nutrition and flavour from deteriorating (Paull, 1999). Low temperature storage therefore ensures that stored grapes deteriorate slower and are still marketable after long periods of storage.

Low temperatures also slow down or stop the growth of fungi. The SO_2 gas that is used to control and kill mycelia is temperature dependant. The lower the temperature, the lower the killing effect of the gas, but with an increase in temperature a higher occurrence of SO_2 damage can be expected (Smilanick et al., 1990a). Higher temperatures also increase the sulphite residues and the SO_2 source is depleted earlier than expected, leaving grapes unprotected.

Temperature also influences the abscission process in certain grape cultivars such as 'Thompson Seedless' and 'Waltham Cross'. Low temperatures lessened the occurrence of berry abscission in packed cartons. High temperatures can be the cause of berry split and can aggravate stem browning (Burger, 2000).

1.2.1.1 Cooling of grapes

In the packaging, handling, transport, marketing and distribution of grapes, a great number of changes in the industry had a direct influence on the actual requirements of cooling. New

packaging materials, new packing methods and different pallets increase the difficulty of cooling grapes rapidly and effectively (Mitchell, 1978).

In South Africa, table grapes are packed in non-perforated liners and are typically forced-air cooled to –0.5 °C over a 36 to 72 hour period (Combrink et al., 1978). This method is time consuming and can cause congestion at cooling facilities over peak times (Thompson et al., 2002). Other cooling methods such as vacuum cooling or hydro-cooling are not suitable for grapes (Nelson, 1978). Some exporters use perforated liners to increase the cooling rate. The rate at which the pulp temperature decreases, depends on the volume of cold air, the speed at which the cold air is moving and the amount of contact that it makes with the berries. Efficient forced-air cooling requires packaging designed so that cold air flows past individual parts of the product and air is kept at a consistent low temperature (Thompson et al., 2002). Perforated liners will therefore have an advantage with regards to the cooling rate, because cold air is moving directly through the grape bunches and this will increase the volume of air movement. This will enhance the heat transfer from grapes to the air returning to the coil. Non-perforated liners rely more on conduction than convection for cooling (Nelson, 1978).

To prolong shelf life and to ensure top quality export grapes, cooling equipment has been designed to meet South African conditions. In the Lower Orange River the grape pre-cooler removes field heat from freshly picked grapes from as high as 40 °C and cools the product down to 18 °C before being packed in a pack house where the temperature is kept at 20 °C. Grapes are picked in plastic crates, stacked on pallets and placed in the pre-cooler to remove the field heat. Once the target temperature is reached, the crates are removed from the pre-cooler and are fed into the pack house via a conveyer system.

An evaporative cooler is ideal for regions with high temperatures and low humidity like the Lower Orange River. The air in the pre-cooler is cooled and humidified by evaporation of water from a 'wet wall' heat exchanger. Wet wall coolers are less effective in the production areas of South Africa where temperatures are generally lower and humidities higher. In these regions, mechanical refrigeration systems are required for effective pre-cooling.

1.2.1.2 Factors influencing cooling

1.2.1.2.1 Pre-cooling and delays

Wedgwood (2001) claims that pre-cooling grapes to ± 20 °C has the advantage of rapid removal of field heat. This causes a higher humidity inside the carton that preserves the natural freshness and appearance of the grapes as well as reducing the appearance of dry stems and berry abscission. It will also extend shelf life and prevent weight loss. Pre-cooling can reduce the free moisture in polyethylene liners once grapes have been packed.

Ginsburg and Combrink (1972) define pre-cooling as the reduction of product temperature, at arrival at the cold store, to the optimum low temperature at which the product must be cold stored. The term pre-cooling can also describe the partial removal of field heat from grapes to ± 20 °C. Burger (2000) compared field heat removed grapes with grapes that were kept in the shade before packing. No significant difference was found in the post storage incidence of berry split and berries that were abscised. Pre-cooling had a beneficial effect on berry quality, with less *Botrytis* decay and better stem quality in grapes that were stored for five weeks at 0 °C. The evident difference that field heat removal made in quality was lost after the shelf life period of seven days at 10 °C.

Burger (2000) found that delays in cooling prior to packing, aggravated berry abscission. When forced air-cooling was delayed for eighteen hours, grapes had significantly higher levels of berry split directly after the delay period compared to shorter delay times. In addition, the incidence of *Botrytis* decay increased significantly for grapes which had a delay period of twelve hours before packaging. Gentry and Nelson (1968) found that grapes packed in perforated liners after a one or two day pre-cooling delay, led to a drastic deterioration in fruit quality compared to grapes that were cooled immediately.

1.2.1.2.2 Packaging

Sealed packaging will increase relative humidity which in turn will delay senescence and retain firmness of fruits and vegetables by alleviating water stress (Ben-Yehoshua et al., 1983; Polderdijk, 1983). It takes longer to cool non-perforated liners, but less moisture is lost out of the direct environment around the grapes (Gentry and Nelson, 1964), ensuring a higher

humidity around grapes making them less susceptible to moisture loss (Guelfat-Reich and Safran, 1973).

Nam et al. (1998) stored grapes for 80 days using liners that were 0.05 mm and 0.03 mm thick. They were compared to grapes of the control that were packed with no liner. Grapes from the control lost 11.7 % in weight after 80 days of storage at 0 °C and 90 % relative humidity. Grapes packed with the liner treatments lost only 0.5-1.5 % in weight. Firmness of the berries decreased with an increase in storage duration. Although the liners maintained the appearance of the grapes, flavour quality was very poor.

Söylemezoglu and Agaoglu (1993) evaluated stored grapes that were packed in perforated or non-perforated liners with or without SO_2-generator sheets. SO_2 treated grapes were stored for 105 days. Appearance and flavour did not differ much between treatments except for the control (without SO_2-sheet) which had a significant loss in quality after two months. Grapes stored in perforated liners had a better flavour. Grape bunches packed in non-perforated liners had less weight loss. Gentry and Nelson (1968) stored grapes in perforated and non-perforated packaging with SO_2-generating sheets. SO_2 damage increased in the packaging where non-perforated liners were used.

The type of packaging material used can have a direct influence on the SO_2 concentration inside the liner. Packing material can absorb SO_2 and lessen its effectiveness. During long-term storage, re-absorption of SO_2 from packaging can occur due to factors such as temperature and humidity changes. This is unpredictable and can cause SO_2 concentrations to rise above tolerance limits (Lagunas-Solar et al., 1992).

1.2.2 Growth regulators

The use of growth regulators is a common practice in the table grape industry. The application of 2-chloro ethyl-phosphonic acid, which releases ethylene, can be used to advance maturation and improve colour on cultivars such as 'Barlinka' (Blommaert et al., 1974). This practice does not influence berry size as with other growth regulators. The size of berries and the compactness or looseness of the bunch influences the rate of cooling. 'Thompson Seedless' and other seedless grapes are sprayed with gibberellic acid (GA_3).

Together with girdling, this increases the size of the berries, affecting the looseness or compactness of the bunch (Salisbury and Ross, 1992). Excessive GA_3 concentrations cause problems such as corkiness on stems and berries, berry split, decay (Jawanda et al., 1974) and delayed ripening (Singh et al., 1978). The synthetic cytokinin, forchlorfenuron (CPPU) is also used on table grapes to increase berry size (Das et al., 2001). If applied correctly the cytokinin can improve berry attachment leading to less berry abscission. It also thickens the berry skin resulting in less berry split, although excessive application can cause too much thickening and lower the eating quality (Lombard, 2003).

Bigger spaces between berries will lessen the chance of fungal attacks (Salisbury and Ross, 1992). Studies showed that indole-3-acetic acid (IAA) also increased berry weight and elongation of bunches, but not as much as GA_3 (Jawanda et al., 1974).

1.2.3 Decay

Two types of fungal decay are common in table grapes. The first type is bunch rot caused by primary pathogens such as *B. cinerea*. *Aspergillus niger* and *Rhizopus stolonifer* are two examples of the other type known as sour rot (Witbooi et al., 2000).

B. cinerea is the pathogen that is responsible for the most postharvest decay in table grape storage (Retamales et al., 2003). A very low disease level (<0.5 %) is normally tolerated by importing countries (Zoffoli et al., 1999). The disease can be severe in pre-harvest conditions when wet weather prevails, coinciding with berry ripening (Broome et al., 1995). Other ornamental and edible crops across the world are affected by it in storage as well as in the fields. The fungus commonly causes decay by latently infecting the flowers of produce and then causing decay on the berries. This process includes the fungi feeding and altering host nutrients causing the characteristic berry 'slip skin' (Williamson, 1997). According to Nelson (1979) annual losses due to berry rots caused by other pathogens are usually negligible.

Recent research has identified a disorder exhibiting symptoms similar to SO_2 damage and/or *Botrytis* decay, with severe flesh tissue maceration (Witbooi and Fourie, 2002). It is called soft tissue breakdown (STB) and differs from *Botrytis* decay in the way that the skin and the

berry flesh of infected parts will slide away if the 'slip-skin' method is applied. Berries with *Botrytis* decay will have a 'slip-skin' on infected parts if rubbed, with only the skin sliding off the flesh. SO_2 damage occurs on pedicel ends and the berry surface causing a bleached area with the berry remaining firm. STB symptoms are similar but characteristically the affected area will be soft and tissue will be macerated. Due to the similar symptoms, STB may have been identified as other quality disorders in the past and was not held responsible for losses in berry decay. It is important to identify the cause of the disorder in order to follow the correct control strategy. Research indicated that STB is caused by the pathogens *Penicillium*, *R. stolonifer* and *A. niger*. These fungi are also associated with the cause of sour rot in vineyards (Witbooi et al., 2000). STB infection occurs prior to harvest and is exacerbated by the use of SO_2-generating sheets (Witbooi and Fourie, 2002).

1.2.3.1 Weather

A high disease incidence occurs when cool and wet weather conditions prevail during harvest. The free water on the berries and the accompanying high relative humidity appear to be important factors in contributing to rapid development of decay (Nelson, 1951). Packing grapes in liners directly after rain creates conditions ideal for disease development, lengthening the infection and growth period. Large economic losses may occur when these grapes are stored or transported. Palou et al. (2002) found less incidence and nesting of *Botrytis* decay at 65 – 75 % humidity than at 95 – 98 %. Results in trials by Nelson (1951), showed that *Botrytis* infection would halt at a temperature of 12 °C and relative humidity of 80 %. Only when the relative humidity was raised above 90 %, did the fungus start growing again. The lowering of humidity cannot be used to control decay, because it will cause stem and pedicel desiccation (Gentry and Nelson, 1968). The current strategy of the South African grape industry regarding pack after rain, is to wait a few days until grapes are dry, at which time identification and elimination of infected berries is possible.

1.2.3.2 Postharvest treatments that control decay

1.2.3.2.1 Sulphur dioxide (SO_2)

Considering financial and practical factors, there is no alternative to the use of sulphur dioxide by the industry. SO_2 gas is a very effective contact fungicide that inhibits the

development of *B. cinerea* during the transportation and storage of grapes over long intervals (Ben-Arie et al., 1995, Yun et al., 1995). SO_2 gas is not effective to control fungi growth inside berries, and therefore it is standard procedure to remove infected berries before packaging. SO_2 generating sheets enclosed in a liner are commonly used by the South African table grape industry. In certain conditions, this method can create a phytotoxic environment in the liner (Ben-Arie et al., 1995). The use of liners, as well as the type of liner in the carton, greatly influences the effectiveness of the generating sheet, as it retains SO_2 gas and prevents excessive moisture loss (Morris et al., 1992).

In other parts of the world, such as Chile and California, grapes are fumigated with SO_2 gas. Harvested grapes are fumigated as soon as possible with an initial dose of 1000 - 10000 $\mu l . l^{-1}$ SO_2, killing spores and mycelium growth on the surface of bunches. Subsequently grapes are fumigated weekly with 500 - 2500 $\mu l . l^{-1}$ SO_2 gas in cold storage to retard surface growth and prevent the development of latent infection (Smilanick et al., 1990a). Smilanick and Henson (1992) proposed a refinement on this 60-year-old practice. They did this by finding the minimum effective dosage, thus making it more reliable and safe. They found that SO_2 gas could be applied before cooling, during cooling or after cooling, bearing in mind that temperature influences SO_2 toxicity to spores. A rise in temperature of 10 °C between 0 °C and 20 °C, increased SO_2 toxicity to *Botrytis* spores about 1.9 fold. Smilanick et al. (1990a) found that the sensitivity of *Botrytis* spores increased two- to fourfold for each increase in 10 °C for a temperature range between 0 °C and 32 °C.

Smilanick et al. (1990b) found that the concentration of SO_2 gas used in commercial fumigations exceeded the required amount that killed spores in chamber studies. In their trials, they used grape juice to test the effectiveness of SO_2 against *B. cinerea* at different temperatures and pH's. They confirmed that SO_2 was the primary toxic form in which it occurs. The lower the temperature, the higher the SO_2 concentration had to be to kill 99 % of the spores. This confirmed what Smilanick et al. (1990a) found regarding the influence that higher temperatures had on SO_2 toxicity to *Botrytis* spores.

Studies done by Pieser and Yang (1985) established the amount of residual sulphite in 'Thompson Seedless' berries. The residual sulphite was investigated after berries were

fumigated with 500 $\mu l . l^{-1}$ SO_2 at 0 °C. They found two forms of sulphite: free and bound. The free sulphite makes up 70 % of the total sulphite and is lost quickly with a half-life of four hours. The bound part is much more stable and has a half-life of 20 hours. They considered the bound fraction as the important form in which sulphite is stored and readily released as the free fraction dissipates. Their results pointed out that the levels of sulphite decrease rapidly and only 15 % remained after one day. This highlights the importance of the initial fumigation having a high enough concentration to inhibit spore germination and protecting grapes until the next fumigation. A trade-off must be found between a high enough amount of fumigation to last until the next fumigation, but not damaging the berries.

Smilanick et al. (1990a) found that berries with cuts accumulated seven times more sulphite than healthy berries. Residues can be minimised by selecting and packing healthy berries, using the minimum fumigation dose and by storing grapes until SO_2 diminishes. The current European Union maximum residue limit for sulphite is 10 $\mu g.kg^{-1}$.

SO_2 fumigation and SO_2-generating sheets can both cause bleaching of the berry or hairline splits on the berry surface (Palou et al., 2002). This disorder is especially detrimental in coloured table grape cultivars (Retamales et al., 2003). Bleached or sunken areas occur when the gas is released in excessive amounts and penetrates into skin wounds or stem ends. The gas dissolves in water to form sulphurous acid. The incidence of these injuries depends on the cultivar, the type of sheet or fumigation used, postharvest handling, condition of the bunch and environmental conditions (Palou et al., 2002). The disorder is aggravated when grapes are packed on a warm day in non-perforated liners. This causes conditions ideal for berry bleaching, viz. high temperature and high humidity inside the liner (Nelson and Ahmedullah, 1973). SO_2-generating sheets are designed to release the gas when it is exposed to moisture (Morris et al., 1992; Adams, pers. com., 2003). When water condensation occurs inside the liner due to temperature fluctuations (Paull, 1999), excessive amounts of SO_2 gas will be released. This will not only cause damage, but will also deplete the sodium metabisulphite and leave grapes unprotected against decay during further storage. Gentry and Nelson (1968) used cooling delays to study the effect on SO_2-generating sheets. At higher temperatures, the sheets generated higher levels of SO_2. This is due to the water vapour pressure having a direct relationship with temperature (Ginsburg and Combrink,

1972). Higher temperatures result in higher amounts of free moisture reaching the sodium metabisulphite and increasing the generation of SO_2 gas.

There is an ever-increasing pressure on exporters to develop alternative ways of protecting grapes from decay (Retamales et al., 2003). Asthma, bronchitis, pulmonary resistance and bronchoconstriction are ever increasing problems related with SO_2 gas (Smilanick et al., 1990a).

Studies have shown that even with SO_2 fumigation at higher than recommended dosages, 'Thompson Seedless' grapes can be held in storage for 15 weeks without exceeding 10 $\mu g.g^{-1}$ SO_2 level. This is the tolerance level used in the USA (Austin et al., 1997). Söylemezoglu and Agaoglu (1993) evaluated stored grapes that were packed in six kg cartons with non-perforated liners containing SO_2-generating sheets. Over a period of 105 days, they measured the maximum SO_2 levels and always found them within maximum permissible levels.

Lagunas-Solar et al. (1992) studied the uptake, retention and distribution of SO_2 gas in commercially important table grapes cultivars. Either a process in the berries or the atmosphere in the package oxidizes the SO_2 which is generated inside the carton. These two processes affect the overall sulphite residue on grapes. Higher temperatures after fumigation increased the loss of sulphite residues. They also found that by exposing grapes to SO_2 only sulphates or sulphites were formed and no other S-containing chemical.

Smilanick et al. (1990b) investigated commercial fumigation with SO_2 and identified factors that can influence residues in this process. The authors found that SO_2 has a half-life of 24-36 hours at 0 °C. As in other studies, they emphasised the importance of using undamaged berries to minimise the uptake of sulphite. Infected or damaged berries accumulated seven times more SO_2 than undamaged berries. Grapes fumigated at higher temperatures accumulated more SO_2, but residues dissipated more readily. Immature grape berries from three out of the four cultivars tested, accumulated more SO_2.

There are three different types of SO_2 generating sheets that are used for different conditions or different storage times:

Quick or fast release, first stage

This type of sheet is used when storage or transportation is only a few days long. High levels of gas (> 200 $\mu l . l^{-1}$) are produced, which fumigate the exterior of the bunches, killing surface fungal spores (Smilanick and Henson, 1992). Typically, the generator is exhausted after 24 hours at 0 °C.

Slow release, second stage

The second, or slow release stage, combats any latent infection that may emerge from the stems or berries during storage (Palou et al., 2002). It is designed to be used in conjunction with fumigation or a fast release generator. After the initial high SO_2 dosage by the first-stage generator, this sheet protects grapes with a low SO_2 concentration for a long period. Typically, the sheet will emit SO_2 gas at a concentration of 2-3 $\mu l . l^{-1}$ for up to six months (Adams, pers. com., 2003).

Dual stage

This sheet is a combination of stages one and two, and is designed to be used on its own when the grapes are stored for longer than 3 weeks (Nelson and Ahmedullah, 1972). These sheets can produce sufficient amounts of SO_2 gas for several weeks in high humidity, low temperature environments (Lagunas-Solar et al., 1992; Morris et al., 1992).

The size of the generating sheet also influences the control of decay. If the generator covers the total area of the grape bunches, the control of decay will be uniform. Effective SO_2 gas contact can be maximised by placing generator sheets on top and underneath grapes, thus increasing uniform exposure (Nelson and Ahmedullah, 1972). Gentry and Nelson (1968) measured the concentration of SO_2 gas from generating sheets as it moved through packed grapes. They found a very steep gradient of gas close to the generating sheet. The SO_2 concentration fifteen centimetres away from the sheet, can be only a seventh of the concentration close to the sheet. They also had indications that this gas gradient can be increased if berries are smaller.

1.2.3.2.2 Chlorine (Cl_2)

Chlorine has long been accepted as a potent disinfectant used worldwide as a postharvest fungicide and bactericide to treat fruits and vegetables. Chlorine (as hypochlorous acid) is an effective and economical biocide that has been extensively used and is recognized as safe in many countries (Segall, 1968). Chlorine readily reduced populations of decay fungi but unfortunately table grapes cannot be subjected to water immersion treatments without altering quality and storage potential (Segall, 1968). Recently the possibility of replacing SO_2-generators with chlorine generators to control *Botrytis* decay in table grapes has been evaluated. Zoffoli et al. (1999) found that the degree of protection given by chlorine generators compared favourably to SO_2-generating sheets. Chlorine gas (Cl_2) produced by a salt mixture during 25 days of storage at 0 °C significantly reduced *Botrytis* decay in artificially-inoculated table grapes using cultivars such as 'Flame Seedless', 'Thompson Seedless', and 'Ribier'. Infections by conidia or mycelium of *B. cinerea* were suppressed for up to 45 days in cold storage, providing a similar degree of protection to that of one SO_2-sheet. It is widely accepted that conidia contaminating the surface of grape berries, and the mycelia of *B. cinerea* developed from diseased berries, are potential inocula for postharvest *Botrytis* decay during the storage of table grapes. Decay damage is also caused by latent infections caused by surface conidia, which is why grapes must be protected against decay throughout storage. The chlorine gas generator evaluated in this study significantly reduced *Botrytis* decay developed on artificially-inoculated grapes, with either conidia or mycelia, even after 45 days at 0°C, and without affecting fruit quality or acceptability by consumers. Furthermore, it may be an alternative to SO_2-generator sheets, particularly for grapes shipped to countries where the use of SO_2 is not allowed. Chlorine is corrosive and can cause damage to metal parts of cold stores. Chlorine dioxide (ClO_2) is more stable than chlorine and it is less corrosive and can also be used as a pre-harvest disinfectant (Cembali et al., 1999).

1.2.3.2.3 Carbonate and bicarbonate salts

Mlikota Gabler and Smilanick (2001) evaluated carbonate, bicarbonate and ozone solutions as a method to control the germination of spores of *B. cinerea*. The efficiency of the solution

alone, or in combinations, was determined and evaluations were carried out to investigate what impact it had on berry quality. Sodium carbonate, potassium carbonate, sodium bicarbonate, potassium bicarbonate and ammonium bicarbonate were evaluated for toxicity to spores of *B. cinerea in vitro* without controlling the pH. The concentrations that stopped 95 % (EC95) of spores germinating were 16, 17, 36, 58 and 163 mM, respectively. The bicarbonate solutions were adjusted to pH 7.2 and the mean EC95 concentrations for two *B. cinerea* strains of ammonium bicarbonate, sodium bicarbonate and potassium bicarbonate were 48, 102 and 112 mM, respectively. With the bicarbonates applied at 500 mM, ammonium bicarbonate controlled decay significantly better than the other two solutions. It was also more effective than potassium carbonate (100 mM) and chlorine (200 $ug.ml^{-1}$), and was equally effective to sodium carbonate (100 mM) and ethanol (70 % w/v). After treatments with ammonium bicarbonate, sodium bicarbonate, ethanol and chlorine, the quality of grapes was acceptable. Severe injuries, such as brown spots, may occur after treatment with sodium carbonate, potassium carbonate and potassium bicarbonate.

1.2.3.2.4 Ozone (O_3)

Ozone treatments significantly reduced the extent of berry decay caused by fungi following cold storage, and increased shelf life (Sarig et al., 1996). A significant decrease in decay was observed in berries that were treated with ozone either before or after being inoculated with *R. stolonifer.* This finding indicates that, in addition to its sterilizing effect, ozone also induced resistance to postharvest decay development. The phytoalexin resveratrol was elicited by ozone treatments, at levels similar to those produced by UV-C irradiation. Exposing berries to ozone was almost as effective as SO_2 fumigation for the control of storage decay caused by *R. stolonifer*, and no deleterious effects were observed on the appearance of the grape bunch. Ozone treatments can therefore be considered as a possible substitute for SO_2 fumigation for the control of postharvest decay.

Mlikota Gabler and Smilanick (2001) found that ozone in water at 10 $ug.ml^{-1}$ significantly controlled grey mould, although its efficiency was dependent on grape condition. The ozone treatment was responsible for minor rachis burning on the treated grapes.

1.2.3.2.5 Methyl jasmonate (MeJA)

Botrytis decay also occurs on greenhouse roses. Flower petals are infected and humid conditions and high temperatures aggravate fungal growth. Meir et al. (1998) examined methyl jasmonate (MeJA) as a means for postharvest control of *Botrytis* decay in cut rose flowers, and some significant levels of suppression of *Botrytis* decay were found. *Alternaria brassicicola* or *B. cinerea* disease development were efficiently reduced on Arabidopsis plants by pre-treatment with gaseous MeJA (Thomma et al., 2000).

1.2.3.2.6 Modified atmosphere packaging (MAP)

Packaging which can alter or manipulate the atmosphere around grapes is being investigated to address issues such as pathogen infection and water loss. Packaging of horticultural crops within plastic films creates a modified atmosphere (MA) higher in CO_2 and H_2O and lower in O_2 than ambient levels, in response to the respiration of and moisture loss from the commodity (Pesis et al., 2000). If the product and film permeability characteristics match properly with a package, the desired modified atmosphere can be generated passively via the respiration of the product (Kader and Watkins, 2000). Using MAP may lessen the dehydration of stems or lessen the effect of ethylene, if any, on postharvest table grapes. Controlled or modified atmospheres have been shown to suppress the development of *B. cinerea* on a number of fruits (Polderdijk et al., 1983) and these methods may therefore provide an alternative to the use of conventional SO_2 sheets.

1.2.3.2.7 Controlled atmosphere (CA)

Optimal controlled atmosphere (CA) combinations of low O_2 and high CO_2 levels have been developed for different fruit species and even cultivars within the same species (Kader, 1997), but CA is not recommended for commercial use on table grapes (Nelson, 1969). However, until recently, limited research has been conducted on the benefits of CA during postharvest handling of table grapes (Retamales et al., 2003). Ever-increasing pressure from consumers to use lower SO_2 concentrations highlights the importance of finding an alternative for decay control. This has caused researchers to re-evaluate CA because it offers an environmentally-friendly alternative to SO_2 gas. The influence of CA conditions with an

emphasis on *Botrytis* decay development has been evaluated for 'Emperor' grapes (Uota, 1957 as cited by Crisosto et al, 2002). Berry and Aked (1997) and Uota (1957) included the following among CA benefits for grapes: delaying senescence, decreasing stem and berry respiration, reducing stem browning, maintaining berry firmness, and delaying decay development. However, formation of off-flavours and berry browning are a concern (Nelson, 1969). In early harvested 'Thompson Seedless' grapes from the Coachella Valley, Nelson (1969) found that berry internal browning overshadowed the potential benefits of CA.

Retamales et al. (2003) tested the efficacy of CO_2 enriched atmospheres on decay control of organically-grown 'Thompson Seedless' and 'Red Globe' table grapes during storage at 0 °C. Treatments included storage with or without SO_2-generating sheets and berries with or without *Botrytis* inoculation. They concluded that a CA with 15 % or higher CO_2 resulted in similar control than a SO_2-generating sheet. However, the use of a CO_2-enriched atmosphere aggravated stem browning.

1.2.3.2.8 Ultra violet-C light

Ultra violet (UV) radiation can cause weak stress responses in plants often associated with plants developing higher levels of resistance against pathogen attacks (Hadwiger and Schowochau, 1971). A trial by Nigro et al. (1998) with UV-C light (190-280 nm wavelengths) tested the effect that it had on grape berries. They found that pre-treatment with low UV-C doses followed by artificial inoculation with *B. cinerea*, reduced postharvest grey mould development on table grapes.

Jeandet et al. (1991) studied the phytoalexin, resveratrol, which is formed in grape berries in response to UV-irradiation. Resveratrol can resist the growth and development of *B. cinerea* (grey mould). Their trials showed that the phytoalexin decreased in content as the grapes matured and the sugar levels increased. They also found that resveratrol was synthesized in the berry skin and only occurred in a very low concentration in the berry flesh.

1.2.3.2.9 Ethanol dip

Grape bunches dipped in 50, 40 and 33 % ethanol prior to packaging had less or the same levels of decay than grapes protected with SO_2-generating sheets. The 20 % ethanol solution was less effective than the SO_2 gas method. Decay control was generally feasible for a cold storage period of four to five weeks and sometimes longer (Lichter et al., 2002).

1.2.3.2.10 Early detection of decay

Tomatoes were inoculated with a spore suspension of *B. cinerea* to identify the production of gases from the pathogen (Polevaya et al., 2002). The production of acetaldehyde, ethanol, ethylene and carbon dioxide were measured at 22 °C. The aim was to determine whether infections could be detected before the disease symptoms became evident. Although decay became visible between days two and three following inoculation, ethylene could be detected more than 24 hours before the first decay symptom was noticeable. A significant increase in CO_2 was detected only after four days. The higher CO_2 was associated with decay development. Acetaldehyde development in *Botrytis*-inoculated fruit increased from day three to five and then declined. A noticeable increase in ethanol evolution was detected from day five only (Polevaya et al., 2002).

Qadir et al. (1997) found that ethylene production by *Botrytis* spores was detectable especially if methionine was used as a growth medium. Ethylene production could be used as an early indicator for infection in harvested fresh produce (Polevaya et al., 2002). If the extent of the disease is known early, an effective control can be chosen without unnecessary damage to berries.

1.2.3.3 Sulphur dioxide as a predisposing factor to *Botrytis* decay

Taylor et al. (1990) studied the influence of SO_2 gas on grape berries. SO_2-generating sheets protect grapes from infection, but can also damage the berries' natural defences. They found that 'Waltham Cross' berries, with SO_2 damage, started to decay before the undamaged berries. The authors concluded that the shelf life of 'Waltham Cross' grapes can be significantly reduced due to SO_2 damage. The damage on the grape skin and pedicel-end opens the way for pathogens, causing decay. This problem may be cultivar-dependent

because the 'Barlinka' cultivar showed no difference between damaged and undamaged berries.

1.2.4 Berry abscission

Grapes often become detached from bunches while handling, transport and marketing are taking place (Ben-Tal, 1990). Berry drop and shatter are also terms used to describe this phenomenon. Predisposing factors such as moisture stress during the growing season, high temperatures at harvest and delays in cooling the grapes, may all play a part in aggravating berry abscission (Burger, 2000).

Wolf (1991) found that a temperature of 30 °C and higher during harvest increased the amount of postharvest berry abscission. Grapes harvested at low temperatures early in the morning, developed less berry abscission than grapes harvested at higher temperatures in the afternoon. Wagenaar (1985) concurred that berry abscission occurs when grapes are harvested under warm, dry conditions and increases even more if cold storage is delayed for 12 hours or longer.

Sandhu et al. (1990) packed 'Perlette' grapes in a polyethylene bag with 0.56, 0.84, 1.12, 1.40 and 1.68 % perforations. The lowest perforation (0.56 %) and lowest packing temperature had the least berry abscission while the highest perforation and highest packing temperature had the most berry abscission. Berry and Aked (1996) found that additional berry abscission would occur when prolonging the shelf life period. Grapes stored at 4 °C had significantly less berry abscission than grapes stored at 25 °C (Wu et al., 1992).

Burger (2000) found that abscission of berries increased with increased harvest maturity in 'Thompson Seedless' grapes. The abscission zones on older stems start to increase ethylene production as they get closer to senescing. An increase in ethylene production induces plant organ senescence and abscission (Salisbury and Ross, 1992). Ethylene production in plant tissue can be increased by stresses such as water stress (Berry and Aked, 1996). Therefore, if water loss during storage can be minimised, it is possible that production of ethylene will decrease and will result in directly decreasing berry abscission. Water loss can be inhibited by using non-perforated packaging. Yun et al. (1995) stored table grapes ('Campbell Early',

'Muscat Baily A', 'Tano Red', 'Sheridan' and 'Daebong') with an ethylene scrubber and the rate of berry abscission was reduced significantly.

Hedberg and Goodwin (1980) did studies on factors affecting grape abscission. Mechanical grape harvesting is a common practice used in the wine industry. Natural and ethephon-induced berry abscission were studied to improve on this process. During the cooler times of the day, berries were shaken off more easily. They concluded that the higher turgor pressure of the berries enhanced berry abscission. In table grapes, berry abscission can be aggravated by packing grapes with a high turgor in an enclosed environment. Similar to table grape cultivars studied by Burger (2000), Hedberg and Goodwin (1980) found that grape abscission varied between cultivars and that the sensitivity towards ethylene depended on cultivar and maturity.

1.2.5 Berry splitting

The occurrence of split berries in cartons is a common problem in the table grape industry. Berry split can be the cause of huge financial losses especially if grapes are packed after rain coinciding with humid conditions. According to Uys and Calitz (1997) as little as 10 mm rain at harvest time can cause a total loss due to berries that split. Cultivars such as 'Thompson Seedless' are very sensitive and split occurs even with the best postharvest handling.

Studies on packed grapes have shown that berries with higher sugar levels are less prone to split. Trials by Burger (2000) showed that grapes harvested at higher maturities had significantly less berry split. Pectic substances are mainly responsible for cell wall cohesion in association with calcium ions. As grapes mature, connections between individual cells loosen and cell walls degrade (Bernstein and Lustig, 1985). This might be due to the higher levels of the polygalacturonase enzyme in ripe grape berries. The Ca levels also decreased with ripeness (Cabanne and Donèche, 2001). Both these factors soften the berry skin and flesh making it less prone to split.

Studies from Meynhardt (1956) demonstrated that splitting was related to the osmotic potential of the vacuolar solution within the berry. Failure of the epidermis occurred only at

high atmospheric humidity. Under moderate conditions, enough water can evaporate out of the berry, relieving turgor pressure created by the dissolved solutes.

Considine and Kriedemann (1972) determined the critical turgor pressure where grape berries start to split. They found that cultivars prone to berry split could handle a turgor of up to 150 kPa before splitting commenced. Turgor inside resistant cultivars was increased to up to 400 kPa before the skin of the berry ruptured. They also found that the growth regulator p-chlorophenoxyacetic acid lowered critical pressure and gibberellic acid caused pressure to increase. The cells in the pericarp are able to absorb much more water than the epidermal tissue. This demonstrated that pericarp tissue is more viscoelastic than its surrounding epidermal tissue. Coombe (1987) found that there is a difference of solute accumulation between berry flesh and skin. These concentration differences and the anatomical differences between these two types of cells suggest why the skin splits and the underlying flesh does not.

Burger (2000) packed 'Thompson Seedless' table grapes in perforated and non-perforated liners at high (29.4 °C) and low (24.5 °C) temperatures. High temperatures aggravated berry split significantly, especially for grapes packed in non-perforated liners. Perforated liners significantly reduced berry split by 80 – 90 % compared to non-perforated liners.

1.2.6 Total soluble solids and acids

The stage of maturity not only determines the eating quality of grapes, but also influences the quality of grapes in cold storage (László and Loubser, 1995). Ripe grape berries contain high levels of sugar, which are important for flavour. Accumulating sugars create a driving force for cell expansion (Manning et al., 2001). Sugars start to accumulate at veraison, which is the onset of ripening. A ten-fold increase of hexose is common at this stage (Davies and Robinson, 1996). Glucose and fructose are the soluble sugars that mainly accumulate in the cell vacuole (Manning et al., 2001). Sucrose is the main form of photoassimilate transported to the grape berry (Coombe, 1992).

Perkins-Veazie et al. (1992) found no change in soluble solids during storage of 'Reliance', 'Saturn' and 'Venus' table grapes stored for six weeks. Morris et al. (1992) found that SO_2-

generating sheets had no effect on the percentage of soluble solids or on the pH. The pH and the acidity decreased significantly from seven weeks of storage to 10 weeks of storage at 2 °C.

Zhang et al. (2001) monitored biochemical changes of grapes during cold storage at 0 °C. The change of soluble solids content, reductive sugar content, total acid content, respiratory activity and pressure resistance during storage were studied. The causes of changes and the relation among those changes were analysed. The results showed that the changes of grapes during 60 days of cold storage were small, and no distinctive difference in texture and flavour between tested grapes and fresh grapes could be found.

1.2.7 Transpiration

Water loss causes faster deterioration due to wilting and shrivelling of berries. Berries will also lose crispness and juiciness. The loss of water through the berry cuticle or through the stem can be influenced by factors such as temperature, relative humidity, air movement and atmospheric pressure (Crisosto and Mitchell, 2002). Relative humidity is an environmental factor that influences rates of water loss of whole plant or excised plant organs such as grape bunches (Forney and Brandle, 1992). Cooling grapes, maintaining the cold chain and controlling relative humidity, can manipulate water loss. Relative humidity is very temperature-sensitive and any fluctuations in temperature at high relative humidity could result in condensation on the bunches. This will cause favourable conditions for decay development. At a relative humidity of 97 %, a fluctuation in temperature of as little as 0.25 °C can cause condensation (Grierson and Wardowski, 1978). Liners inside packaging slow down air movement. Anatomical differences such as the thickness of wax coatings on grapes or morphological differences such as surface-to-volume ratios are cultivar dependant (Chambers and Possingham, 1963; Kader, 1992). These cultivar-dependant factors must be taken into consideration when a specific cultivar is being handled and conditions must be adjusted accordingly.

1.2.8 Stem condition (Rachis browning)

Harvested grapes lose water and their firmness and turgor pressure decrease. Factors such as irrigation practices, cultivar and the handling of the grapes, influence the rate at which water

loss will take place in postharvest conditions (Crisosto et al., 2001). Trials done by Crisosto et al. (2002) emphasized the fact that cooling delays at high temperatures can aggravate stem browning. Firmness is one of the main indicators of quality in table grapes (Bernstein and Lustig, 1985). The failure of berries and stems to retain moisture causes the fruit stem to dry out and eventually the berries will shrivel and the stems will turn brown. Grape stems have a respiration rate of up to 15 times higher than the berries (Crisosto and Mitchell, 2002). Dehydration can be detected on stems long before grape berries start to wilt (Berry and Aked, 1996).

Gentry and Nelson (1968) conducted storage trials on 'Thompson Seedless' and found highly significant differences in stem condition between vented containers and unvented containers. They evaluated stem condition by estimating the percentage of the length of the main stems and laterals that were dry and brown for each cluster. The stems were 57 % dry and 45 % brown in the vented and 2 % dry and 4 % brown in the unvented container. Perkins-Veazie et al. (1992) had similar results. Grapes that had a barrier which restricted airflow, had much less rachis browning. Morris et al. (1992) also found that grapes protected by liners had less shrivelling and thus better stem condition than grapes packed without liners. Guelfat-Reich and Safran (1973) covered grapes with polyethylene covers and over a span of three weeks these barriers lessened stem desiccation. Burger (2000) showed that grapes harvested too mature showed an increase in stem desiccation, grapes packed in non-perforated liners lost significantly less moisture than perforated liners, and stem desiccation was significantly higher in the perforated liners.

1.3 CONCLUSION

Even with all the recent developments in other ways of controlling decay, SO_2 gas is still the most effective and widely used. The use of ozone and chlorine are showing promise, but have not been elevated to large scale use. The pressure from consumers to lower SO_2 residues or even stop using it is evident and alternatives for decay control must be found. There is also evidence that the use of SO_2 can have a detrimental effect on the berries, weakening natural barriers like the berry skin. This can cause berries to develop decay later on, even though precaution against it has been taken.

With the higher sensitivity towards SO_2 from the consumer the application process can be controlled more effectively. Using different strengths of SO_2-generators while taking cultivar and environmental conditions into account can be implemented to lower the overall application of SO_2. The distribution of the gas through the grape bunches must be evaluated due to the influence that the use of different packaging material can have on it.

The modification and manipulation of the packaging environment has been looked at as a way of keeping quality. The use of ethylene absorbers to lessen the occurrence of berry abscission and the control of CO_2 and O_2 to lessen decay can be used to improve on quality.

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ARTICLE I THE EFFECT OF DEGREE OF LINER PERFORATION ON THE QUALITY OF 'THOMPSON SEEDLESS' AND 'RED GLOBE' TABLE GRAPES.

ABSTRACT

In two consecutive seasons, 'Thompson Seedless' and 'Red Globe' cultivars were used to assess the quality influences of the following liners: a) standard, non-perforated liner, b) needle perforated liner, c) 2 mm perforated liner with 54 perforations, d) 2 mm perforated liner with 18 of the 54 perforations closed, and e) 2 mm perforated liner with 36 of the 54 perforations closed. Grapes were stored at -0.5 °C for 5 to 8 weeks and had a subsequent shelf life of one week at 15 °C. Berry abscission in both cultivars was not influenced significantly by liner type or by an increase in storage time. Averaging overall, the 'Red Globe' cultivar had higher levels of SO_2 damage, but had much lower levels of berry split than 'Thompson Seedless'. These quality disorders were influenced by liner type, showing similar tendencies in both cultivars. SO_2 damage was influenced significantly by liner type after five weeks storage at -0.5 °C. Grapes packed with the non-perforated liner had 19.5 % SO_2 damage which was significantly higher than for grapes packed with the needle perforated liner (11.8 %). Grapes packed with the 2 mm liner group did not differ significantly from either of the abovementioned, but they showed an increase in SO_2 damage as the degree of perforation decreased. Berry split was influenced significantly by liner type when averaged over cold storage evaluations. The non-perforated liner (10.8 %) resulted in significantly more berry split than all the other treatments. Overall the Botrytis decay levels were low and were not influenced by liner type for 'Thompson Seedless' or 'Red Globe'. In both cultivars the SO_2 damage, berry split, Botrytis decay and stem deterioration increased significantly as the storage time increased. In the case of 'Red Globe' stem condition deteriorated more rapidly and to a greater extent than 'Thompson Seedless'. Throughout the trials it was evident that grapes evaluated after the shelf life period had higher levels of the above quality disorders due to the extra week of storage at a higher temperature. Stem quality deteriorated slower in non-perforated liners. SO_2 damage and berry split decreased with an increase in degree of liner perforation, irrespective of the cultivars' sensitivity to the disorder. To choose the correct level of perforation, the specific sensitivity and characteristics of the quality disorders of the cultivar must be taken into account.

Additionally, packing conditions such as product temperature and humidity must be considered. The specific costs associated with the advantages and disadvantages influenced by the degree of liner perforation will be the deciding factor in liner selection.

KEYWORDS : Berry split, abscission, *Botrytis*, SO_2 damage, moisture in carton, stem quality, perforation, cooling rate

INTRODUCTION

The table grape industry is faced with numerous permutations of packaging all with their individual advantages and disadvantages. A liner with perforation or no perforation can influence the quality of grapes so much that the choice can determine if grapes will reach an export destination with a level of suitable quality. If a perforated liner is chosen, the level of perforation needs to be optimized to ensure that the most advantages are utilised. With all the different conditions affecting table grapes in a postharvest environment, the industry therefore needs to identify a liner combination that will give reproducible results commercially for the majority of export situations.

Vitis vinifera L cv. 'Sultanina' (Thompson Seedless) is one of the main export grape cultivars in South Africa. Nine million cartons were exported in the 2001/2002 season (Viljoen, pers. com., 2003). This cultivar develops quality disorders after packaging and storage. Splitting, abscission and decay of berries are responsible for large financial losses in the international table grape industry (Ben-Arie et al., 1995; Considine and Kriedemann, 1972; Uys and Calitz, 1997; Ben-Tal, 1990). 'Red Globe' table grapes are also an important export cultivar with seven million cartons being exported in the 2001/2002 season (Viljoen, pers. com., 2003). In storage, 'Red Globe' grapes are prone to develop SO_2 damage and stems that are dry with a brown colour (Retamales et al., 2003; Viljoen, pers. com., 2003). These conditions will be aggravated with an increase of storage period (Crisosto and Mitchell, 2002).

The bulk of the export crop is packed in 4.5 kg closed top corrugated cartons. Bunches are individually packed in plastic carry bags on top of a corrugated sheet and then enclosed in the carton with a 20 µm polyethylene liner. Before the liner is closed and taped, an SO_2-

generating sheet is placed on top of the grapes to prevent decay. To lessen damage by SO_2 gas some producers place a moisture-absorbing sheet (Mam-sheet) between the SO_2-sheet and the grape bunches.

Conventionally producers use non-perforated liners in grape cartons although perforated liners are increasingly being used. With non-perforated liners, SO_2-generating sheets can work effectively with no gas being lost through perforations (Combrink et al., 1978). This closed environment can cause a lot of moisture to condense on the inside of the liner (Nelson, 1983). At the onset of cooling, grapes have temperatures typically in excess of 25 °C. The higher the temperature, the higher the water vapour pressures in the berries and the higher the vapour pressure deficit between berries and the air inside the carton (Thompson, 2002). The air in the cold room has a temperature of –0.5 °C. As the cooling process commences, the moisture in the carton is cooled. When the air is saturated with vapour, dew point will be reached and vapour will condense on the inside of the liner. This occurs because the liner is in direct contact with cold air in the room (Burger, 2000).

A high humidity is needed to release SO_2 gas from a SO_2-generating sheet to prevent decay. Too much moisture, however, will release an excessive concentration of SO_2 gas and this can damage berries (László et al., 1981). SO_2-generating sheets can cause bleaching of the berry or hairline splits on the berry surface (Palou et al., 2002). Bleached or sunken areas occur when the gas is released in excessive amounts and penetrates into skin wounds or stem ends. The gas dissolves in water to form sulphurous acid. The incidence of these injuries depends on the cultivar, the type of sheet or fumigation used, postharvest handling, condition of the bunch and environmental conditions (Palou et al., 2002). The disorder is aggravated when grapes are packed on a warm day in non-perforated liners. This causes conditions ideal for berry bleaching, viz. high temperature and high humidity inside the liner (Nelson and Ahmedullah, 1973).

It is believed that berry abscission is genetically determined (Burger, 2000). Other factors such as moisture stress during growing, high temperatures at harvesting and delays in cooling of packed grapes also play a role. Ethylene production in plant tissue can be increased by stresses such as water stress (Berry and Aked, 1996). Therefore, if water loss during storage

can be minimised, it is possible that production of ethylene will decrease and will result in directly decreasing berry abscission. Subjecting sensitive cultivars to violent shaking and bumpy handling will increase berry abscission (Burger, 2000).

According to Considine and Kriedemann (1972), turgor pressure plays an important role in fruit splitting. Due to solutes present in the grape berry and because of water loss at the onset of cooling, berries exhibit lower water potential than free moisture inside the liner. This water potential gradient will force water to move through the cuticle and cell membranes into the epidermal cells. The pressure on the berry skin increases due to the subsequent increase in turgor. If this pressure is large enough, cells will rupture and this can cause berries to split or pedicels to detach from berries (Bernstein and Lustig, 1985).

Conventional packaging contains a moisture absorbing sheet (Mam-sheet) to absorb excessive moisture and prevent berry split, SO_2 damage and decay. Cultivars such as 'Thompson Seedless' still have large percentages of berries that split (Burger, 2000). This quality disorder can be reduced by using packaging that absorbs more moisture or has perforations that will aid in lowering the humidity inside the liner. However, these two methods may create an environment suitable for moisture loss out of stems, and lead to stem browning (Crisosto et al., 2001). With less moisture inside the carton, SO_2-sheets might not work as effectively and more berries will decay.

The lack of space and the time to forced air cool grapes in commercial cooling rooms will always be a constraint in the growing industry. To increase the throughput of cooling rooms the cooling rate of grapes can be enhanced by the use of perforated liners. Earlier evaluations of liners with 54 openings concluded that the 2 mm size perforations had more benefits than the 4 mm size (Gütschow et al., 2002). The purpose of the study was to evaluate liners with less perforation than the standard 2 mm liner for quality disorders on table grapes.

MATERIALS AND METHODS

PACKAGING

Five different liner types were used, viz. a) a standard, non-perforated liner (non), b) a needle perforated liner (needle), c) 2 mm perforated liner with 54 perforations ($^0/_3$), d) 2 mm

perforated liner with eighteen of the 54 perforations closed ($^1/_3$) and e) 2 mm perforated liner with 36 of the 54 perforations closed ($^2/_3$). All the liners were 20 µm thick. All the treatments were packed in a super vent carton (height = 118mm, length = 400 mm and width = 300 mm). The average net weight of each carton was 4.5 kg. To prevent decay, a 'Uvasys' green SO_2-generating sheet (Grapetek, South Africa) was placed on top of the grape bunches. A moisture-absorbing sheet (30 g/m^2) was placed between the grapes and the SO_2-generating sheet to prevent it from touching the grapes directly. The moisture-absorbing sheet and corrugated-sheet (which was placed under the grapes) absorbed moisture out of the air inside the liner.

CULTIVARS AND EVALUATIONS

Export quality table grapes from the Western Cape, South Africa, were packed in the middle of the picking window for a number of trials as follows:

2001/2002 season: 'Thompson Seedless' from the Hex River Valley (Trials 1 and 2), 'Red Globe' from the Berg River Valley (Trial 5) and Hex River Valley (Trial 6).

2002/2003 season: 'Thompson Seedless' from the Berg River Valley (Trial 3) and Hex River Valley (Trial 4), 'Red Globe' from the Hex River Valley (Trial 7) and Berg River Valley (Trial 8). In all trials, 180 cartons of grapes were packed and cooled according to commercial export standards.

On all the sampled grapes standard cultural practices were followed as far as irrigation, fertilisation, cluster preparation, pest and disease control and foliage management were concerned. Palletised grapes were forced-air cooled under commercial conditions to -0.5 °C and stored at -0.5 °C. All the grapes were harvested in the morning and weather conditions did not differ between trial dates, with hot sunny days as the norm. On the packing day, after five weeks and after seven weeks, 60 cartons of 'Thompson Seedless' were sampled, of which 30 were evaluated immediately. The remaining 30 were placed in 15 °C storage for seven days, before shelf life evaluation. Seven days of shelf life is considered as a very harsh treatment and was chosen to test grape quality to the limit. 'Red Globe' had six or eight week cold storage periods at -0.5 °C, followed by seven days at 15 °C.

Moisture in the cartons was evaluated subjectively using a rating of one for dry, two for limited condensation and three for excessive free moisture. Stems were also evaluated for colour and dryness, on a five-point scale, awarding one for fresh green stems and up to five for very brown and dry stems. The mass of the grapes was determined. Abscised berries in the carton were weighed, and then all the decayed berries were removed and weighed. The same method was carried out for split berries and berries damaged by sulphurous acid. The evaluation was always done in this specific order. Berries that could be classified with more than one of these disorders were only classified and weighed with the disorder that was ranked the highest. The ranking used was as follow: Berry abscission > decayed berries > split berries > SO_2 damaged berries. Measurement of total soluble solids (TSS) and titratable acid level (TA) were done by randomly selecting 50 berries out of a carton. The berries were juiced in a liquidiser and filtered. The percentage soluble solids was measured with an Atago DBX digital refractometer and expressed as degrees Brix. Titratable acidity was determined by titrating a 10 g aliquot of juice with 0.1N NaOH to a pH end point of 8.2, using an auto Metrohm 719 S Titrino titrator. The titratable acidity was expressed as percentage tartaric acid. Both of the instruments are equipped with automated temperature compensators.

STATISTICAL DESIGN AND ANALYSIS

A completely randomised design was used in the experimental pallet. The treatment design was a 5 x 3 factorial with liner treatments and storage times as factors. Evaluation times consisted of evaluations following cold room storage and following shelf life storage. Each treatment was replicated six times with one carton constituting as a single replicate. The statistical software programme SAS (Statistical Analysis Systems Institute, 1996) was used to calculate significant differences ($P \leq 0.05$) between liner type and storage times by using arcsin transformed data. Means are separated by Bonferroni multiple comparisons procedure ($P \leq 0.05$). The chi-square ($\chi^2 \leq 0.05$) test was used to determine liner type effects on non-parametric (subjective) data. Correlations between quality disorders were done with Pearson correlation ($P \leq 0.05$).

RESULTS AND DISCUSSION

Harvest maturities

Harvest maturities for 'Thompson Seedless' were 18.0 °Brix and 0.65 % TA (Trial 1), 18.8 °Brix and 0.52 % TA (Trial 2), 16.8 °Brix and 0.59 % TA (Trial 3) and 18.0 °Brix and 0.59 % TA (Trial 4). Harvest maturity for 'Red Globe' were 14.7 °Brix and 0.52 % TA (Trial 5), 15.7 °Brix and 0.50 % TA (Trial 6), 14.4 °Brix and 0.35 % TA (Trial 7) and 18.2 °Brix and 0.39 % TA (Trial 8). TSS and TA did not differ significantly between liner types for either cultivar following cold storage or shelf life (data not shown).

Cold storage: quality after storage at -0.5 °C

Berry abscission. In the 'Thompson Seedless' trials, in both seasons, average berry abscission levels ranged between 1.2 % and 4.8 % (data not shown). Berry abscission increased significantly when storage times increased only in Trial 2 (data not shown), but for the remaining trials, storage did not influence berry abscission significantly as represented by Trial 4 (Figure 1). In the 'Red Globe' trials, the percentages of berry abscission remained low and constant over time, as represented by Trial 7 (Figure 2). For both cultivars, berry abscission was not influenced by liner type.

SO_2 damage. In the 'Thompson Seedless' Trials 1, 2 and 4 the SO_2 damage levels were under 5 % for, irrespective of storage time (data not shown). In Trial 3 the SO_2 damage levels were very high, especially after five and seven weeks storage at -0.5 °C, ranging between 13.9 % and 19.5 % (data not shown). In Trials 5, 6 and 8 high SO_2 damage on 'Red Globe' was the norm after storage for six and eight weeks at -0.5 °C, ranging between ±4.4 % and ±13.5 % (data not shown). Even with the high levels in various trials, liner type had similar influences throughout both seasons and both cultivars. Trial 3 gives a representative example of the overall influences of liner type. SO_2 damage was influenced significantly ($P = 0.0330$) by liner type after five weeks storage at -0.5 °C (Figure 3). Grapes packed with the non-perforated liner had 19.5 % damage and this was significantly higher than for grapes packed with the needle perforated liner that had 11.8 %. The 2 mm liner group did not differ significantly from either of the above mentioned, but grapes packed with these 2 mm liners showed an increase in SO_2 damage as the degree of perforation decreased. In 'Thompson

Seedless' and 'Red Globe' trials, SO_2 damage increased significantly with storage and this is represented by Trial 4 (Figure 1) and Trial 7 (Figure 2), respectively.

Decay. *Botrytis* decay levels were not influenced by liner type for either cultivar (data not shown). The quality disorder increased significantly from day of packing to storage evaluations for both cultivars as represented by Trial 4 (Figure 1) and Trial 7 (Figure 2).

Berry split. 'Thompson Seedless' had very high berry split percentages in the 2002 season, in Trials 1 and 2, reaching levels of over 20 % in both trials after storage for five and seven weeks at -0.5 °C (data not shown). In 'Red Globe' trials the berry split percentages were very low, except in Trial 8 after six and eight weeks of storage at -0.5 °C (data not shown). Even with high levels in certain trials, the following example from the 2003 season represents the influences due to degree of liner perforation for both cultivars. In Trial 3, berry split was influenced significantly ($P < 0.0001$) by liner type when averaged over cold storage evaluations (Figure 4). The non-perforated liner (10.8 %) had significantly more berry split than all the other treatments. In both cultivars berry split increased significantly as the storage time increased. All the trials had almost similar results, as are represented by Trial 4 (Figure 1) and Trial 7 (Figure 2).

Moisture in carton. Liner type had a similar influence on moisture in the carton, regardless of cultivar. For example, in Trial 3 the amount of moisture in the carton was influenced significantly ($\chi^2 = 0.0014$) by liner type when averaged over cold storage (Figure 5). The non-perforated liner (1.67) had higher moisture ratings than the remaining liner types, with the needle perforated liner (1.16) and the $^0/_3$ closed liner (1.16) having the lowest ratings. In this example the 2 mm liner group had a typical trend of decreasing amount of moisture in the carton as the degree of perforation increased. In various trials, the non-perforated liner had significantly more moisture than all the other treatments. There was no apparent trend for moisture values relating to influences from storage times.

Stem condition. Liner type had a similar influence on stem condition regardless of cultivar. For example in Trial 3, the stem quality was influenced significantly ($\chi^2 < 0.0001$) by liner type after seven weeks at -0.5 °C (Figure 6). Grapes packed with the $^0/_3$ closed liner (2.83)

had the worst stems in this evaluation, and grapes packed with the 2 mm liner group worsened in stem condition as the degree of perforation increased. Although the influence from liner type was the same, an apparent difference in stem condition values was evident between cultivars. Stem condition deteriorated with lengthening storage for both cultivars, but 'Red Globe' reached much higher values. In all the 'Red Globe' trials, especially after storage for eight weeks at -0.5 °C, stem condition levels went beyond a rating of three (data not shown). In several of these trials the stem condition was the worst in the $^{0}/_{3}$ closed liner.

'Thompson Seedless' is more prone to berry abscission than 'Red Globe' and levels were high even on packing days, but for both cultivars the levels of berry abscission remained fairly constant over storage times. *Botrytis* decay levels were mostly not influenced by liner type, but lengthening of storage time aggravated the disorder. SO_2 damage and berry split had similar results in most of the trials. The disorders worsened significantly as storage progressed. Even with berry split levels in the 'Thompson Seedless' trials of between 20 % and 40 %, which are commercially unacceptable, the same differences between liner types remained evident through the trials for both seasons. Grapes packed with the non-perforated liner usually had the most berry split and highest SO_2 damage. The needle perforated liner resulted in low levels of SO_2 damage, but in some cases it resulted in the second worst split and in others it resulted in some of the lowest levels of split. This variation of influence on berry split may be due to the easy tearing of the needle perforations. This can increase the perforations on certain cartons, influencing overall results. The 2 mm liner group showed the same tendency regarding berry split and SO_2 damage, viz. as the degree of perforation decreased the, the levels of berry split and SO_2 damage increased. The 2 mm liner group resulted in lower berry split and SO_2 damage than the non-perforated liner. SO_2 damage and berry split are both influenced by moisture and temperature and the significantly higher moisture in the non-perforated liner than the perforated liners was the cause of higher levels of these two disorders. Stem condition was also influenced by moisture, where less moisture in the perforated liners aggravated the condition.

The significant negative correlation between stem condition and moisture in the carton in Trials 1 and 2, suggests that the use of perforation can have a detrimental effect on stem condition (Table 1). Conflicting results occurred in Trials 3, 4, 5, 7 and 8 where a significant

positive correlation was evident and therefore the results cannot be explained. Perforated liners had significantly less moisture than the non-perforated type. A positive correlation was found for moisture in the carton vs. berry split, and moisture in the carton vs. SO_2 damage, in Trials 3, 4, 5, 6 and 7 (Table 1). The advantage of better stems must be weighed up against the disadvantages of having more SO_2 damage and higher berry split. A positive correlation between stem condition and berry abscission in Trials 2 and 5 suggests that stem deterioration can increase berry abscission (Table 1).

Shelf life: quality after storage at -0.5 °C and one week at 15 °C

Berry abscission. In 'Thompson Seedless' trials the 2002 season resulted in higher levels of berry abscission compared to the 2003 season (data not shown). Berry abscission did not increase significantly with lengthening of storage time for any of the 'Thompson Seedless' trials except in Trial 2 (Figure 7). Berry abscission percentages, especially in the 'Red Globe' trials, were very low as represented by Trial 7 (Figure 8). No apparent increase in berry abscission due to the extra shelf life period could be found in either cultivar (data not shown).

SO_2 damage. In 'Thompson Seedless', SO_2 damage levels after shelf life were very high in the 2003 season for Trial 3, with levels above 14 % after storage for five or seven weeks at -0.5 °C and one week at 15 °C (data not shown). In 'Red Globe', in Trials 5, 6 and 8 the SO_2 damage levels after cold storage and shelf life ranged between 7.0 % and 13.0 %, irrespective of liner type (data not shown). This is much higher than accepted standards. Even with high levels masking the influence of liner type, various evaluations in both cultivars had similar results. In Trial 5, SO_2 damage was influenced significantly ($P = 0.0052$) by liner type after eight weeks of storage at -0.5 °C and one week at 15 °C (Figure 9). Although not always significant, this result typifies liner type influences in various trials, irrespective of cultivar. The $^0/_3$ closed liner (4.6 %) resulted in the lowest SO_2 damage and the non-perforated liner (10.4 %), needle perforated liner (10.6 %) and the $^2/_3$ closed liner (11.0 %) resulted in significantly higher levels of SO_2 damage. The $^1/_3$ closed liner (7.1 %) did not differ significantly from any of the other treatments. SO_2 damage increased significantly in both cultivars from day of packing to storage evaluations. All the trials had similar results as represented by Trial 2 (Figure 7) and Trial 7 (Figure 8).

Decay. In the 2002 season, *Botrytis* decay levels in the 'Thompson Seedless' trials, averaged over shelf life evaluations and liner type, ranged between 10.0 % and 20.5 % (data not shown). These are very high percentages and grapes stored for only a week at 15 °C had levels exceeding commercially acceptable standards. In 'Thompson Seedless' and 'Red Globe', *Botrytis* decay differed significantly, between evaluation times as represented by Trial 2 (Figure 7) and Trial 7 (Figure 8). In almost all trials, *Botrytis* decay was not significantly influenced by liner type. In 'Red Globe', exceptionally high levels of decay occurred in Trial 8 following cold storage and shelf life. Average levels irrespective of liner type influences ranged, from 5.5 % to 7.8 % (data not shown). This exceeds commercially acceptable levels and is not expected for the 'Red Globe' cultivar. Average decay incidences increased during the shelf life period. For example, in Trial 1 the average percentage *Botrytis* decay following cold storage at -0.5 °C was 1.5 %, whereas the average in the shelf life evaluation went up to almost 20.0 % (data not shown).

Berry split. In 'Thompson Seedless' average berry split percentages for the 2002 season (Trials 1 and 2) ranged between 16.9 % and 29.2 %, and for the 2003 season Trial 4 had average levels ranging between 17.4 % and 23.8 % (data not shown). In Trial 3, however, the values ranged from 8.3 % to 15.1 % (data not shown). Berry split was low in all 'Red Globe' trials, except in Trial 8 following cold storage and shelf life and regardless of liner type, levels ranged between 5.1 % and 6.6 % (data not shown). These high levels in both cultivars exceeded commercially acceptable levels. Various trials had significant liner influences similar to Trial 3: Berry split was significantly ($P = 0.0118$) influenced by liner type (Figure 10). The non-perforated liner (15.1 %) resulted in significantly more berry split than the needle perforated liner (9.1 %) and the $^{0}/_{3}$ closed liner (8.3 %). The $^{2}/_{3}$ closed liner (11.7 %) and the $^{1}/_{3}$ closed liner (12.1 %) did not differ significantly from any of the other perforated liner types or the non-perforated liner. The 2 mm liner group tended to increase berry split with a decrease in degree of perforation for several of the trials, including both cultivars, similar to Trial 5 (Figure 11). Average berry split incidences increased during the shelf life period. For example in Trial 4 the average percentage following cold storage at -0.5 °C was 7.1 %, whereas the average in the shelf life evaluation went up to almost 21.0 % (data not shown).

Moisture in carton. The influence of liner type on the amount of moisture in the carton were very similar in both cultivars following shelf life. For example, the amount of moisture in Trial 2 was influenced significantly ($\chi^2 = 0.019$) by liner type when averaged over shelf life evaluations (Figure 12). The non-perforated liner (1.89) had the highest amount of moisture in the carton. Differences were not as clear as in the cold storage evaluations where the non-perforated liner or the $^2/_3$ closed liner usually had the most moisture in the carton.

Stem condition. 'Red Globe' grapes had much worse stem condition than 'Thompson Seedless' after exposure to shelf life conditions. In all the 'Red Globe' trials the stem condition rating went over 3.5 following eight weeks of cold storage and shelf life, regardless of liner type. The influence of liner type on stem quality was consistent across cultivars. For example, in Trial 5 the stem quality was influenced significantly ($\chi^2 = 0.0229$) by liner type when averaged over shelf life evaluations (Figure 13). The $^0/_3$ closed liner had the worst stems of all the treatments and this was evident in various evaluations. For grapes packed with the 2 mm liner group, the stems worsened as the degree of perforation increased. Overall the average stem condition worsened with an increase in storage duration (data not shown). Average stem condition deteriorated more during the shelf life period compared to cold storage.

Berry abscission is not a problem in 'Red Globe' and it was not influenced by liner type. Although not always significant, the non-perforated liner, the $^2/_3$ closed liner or the needle perforated liner often resulted in higher SO_2 damage levels than the other liner types. In most of the trials, the non-perforated liner resulted in more SO_2 damage than the perforated liners. In the 2 mm liner group the SO_2 damage usually increased with lowering of degree of perforation. The non-perforated liner always resulted in the highest amount of berry split. In various trials, the needle perforated liner resulted in almost the highest levels of split and in others, it resulted in some of the lowest. This variation of influence on berry split may be due to the easy tearing of the needle perforation. This can increase perforation on certain cartons, influencing overall results. The 2 mm liner group showed the same tendency as with SO_2 damage, viz. as the degree of perforation decreased the grapes had a higher tendency to split.

Throughout both seasons, *Botrytis* decay and berry abscission levels differed between liner types, but this cannot be ascribed to the use of different degrees of perforation. *Botrytis* decay was hardly influenced by liner type. The advantage of a non-perforated liner is that no SO_2 gas is lost through perforation, but a non-perforated liner is also the cause of high humidity, favouring decay. With a perforated liner, the control with SO_2 gas is less, but the conditions for development of decay are also less favourable due to lower humidity, which is why no liner type was significantly better in controlling decay. The quality of the grapes in terms of all disorders significantly declined as storage time lengthened, with the exception of berry abscission in 2003 (data not shown). The increase of decay and berry split in the shelf life period is due to free water condensing inside the liner due to the temperature difference. The extra moisture causes conditions that favour these disorders. The increase in temperature will also cause stem browning to increase. The free water and higher temperature in the shelf life period increased the generation of SO_2 gas which increased the amount of SO_2 damage, on the grapes.

The non-perforated liner had the highest amount of moisture in the carton. Following the shelf life period, differences in stem condition between liner types were not as definite. The negative correlation between stem condition and moisture in the carton following shelf life in Trials 1, 2, 3 and 5, stresses the importance that humidity has on stem condition (Table 1). In Trials 2 and 7 a positive correlation between stem condition and berry abscission suggests that stem desiccation may promote berry abscission (Table 1). In Trial 6, moisture in the carton vs. berry split had a significantly positive correlation (Table 1). This was contradicted in Trial 1 and 5 where moisture in the carton vs. berry split had a significantly negative correlation (Table 1).

CONCLUSION

Throughout various trials, significant advantages and disadvantages were apparent in all liner types. The non-perforated liner kept SO_2 gas from leaking out of the liner by creating a barrier retaining moisture and gas. This was also a disadvantage, because data showed that the higher moisture in the non-perforated liner is usually correlated to higher SO_2 damage and higher berry split. The higher humidity caused conditions ideal for decay development, especially when the temperature was raised in the shelf life period.

The advantages of using perforated liners were in the significant lowering of berry split and SO_2 damage by controlling the moisture diffusion out of the liner. The ventilation lowered the humidity that creates less favourable conditions for decay to develop, but with SO_2 gas leaking out of the liner the level of decay control was lowered. However, too much perforation will cause the stem condition to worsen significantly and there is reason to believe that this will increase berry abscission (Burger, 2000).

The advantages and disadvantages of the various liners must be weighed up against each other for specific conditions, taking in consideration factors such as cultivar sensitivity to different disorders, the temperature of the product, the time it will take to start the cooling process and the severity of forced air cooling (FAC). 'Red Globe' grapes are sensitive to stem browning and SO_2 damage. Using a non-perforated liner will reduce stem browning, but will increase SO_2 damage. 'Thompson Seedless' is sensitive to berry split and is prone to develop decay especially after rain. In this case the use of a perforated liner will lessen both defects, by relieving the relative humidity inside the liner. The loss of SO_2 gas through perforations can decrease the efficiency of killing surface spores and mycelium. Infection will occur either slowly due to low storage temperatures or faster on a later occasion when temperatures rise due to a break in the cold chain or exposure to shelf life conditions. Ideally, a cost benefit analysis must be drawn up for every occasion taking in consideration as many influencing factors as possible. The cost of every disorder for the specific cultivar can be determined and the liner that offers the most financial advantage must be chosen.

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Table 1 Correlation table of the 2002 and 2003 seasons for 'Thompson Seedless' trials.

	Correlation Coefficient [x]	**P ≤ 0.05**	**Correlation Coefficient**	**P ≤ 0.05**
2002 season	Hex River Valley (Trial 1)		Hex River Valley (Trial 2)	
Average storage at -0.5 °C				
Stem condition vs. Moisture	-0.48	<0.0001	-0.34	<0.0001
Moisture vs. Berry split	-0.45	<0.0001	-0.01	0.931
Moisture vs. SO_2 damage	-0.43	<0.0001	-0.44	<0.0001
Stem condition vs. Berry abscission	-0.01	0.947	0.34	0.001
Average storage at -0.5 °C and shelf life				
Stem condition vs. Moisture	-0.61	<0.0001	-0.22	0.041
Moisture vs. Berry split	-0.45	<0.0001	-0.18	0.099
Moisture vs. SO_2 damage	-0.48	<0.0001	-0.46	<0.0001
Stem condition vs. Berry abscission	-0.21	0.052	0.26	0.012
2003 season	Berg River Valley (Trial 3)		Hex River Valley (Trial 4)	
Average storage at -0.5 °C				
Stem condition vs. Moisture	0.25	0.018	0.83	<0.0001
Moisture vs. Berry split	0.55	<0.0001	0.60	<0.0001
Moisture vs. SO_2 damage	0.62	<0.0001	0.76	<0.0001
Stem condition vs. Berry abscission	0.15	0.052	-0.01	0.922
Average storage at -0.5 °C and shelf life				
Stem condition vs. Moisture	-0.35	0.011	0.15	0.146
Moisture vs. Berry split	0.13	0.214	0.06	0.577
Moisture vs. SO_2 damage	-0.25	0.019	0.13	0.219
Stem condition vs. Berry abscission	-0.17	0.115	-0.31	0.386

[x] Pearson correlation coefficient calculated with data pooled across all three evaluations (cold storage and shelf life).

Table 1 (cont.) Correlation table of the 2002 and 2003 seasons for 'Red Globe' trials.

	Correlation Coefficient [x]	P ≤ 0.05	Correlation Coefficient	P ≤ 0.05
2002 season	Berg River Valley (Trial 5)		Hex River Valley (Trial 6)	
Average storage at -0.5 °C				
Stem condition vs. Moisture	0.39	<0.0001	0.16	0.143
Moisture vs. Berry split	0.47	<0.0001	0.27	0.010
Moisture vs. SO_2 damage	0.39	<0.0001	0.41	<0.0001
Stem condition vs. Berry abscission	0.34	0.010	0.13	0.215
Average storage at -0.5 °C and shelf life				
Stem condition vs. Moisture	-0.43	<0.0001	-0.19	0.076
Moisture vs. Berry split	-0.42	<0.0001	0.22	0.040
Moisture vs. SO_2 damage	-0.73	<0.0001	-0.12	0.276
Stem condition vs. Berry abscission	0.00	N/V	0.04	0.701
2003 season	Hex River Valley (Trial 7)		Berg River Valley (Trial 8)	
Average storage at -0.5 °C				
Stem condition vs. Moisture	0.53	<0.0001	0.27	0.011
Moisture vs. Berry split	0.38	<0.0001	0.02	0.825
Moisture vs. SO_2 damage	0.56	<0.0001	0.31	0.003
Stem condition vs. Berry abscission	0.14	0.199	0.09	0.382
Average storage at -0.5 °C and shelf life				
Stem condition vs. moisture	-0.09	0.399	0.15	0.156
Moisture vs. Split	-0.03	0.791	0.03	0.790
Moisture vs. SO_2 damage	0.04	0.740	-0.11	0.304
Stem condition vs. Berry abscission	0.22	0.035	0.04	0.716

[x] Pearson correlation coefficient calculated with data pooled across all three evaluations (cold storage and shelf life).

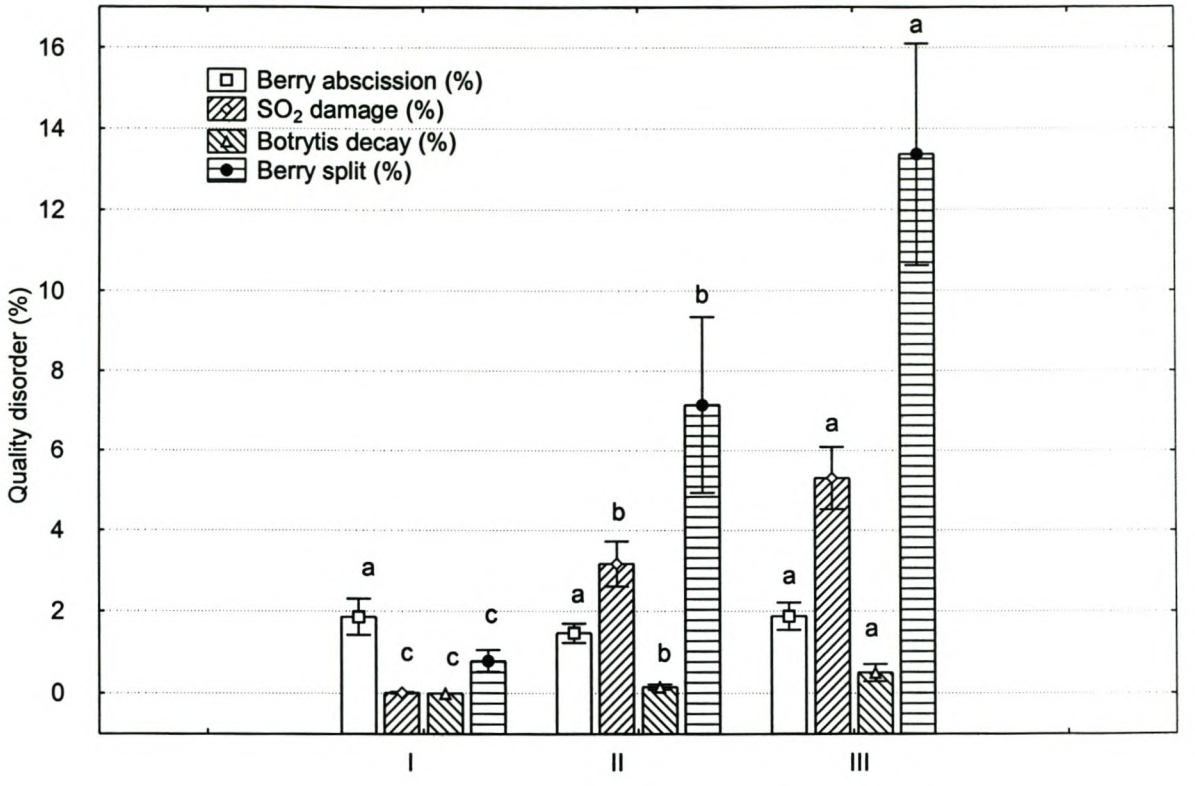

Figure 1 Quality disorders of 'Thompson Seedless' table grapes from the Hex River Valley (Trial 4), on the day of packing (I), after five weeks at -0.5 °C (II) and after seven weeks at -0.5 °C (III). Berry abscission ($P = 0.1897$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P < 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

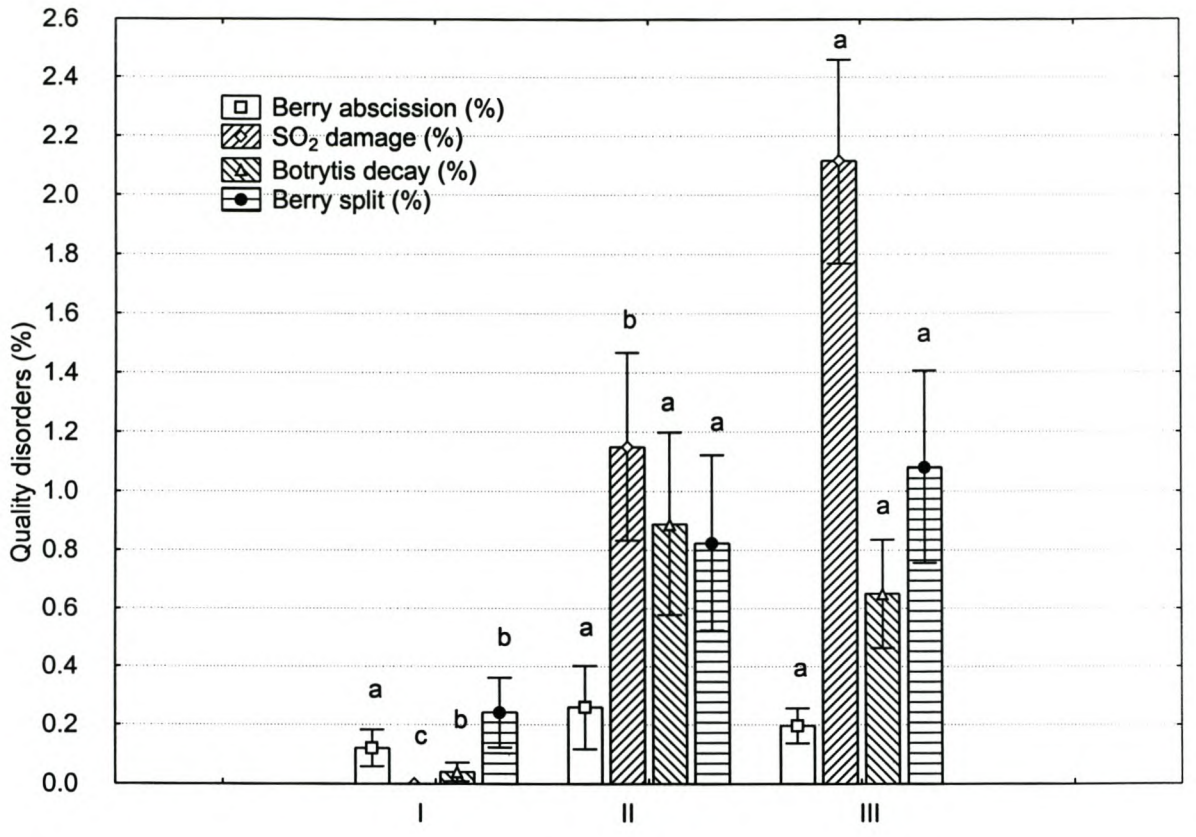

Figure 2 Quality disorders of 'Red Globe' table grapes from the Hex River Valley (Trial 7), on the day of packing (I), after five weeks at -0.5 °C (II) and after seven weeks at -0.5 °C (III). Berry abscission ($P = 0.0914$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P < 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

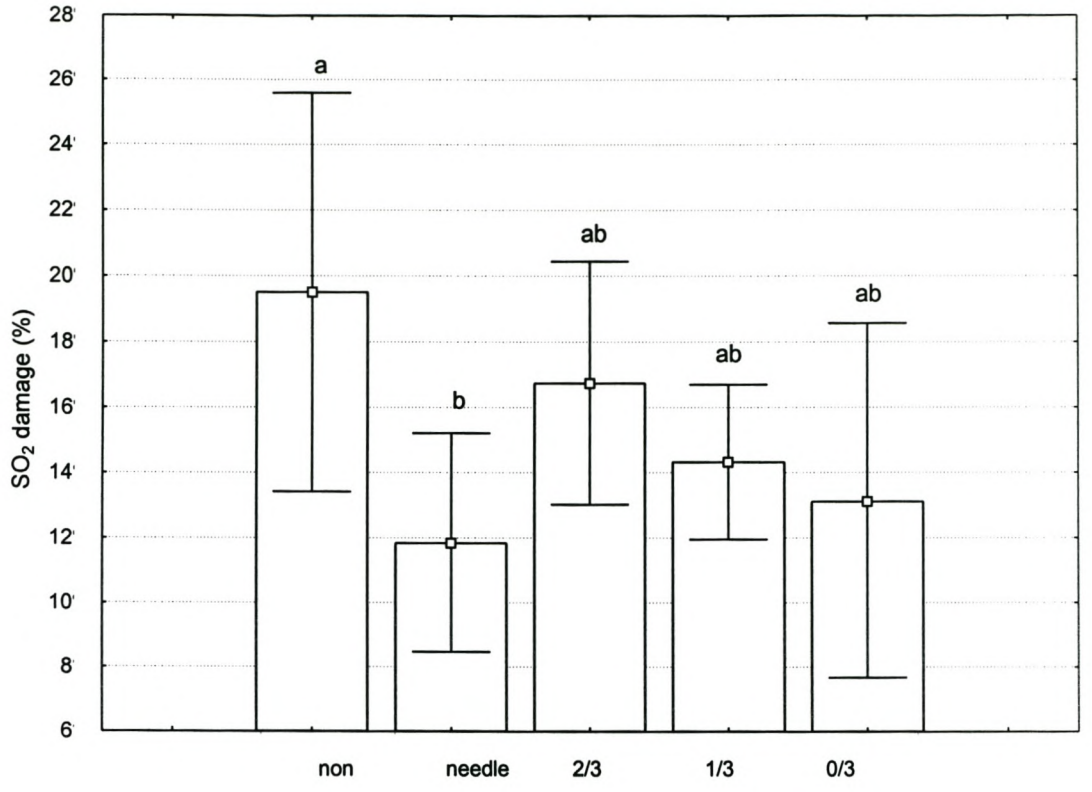

Figure 3 Means/error plot of SO_2 damage percentage of 'Thompson Seedless' table grapes with different liner types from Berg River Valley (Trial 3) after five weeks of storage at –0.5 °C (P = 0.0330). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

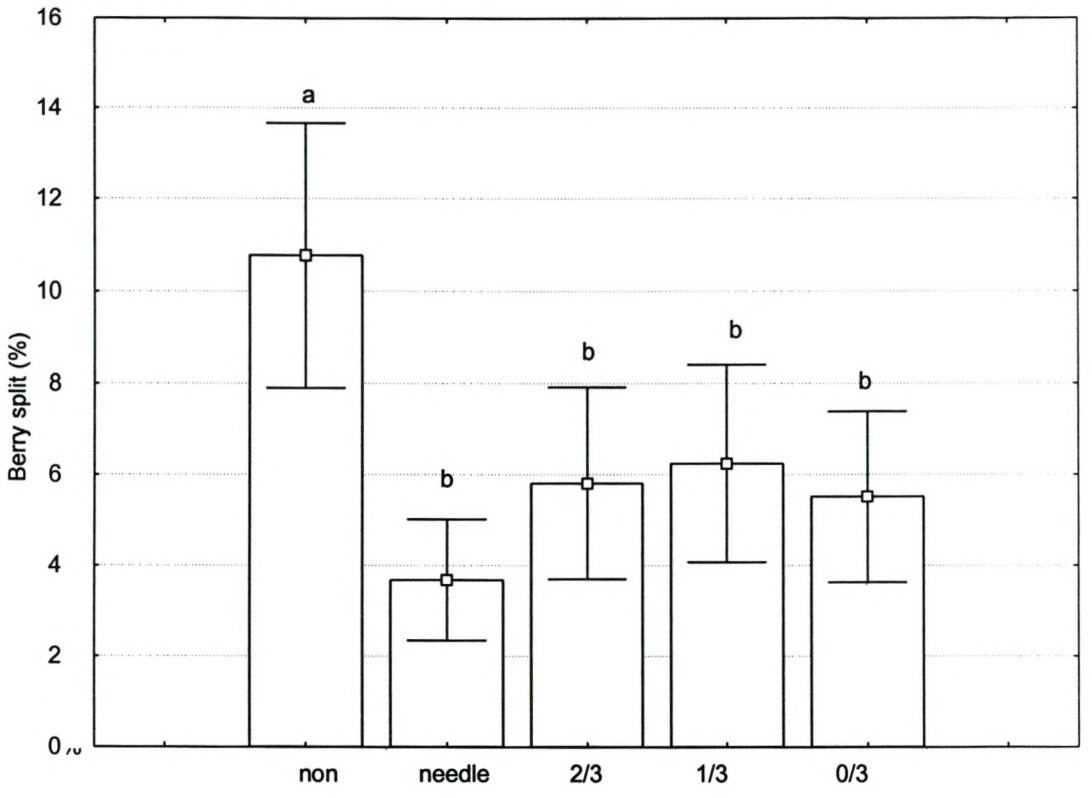

Figure 4 Means/error plot of berry split percentage of 'Thompson Seedless' table grapes with different liner types from Berg River Valley (Trial 3) averaged over cold storage duration ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

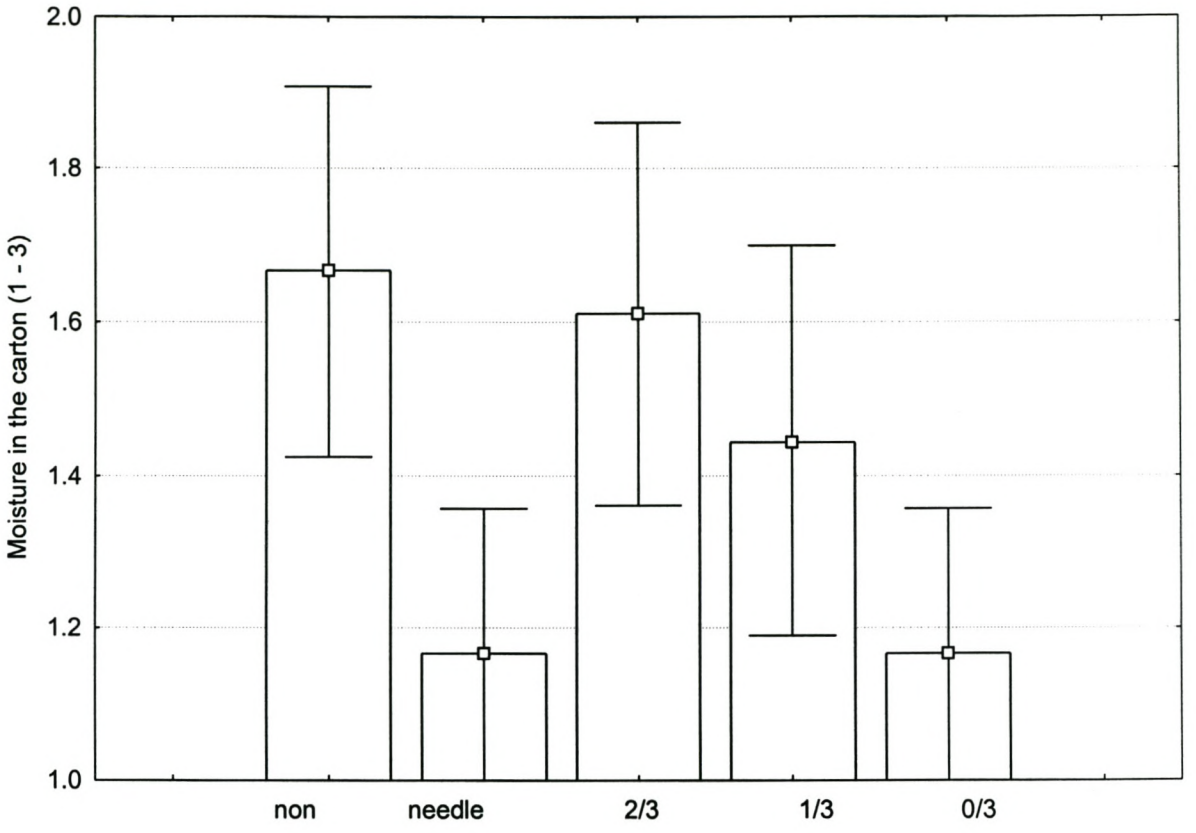

Figure 5 Means plot of moisture in the carton of 'Thompson Seedless' table grapes with different liner types from Berg River Valley (Trial 3) when averaged over cold storage duration (χ^2 = 0.0014). Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture.

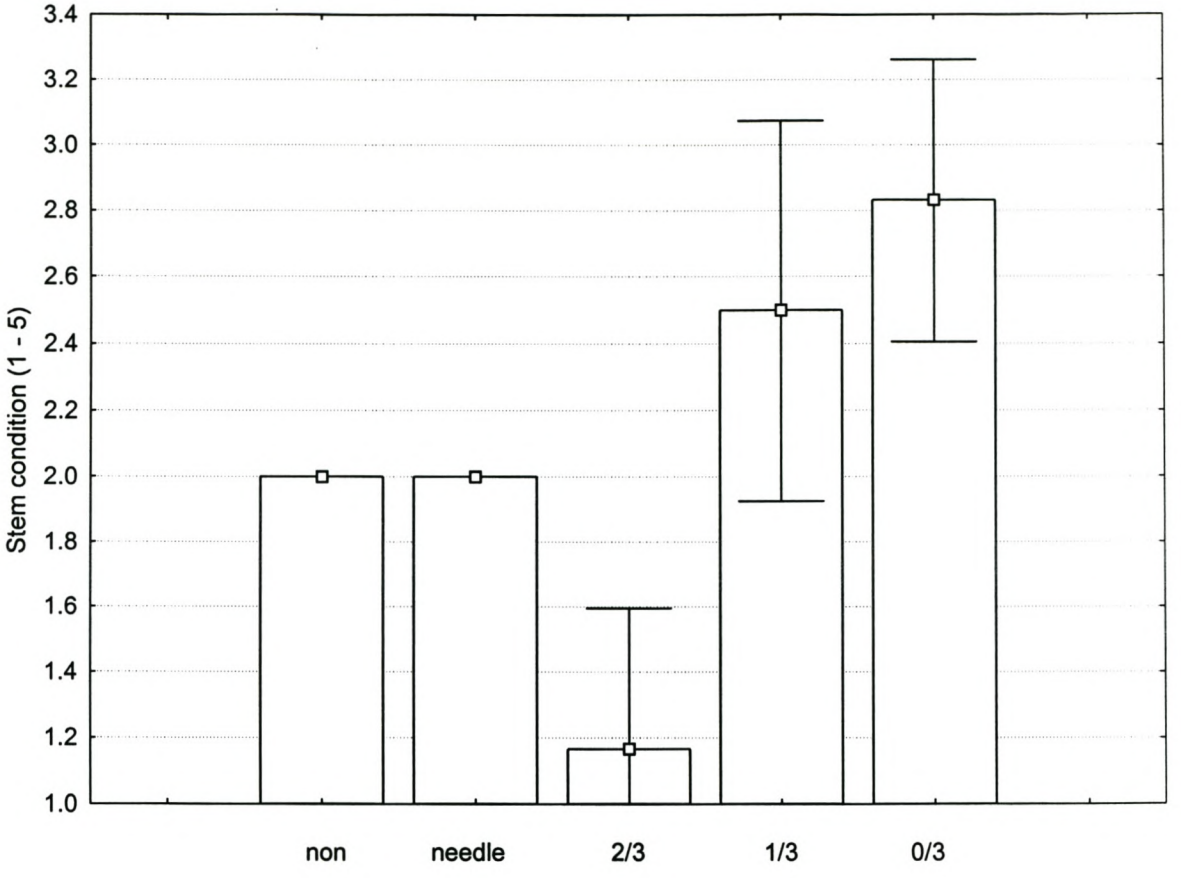

Figure 6 Means plot of stem condition of 'Thompson Seedless' table grapes with different liner types from Berg River Valley (Trial 3) determined after seven weeks of storage at -0.5 °C ($\chi^2 < 0.0001$). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems.

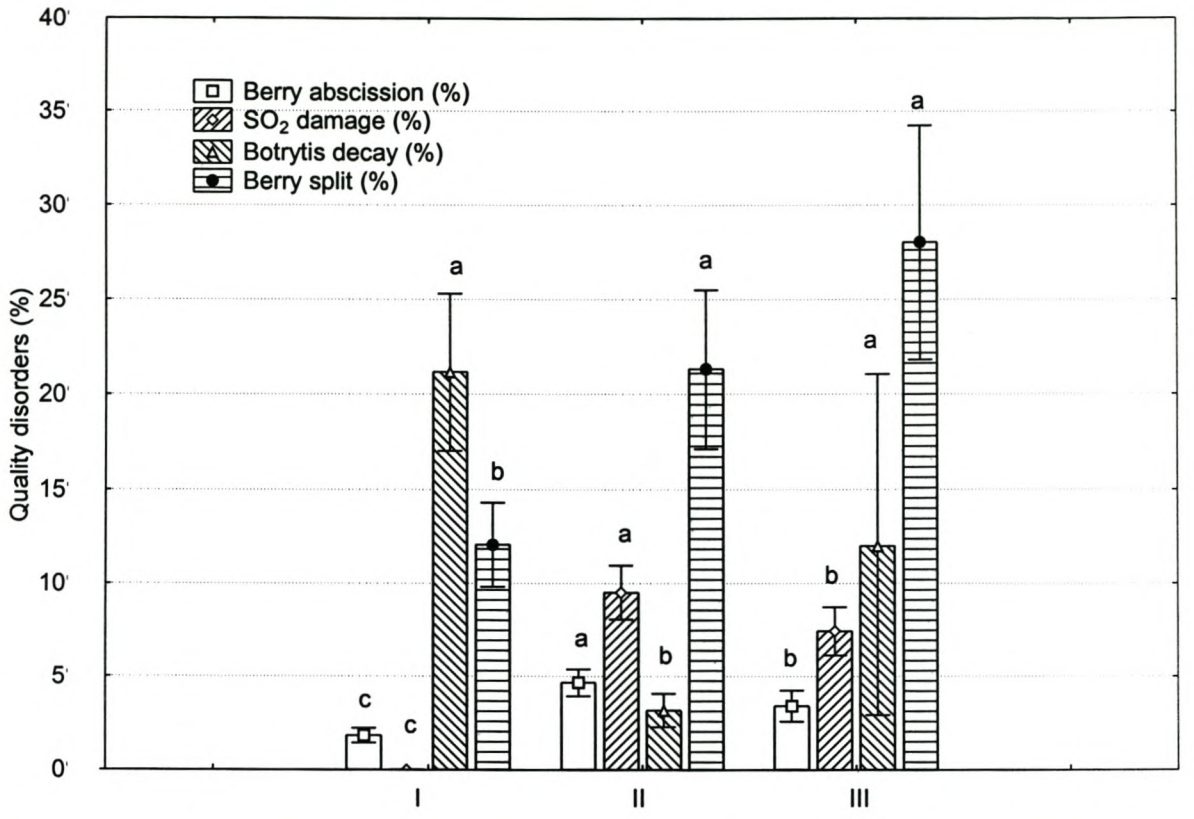

Figure 7 Quality disorders of 'Thompson Seedless' table grape from the Hex River Valley (Trial 2), after one week at 15 °C (I), after five weeks at -0.5 °C and one week at 15 °C (II) or after seven weeks at -0.5 °C and one week at 15 °C (III). Berry abscission ($P = 0.0146$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P = 0.0006$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

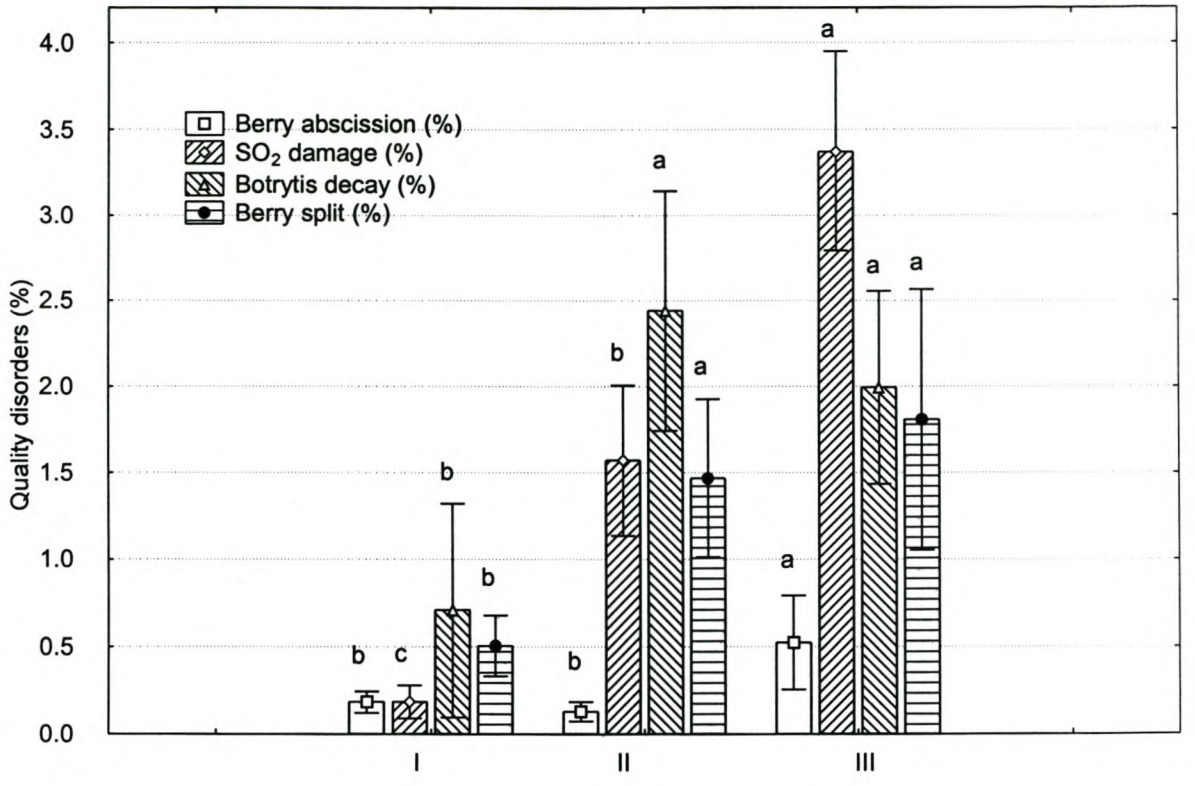

Figure 8 Quality disorders of 'Red Globe' table grape from the Hex River Valley (Trial 7), after one week at 15 °C (I), after five weeks at -0.5 °C and one week at 15 °C (II) or after seven weeks at -0.5 °C and one week at 15 °C (III). Berry abscission ($P = 0.0001$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P = 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

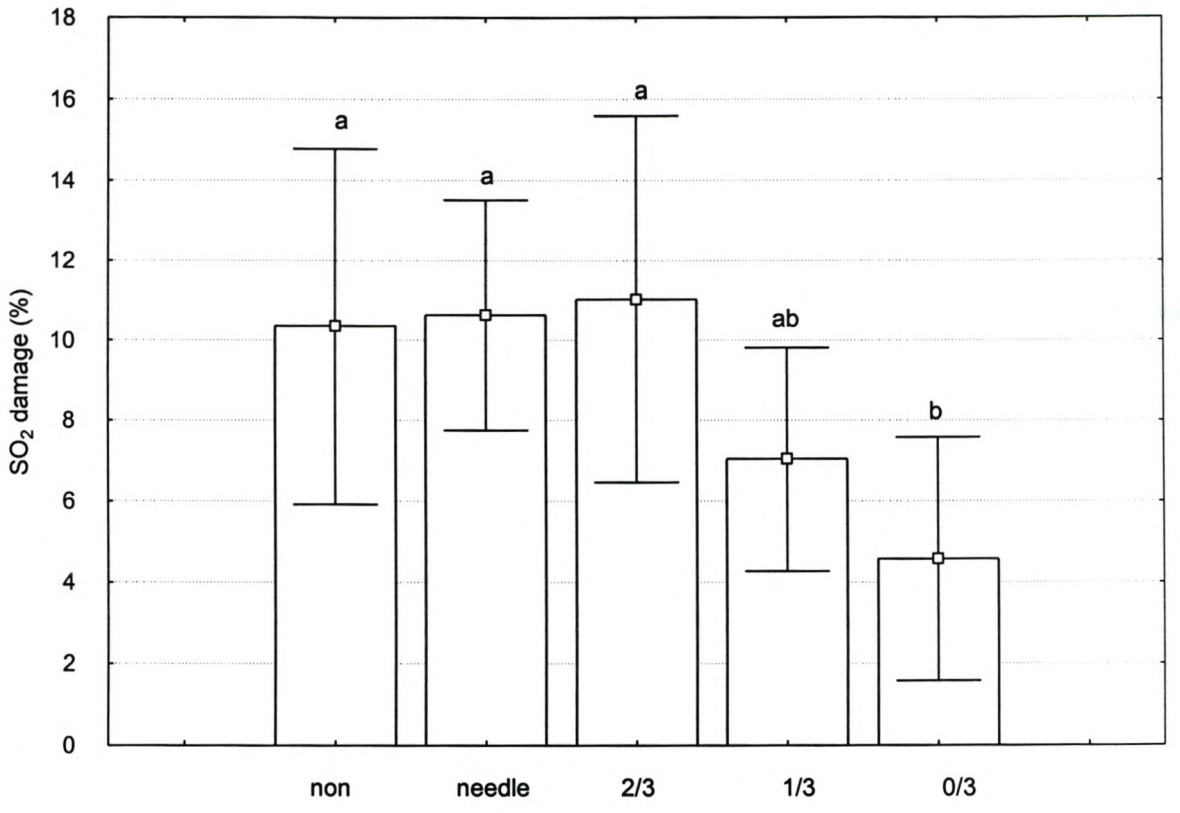

Figure 9 Means/error plot of SO_2 damage percentage of 'Red Globe' table grapes with different liner types from Berg River Valley (Trial 5) determined after eight weeks of storage at -0.5 °C and one week at 15 °C (P = 0.0052). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

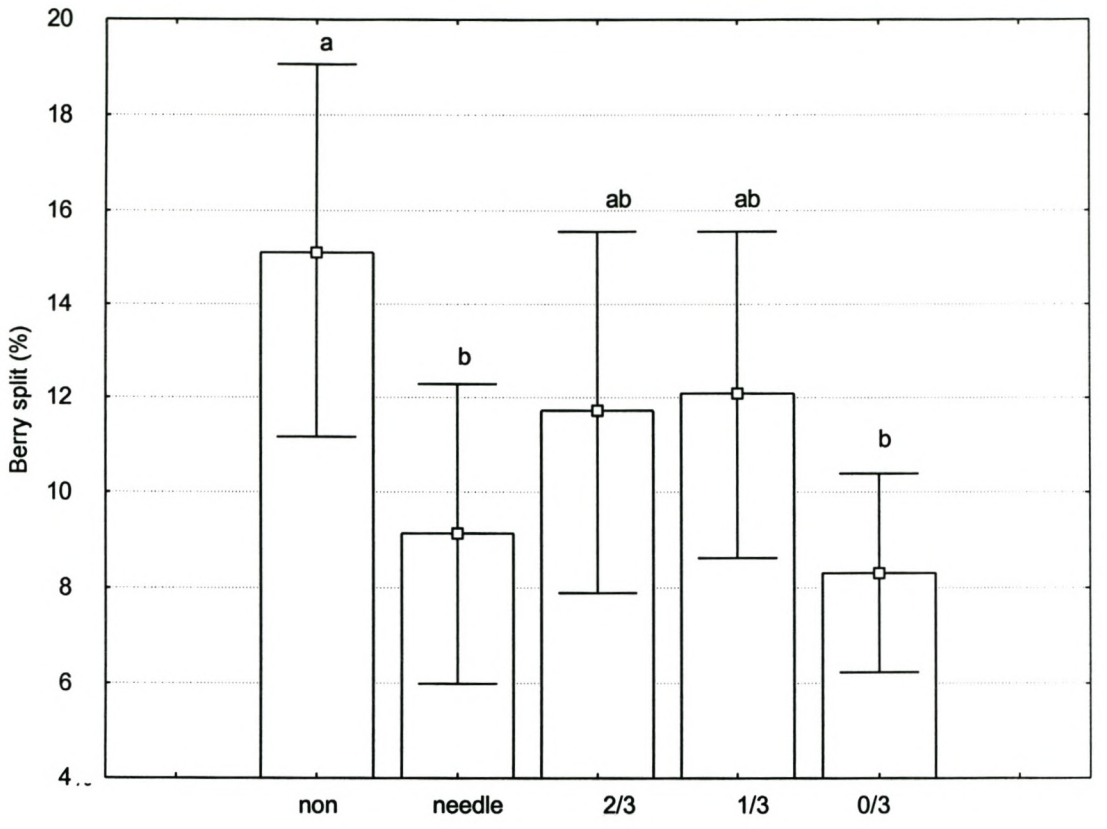

Figure 10 Means/error plot of berry split percentage of 'Thompson Seedless' table grapes with different liner types from Berg River Valley (Trial 3) averaged over shelf life evaluations (P = 0.0118). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

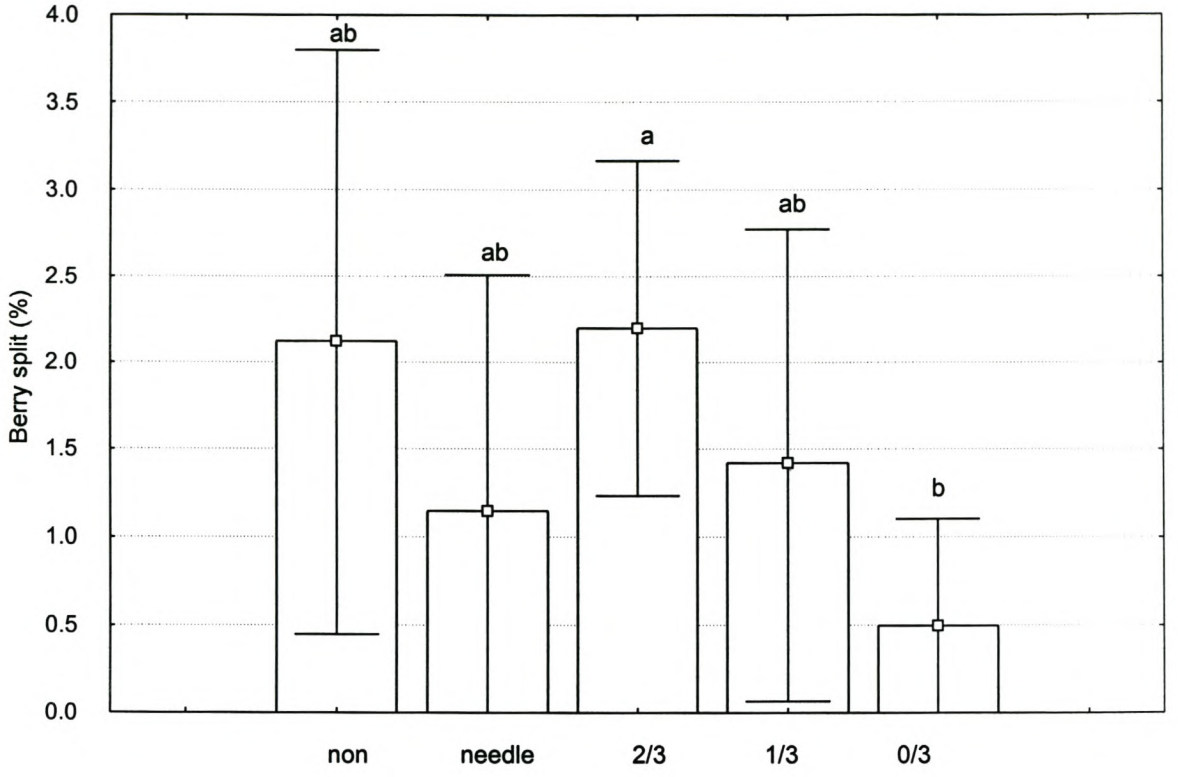

Figure 11 Means/error plot of berry split percentage of 'Red Globe' table grapes with different liner types from Berg River Valley (Trial 5) determined after eight weeks of storage at -0.5 °C and one week at 15 °C (P = 0.0269). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

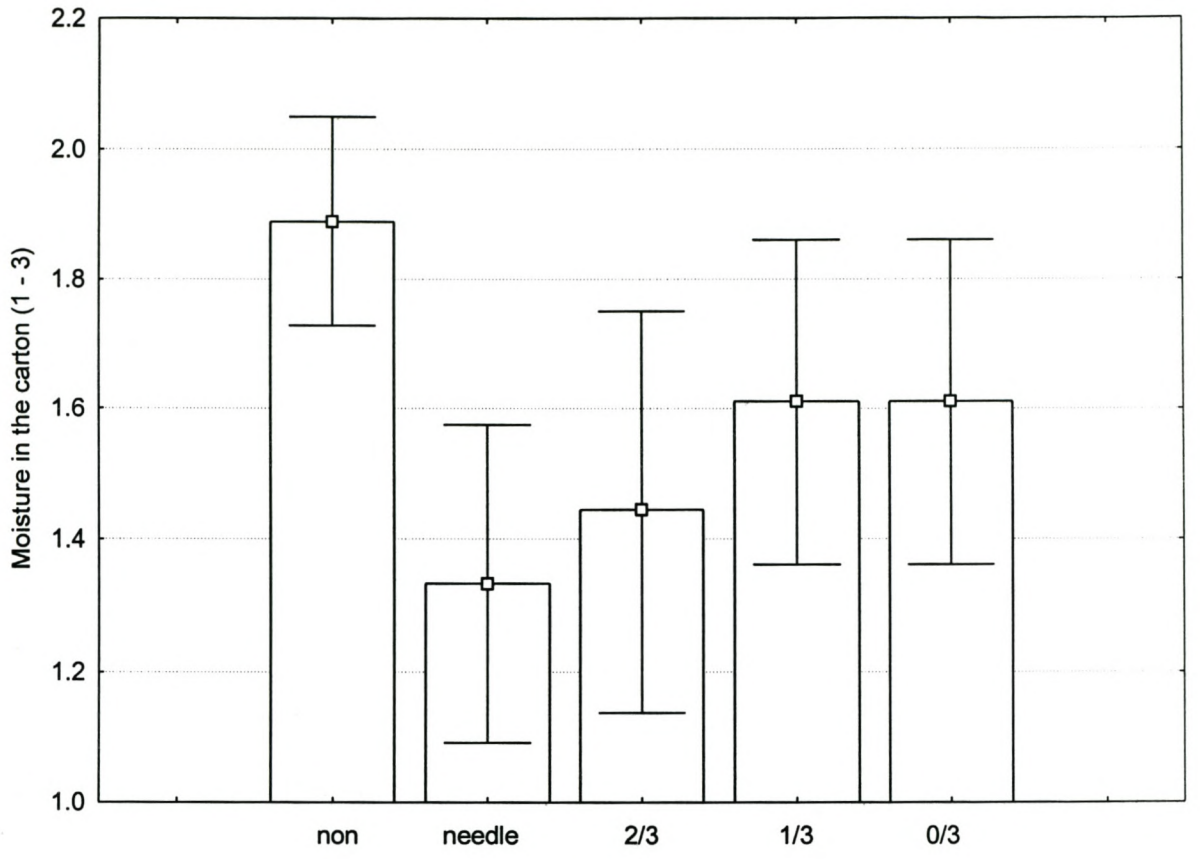

Figure 12 Means plot of moisture in the carton of 'Thompson Seedless' table grapes with different liner types from Hex River Valley (Trial 2) when averaged over shelf life evaluations ($\chi^2 = 0.019$). Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture.

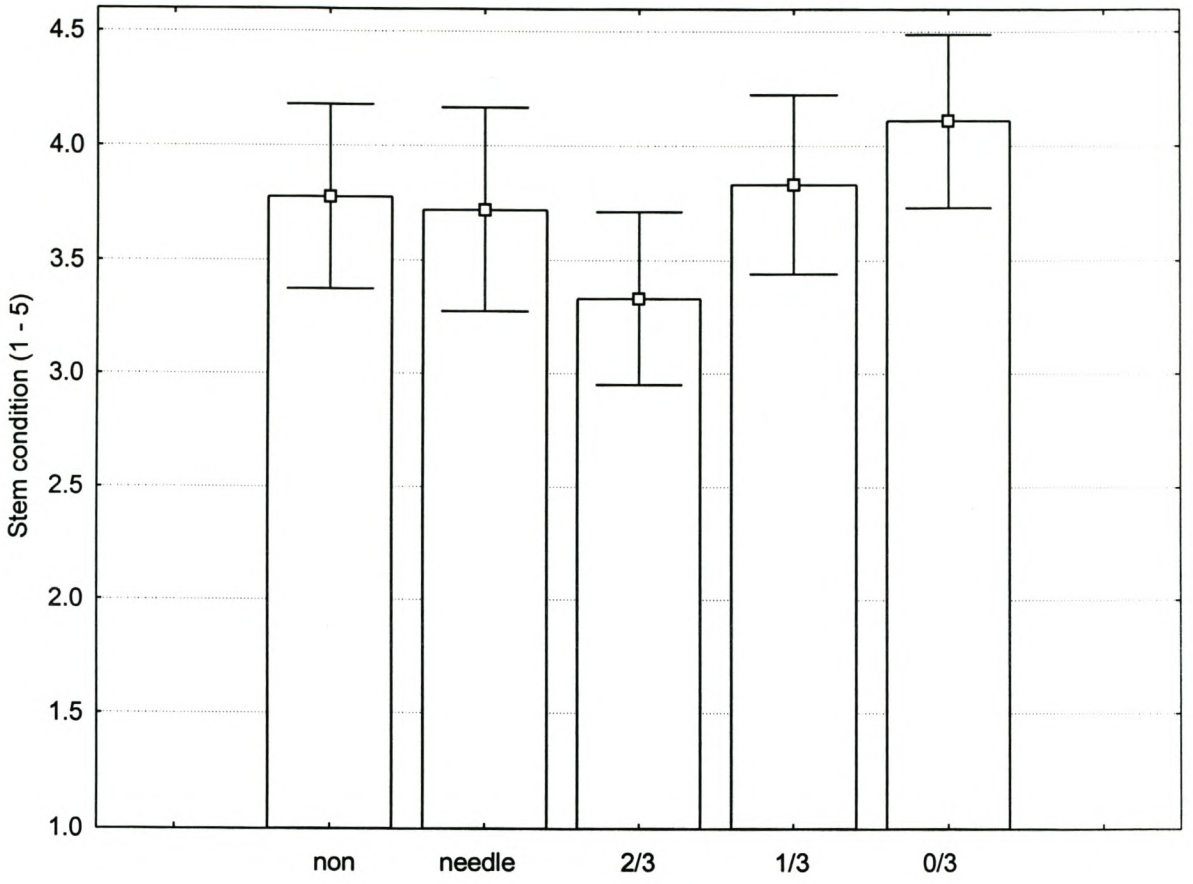

Figure 13 Means plot of stem condition of 'Red Globe' table grapes with different liner types in the 2002 season from Berg River Valley (Trial 5) when averaged over shelf life evaluations ($\chi^2 = 0.0229$). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems.

ARTICLE II EVALUATION OF A MOISTURE ABSORBING SHEET FOR 'THOMPSON SEEDLESS' AND 'RED GLOBE' TABLE GRAPES.

ABSTRACT

The effects that a clay-containing, moisture absorbing sheet had on quality in table grapes, were evaluated for 'Thompson Seedless' and 'Red Globe' cultivars during two consecutive seasons. These cultivars were stored at -0.5 °C for five and six weeks, respectively, and had a subsequent shelf life of one week at 15 °C. 'Thompson Seedless' grapes that were stored for 5 weeks at -0.5 °C abscised significantly more in the desiccant packaging. Grapes subjected to shelf life (15 °C) for a week, after five weeks at -0.5 °C, had significantly less abscised berries in the desiccant packaging. In all the 'Thompson Seedless' trials, grapes had significantly more SO_2 damage in the conventional packaging. For all the 'Thompson Seedless' trials, berries in the desiccant packaging had significantly more decay. After five weeks at -0.5 °C and one week at 15 °C, 'Thompson Seedless' grapes in desiccant packaging had an average of 95.6 % decay. In all the 'Thompson Seedless' trials, all the berries packed in desiccant packaging had significantly less split than the conventional packaging. In all the 'Red Globe' trials, grapes had significantly more SO_2 damage in the conventional packaging. 'Red Globe' that came from Hex River Valley, subjected to six weeks at –0.5 °C and one week at 15 °C shelf life, had significantly more decay in the desiccant packaging. Except for one case, all the desiccant packaging containing 'Red Globe' grapes had significantly less berry split than conventional packaging. The desiccant sheet absorbs moisture out of the atmosphere inside the liner and less berry split occurs and less SO_2 damage occurs. The fact that the sheet absorbs SO_2 gas and that moisture is needed to activate the release of SO_2 gas increases the occurrence of decay.

KEYWORDS : Berry split, abscission, *Botrytis*, SO_2 damage, moisture in carton, stem quality, desiccant

INTRODUCTION

Vitis vinifera L cv. 'Sultanina' (Thompson Seedless) is one of the main export grape cultivars in South Africa, with nine million cartons exported in the 2001/2002 season (Viljoen, pers.

com., 2003). This cultivar is also prone to develop quality disorders after packaging and storage. Splitting, abscission and decay of berries are responsible for large financial losses in the international table grape industry (Ben-Arie et al., 1995; Considine and Kriedemann, 1972; Uys and Calitz, 1997; Ben-Tal, 1990). 'Red Globe' table grapes are also an important export cultivar with seven million cartons being exported in the 2001/2002 season (Viljoen, pers. com., 2003). In storage, 'Red Globe' grapes are prone to develop sulphur dioxide (SO_2) damage and stems which are dry with a brown colour (Retamales et al., 2003; Viljoen, pers. com., 2003). These conditions will be aggravated with long periods of storage (Crisosto et al., 2001).

The bulk of the exported grapes are packed in 4.5 kg closed top corrugated cartons. Bunches are individually packed in plastic carry bags and then enclosed in the carton with a 20 μm polyethylene liner. Before the liner is closed and taped, an SO_2-sheet is placed on top of the grapes to prevent decay.

Conventionally, producers use non-perforated liners in grape cartons although perforated liners are increasingly being used. With non-perforated liners, SO_2-generating sheets that are placed inside the liner can work effectively with no gas being lost through perforations (Combrink et al., 1978). This closed environment can cause a lot of moisture to condense on the inside of the liner (Nelson, 1983). At the onset of cooling, grapes have temperatures typically in excess of 25 °C. The higher the temperature, the higher the water vapour pressure in the berries and the higher the vapour pressure deficit between berries and the air inside the carton (Burger, 2000). The air in the cold room has a temperature of –0.5 °C. As the cooling process commences, the moisture in the carton is cooled. When the air is saturated with vapour, dew point will be reached and vapour will condense on the inside of the liner. This occurs because the liner is in direct contact with cold air in the room (Burger, 2000).

A high humidity is needed to release SO_2 gas from a SO_2-generating sheet to prevent decay (Nelson, 1983). However, excessive moisture and condensation forming in the liner will release too high concentrations of SO_2 gas and this can damage berries (László et al., 1981; Gentry and Nelson, 1968). Injury is commonly seen on the capstem end of the berry where it

is attached to the pedicel. The SO_2 gas also affects skin wounds and causes the berry skin to bleach resulting in sunken areas on the berry (Berry and Aked, 1996). The SO_2 damage is especially detrimental in coloured table grape cultivars (Retamales et al., 2003 as cited by Winkler et al., 1974).

It is believed that berry abscission is genetically determined (Burger, 2000). Other factors such as moisture stress during growing, high temperatures at harvesting and delays in cooling of packed grapes also play a role. Incorrect handling of sensitive cultivars may also increase berry abscission (Burger, 2000).

According to Considine and Kriedemann (1972) turgor pressure plays an important role in fruit splitting. Due to solutes present in the grape berry and because of water loss at the onset of cooling, berries exhibit lower water potential than free moisture in the liner. The water potential gradient that exists will force water to move through the cuticle and cell membrane into the epidermal cells. The pressure on the berry skin increases due to increase in turgor. If this pressure is large enough, cells will rupture and this can cause berries to split or pedicels to detach from berries (Bernstein and Lustig, 1985).

Conventional packaging contains a Mam-sheet (moisture absorbing material sheet) to absorb excessive moisture and therefore possibly prevent moisture related defects. Cultivars such as 'Thompson Seedless' still have large percentages of berries that split (Burger, 2000). Berry split is especially aggravated by packing grapes with high pulp temperatures and in high humidity conditions (Burger, 2000). Using packaging that absorbs more moisture may alleviate this problem. Moisture absorption is necessary when grapes are cooled or if temperature fluctuations occur during storage.

In an attempt to alleviate quality disorders that occur from too much wetness in the carton, a clay moisture-absorbing sheet was evaluated in this trial. Non-perforated liners were compared to different levels of perforations. The aim of the study was to focus on the difference in conventional and desiccant packaging, and the influence on grape quality.

MATERIALS AND METHODS

PACKAGING

Four different liner types were used in the 2002 season, 1) a standard non-perforated liner (non), 2) a 2 mm perforated liner with 54 perforations ($^0/_3$), 3) a 2 mm perforated liner of which every third perforation was sealed ($^1/_3$), and 4) a 2 mm perforated liner of which two of every three perforations were sealed ($^2/_3$). All the liners were 20 µm thick. In 2003 only the $^0/_3$ closed liner and the non-perforated liner were used. All the treatments were packed in a super vent carton (height = 118 mm, length = 400 mm and width = 300 mm). The average net weight of each carton was 4.5 kg. To prevent decay a 'Uvasys' green SO_2-generating sheet (Grapetek, S.A.) was placed on top of the grape bunches. For half of the cartons per trial a Mam-sheet (30g/m^2) was placed between the grapes and the SO_2-generating sheet to prevent direct contact of the SO_2 sheet with the grapes. The other half of the cartons were packed with the desiccant sheet. The Mam-sheet and desiccant sheet absorbed moisture out of the atmosphere inside the liner. In the 2002/2003 season the desiccant sheet was slightly larger than in the2001/2002 season.

CULTIVARS AND EVALUATIONS

Export quality table grapes from the Western Cape, South Africa, were packed in the middle of the picking window for a number of trials as follows:

2001/2002 season: 'Thompson Seedless' from the Hex River Valley (Trials 1 and 2), 'Red Globe' from the Berg River Valley (Trial 4) and Hex River Valley (Trial 5).

2002/2003 season: 'Thompson Seedless' from the Hex River Valley (Trial 3), 'Red Globe' from the Hex River Valley (Trial 6) and Berg River Valley (Trial 7). In all trials, 88 cartons of grapes were packed and cooled accordingly to commercial export standards.

On all the sampled grapes, normal cultural practices were followed as far as irrigation, fertilisation, cluster preparation, pest and disease control and foliage management were concerned. All the grapes were harvested in the morning and weather conditions did not differ between trial dates, with hot sunny days as the norm. On the day of packing, 48 cartons containing 'Thompson Seedless' were sampled of which 24 were evaluated on the day and the other 24 were then placed in 15 °C storage for a week, before they were evaluated for shelf life ability. From the day of packing 40 cartons were stored for five

weeks at -0.5 °C, 20 cartons were evaluated on that day and the remaining 20 were then placed in 15 °C storage for a week, before they were evaluated for shelf life ability. One week at 15 °C is considered as a very harsh treatment and was preferred to test grapes to the limit. 'Red Globe' had a six week cold storage period.

Moisture in the carton was evaluated subjectively on a scale of 1-3 (dry (1), limited condensation (2) and excessive free moisture (3)). Stems were also evaluated subjectively for colour and dryness on a scale of 1-5 (1 for green stems and up to 5 for very brown and dry stems). The mass of the grape bunches was determined for each carton. Abscised berries in the carton were weighed, and then all the *Botrytis* infected berries were removed and weighed. The same was done for split berries and berries damaged by sulphur dioxide. The evaluation was always done in this specific order. Berries that could be classified with more than one of these disorders were only classified and weighed with the disorder that was ranked the highest. The ranking used was as follow: Berry abscission > decayed berries > split berries > SO_2 damaged berries. The desiccant sheets were weighed before packing and on the evaluation days, and the amount of water absorbed was expressed as a percentage of the weight before packing.

Measurement of total soluble solids (TSS) and titratable acidity (TA) was done by randomly selecting 50 berries out of a carton. The berries were juiced in a liquidiser and filtered. The percentage of soluble solids found in the filtrate, was measured with an Atago DBX digital refractometer and expressed as degrees Brix. TA was determined by titrating a 10 g aliquot of juice with 0.1N NaOH to a pH end point of 8.2, using an auto Metrohm 719 S Titrino titrator. The titratable acidity was expressed as percentage tartaric acid. Both of the instruments are equipped with automated temperature compensation.

STATISTICAL DESIGN AND ANALYSIS

A randomised design was used for all the pallets. Each treatment was replicated five or six times, with one carton constituting a single replicate. The statistical software programme SAS (Statistical Analysis Systems Institute, 1996) was used to calculate significant differences ($P \leq 0.05$) between liner types by using arcsin transformed data. Means are

separated by Bonferroni multiple comparisons procedure ($P \leq 0.05$). The chi-square test ($\chi^2 \leq 0.05$) was used to determine liner type effects on non-parametric (subjective) data.

RESULTS AND DISCUSSION

'Thompson Seedless' grapes

Harvest maturity

Harvest maturities for 'Thompson Seedless' were 18.2 °Brix and 0.67 % TA (Trial 1), 19.2 °Brix and 0.60 % TA (Trial 2) and 18.6 °Brix and 0.55 % TA (Trial 3). TSS and TA did not differ significantly between grapes packed with different liners or moisture absorbing sheets following cold storage or shelf life (data not shown).

Grape quality on packing day and after 1 week at 15 °C

On the day of packing or after one week at 15 °C, grapes packed with different liners or moisture absorbing sheets did not differ significantly in grape quality (data not shown).

Cold storage: quality after five weeks at –0.5 °C

In 2002, the desiccant sheet absorbed an average of 84.5 g (48 % (of the sheet's dry weight)) of water per carton in Trial 1 and an average of 78.0 g (46 %) per carton in Trial 2 (data not shown). In 2003, the desiccant sheet absorbed an average of 125.3 g (49 %) per carton in Trial 3 (data not shown). Trial 2 gives a representative example of the influences of the two moisture sheet types on berry abscission, SO_2 damage, *Botrytis* decay and berry split for both seasons (Figure 1).

Berry abscission. Berry abscission was significantly ($P = 0.0027$) higher in the desiccant packaging (4.8 %) than in conventional packaging (2.6 %).

SO_2 damage. SO_2 damage was significantly ($P < 0.0001$) lower in the desiccant packaging (4.1 %) than in conventional packaging (7.2 %).

Decay. *Botrytis* decay was significantly ($P < 0.0001$) higher in the desiccant packaging (2.7 %) than in conventional packaging (0.5 %).

Berry split. Berry split was significantly ($P < 0.0001$) lower in the desiccant packaging (7.4 %) than in the conventional packaging (20.3 %). Significant interaction occurred between liner type and moisture sheet type for berry split in Trial 1 (data not shown). Individually all the liner types had significantly less split in the desiccant packaging than in the conventional packaging.

Trial 2 gives a representative example of the influences of the two moisture sheet types on moisture in the carton and stem condition for both seasons (Figure 2).

Moisture in carton. The moisture in the carton in the desiccant packaging (1.10) was significantly ($\chi^2 = 0.0297$) lower than in the conventional packaging (1.38).

Stem condition. The stem condition in the desiccant packaging (3.00) was significantly ($\chi^2 = 0.0013$) worse than in the conventional packaging (2.16).

Shelf life: quality after five weeks at –0.5 °C and one week at 15 °C

In 2002, the desiccant sheet absorbed an average of 87.1 g (49 % (of the sheet's dry weight)) of water per carton in Trial 1 and an average of 84.1 g (48 %) of water per carton in Trial 2 (data not shown). In 2003, the desiccant sheet absorbed an average of 121.9 g (48 %) of water per carton from Trial 3 (data not shown). Trial 1 gives a representative example of the influences of the two moisture sheet types on berry abscission, SO_2 damage, *Botrytis* decay and berry split for both seasons (Figure 3).

Berry abscission. Berry abscission was significantly ($P = 0.0053$) lower in the desiccant packaging (0.1 %) compared to the conventional packaging (2.7 %).

SO_2 damage. SO_2 damage was significantly ($P < 0.0001$) lower in the desiccant packaging (0.3 %) than in the conventional packaging (4.1 %). Significant interaction occurred between liner type and moisture sheet type for SO_2 damage in Trials 2 and 3 (data not shown). For all liner types, SO_2 damage was significantly lower in the desiccant packaging compared to conventional packaging.

Decay. *Botrytis* decay was significantly ($P < 0.0001$) higher in the desiccant packaging (95.6 %) than in the conventional packaging (8.7 %). Average *Botrytis* decay increased during the shelf life period compared to cold storage (data not shown). Decay in the desiccant packaging after the shelf life period increased to very high levels which is highly undesirable and a big concern (Figure 3).

Berry split. Berry split was significantly ($P < 0.0001$) lower in the desiccant packaging (1.5 %) than in the conventional packaging (44.2 %). This percentage for berry split in the conventional packaging is very high and unacceptable according to industry standards.

Trial 3 gives a representative example of the influences of the two moisture sheet types on moisture in the carton and stem condition for both seasons (Figure 4).

Moisture in carton. Moisture in the carton in the desiccant packaging (1.40) was significantly ($\chi^2 = 0.0003$) less than in the conventional packaging (2.00).

Stem condition. Stem condition was significantly ($\chi^2 = 0.0051$) worse in the conventional packaging (2.58) than in the desiccant packaging (1.95). In Trial 2, the desiccant packaging resulted in significantly worse stem condition than the desiccant packaging, and this contradicted the results from Trial 3. No apparent worsening of stem condition due to the extra shelf life period could be found.

In all the trials, irrespective of grapes being subjected to cold storage or shelf life conditions, the grapes in conventional packaging had more SO_2 damage. This correlates negatively with the occurrence of decay in the conventional packaging. Conventional packaging resulted in much less decay than cartons with the desiccant sheet. Decay was much worse after shelf life evaluations than after cold storage. Some of the cartons with desiccant packaging had 100 % *Botrytis* infection after shelf life evaluations. Additional to more vigorous growth of *Botrytis* at higher temperatures, the elevation of the storage temperature would also cause more condensation on the grapes and this extra moisture will promote decay through spore germination (Ginsburg and Combrink, 1972).

Another reason for the higher decay is that SO_2-generating sheets need moisture to release the gas from the generators (Morris et al., 1992). SO_2 gas diffuses into the air surrounding the grape bunches, killing conidia spores on the surface of the berries (Harvey, 1955). Nelson and Ahmedullah (1973) found an inverse relationship between decay and exposure to SO_2 gas. The desiccant sheet is placed between the grapes and the SO_2-sheet. The desiccant sheet not only absorbs more moisture, but it might also absorb SO_2 gas and this lessens its effectiveness. Where the desiccant sheet touches the grape berries, a very beneficial environment is created for *Botrytis* infection. It is very wet from all the moisture that the sheet absorbs, and SO_2 gas cannot penetrate this area to control decay. Evaluation of individual liner types showed that the use of different liner types did not have a significant influence on the effect of the moisture absorbing sheet.

Grapes packed with the conventional packaging had significantly more berry split compared to grapes packed with the desiccant packaging. Rapid cooling and temperature fluctuations will cause water to condense inside the liners. Berries will absorb free moisture, causing the turgor pressure to increase and berries to split (Meynhardt, 1956). The desiccant sheet absorbs a lot of this extra moisture and controls this quality disorder.

It can be expected that stem quality will deteriorate more in the desiccant packaging. According to Nelson (1979) the desiccation of stems is a secondary symptom of water loss. Extra moisture is absorbed, by the desiccant sheet, from the atmosphere inside the liner and a higher vapour-pressure difference exists between grape bunches and the surrounding air. Transpiration of grape bunches will increase and stems and berries will lose more water. The data verified this, especially in Trial 2. There was less moisture in the liner with the desiccant sheet and the stem condition was worse than in the conventional packaging. This was true for cold storage and shelf life evaluations, although shelf life data of Trials 1 and 3 gave contradictory results. The higher temperature during the shelf life period will also increase vapour-pressure difference, but in these trials grapes subjected to the shelf life period did not desiccate more than grapes that were only subjected to cold storage.

'Red Globe' grapes

Harvest maturity

Harvest maturity for 'Red Globe' was 14.8 °Brix and 0.28 % TA (Trial 4), 17.8 °Brix and 0.32 % TA (Trial 5), 15.1 °Brix and 0.42 % TA (Trial 6) and 15.0 °Brix and 0.36 % TA (Trial 7). TSS and TA did not differ significantly between grapes packed with different liners and moisture absorbing sheets following cold storage or shelf life (data not shown).

Grape quality on packing day and after 1 week at 15 °C

On the day of packing or after one week at 15 °C, grapes packed with different liners or moisture absorbing sheets did not differ significantly in grape quality (data not shown).

Cold storage: quality after six weeks at –0.5 °C

In 2002, the desiccant sheet in Trial 4 absorbed an average of 66.3 g (42 % (of the sheet's dry weight)) of water per carton, and in Trial 5 the sheet absorbed an average of 70.8 g (44 %) per carton (data not shown). In 2003, the desiccant sheet absorbed an average of 122.9 g (48 %) of water per carton in Trial 6, and an average of 157.5 g of water per carton in Trial 7 (data not shown). Trial 5 gives a representative example of the influences of the two moisture sheet types on berry abscission, SO_2 damage, *Botrytis* decay and berry split for both seasons (Figure 5).

Berry abscission. Berry abscission was not significantly (P = 0.3201) influenced in the desiccant packaging (0.1 %) compared to the conventional packaging (0.08 %). In all the trials berry abscission was very low.

SO_2 damage. SO_2 damage was significantly (P = 0.0017) less in the desiccant packaging (2.6 %) compared to the conventional packaging (5.4 %). A significant interaction between liner type and sheet type occurred for SO_2 damage in Trial 4 (data not shown). Individually all the liner types with desiccant sheets resulted in less SO_2 damage, except for the $^0/_3$ closed liner where no significant difference occurred between the moisture absorbing sheet types.

Decay. *Botrytis* decay was not significantly (P = 0.0899) influenced in the desiccant packaging (0.5 %) compared to the conventional packaging (0.3 %). *Botrytis* decay was low in all trials.

Berry split. Berry split in Trial 5 was not significantly (P = 0.0576) influenced in the desiccant packaging (0.7 %) compared to the conventional packaging (0.4 %). A significant interaction occurred between liner type and sheet type for berry split in Trials 4 and 7 (data not shown). In Trial 4, the non-perforated liner and the $^{1}/_{3}$ closed liner resulted in significantly less berry split in the desiccant packaging than in the conventional packaging, and grapes packed in the $^{2}/_{3}$ and $^{0}/_{3}$ closed liners were not significantly influenced by the moisture absorbing sheet regarding berry split. In Trial 7, the desiccant packaging resulted in significantly lower berry split than the conventional packaging when grapes were packed in non-perforated liners, and for the $^{0}/_{3}$ closed liner the desiccant packaging resulted in significantly more berry split.

Trial 6 gives a representative example of the influences of the two moisture sheet types on moisture in the carton and stem condition for both seasons (Figure 6).

Moisture in carton. There was significantly ($\chi^2 < 0.0001$) less moisture in the desiccant packaging (2.00) compared to conventional packaging (2.17). Contradicting data did occur in Trial 4 and 7, where moisture in the carton was significantly more in the desiccant packaging than in conventional packaging.

Stem condition. Stem condition was significantly ($\chi^2 < 0.0001$) worse in the desiccant packaging (3.90) compared to conventional packaging (1.92).

Shelf life: quality after six weeks at –0.5 °C and one week at 15 °C

In 2002, the desiccant sheet from Hex River Valley (Trial 4) absorbed an average of 65.8 g (42 % (of the sheet's dry weight)) of water per carton and in Berg River Valley (Trial 5) the sheet absorbed an average of 74.4 g (45 %) per carton (data not shown). In 2003, the desiccant sheet absorbed an average of 125.8 g (49 %) of water per carton from the Hex River Valley (Trial 6) and an average of 157.5 g (54 %) of water per carton from the Berg

River Valley (Trial 7) (data not shown). Trial 5 gives a representative example of the influence of the two moisture sheet types on berry abscission, SO_2 damage, *Botrytis* decay and berry split for both seasons (Figure 7).

Berry abscission. Berry abscission was not significantly ($P = 0.5621$) influenced in the desiccant packaging (0.2 %) compared to conventional packaging (0.2 %). Berry abscission in all trials was very low and did not increase due to the shelf life period (data not shown).

SO_2 damage. SO_2 damage was significantly ($P < 0.0001$) less in the desiccant packaging (0.2 %) than in the conventional packaging (6.5 %). SO_2 damage in all trials that were subjected to the shelf life period did not increase compared to cold storage (data not shown).

Decay. Botrytis decay was significantly ($P < 0.0001$) higher in the desiccant packaging (9.2 %) compared to the conventional packaging (3.0 %). For all the trials subjected to the shelf life period, decay increased considerably when compared to cold storage (data not shown).

Berry split. Berry split was significantly ($P < 0.0001$) lower in the desiccant packaging (0.2 %) compared to the conventional packaging (2.0 %). A significant interaction occurred between liner type and sheet type for berry split in Trials 4 and 6 (data not shown). In Trial 4, the non-perforated liner and the $^0/_3$ closed liner resulted in significantly less berry split in the desiccant packaging than in the conventional packaging, and berry split in the $^2/_3$ and the $^1/_3$ closed liners were not significantly influenced by the moisture absorbing sheet. In Trial 6, berry split was significantly less in the desiccant packaging compared to conventional packaging when packed in the non-perforated liner.

Trial 5 gives a representative example of the influences of the two moisture sheet types on moisture in the carton and stem condition for both seasons (Figure 8).

Moisture in carton. There was not a significant ($\chi^2 = 0.0815$) difference for moisture in the carton for desiccant packaging (1.45) compared to conventional packaging (1.70).

Stem condition. Stem condition was significantly (χ^2 = 0.0242) worse in the desiccant packaging (3.78) compared to conventional packaging (3.41). Average stem condition deteriorated more during the shelf life period compared to cold storage.

'Red Globe' is prone to develop dry, brown stems (Viljoen, pers. com. 2003). In all trials, irrespective of evaluation times, grape bunches packed in desiccant packaging had worse stem quality. The desiccant sheet absorbs more moisture, and as explained previously, stems will therefore lose more moisture. 'Red Globe' had considerable lower levels of decay than 'Thompson Seedless'. For 'Red Globe', the decrease in SO_2 gas did not influence the amount of decay between the two packaging treatments as much as in the 'Thompson Seedless' trials.

'Red Globe' is susceptible to split, and the desiccant sheet did lessen the occurrence of berry split. As explained previously, free moisture can be absorbed by berries and increase the turgor pressure. The desiccant sheet absorbs a lot of this extra moisture and prevents berry split. SO_2 damage was more apparent after the shelf life period due to the increase in temperature which is responsible for higher SO_2 damage (Nelson, 1983). After shelf life evaluation the higher temperature and added condensation masked the difference in moisture in the carton between the two moisture absorbing sheets. On a few occasions, the effect of the moisture sheet type was influenced differently by liner type for berry split and SO_2 damage. Evaluations of liner type individually showed that the use of different liner types did not have a significant influence on the effect of the two moisture absorbing sheet types that were evaluated. It can be considered that the use of the desiccant sheet had more of an influence on moisture in the carton than the use of liners with different perforations.

CONCLUSION

Packaging that absorbs too much moisture might aggravate the dry stem problem (Crisosto and Mitchell, 2002). With less moisture inside the carton, SO_2 sheets might not work as effectively and more berries will decay. According to Ginsburg and Combrink (1972) *Botrytis* decay is the most important quality factor in the table grape industry. There is a clear disadvantage in the use of the thick desiccant sheet with 'Thompson Seedless' or 'Red Globe', because it increased the occurrence of decay to significantly high percentages. It did

have advantages in lowering berry split dramatically and, in some instances, fewer berries abscised in the carton padded with the desiccant sheet. However, there is evidence that dryer stems will aggravate berry abscission (Burger, 2000). SO_2 damage was also less but this benefit was clearly the cause of a discernible increase in *Botrytis* decay.

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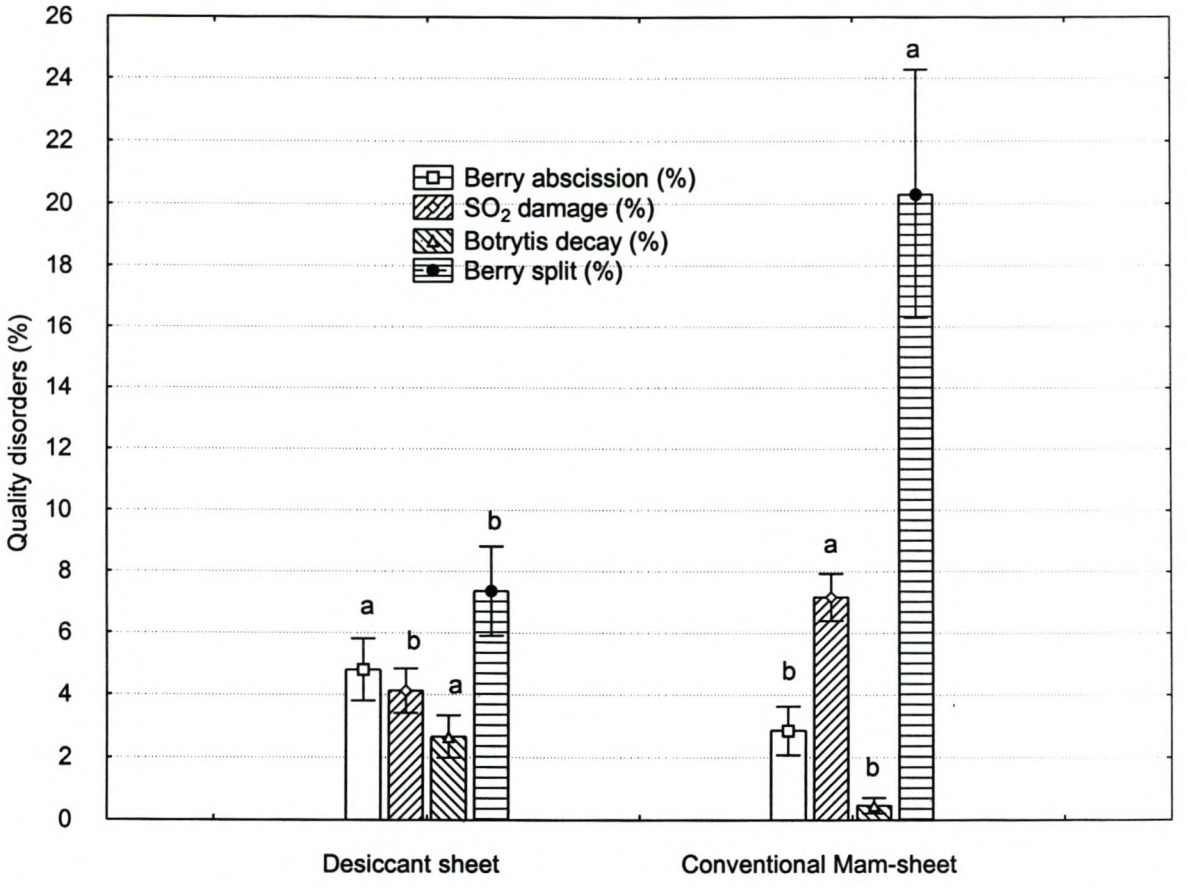

Figure 1 Quality disorders of 'Thompson Seedless' table grapes from the Hex River Valley (Trial 2) with different moisture sheet types, after five weeks at -0.5 °C. Berry abscission ($P = 0.0027$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P < 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

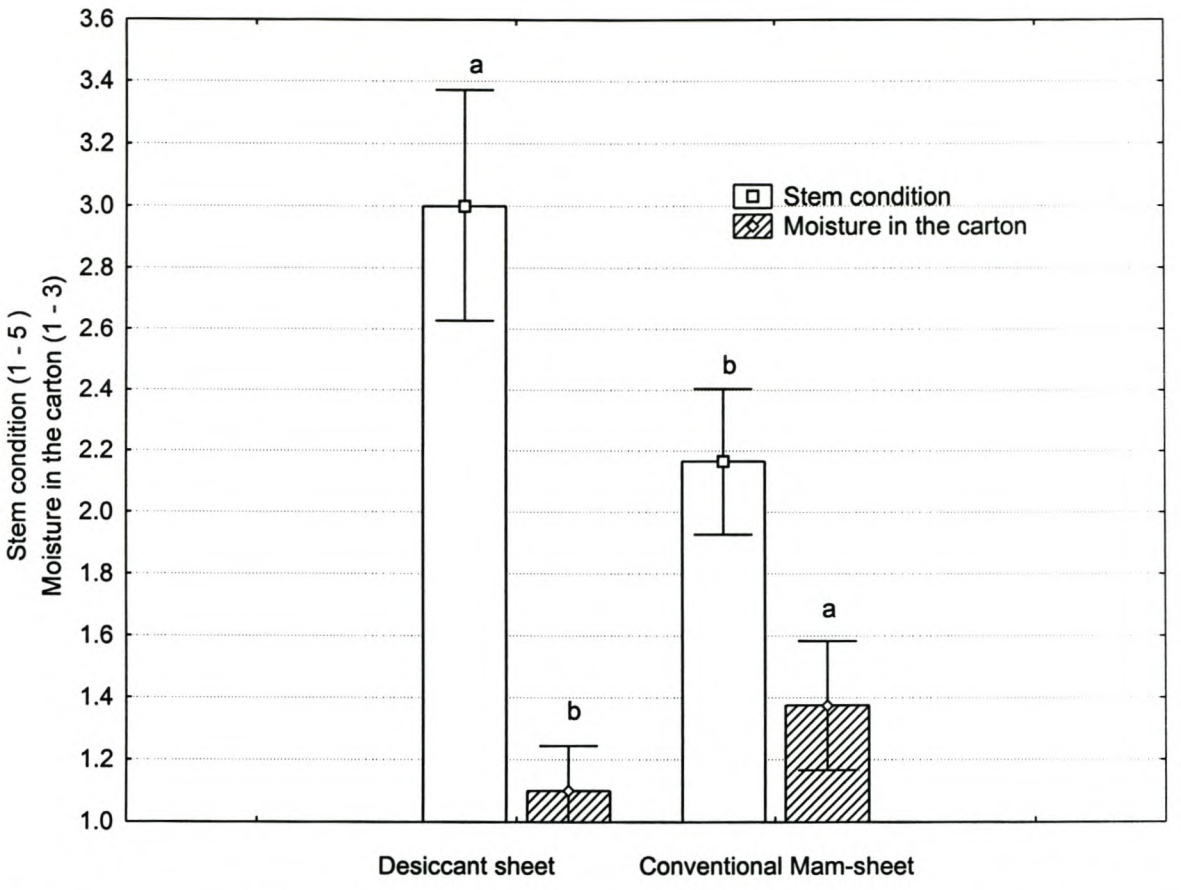

Figure 2 Moisture in the carton and stem condition of 'Thompson Seedless' table grapes from the Hex River Valley (Trial 2) with different moisture sheet types, after five weeks at -0.5 °C. Stem condition (χ^2 = 0.0013) and moisture in the carton (χ^2 = 0.0297). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems. Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture. Means followed by the same letter do not differ significantly at the 5 % level as determined by chi-square test.

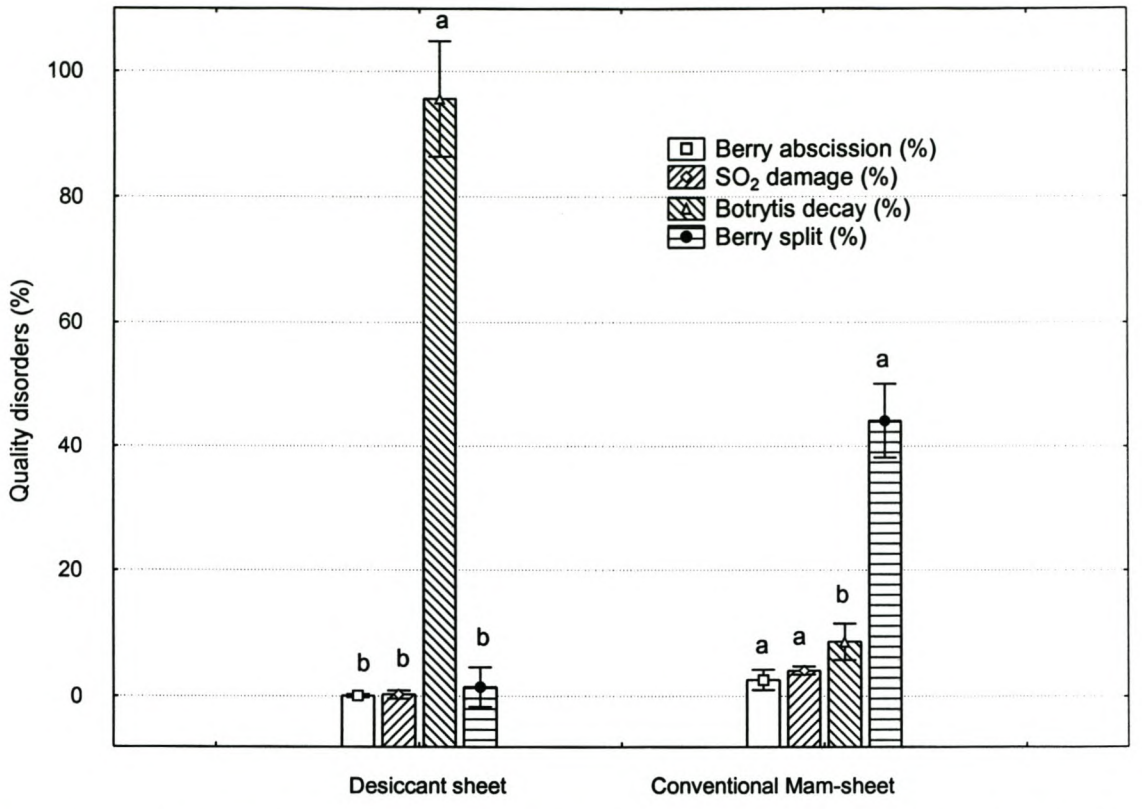

Figure 3 Quality disorders of 'Thompson Seedless' table grapes from the Hex River Valley (Trial 1) with different moisture sheet types, after five weeks at -0.5 °C plus one week at 15 °C. Berry abscission ($P = 0.0053$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P < 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

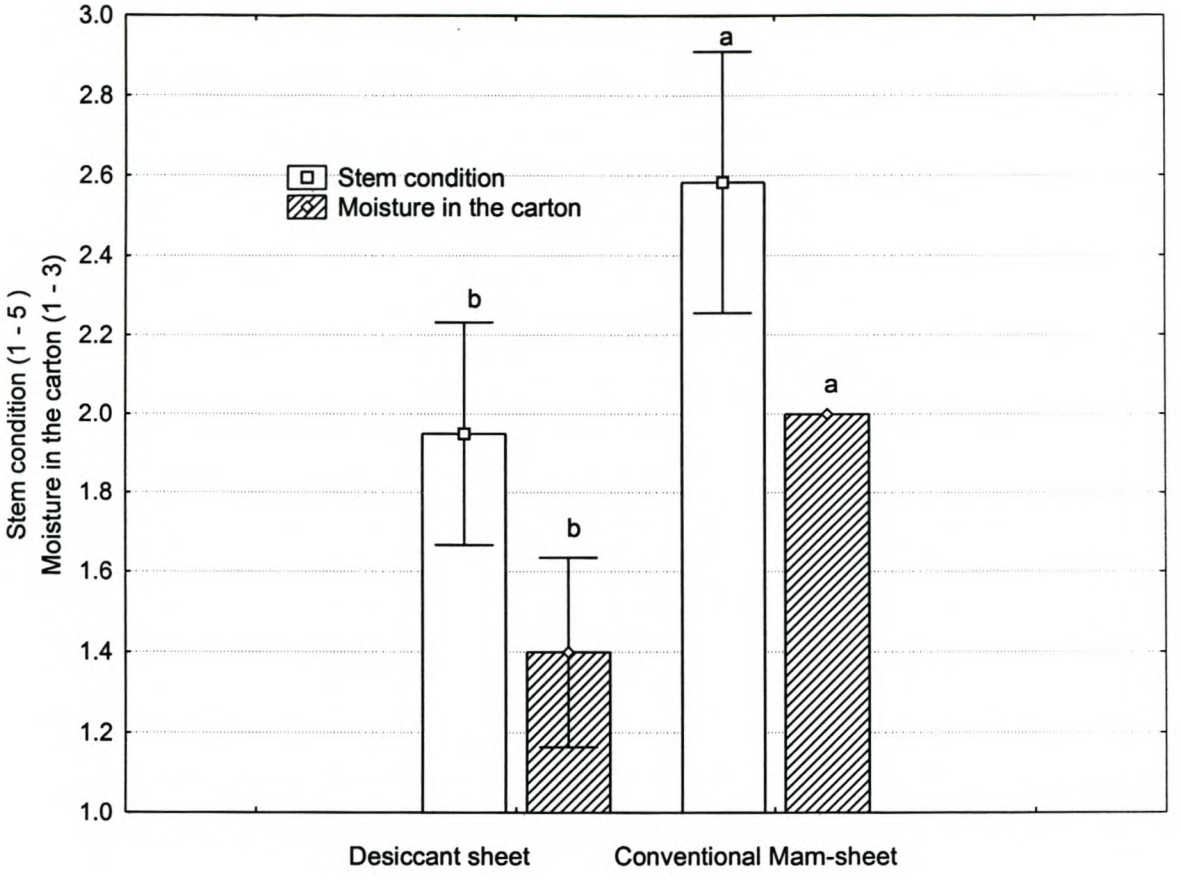

Figure 4 Moisture in the carton and stem condition of 'Thompson Seedless' table grapes from the Hex River Valley (Trial 3) with different moisture sheet types, after five weeks at -0.5 °C plus one week at 15 °C. Stem condition (χ^2 = 0.0051) and moisture in the carton (χ^2 = 0.0003). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems. Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture. Means followed by the same letter do not differ significantly at the 5 % level as determined by chi-square test.

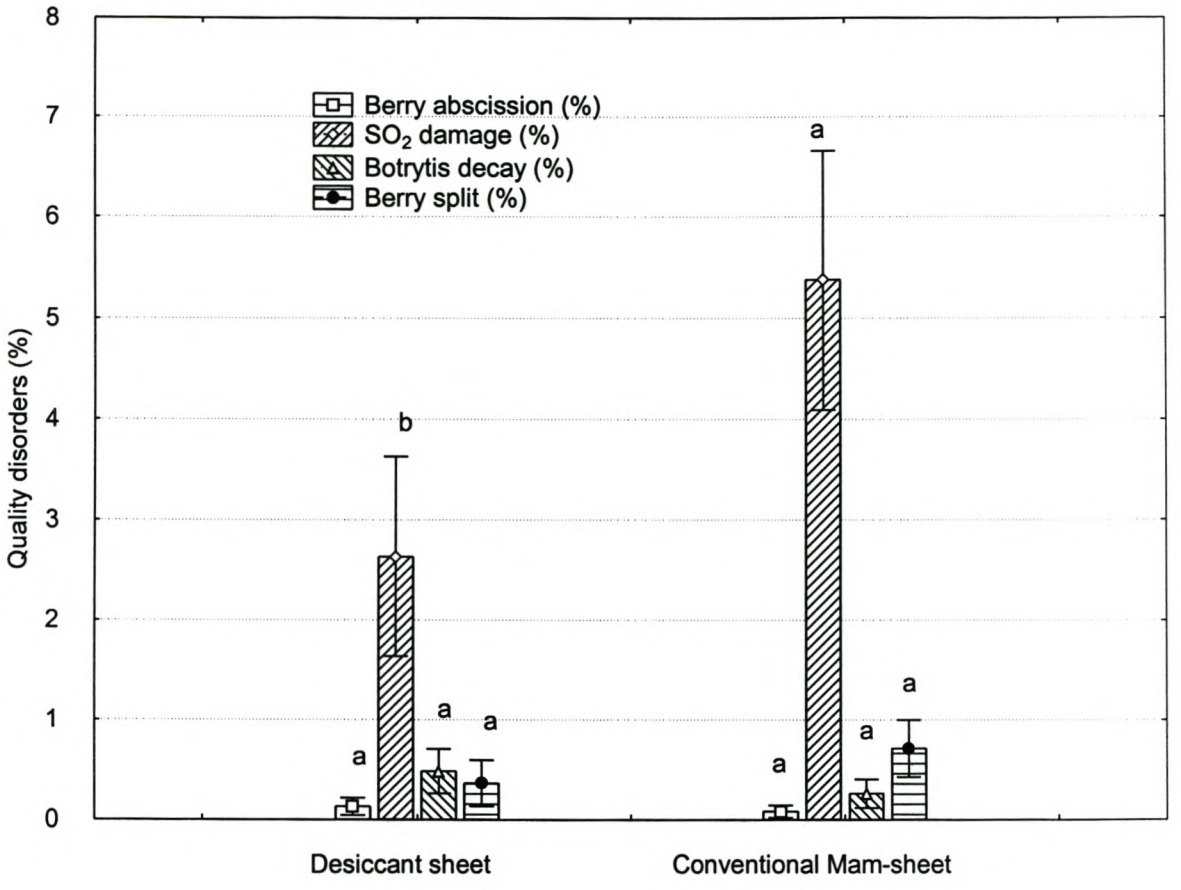

Figure 5 Quality disorders of 'Red Globe' table grapes from the Hex River Valley (Trial 5) with different moisture sheet types, after six weeks at -0.5 °C. Berry abscission (P = 0.3201), SO_2 damage (P = 0.0017), *Botrytis* decay (P = 0.0899) and berry split (P = 0.0576). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

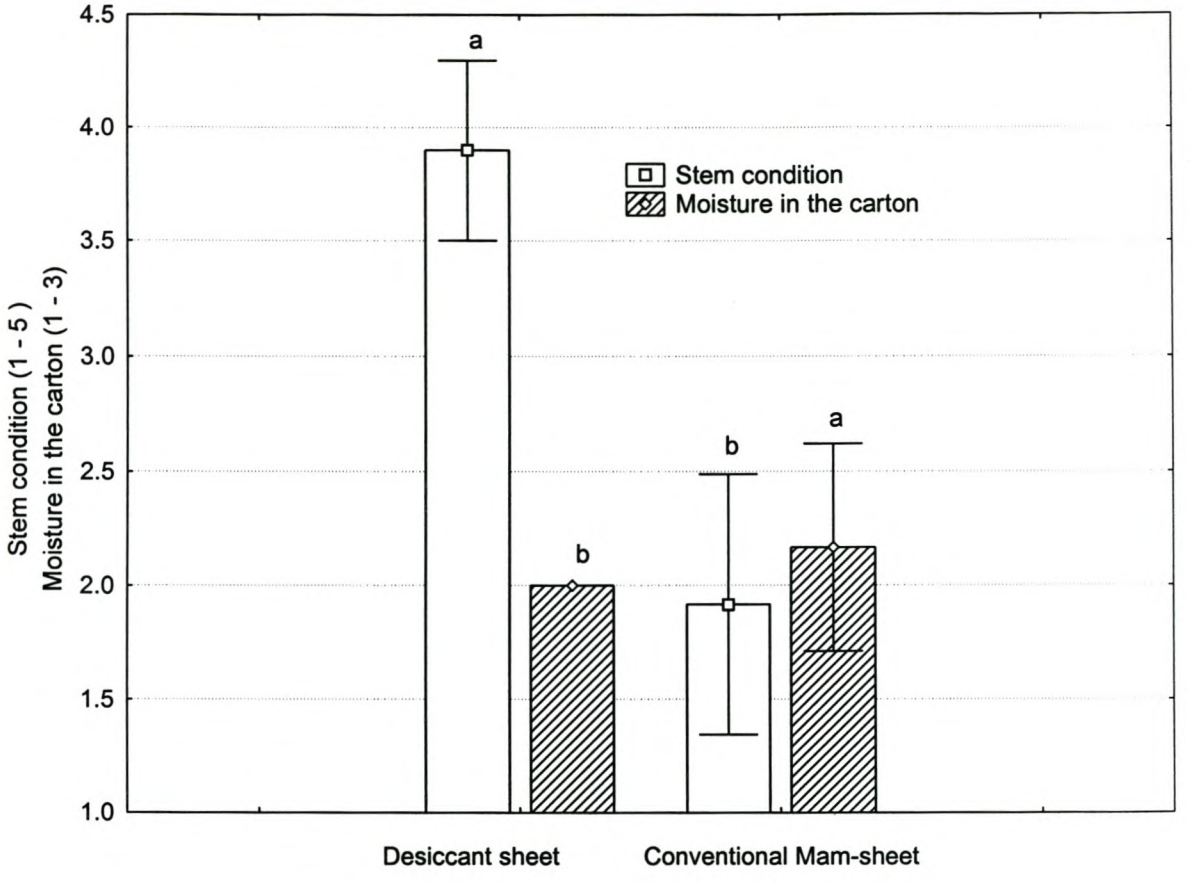

Figure 6 Moisture in the carton and stem condition of 'Red Globe' table grapes from the Hex River Valley (Trial 6) with different moisture sheet types, after six weeks at -0.5 °C. Stem condition ($\chi^2 < 0.0001$) and moisture in the carton ($\chi^2 < 0.0001$). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems. Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture. Means followed by the same letter do not differ significantly at the 5 % level as determined by chi-square test.

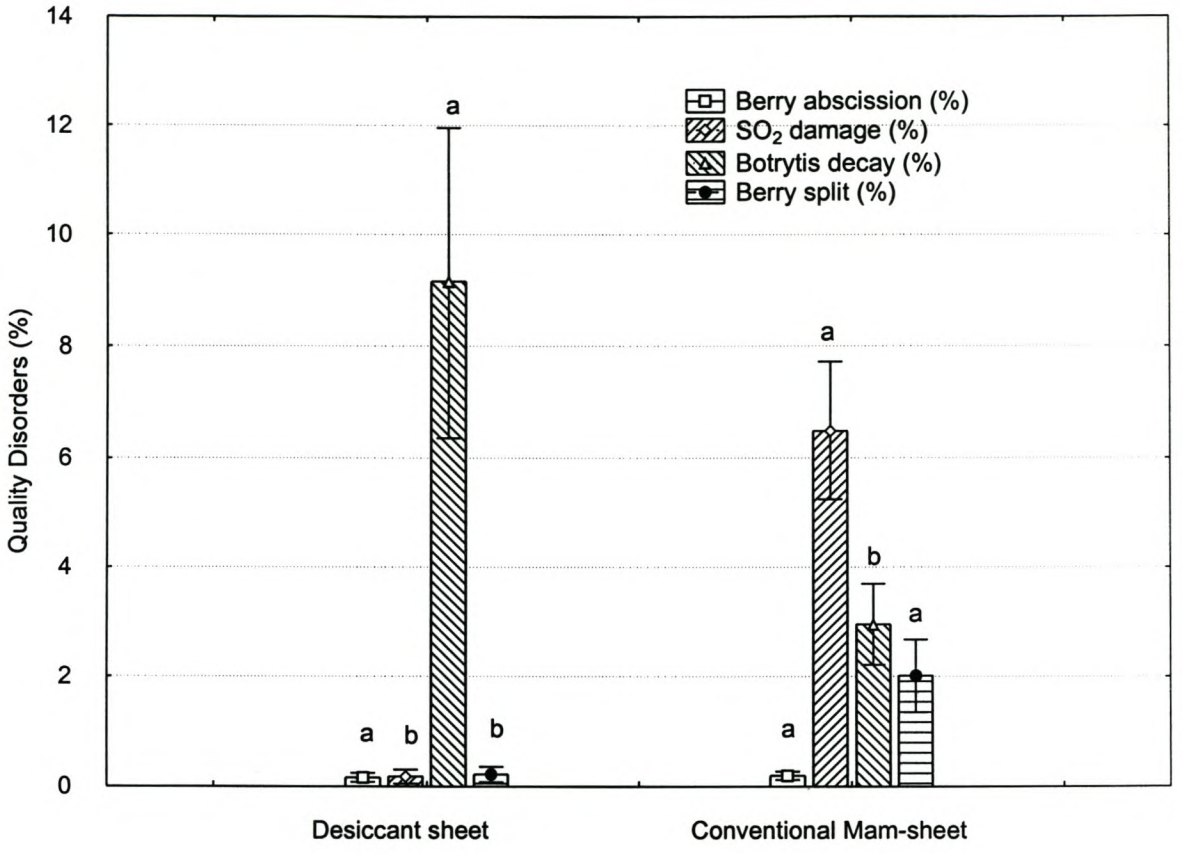

Figure 7 Quality disorders of 'Red Globe' table grapes from the Hex River Valley (Trial 5) with different moisture sheet types, after six weeks at -0.5 °C plus one week at 15 °C. Berry abscission ($P = 0.5621$), SO_2 damage ($P < 0.0001$), *Botrytis* decay ($P < 0.0001$) and berry split ($P < 0.0001$). Means followed by the same letter do not differ significantly at the 5 % level as determined by Bonferroni test.

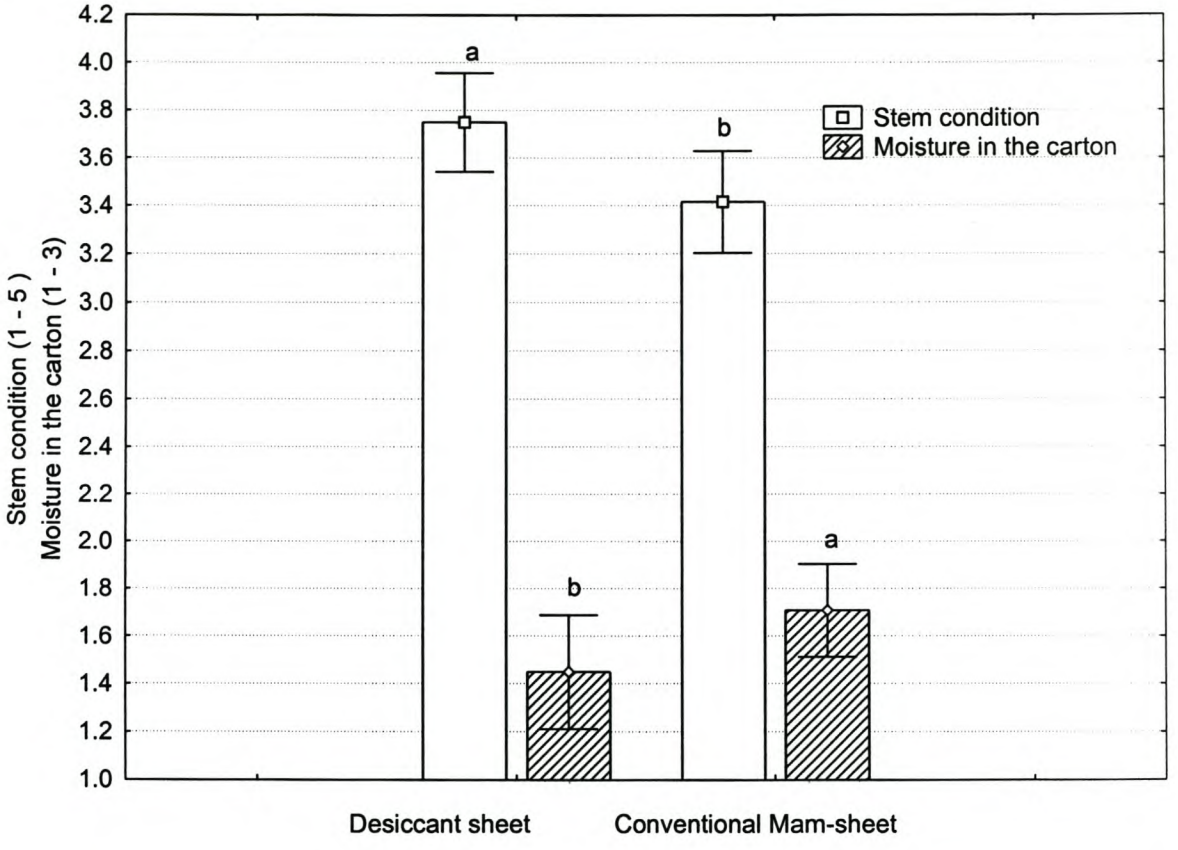

Figure 8 Moisture in the carton and stem condition of 'Red Globe' table grapes from the Hex River Valley (Trial 5) with different moisture sheet types, after six weeks at -0.5 °C plus one week at 15 °C. Stem condition (χ^2 = 0.0242) and moisture in the carton (χ^2 = 0.0815). Stem condition was rated on a scale of 1 – 5, with 1 = fresh, green stems and 5 = dry, brown stems. Moisture was rated on a scale of 1 – 3, with 1 = dry, 2 = limited condensation and 3 = excessive free moisture. Means followed by the same letter do not differ significantly at the 5 % level as determined by chi-square test.

ARTICLE III INFLUENCE OF DEGREE OF LINER PERFORATION AND CARRY BAG TYPE ON COOLING RATE OF TABLE GRAPES.

ABSTRACT

A mini forced-air cooler was used at static pressure of 6, 12 or 18 mm water gauge to compare the cooling rates of the following liners: a) standard, non-perforated liner, b) needle perforated liner, c) 2 mm perforated liner with 54 perforations, d) 2 mm perforated liner with 18 of the 54 perforations closed, and e) 2 mm perforated liner with 36 of the 54 perforations closed. The cooling rate of various sealable carry bags was also compared, using a non-perforated liner and a static pressure of 10 mm water gauge. The non-perforated liner had the slowest cooling rate, and the needle perforated liner was most influenced by pressure changes. The 2 mm liner had the fastest cooling rate. All the cooling rates increased with an increase in static pressure. The various carry bags had the same cooling rates in the same seasons and this is due to the large influence the non-perforated liner had on cooling. The diffusion of water through the various perforated liners was not directly proportional to an increase either in perforation percentage or pore size.

KEYWORDS : 'Barlinka', 'Red Globe', forced air cooling, sealable

INTRODUCTION

In order to increase storage times and improve grape quality, it is important to cool grapes as quickly and effectively as possible. New packaging materials, new packing methods and different pallets increase the difficult task of cooling the grapes fast and effectively (Mitchell, 1978). Grapes have a low respiration rate (Kader, 1992) falling in the 5-10 mg $CO_2.kg^{-1}.h^{-1}$ range at 5 °C. The rates at which products deteriorate are proportional to their respiration rates. Respiration can be slowed down dramatically by cooling.

Effective cooling will minimise water loss from the fruit and stems (Mitchell et al., 2002). This is achieved by cooling the surrounding temperature of grape bunches down to –0.5 °C as rapidly as possible. The magnitude of water loss in grapes is directly related to the length of

exposure, the temperature during delay before cooling and the type of material grapes are stored in (Crisosto and Mitchell, 2002). While there is still a temperature difference between the grape bunch and the surrounding air, a vapour pressure gradient will be maintained, and grapes will lose moisture (Mitchell et al., 2002).

The driving force for transpiration is the gradient in water vapour density from within the plant organ to the atmosphere (Mitchell et al., 2002). In this instance, the surrounding air is the enclosed air inside the liner of a grape carton. The vapour pressure deficit is largely determined by the temperature of the produce and the surrounding air. The larger the temperature differences, the higher the deficit. A temperature gradient between packed grapes (25 °C and more) and the cold room (less than -0.5 °C) will greatly accentuate the vapour gradient. A high relative humidity inside the liner will cause the deficit to drop (Mitchell et al., 2002). Even with a small deficit, transpiration will continue. Surrounding air will form a boundary layer with a high water vapour density restricting water movement (Salisbury and Ross, 1992). Air movement determines the thickness of the layer. In the case of using a non-perforated liner, air movement will be almost irrelevant. In the case of perforated liners the size and the degree of perforations will influence the thickness of the boundary layer.

The use of perforated or non-perforated liners has to be taken into consideration when delivery air temperatures (DAT) are chosen. Cooling in an unvented carton is slower than in a vented carton (Gentry and Nelson, 1964). Choosing the optimum pressure difference across pallets is always a trade-off between increasing the pressure, which will increase the cooling rate, and worsening stem browning due to the higher airflow (Mitchell et al., 2002). The increase in pressure can also increase the temperature difference across cartons in pallets. This can cause cartons closest to the coil to freeze before the remainder of the pallet is even close to the desired temperature.

There is a growing demand from UK supermarkets to pack individual table grape bunches in sealable carry bags. Sealed carry bags will minimise the loss of bunch mass due to customers

that pick berries before they buy. Loose berries on floors, that can cause customer injuries, can also be eliminated. Many different carry bags are used to export grapes to the UK (Burger and Du Plessis, 2003).

The objectives of this trial are to quantify the cooling rate of table grapes under standardised and quantified conditions using various liners and carry bags. Information is required to extrapolate cooling time from small scale trials to a commercial cooling tunnel for each liner. Scientific results are needed to test the effect carry bags have on the cooling of grapes before they can be used.

MATERIALS AND METHODS

Trials were conducted in the 2001/2002 and 2002/2003 seasons with grapes sampled from the Hex River Valley in the Western Cape, South Africa. Evaluations on liners and carry bags were conducted using 'Red Globe' and 'Barlinka' table grapes, respectively. Standard cultural practices were followed as far as irrigation, fertilisation, cluster preparation, pest and disease control and foliage management were concerned.

All the treatments were packed in a super vent carton (height = 118 mm, length = 400 mm and width = 300 mm). The average net weight of each carton was 4.5 kg. All the liners were 20 μm thick. The liner evaluations were done by packing grape bunches in standard round bottom, open top carry bags and placing them in different polyethylene liners. Adhesive tape was used to close the liner. All the cartons had a 'Uvasys' SO_2-sheet (Grapetek, S.A.) on top of the grape bunches with a moisture absorbing sheet between the grapes and the SO_2-sheet. Carry bag evaluations were done with the same packaging except that a non-perforated liner was always used while alternating between the various carry bag treatments.

For the 2001/2002 season, five different liner types were used, viz. a) a standard, non-perforated liner (non), b) a needle perforated liner (needle) with ± 0.0015 % perforation, c) a 2 mm perforated liner with 54 perforations ($^0/_3$), d) a 2 mm perforated liner with 18 of the 54 perforations closed ($^1/_3$) and e) a 2 mm perforated liner with 36 of the 54 perforations closed

($^2/_3$). The 2 mm liner group had perforation percentages of 0.0419 %, 0.0279 % and 0.0140 %, respectively. In the 2002/2003 season only the non-perforated liner, the needle perforated liner and the standard 2 mm perforated liner were used.

In the 2001/2002 season, five different types of carry bags were used: a) round bottom, open top carry bag (control), b) round bottom, with a zip lock and a handle below the lock mechanism, c) round bottom, with a zip lock and a handle above the lock mechanism, d) square bottom, with a zip lock with a slider, and e) square bottom, with a zip lock and a handle above the lock mechanism. In the 2002/2003 season four different carry bags were used: a) round bottom, open top carry bag (control), b) square bottom, with a zip lock with a slider, c) square bottom, with Velcro as lock mechanism, and d) square bottom, with a zip lock.

A simulation of forced-air cooling was done using 40 cartons stacked on an export pallet base (1 m x 1.2 m). The mini pallet was four cartons high with ten cartons per layer. The pallet was kept in a room at 25 °C until berries had a pulp temperature of ± 25 °C. Subsequently the grapes were cooled down in a cold room with an average delivery air temperature (DAT) of 0.67 °C. Air was drawn through the 1 m sides of the pallet, across the 1.2 m breadth. This was done by sealing the whole pallet off, except for the two 1m sides where air had to go through. A fan with a constant speed was used to generate a pressure differential across the pallet, causing forced air cooling. The return air had to move through an air outlet with a 75 mm radius. The mini forced-air cooler has an adjustable air vent to regulate the pressure across the pallet. Three different static pressures across the pallet were used in the experiment, viz. 6, 12 or 18 mm. For every static pressure the volume of air passing through the cartons was calculated by taking a reading from the manometer and converting it to airflow ($m^3.s^{-1}$) by using a pressure : flow graph (Anonymous, 1998). The cooling of the grapes continued until the pulp temperature of the grapes in the middle carton reached 1 °C.

Berry and air temperatures were measured using copper/constantan thermocouples. A thermocouple wire was inserted in a berry, in the outermost carton closest to the coil, another was inserted in the middle of the pallet and a third was inserted in a carton on the other side closest to the fan. The DAT and return air temperature (RAT) were also measured.

Temperatures were logged every 10 minutes with a Squirrel logger (Grant Instruments Ltd., Cambridge).

In the 2001/2002 season, one replicate per treatment was carried out and in the 2002/2003 season two replicates per treatment were carried out for the liner evaluation. In the carry bag evaluations, one replicate per treatment was carried out for both seasons.

The difference in diffusion rate through the four perforated liners was determined in 2002/2003 with the following procedure. A non-perforated plastic tray (52 cm x 42 cm x 7 cm) was sealed off with the different liner types after one litre of water was added to the trays. Trays were kept in a laboratory at room temperature. The containers were weighed once water had been added and then every two to three days for a period of 30 days. Three replicates per treatment were used.

STATISTICAL DESIGN AND ANALYSIS

No statistical analysis was done for the cooling trials, because the treatments were replicated only once and twice in the 2001/2002 and 2002/2003 seasons, respectively. In the liner diffusion rate trial the statistical software programme SAS (Statistical Analysis Systems Institute, 1996) was used to calculate significant differences between the rates of water loss by using a one way ANOVA. Means are separated by Bonferroni multiple comparisons procedure ($P \leq 0.05$).

RESULTS AND DISCUSSION

All the liner type and carry bag treatments had similar cooling profiles, and therefore only data from the needle perforated liner are shown (Figure 1). Cooling rate decreased from the outer carton to the inner carton (Figure 1). This is due to the DAT rising as it moves through the pallet and this creates a temperature difference between the cartons in a pallet. Cold store operators typically measure pulp temperatures in the centre of pallets, as this is the temperature used by the Perishable Products Export Control Board (PPECB) to determine whether grapes have been cooled sufficiently for shipping. However, this localised measurement is not representative of the remaining cartons in the pallet (Figure 1). As is

evident from Figure 1, the pulp temperature of grapes in the inner carton was about 2.5 °C when forced air cooling terminated upon the middle carton reaching the statutory 1 °C. At that time, the outer carton was at a temperature of -1 °C. To keep the outer cartons from freezing the DAT needs to be kept above -1 °C. The temperature gradient is aggravated with the use of perforated liners, because the perforations increase the temperature difference across the pallet (Table 1).

Liner type evaluation. All cartons cooled faster with an increase of static pressure, irrespective of liner type (Table 2). The needle perforated liners were influenced the most by changes in pressure. Averaging overall, the non-perforated liner had the longest cooling time (24h30min). The needle perforated liner (21h10min) had a faster cooling time. The 2 mm liner group cooled down the fastest and had similar cooling times. The $^{2}/_{3}$ closed liner, $^{1}/_{3}$ closed liner and the $^{0}/_{3}$ closed liner had cooling times of 19h00min, 19h30min and 20h00min, respectively. It was expected that the decrease in perforation would increase cooling times, but the differences between liners was small, making it less evident. The airflow through the pallet did not differ much between liner types except for the non-perforated liner. This suggests that degree of perforation is not the limiting factor, but rather static pressure across the pallet. The airflow increased with similar increments for all the liner types when the static pressure was increased.

The pulp temperature of berries in the non-perforated liner took longer to decrease to 1 °C than in the $^{0}/_{3}$ closed liner and the needle perforated liner (Figure 2). Grapes packed in the non-perforated liner will always take longer to cool due to air moving around the liner and heat loss from grapes being dependant on conduction through the plastic barrier (Burger, 2000). The perforations in other liner types mediate the passing of cold air directly through the grape bunches, thereby increasing the cooling rate through convection. Air movement can be enhanced by an increase of degree of perforation and an increase of static pressure.

The maximum temperature difference between the outer carton and the inner carton on a pallet demonstrates how liner perforation influences cooling rates (Table 1). Averaging

overall the non-perforated liner had a smaller temperature difference across the pallet compared to the needle perforated liner and $^{0}/_{3}$ closed liner. Perforation of liners allows delivery air to move past the bunches and heat is removed through convection. This causes more rapid cooling compared to no perforation of liners where heat has to pass through the plastic barrier by conduction. The increase of heat exchange with the grapes causes the delivery air to increase in temperature and as it moves through the cartons, cooling efficiency is reduced. This will cause uneven cooling with produce in the outer carton being at a much lower temperature than produce in the inner carton. The temperature difference can be reduced by increasing the static pressure across the pallet. This will increase airflow and allow more cold air to pass through the produce, causing uniform cooling. In Chile, where perforated liners are commonly used, the direction of airflow is reversed near the end of the cooling period in order to counteract this temperature gradient (Huysamer, pers. com., 2003).

Carry bag evaluation. The different carry bags in 2001/2002 and 2002/2003 trials did not differ significantly in cooling times or airflow within a specific season (Table 3). This is due to the non-perforated liner that was used in all the trials and it emphasized that the type of liner is the determining factor in cooling rates. All the carry bags, including those with closed tops, had sufficient perforations to allow air movement and heat loss inside the liner, resulting in similar cooling times. Cooling times in the 2001/2002 season were notably longer than in the 2002/2003 season. No reason could be found for this time difference.

The driving force for transpiration is the gradient in water vapour density between the grape bunches and the air surrounding the bunches in the carton (Mitchell et al., 2002). The water vapour density is determined largely by the temperature and humidity inside the liner.

The surrounding air in contact with the grape bunches has a boundary layer with high humidity, due to transpiration. The water vapour gradient between the bunch and the boundary layer will be low and this will restrict water loss. The degree of restriction will be determined by the thickness of the layer and this in turn is determined by the amount of air movement. In the case of the non-perforated liner air movement should be very little

compared to perforated liners where the number and size of perforations determine air movement.

When warm grapes are packed, the temperature gradient between the grapes (± 25 °C) and DAT (± -0.5 °C) greatly accentuates the water vapour gradient. The difference in temperature will increase the water vapour gradient between the grape bunches and the surrounding air. Effective cooling of grapes will lessen the time grapes are subjected to conditions promoting moisture loss.

Air movement in direct contact with grape bunches, as in the perforated packaging, can be effective in creating a faster cooling rate. However, as explained above, the air movement increases moisture loss. The advantage of faster cooling rates compared to higher moisture loss must be considered when perforation levels are chosen.

Liner diffusion rate evaluation. The needle perforated liner had the slowest rate of diffusion of water (2.24 $g.day^{-1}$) followed by the $^{1}/_{3}$ closed liner (2.32 $g.day^{-1}$), the $^{2}/_{3}$ closed liner (3.00 $g.day^{-1}$) and the $^{0}/_{3}$ closed liner (3.19 $g.day^{-1}$) (Table 4). The liners did not differ significantly from each other in diffusion rate. It can be expected that the needle perforated liner would have a slower diffusion rate due to the much smaller percentage of perforation (0.0015 %). The 2 mm liner group has a perforation range from 0.0140 % to 0.0419 %, i.e. 9- to 28-fold greater. It is not expected that the $^{2}/_{3}$ closed liner will have a higher diffusion rate than the $^{1}/_{3}$ closed liner and almost the same as the $^{0}/_{3}$ closed liner. If the diffusion rate is expressed in $g.day^{-1}.(\%\ perforation)^{-1}$, it becomes evident that the diffusion rate per perforation of the needle perforated liner is by far the largest (Table 4). The $^{2}/_{3}$ closed liner also had a faster diffusion rate than expected, compared to the remaining 2 mm liner group.

Water vapour diffuses through the perforations due to the vapour pressure deficit between the atmosphere outside the liner and air contained inside the liner. A smaller amount of perforation or smaller pores will allow less diffusion while an increase in number of perforations or an enlarged pore size will allow more diffusion of water through the liner. However, these are not the only factors that determine the diffusion rate. Water vapour that

has moved out of the liner will cause the water vapour concentration outside the liner to increase, forming a boundary layer. Less perforation causes a thinner boundary layer to form outside the liner, creating less resistance to diffusion. The increased perforation will have increased diffusivity while the thicker boundary layer will decrease diffusion (Salisbury and Ross, 1992). This explains why the water can diffuse out of the needle perforated liner at a rate similar to liners with much larger perforations and why water diffuses out of the $^{2}/_{3}$ closed liner much faster than expected. The size of the boundary layer will be influenced by air movement, but in this case air movement was not a factor as trays were kept under identical conditions in a laboratory.

CONCLUSION

As expected, the perforated liners increased the contact of grapes with cold air and thus increased cooling rate. This will also be the biggest disadvantage, because the increase in airflow will lessen the humidity inside the liner, resulting in stem desiccation (Gentry and Nelson, 1968). The faster cooling rate caused the DAT to increase as it moved through the pallet, causing uneven cooling of cartons. With an increase in static pressure, a direct increase of airflow and cooling rate was found in all liners. The needle perforated liner was influenced the most by static pressure increase. This is probably due to the nature of the perforations. Many of the perforations made by needles were very small but could enlarge if the pressure was high enough or when they were damaged by berry stems. The temperature difference that can arise in a pallet can be manipulated by using liners with fewer perforations or by changing the pressure drop across the pallet. The lower perforation percentage in the needle perforated liner can actually cause similar diffusion rates to that of the 2 mm liner group. The lesser perforation causes a thinner boundary layer to form outside the liner, creating less resistance to diffusion than in the case of the 2 mm perforations. The larger individual pore size in the latter, however, increases diffusivity. The data generated in the cooling profiles can be extrapolated for commercial scale forced air tunnels, which would enable cold store operators to improve planning of fruit flow through their facilities.

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Table 1 Influence of static pressure on the maximum temperature difference between the outer carton and the inner carton in 'Red Globe' table grapes packed in various liners.

Static pressure	**Liner type[y]**			
2002	**Non**	**Needle**	**$^{0}/_{3}$**	**Average**
6 mm	6.7 °C[x]	9.0 °C	8.4 °C	5.3 °C
12 mm	5.6 °C	11.1 °C	9.6 °C	8.8 °C
18 mm	7.4 °C	9.9 °C	5.9 °C	7.7 °C
Average	6.6 °C	10.0 °C	8.0 °C	

[x] The maximum temperature difference (during forced air cooling) between the outer and the inner carton of a pallet that has been cooled from ±25 °C to 1 °C.

[y] Maximum temperature differences for $^{2}/_{3}$ closed liner and $^{1}/_{3}$ closed liner not available.

Table 2 Influence of static pressure on cooling time and airflow (in parentheses) in 'Red Globe' table grapes packed in various liners.

Static pressure	**Liner type**					
	Non	**Needle**	**$^{2}/_{3}$**	**$^{1}/_{3}$**	**$^{0}/_{3}$**	**Average**
6 mm	27h15min (0.073)[Y]	28h00min (0.058)	N/V	20h50min (0.070)	21h10min (0.075)	25h28min
12 mm	30h00min (0.085)	21h00min (0.080)	19h20min (0.080)	19h10min (0.085)	21h20min (0.0875)	24h06min
18 mm	20h50min (0.100)	17h00min (0.095)	18h40min (0.105)	18h30min (0.100)	17h35min (0.100)	18h28min
Average	24h30min	21h10min	19h00min	19h30min	20h00min	

[Y] Airflow ($m^3.s^{-1}$) (Anonymous, 1998)

Table 3 The cooling times and airflows (in parentheses) of 'Barlinka' table grapes packed in various carry bags.

Carry bag type 2002	**Time**
Round bottom, open top carry bag (Control)	27h30min (0.080)[x]
Round bottom, and a zip lock with a handle below the lock mechanism	26h40min (0.080)
Round bottom, and a zip lock with a handle above the lock mechanism	27h00min (0.075)
Square bottom, with a zip lock with a slider	30h40min (0.080)
Square bottom, with a zip lock and a handle above the lock mechanism	27h10min (0.075)
Carry bag type 2003	
Round bottom, open top carry bag (Control)	20h30min (0.085)
Square bottom, with a zip lock with a slider	17h00min (0.085)
Square bottom, with Velcro as lock mechanism	19h00min (0.070)
Square bottom, with a zip lock	18h00min (0.080)

[x] Airflow ($m^3.s^{-1}$) (Anonymous, 1998)

Table 4 The percentage perforation, rate of water loss and diffusion rate/% perforation for various liner types

	Liner type			
	Needle	**$^{2}/_{3}$**	**$^{1}/_{3}$**	**$^{0}/_{3}$**
Perforation (%)	0.0015	0.0140	0.0279	0.0419
Diffusion rate ($g.day^{-1}$)	2.24^{ax}	3.00^{a}	2.32^{a}	3.19^{a}
Diffusion rate/% perforation ($g.\ day^{-1}.(\%)^{-1}$)	±1493	±215	±83	±76

[x] Means followed by the same letter do not differ at the 5 % level as determined by Bonferroni test.

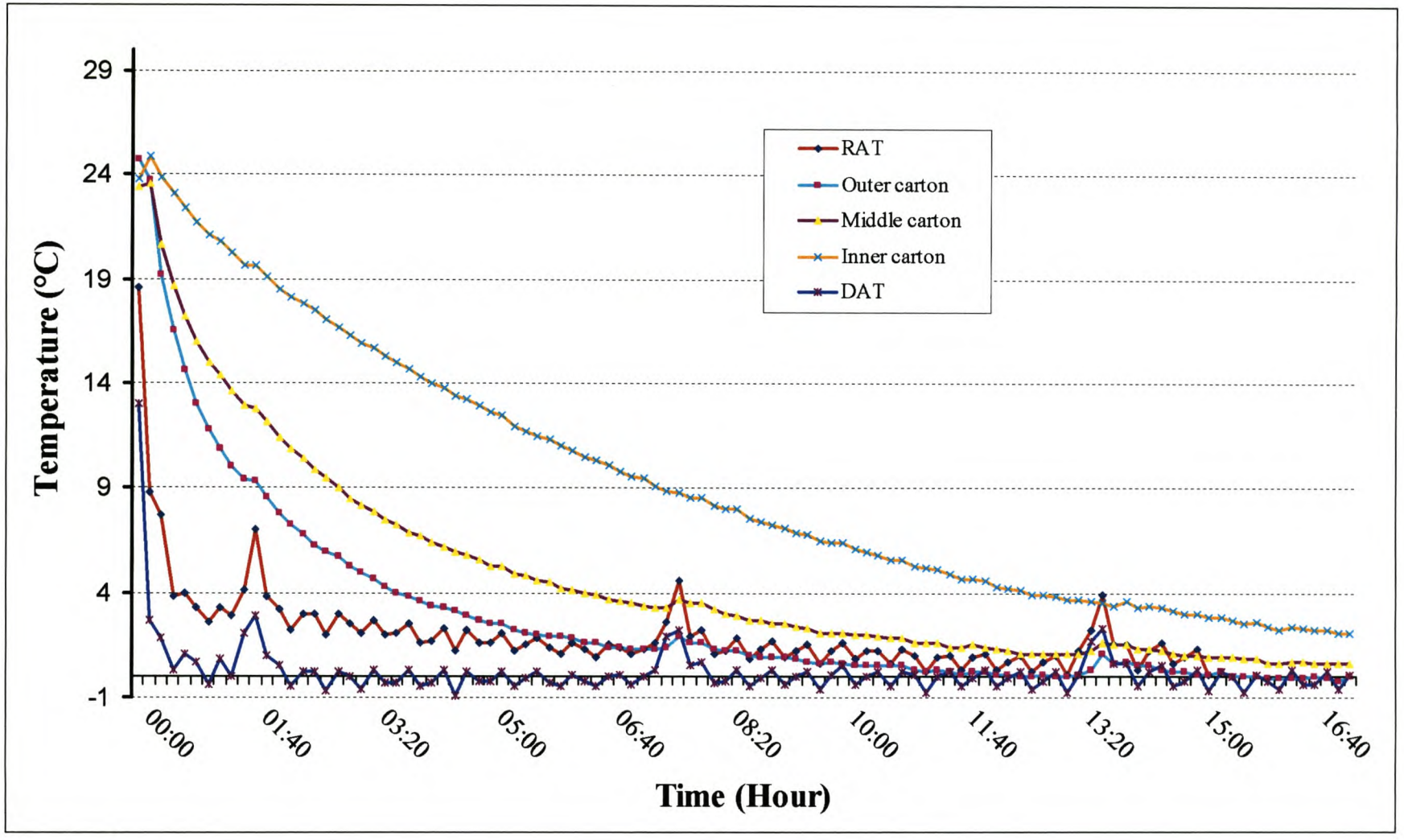

Figure 1 Temperature profile of needle perforated liners at a static pressure of 18 mm water gauge. Forced air cooling was terminated when the middle carton reached the statutory maximum of 1 °C.

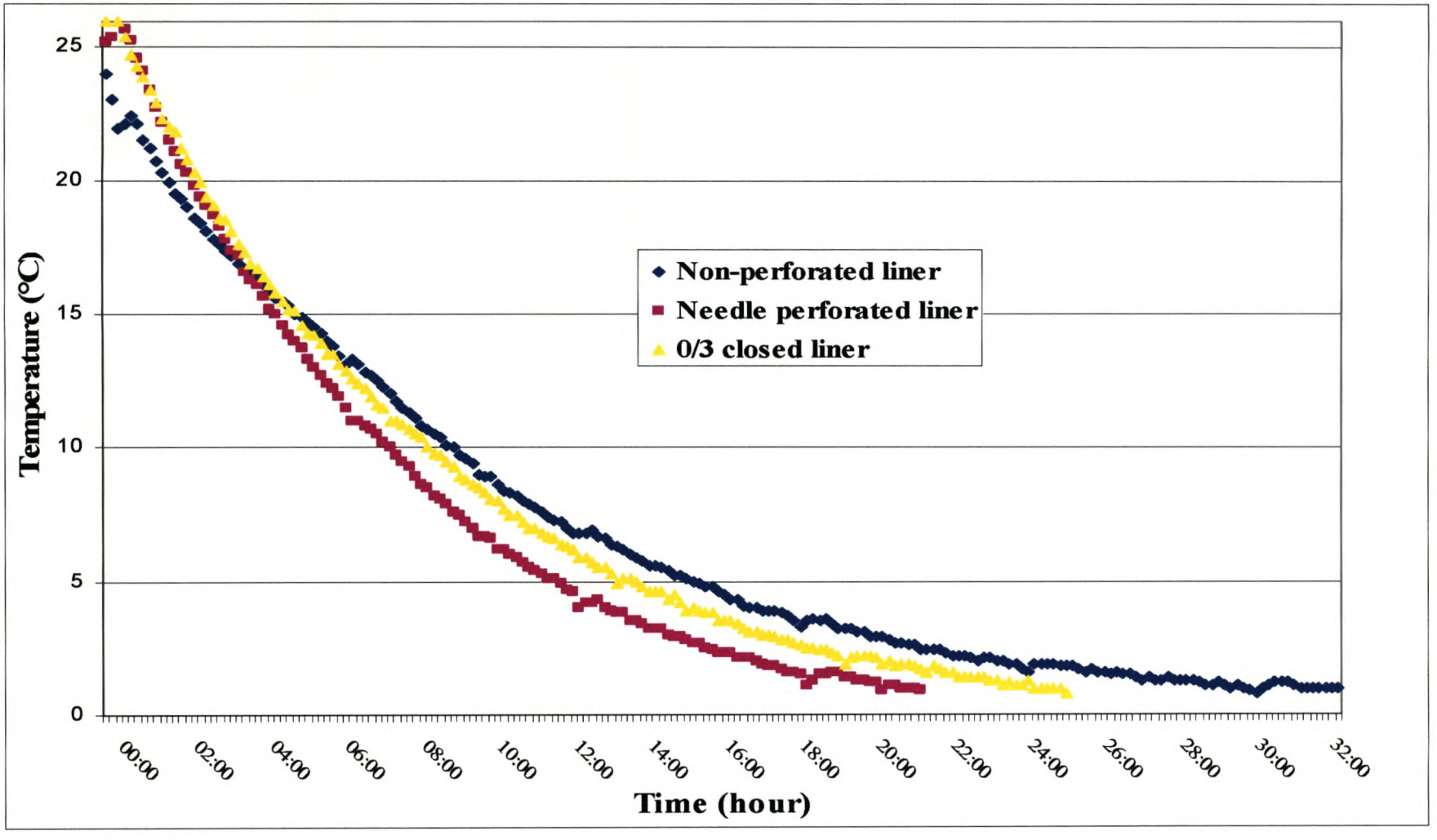

Figure 2 Decrease in berry pulp temperature to 1 °C for the non-perforated liner, needle perforated liner and the $^{0}/_{3}$ closed liner at a static pressure of 12 mm water gauge.

ARTICLE IV STUDY ON MOISTURE LOSS AND STEM BROWNING IN TABLE GRAPES.

ABSTRACT

The development and severity of stem browning of 'Red Globe', 'Waltham Cross', 'Dauphine' and 'Barlinka' table grapes were investigated over 28 days with grapes stored at -0.5 °C. Visually, after 28 days, the 'Red Globe' cultivar had the worst stem condition with 'Barlinka' having the best stem condition. Overall stem condition worsened with lengthening of storage, irrespective of cultivar. Anatomical studies of transections of stems showed very little differences between cultivars. Sealing the stem cut off zones with wax had little effect on overall bunch appearance, and emphasized the importance of waxy substances to water loss and that water loss occurs everywhere on the stems. The worse stem condition of 'Red Globe' grapes can partially be ascribed to the more straggly nature of the cultivar, emphasizing stem condition. The cultivar also had a much higher berry volume to stem weight than all the other cultivars. The lesser amount of stem tissue will dry out faster due to the higher demand for water from berries when favourable conditions for water loss prevail. The larger surface area of the berries will increase transpiration, although water loss through berries is less significant than through stems.

KEYWORDS : 'Red Globe', 'Waltham Cross', 'Dauphine', 'Barlinka'

INTRODUCTION

Table grapes (*Vitis vinifera L.*) can be prone to unsightly stem (rachis) browning and/or drying out of stems in postharvest conditions (Ben-Arie et al., 1995). Drying out of the stems and pedicels impairs the appearance of bunches and compromises the marketing and selling process (Guelfat-Reich and Safran, 1973). It is an accepted fact that some cultivars are more sensitive to the occurrence of this disorder (Viljoen, pers. com., 2003).

Rachis browning occurs after the grape bunches have been removed from the vine and have been stored for later use. Browning and drying out of stems are aggravated by picking at high temperatures or when grapes are exposed to air movement in cooling rooms (Nelson, 1978). The exposure to air movement can be a benefit due to increasing cooling rates. Stem

browning can be reduced by harvesting at low temperatures, using effective pre-cooling methods and protecting bunches from water loss by using polyethylene liners in cartons (Guelfat-Reich and Safran, 1973). The reduction in temperature will reduce respiration. According to Crisosto and Mitchell (2002), the grape stems have a respiration rate of up to fifteen times higher than the berries.

If there is a difference between the amounts of water loss between cultivars, it may be due to anatomical differences in the dermal structure of the stem. The epidermis usually consists of one layer of rectangular shaped cells without intercellular spaces (Burger and Deist, 1981).

The most characteristic feature of epidermal walls is the presence of the fatty substance cutin as an impregnation of the walls and as a separate layer, the cuticle (Esau, 1953). The cuticle protects the stem of the grape bunch against moisture loss and thus aids in conservation of water in the plant (Martin and Juniper, 1970). The cuticle also protects the plant from possible fungal attack (Burger and Deist, 1981). Grapes have stems with a regular formation of complete periderm around the entire circumference, having no loose arrangements of cells (lenticels) (Esau, 1953). The cuticle supplements the action of the stomata in regulating the movement of water out of the plant. Martin and Juniper (1970) suggested that the degree of impregnation of the cuticle with wax, and not the thickness of the cuticle, is the important factor in water loss through stems. The chemical composition of the wax is also a big factor contributing in the efficiency of the cuticle as a water barrier. Grape stems have no lenticels and the cuticle and the pedicel facilitate transpiration via stomata (Burger and Deist, 1981). The waxy bloom of the grape berry limits water loss. The waxy bloom consists of a series of overlapping wax platelets. In normal grape drying, water diffuses in the liquid phase through the parenchyma, pectin and cuticle layers until it reaches the wax-platelet region. Then water has to move as a vapour around and between the platelets. The spaces here are ultramicroscopic and due to the hydrophobic nature of the wax, the water movement is very slow (Chambers and Possingham, 1963).

The literature suggests that very little water loss occurs through the grape berry and that a large amount is lost through the stem of the grape and the cut-off zone. Grape vine xylem has an extraordinarily high conductivity (Huber, 1956 as cited by Considine and Kriedemann,

1972). According to Considine and Kriedemann (1972), grape berries do not lose moisture easily. Therefore, when grapes are held in very humid conditions, turgor pressure builds up in berries and causes the skin to split.

Water loss is not only determined by the inherent properties of the plant organ, but also by the external factors. The movement of water takes place from a high concentration to a low concentration. In storage of grapes, water loss is minimised with fast and effective cooling, but this can also aggravate water loss by increasing the water vapour pressure deficit (Nelson, 1978).

Water moving out of a plant organ is a function of the organ's resistance to water loss and the driving force enhancing water loss. Plant properties such as surface to weight ratio, thickness of the cuticle, degree of impregnation of the cuticle by waxy substances and the nature and number of stomata and lenticels will determine the resistance (Mitchell et al., 2002; Martin and Juniper, 1970). Environmental factors such as temperature, relative humidity and air movement around the plant organ determine the driving force (Nobel, 1983; Mitchell et al., 2002). Rate of moisture loss is also influenced by a product's ratio of surface area to volume (Mitchell et al., 2002).

The objective of the study was to investigate stem browning differences between certain table grape cultivars. The morphology and reaction to external factors were studied on these grape bunches.

MATERIALS AND METHODS

Monitoring of stem browning

Trials were conducted in the 2003 season, using twelve bunches each of 'Red Globe', 'Waltham Cross', 'Dauphine' and 'Barlinka'. Grapes were stored at -0.5 °C in non ventilated plastic trays (52 cm x 42cm x 7 cm) and sealed off with a non-perforated liner maintaining the relative humidity close to 100 %. Six of the twelve bunches were sealed off at the cut off zone with wax. The development of rachis browning was monitored by taking photographs

every second day for 28 days, using a Nikon Coolpix 885 digital camera. Five separate bunches from each cultivar were immediately sampled after harvest and berries were removed and stems were weighed. A random sample of 20 berries from each cultivar was placed in a half filled measuring cylinder and the average volume per berry was calculated by measuring the rise in water volume. An average berry volume to stem mass ratio was calculated for each cultivar.

Anatomical examination of the grape stems

Anatomical studies were conducted on all the cultivars using a light microscope. Samples of stems were fixed in FAA (90 parts ethanol (50 %), 5 parts formalin and 5 parts acetic acid) for 48 hours, followed by dehydration in an ethanol series according to Johansen (1940). Stems were embedded in paraffin wax using standard procedures (Naidoo et al., 1990). Transections were made with a rotary microtome. The wax-embedded samples were de-waxed and attached to glass slides using DPX adhesive (mountant for histology). Samples were stained using the Safranin – Fast green staining technique (Brooks et al., 1950). Glass cover slips were used to cover the samples.

Anatomical studies were done with a Leica light microscope using the Leica QWin LIDA software programme. Electronic images of 40 and 100-fold magnification were created for further observations.

Determining the transpiration rate

Twelve bunches of 'Red Globe' grapes were harvested in the early morning in the Hex River Valley region. Bunches were weighed individually and from six of the bunches all the berries were removed with a pair of scissors. The weights of the berry-less stems were attained individually.

The remainder of the trial was conducted in a room, which had a temperature set point of 15 °C. The six bunches and the berry-less bunches were individually placed inside buckets which were attached to a flow board with twelve stations. Air was passed through a known glycerol-water solution, selected to give a relative humidity of 63 % (Forney and Brandle, 1992), and then through the twelve bunches governed by glass capillaries at a flow rate of ±

95 $ml.min^{-1}$. The weight loss of the whole bunches and the berry-less stems was determined after twelve days. From these data, the transpiration rate was determined, assuming that respiratory weight loss was negligible. A psychometric chart was used to calculate the vapour pressure deficit (Thompson, 2002).

STATISTICAL DESIGN AND ANALYSIS

The statistical software programme SAS (Statistical Analysis Systems Institute, 1996) was used to calculate significant differences ($P \leq 0.05$) between berry volumes, stem weights and berry volume to stem weight ratios for various cultivars. The significant difference between k-values and water loss (transpiration) for whole bunches and berry-less stems were also calculated. Means are separated by Bonferroni multiple comparisons procedure ($P \leq 0.05$).

RESULTS AND DISCUSSION

Monitoring of stem browning

In all the evaluations, with or without covering of the cut off zone, stem browning was the worst on the pedicels and the main rachis close to the cut-off zone. Severity of browning differed between cultivars and worsened as storage time increased. Crisosto et al. (2001) found differences in stem browning between cultivars and that visual stem browning symptoms were significantly and positively related to stem water loss. The only effect of the wax covering of the cut-off zone was a localised maintenance of a fresh green appearance. The overall stem condition was not affected.

'Barlinka' grapes had the best stem condition after 28 days (Figure 1). This subjective observation is probably influenced by the compactness and cylindrical form of the bunch, hiding the stem browning on the pedicels. 'Waltham Cross' (Figure 2) and 'Dauphine' (Figure 3) had very similar stem browning, seemingly more severe than 'Barlinka'. 'Red Globe' had the worst quality stems (Figure 4). The large, straggly bunches with large berries and the long branching inside the bunches, make the stems highly visible and accentuate the cultivar's sensitivity towards stem browning.

'Barlinka' had the lowest berry volume to stem weight ratio, at 40.3 $cm^3.g^{-1}$ (Table 1). This did not differ significantly from 'Dauphine' (52.8 $cm^3.g^{-1}$) and 'Waltham Cross' (73.6

$cm^3.g^{-1}$). 'Red Globe' had a significantly higher volume to weight ratio, with a value of 111.3 $cm^3.g^{-1}$. 'Red Globe' had significantly higher berry volume than all the other cultivars. Stem weights did not differ much although 'Barlinka' (9.9 g) had significantly heavier stems than 'Waltham Cross' (4.9 g) with 'Red Globe' (5.8 g) and 'Dauphine' (6.6 g) not differing significantly from any of the other cultivars.

The data suggest that the high berry volume to stem weight ratio for 'Red Globe' must have added to the cultivar's rapid stem desiccation. 'Barlinka', which had the best quality stems after storage, had the heaviest stems and did not have very high berry volumes. Considering this, the high berry volume in 'Red Globe' most likely creates a larger demand for water that has to be supplied by the relatively average-sized stems, resulting in increased stem desiccation.

Anatomical examination of the grape stems

The transections of stems of 'Barlinka' (Figure 5), 'Waltham Cross' (Figure 6), 'Dauphine' (Figure 7) and 'Red Globe' (Figure 8) appeared to be very similar. At the level of magnification used in this study the only obvious difference in stem morphology between the cultivars was larger structural cavities that were found in the epidermis of 'Waltham Cross' (Figure 6) and 'Red Globe' (Figure 8). All the cultivars had crystalline deposits on the epidermis, identified as part of the cuticle. According to Esau (1953), this wax-containing layer is the main way in which plants protect plant organs from moisture loss. The xylem and phloem were not as well specialised as one year and older stems but were easily detected. Xylem and phloem were well developed.

Determining the transpiration rate

The rate of gas diffusion between two points is a function of the pressure (concentration) at those points. This can be described by the following equation: Flux density = proportionality coefficient x force (Nobel, 1983) or $J = k \times VPD$. In the case of transpiration, the proportionality coefficient is a measure of conductivity of the plant tissue and force is the difference in vapour pressure (VPD) between the tissue and surrounding environment. The berry-less stems lost 71 % of their weight after 12 days and the whole bunches lost only 6 % (Table 2). This emphasizes the stem's ability to lose water due to its higher surface to

volume ratio compared to the whole grape bunches. The k-value for grape bunches with and without berries was calculated (Table 2). From the equation, under conditions of constant VPD, the stems would lose moisture ± 12 times faster than the whole bunches. According to Berry and Aked (1996) dehydration will be detected on stems long before grape berries start to wilt.

The k-value can also be expressed as $k = {}^{A}/_{RH2O}$, where A is the surface area through which vapour can be lost and RH_2O is the coefficient of the resistance of the diffusion of water (Nobel, 1983). If we assume that the resistance to water loss for all the cultivars is the same, then 'Red Globe', which has large berries, will have the highest moisture loss. This can be the reason for poorer stem quality of 'Red Globe', although an increase in surface area will decrease the surface to volume ratio of the berry. The other cultivars will have smaller k values because of the smaller A values in the above equation, but this will actually mediate water loss. Overall, the most water is lost through the stems and the influence of berry size will thus be small.

CONCLUSION

All the cultivars tested had an increase in stem browning when storage time increased. The VPD between the grapes and the surrounding air acted as a driving force for transpiration. The driving force was the same for all cultivars, and the difference in stem condition can only be due to inherent cultivar differences. The amount of impregnation of the cuticle with waxy substances seems to play a bigger role than anatomical size differences (Martin and Juniper, 1970). On the berry cut-off zone where wax was placed, stem condition was very good, but it covered only a small region and it could not prevent the rest of the stem from browning. This suggests that water loss occurs everywhere on the stem and not just at the wound of the cut off zone. The type of grape bunch that is typical of the cultivar also influences the perception of the amount of stem browning. In the case of 'Red Globe' much more of the long stems are visible than in cultivars such as 'Dauphine'. The pre-harvest practices to increase berry size enhance the visibility of stems. If the larger berries start to experience moisture loss, moisture will start moving out of the stems into the berries due to the osmotic driving force that will be created. The lesser amount of stem weight relative to the larger berries may

cause it to lose more moisture than it would have if berry size was smaller or stem weight was more.

The anatomical studies showed the stems to be of similar morphology, except for larger cavities occurring in the 'Red Globe' and 'Waltham Cross' epidermis. These effectively increase the surface area of the stems, leading to greater moisture loss. Although moisture loss out of the berry skin is minimised by the waxy platelets, water loss does occur in this region. According to Crisosto et al. (2001) cumulative water loss occurring during postharvest handling can lead to wilting and shrivelling of berries.

'Red Globe' has a larger berry volume to stem weight ratio, enhancing water loss, and with the relatively smaller amount of stems and the high conductivity of xylem in grapes, it will be detrimental to stem condition.

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Table 1 The calculation of an average berry volume to stem weight ratio for 'Red Globe', 'Barlinka', 'Waltham Cross' and 'Dauphine'.

	'Red Globe' [x]	'Barlinka'	'Waltham Cross'	'Dauphine'	P-value
Berry volume per bunch (cm^3)	648.9^{ay}	388.0^{b}	356.0^{b}	298.3^{b}	< 0.0001
Stem weight (g)	5.8^{ab}	9.9^{a}	4.9^{b}	6.6^{ab}	0.0149
Berry volume to stem weight ratio (cm^3/g)	111.3^{a}	40.3^{b}	73.6^{b}	52.8^{b}	< 0.0001

[x] Five replicates were used for each cultivar.

[y] Means followed by the same letter do not differ at the 5 % level as determined by Bonferroni test.

Table 2 The calculation of proportionality coefficients for 'Red Globe' grape bunches and berry-less stems.

	Weight (g)				
	Day 1	**Day 12**	**Weight loss (%)**	**Transpiration rate (%.day^{-1})**	**k-value (%.day^{-1}.mbar^{-1})**
Whole bunch [y]	635.6	597.7	6.0	0.50[bz]	0.0625[b]
Berry-less stems	6.1	1.7	71.0	5.92[a]	0.7400[a]
P-value				<0.0001	<0.0001

[y] Six replicates were used.

[z] Means within a column followed by the same letter do not differ at the 5 % level as determined by Bonferroni test.

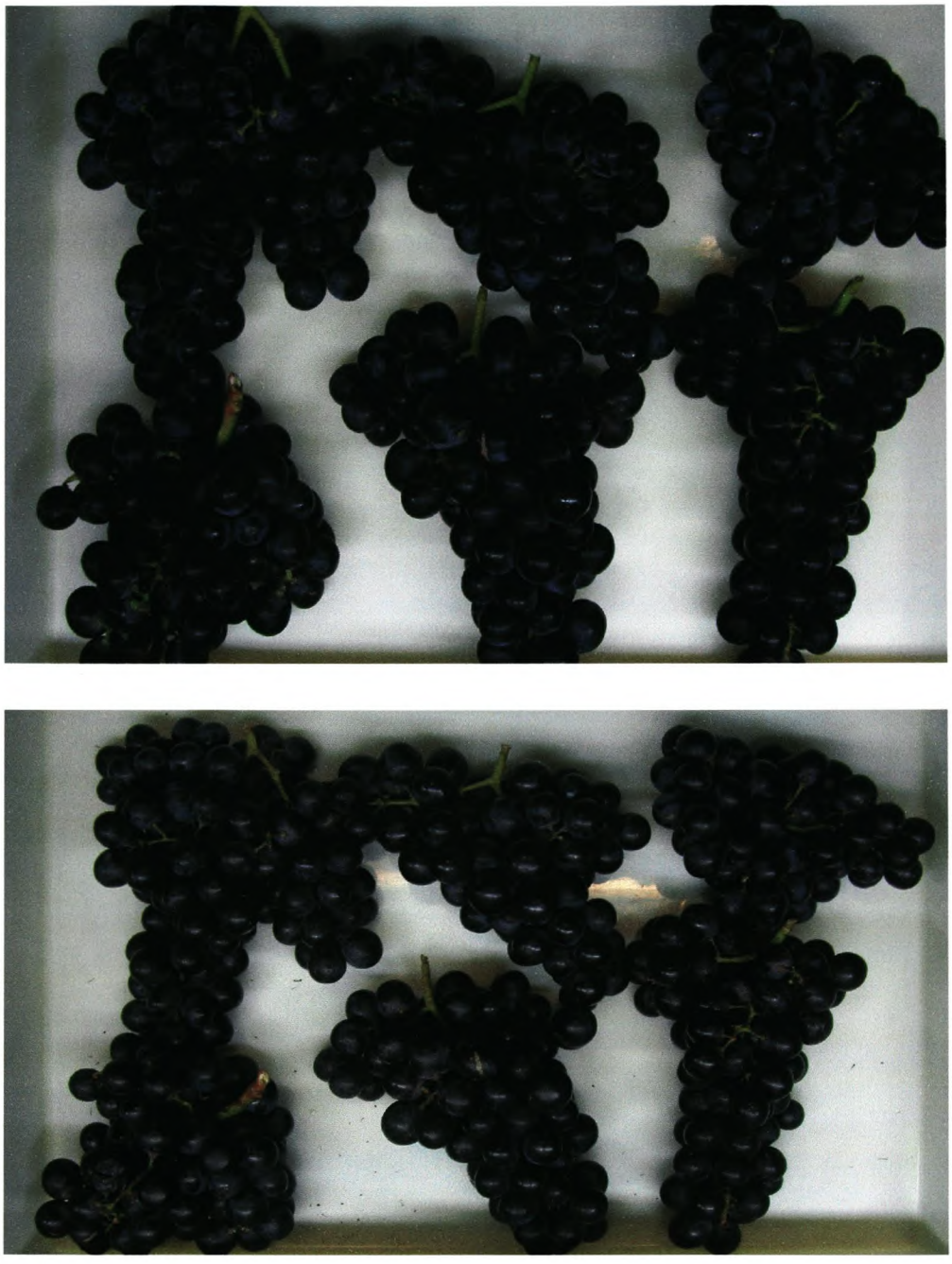

Figure 1 'Barlinka' table grapes in the 2003 season from Berg River Valley on the day of harvest (top picture) and after 28 days at -0.5 °C in a closed environment (bottom picture).

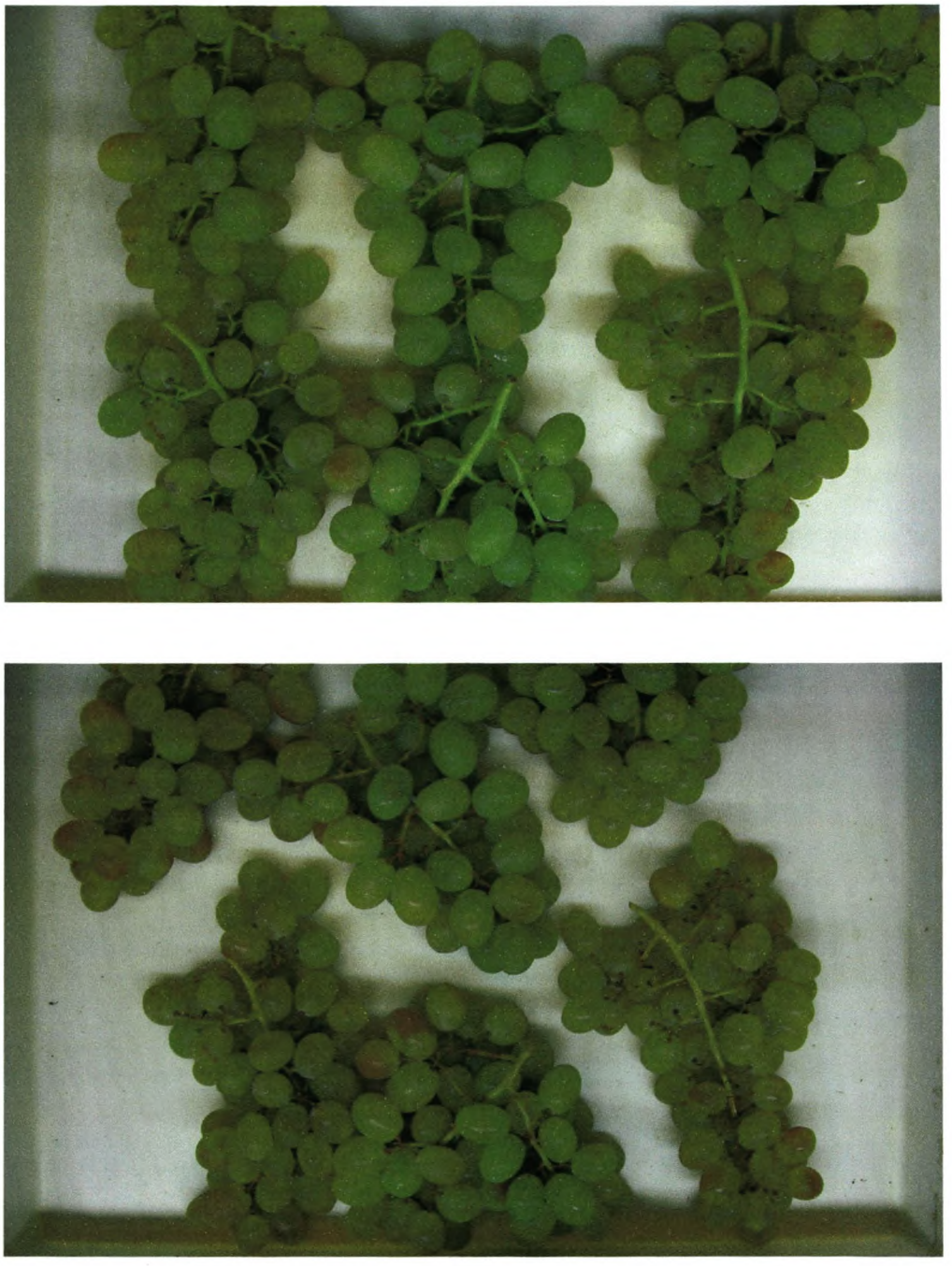

Figure 2 'Waltham Cross' table grapes in the 2003 season from Berg River Valley on the day of harvest (top picture) and after 28 days at -0.5 °C in a closed environment (bottom picture).

Figure 3 'Dauphine' table grapes in the 2003 season from Berg River Valley on the day of harvest (top picture) and after 28 days at -0.5 °C in a closed environment (bottom picture).

Figure 4 'Red Globe' table grapes in the 2003 season from Berg River Valley on the day of harvest (top picture) and after 28 days at -0.5 °C in a closed environment (bottom picture).

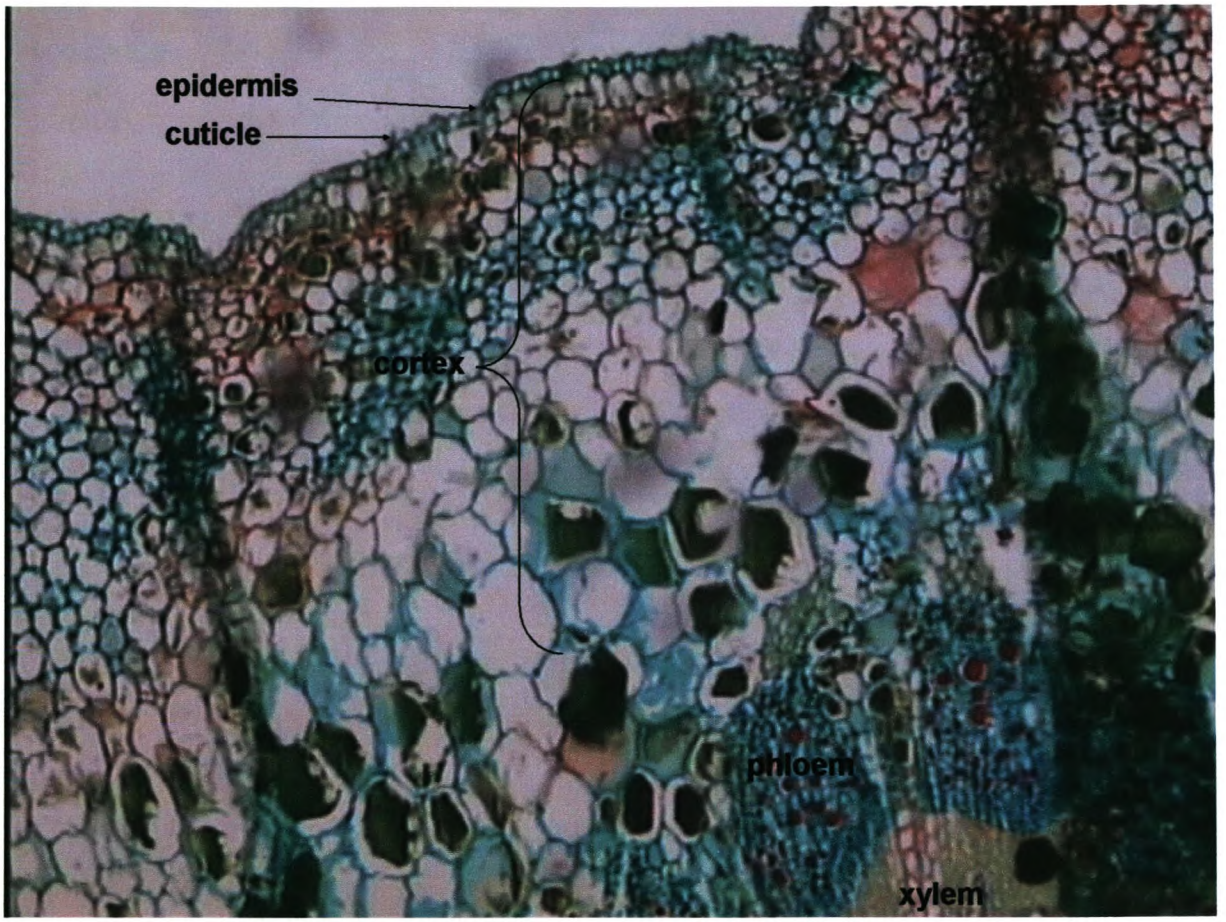

Figure 5 Transection of a stem (rachis) of 'Barlinka' table grapes (100-fold magnification).

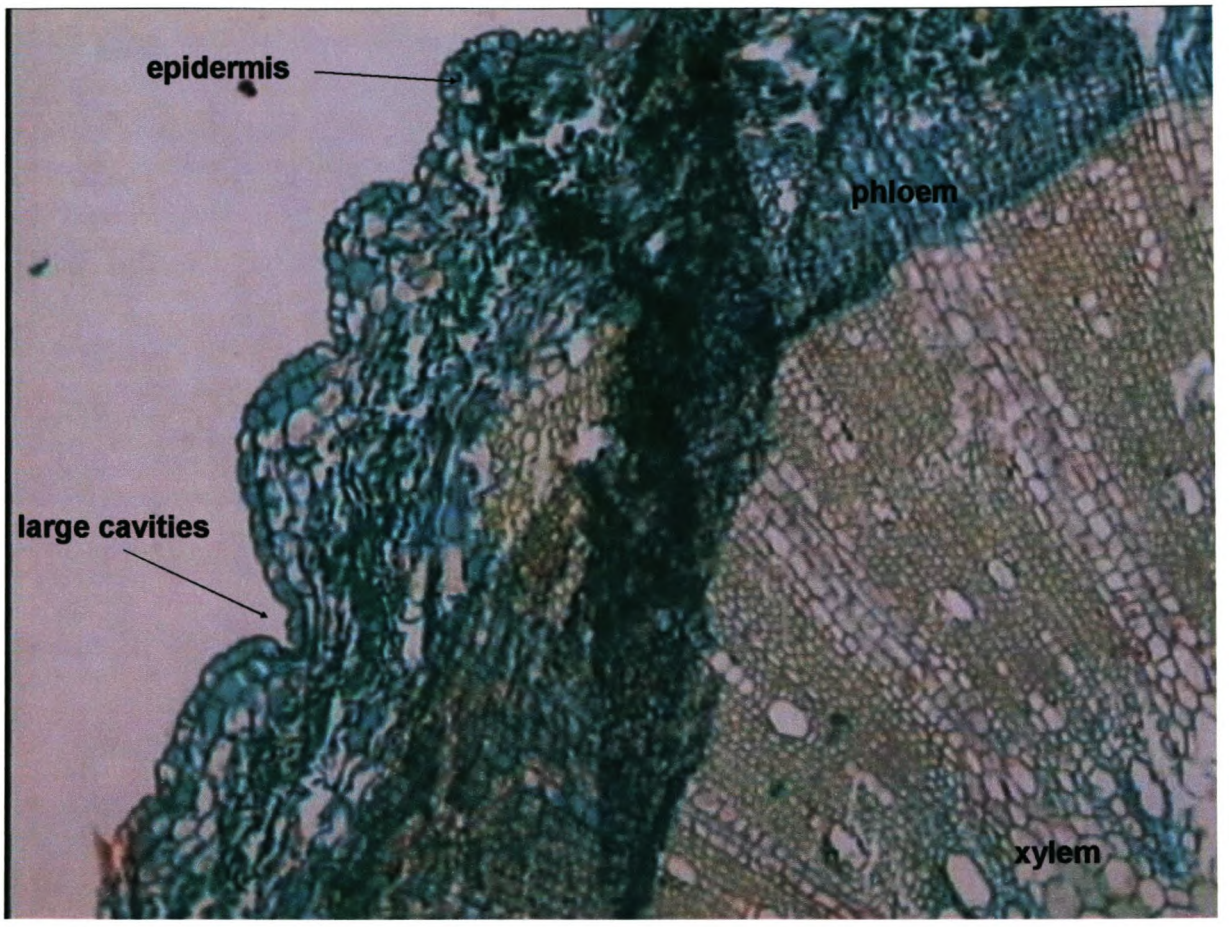

Figure 6 Transection of a stem (rachis) of 'Waltham Cross' table grapes (100-fold magnification).

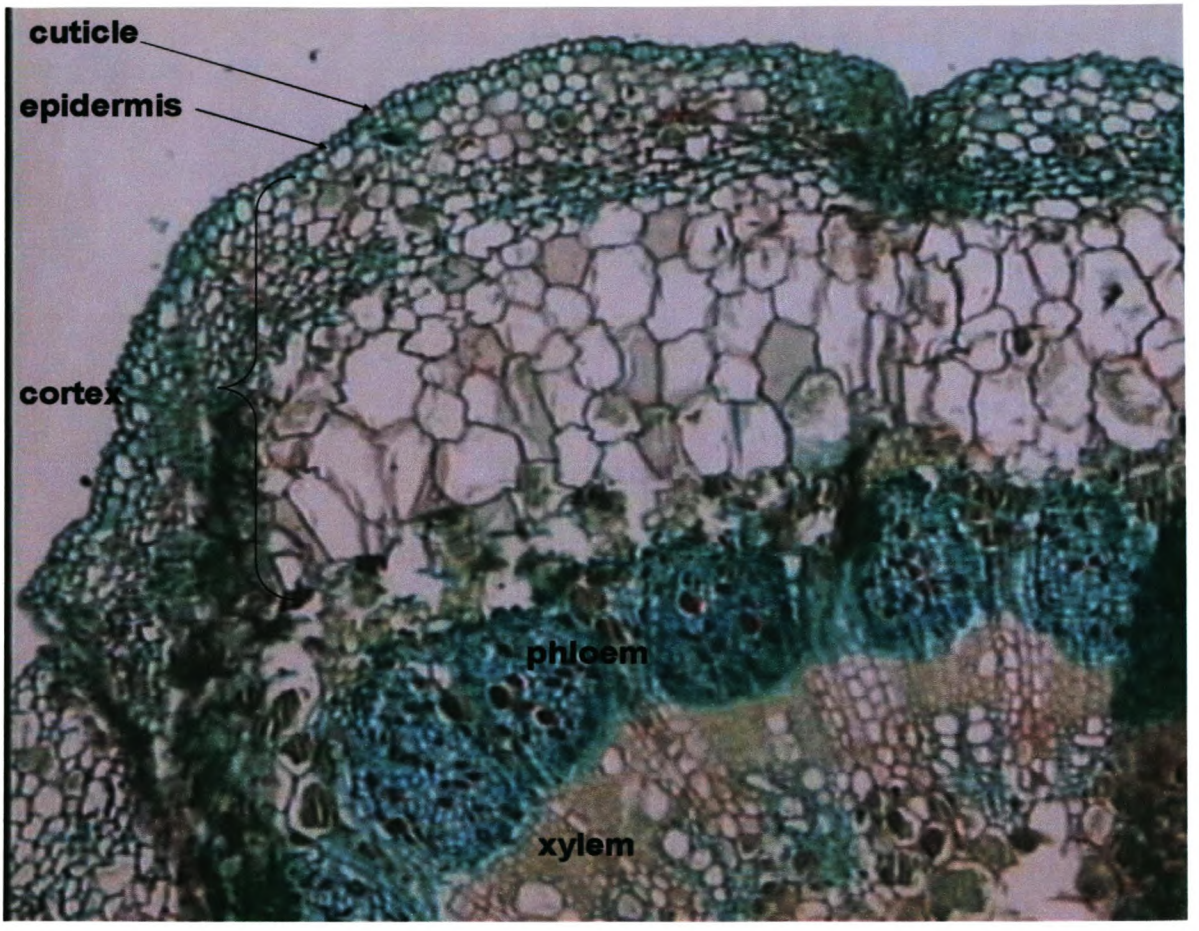

Figure 7 Transection of a stem (rachis) of 'Dauphine' table grapes (100-fold magnification).

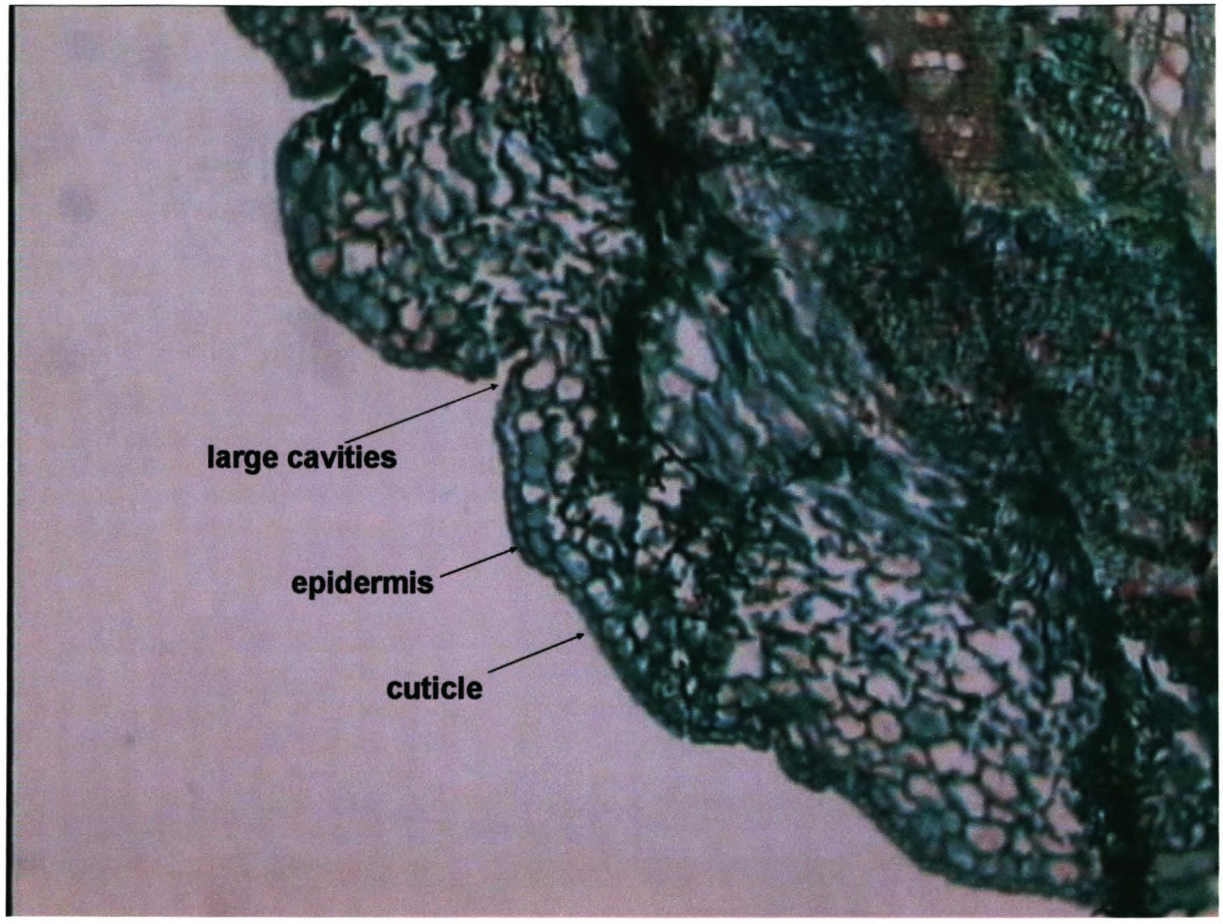

Figure 8 Transection of a stem (rachis) of 'Red Globe' table grapes (100-fold magnification).

GENERAL DISCUSSION AND CONCLUSION

Choosing the correct packaging combination, by taking cultivar characteristics and environmental conditions into consideration, is vital in lowering quality disorders in table grapes. At present, various combinations of packaging materials are being used, not always optimizing grape quality. Studies on the suitability of packaging materials are vital to create scientific results that can be used as guidelines by the industry.

The development of quality disorders in 'Thompson Seedless' and 'Red Globe' grapes were studied after storage in a non-perforated liner or a range of perforated liners. It was apparent that the advantages associated with the non-perforated liner by keeping SO_2 gas from leaking out of the liner was also a disadvantage. The higher humidity was the cause of higher SO_2 damage and higher berry split. The higher humidity caused conditions ideal for decay development, especially if the temperature was raised in the shelf life period. The advantages of using perforated liners were in the significant lowering of berry split and SO_2 damage by controlling the moisture diffusion out of the liner. There was evidence that the two disorders can be lowered by increasing ventilation, but in turn this increase can aggravate stem desiccation. The ventilation lowered the humidity, causing decay to decrease, but with SO_2 gas leaking out of the liner decay control was impaired, remaining on a level similar to that of the non-perforated liner. Perforation also improves the cooling rate of grapes. However, excessive perforation will cause the stem condition to worsen significantly and there is reason to believe that this will increase berry abscission (Burger, 2000). Improvements on quality can be made if perforations in liners open or close actively. For example, perforations that could open due to the pressure difference in forced-air cooling which would have the benefit of faster cooling and less SO_2 damage. Removal from forced air cooling to static storage would then offer the benefits of a non-perforated liner, including reduced stem desiccation and retention of SO_2 gas for decay control.

Quality disorders in grapes are associated with free moisture occurring in liners. If too much moisture is removed stem browning will be aggravated (Crisosto and Mitchell, 2002) or SO_2 sheets might not function as effectively and more berries will decay. The efficacy of a clay moisture absorbing sheet (desiccant) was tested. 'Thompson Seedless' is very sensitive to

decay and the lesser control due to the desiccant sheet increased the occurrence of decay to significantly high percentages. It did had advantages in lowering berry split dramatically and in some instances fewer berries abscised in the carton padded with the desiccant sheet. However, there is evidence that drier stems may aggravate berry abscission. SO_2 damage was also less but this benefit was offset by a discernible increase in *Botrytis* decay. 'Red Globe' is less susceptible to decay and, using the desiccant sheet, only increased decay significantly in a few instances. The desiccant sheet lowered SO_2 damage and berry split. The only disadvantage in using the desiccant sheet was that it aggravated stem browning which is already a large problem even in packaging that maintains much higher humidity. We suggest that the sheet used was too thick and absorbed too much moisture and that better results will be obtained by using a thinner, less absorbent sheet.

To accelerate forced air cooling, grapes can be packed in perforated liners. The effect of the increase in airflow due to perforated liners was evaluated. As expected, the perforated liners increased the contact of grapes with delivery air and thus increased cooling rate. However, this will also be a mayor disadvantage, because the increase in airflow will lessen the humidity inside the liner, resulting in stem browning (Gentry and Nelson, 1968). The faster cooling rate caused the delivery air temperature to increase as it moved through the pallet, causing uneven cooling of cartons. With an increase in static pressure, a direct increase of airflow and cooling rate were found in all liners. The needle perforated liner was influenced the most by static pressure increase. This is probably due to the nature of the perforations. Many of the perforations made by needles were very small but could enlarge if the pressure was high enough or when they were damaged by berry stems. The temperature difference that can arise in a pallet can be manipulated by using liners with fewer perforations or by changing the pressure drop across the pallet. The smaller perforation percentage in the needle perforated liner can actually cause similar diffusion rates to that of the 2 mm liner group. The lesser perforation causes a thinner boundary layer to form outside the liner, creating less resistance to diffusion than in the case of the 2 mm perforations. The larger individual pore size in the latter, however, increases diffusivity.

All the cultivars ('Red Globe', 'Waltham Cross', 'Dauphine' and 'Barlinka') tested had an increase in stem browning when storage time increased. The vapour pressure deficit between

the grapes and the surrounding air acted as a driving force for transpiration. The driving force was the same for all cultivars, and the difference in stem condition can only be due to inherent cultivar differences. The amount of impregnation of the cuticle with waxy substances seems to play a bigger role than anatomical size differences (Martin and Juniper, 1970). On the berry cut-off zone where wax was placed, stem condition was very good, but the wax covered only a small region and could not prevent the rest of the stem from browning. This suggests that water loss occurs everywhere on the stem and not just at the wound of the cut-off zone. The type of grape bunch that is typical of the cultivar also influences the perception of the amount of stem browning. In the case of 'Red Globe' more of the long stems are visible than in a cultivar such as 'Dauphine'. The pre-harvest practices to increase berry size enhance the visibility of stems. If the larger berries start to experience moisture loss, moisture will start moving out of the stems into the berries due to the osmotic driving force that will be created. The lesser amount of stem weight relative to the larger berries may cause stems to lose more moisture than they would have if berry size had been smaller or stem weight had been greater. The anatomical studies showed the stems to be of similar morphology, except for larger cavities occurring in the 'Red Globe' epidermis. Although moisture loss out of the berry skin is minimised by the waxy platelets, water loss does occur in this region. 'Red Globe' berries have a larger volume to stem weight ratio, enhancing water loss, and with the relatively smaller mass of stems and the high conductivity of xylem in grapes, it will be detrimental to stem condition. Special care must be taken to minimise stem browning in 'Red Globe' by cooling grapes as soon as possible and by retaining moisture in the carton with the use of a non-perforated liner.

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APPENDIX A COMPLETE DATA OF ARTICLE I

Table 1 Quality disorders of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 1) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.7116	0.0022	0.4117	2.59	2.73	2.71	2.77	3.15	
SO_2 damage (%)	0.1288	<0.0001	0.0680	3.12	2.99	2.37	1.92	2.99	
Botrytis decay (%)	0.1571	<0.0001	0.5779	0.87	1.69	1.91	1.45	1.57	
Berry split (%)	0.1286	<0.0001	0.1182	26.20	25.20	22.40	19.40	19.40	
After 0 weeks storage									
Berry abscission (%)	0.8498			3.31	2.66	2.98	2.56	2.77	2.88[ab]
SO_2 damage (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Botrytis decay (%)	0.5973			0.00	0.00	0.00	0.00	0.00	0.00[c]
Berry split (%)	0.1146			8.39	4.99	6.99	8.99	4.84	6.84[b]
After 5 weeks storage at -0.5 °C									
Berry abscission (%)	0.3642			1.56	2.35	2.56	1.72	2.79	2.20[b]
SO_2 damage (%)	0.1377			4.76	3.05	2.52	2.37	4.66	3.47[b]
Botrytis decay (%)	0.8042			0.69	0.76	1.05	1.00	0.77	0.85[b]
Berry split (%)	0.0175			41.60	41.25	26.53	27.96	24.63	32.39[a]
After 7 weeks storage at -0.5 °C									
Berry abscission (%)	0.3402			2.89	3.19	2.59	4.03	3.89	3.32[a]
SO_2 damage (%)	0.1514			4.59	5.92	4.58	3.40	4.30	4.56[a]
Botrytis decay (%)	0.2609			1.75	4.17	4.25	3.00	3.80	3.39[a]
Berry split (%)	0.6884			28.60	29.42	33.56	21.29	26.27	27.83[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 2 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 1) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.1354	1.61	1.44	1.56	1.39	1.22	
Stem condition[z]	0.5742	1.72	1.83	1.67	1.89	1.94	
After 0 weeks storage							
Moisture in carton	0.5289	1.83	2.00	1.83	1.83	1.67	1.83
Stem condition	N/V	1.00	1.00	1.00	1.00	1.00	1.00
After 5 weeks storage at -0.5 °C							
Moisture in carton	0.0073	1.00	1.17	1.67	1.00	1.00	1.17
Stem condition	0.2162	2.00	2.67	1.83	2.67	2.67	2.37
After 7 weeks storage at -0.5 °C							
Moisture in carton	0.0006	2.00	1.17	1.17	1.33	1.00	1.33
Stem condition	0.0299	2.17	1.83	2.17	2.00	2.17	2.07

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 3 Quality disorders of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 2) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.5051	<0.0001	0.8014	3.37	2.76	3.51	3.23	2.82	
SO_2 damage (%)	0.7012	<0.0001	0.7254	4.10	3.96	4.94	4.12	4.22	
Botrytis decay (%)	0.3202	<0.0001	0.0379[w]	1.75	0.59	0.97	1.81	0.61	
Berry split (%)	0.3526	0.0003	0.0274[w]	19.46	19.36	19.50	15.94	14.73	
After 0 weeks storage									
Berry abscission (%)	0.2913			2.51	1.73	2.24	2.96	1.73	2.23[b]
SO_2 damage (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Botrytis decay (%)	0.2503			0.03	0.04	0.13	0.00	0.03	0.05[c]
Berry split (%)	0.1615			8.55	7.73	19.01	11.98	14.44	12.34[b]
After 5 weeks storage at -0.5 °C									
Berry abscission (%)	0.641			2.78	2.29	3.85	2.69	2.12	2.74[b]
SO_2 damage (%)	0.1584			6.02	6.72	8.36	7.68	6.61	7.08[a]
Botrytis decay (%)	0.3237			0.17	0.48	0.83	0.45	0.42	0.47[b]
Berry split (%)	0.2723			26.39	26.57	17.26	18.03	19.52	21.56[a]
After 7 weeks storage at -0.5 °C									
Berry abscission (%)	0.9393			4.39	4.43	4.02	4.89	4.43	4.43[a]
SO_2 damage (%)	0.8006			6.28	5.17	6.47	4.67	6.03	5.72[b]
Botrytis decay (%)	0.1285			5.06	1.26	1.96	4.97	1.39	2.93[a]
Berry split (%)	0.0074			23.43	23.76	22.23	17.82	10.21	19.49[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 4 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 2) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.0113	1.83	1.33	1.50	1.67	1.39	
Stem condition[z]	0.0207	1.67	1.50	1.83	1.67	1.61	
After 0 weeks storage							
Moisture in carton	0.2763	1.83	1.67	2.00	2.00	1.83	1.87
Stem condition	N/V	1.00	1.00	1.00	1.00	1.00	1.00
After 5 weeks storage at -0.5 °C							
Moisture in carton	0.0941	1.83	1.33	1.17	1.17	1.33	1.37
Stem condition	0.0002	2.17	1.50	2.67	2.00	1.83	2.03
After 7 weeks storage at -0.5 °C							
Moisture in carton	0.0002	1.83	1.00	1.33	1.83	1.00	1.40
Stem condition	N/V	1.83	2.00	1.83	2.00	2.00	1.93

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 5 Quality disorders of 'Thompson Seedless' table grapes in the 2002/2003 season from Berg River Valley (Trial 3) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	$^2/_3$	$^1/_3$	$^0/_3$	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.0919	0.1229	0.4247	3.25	2.67	2.09	2.44	2.90	
SO_2 damage (%)	0.2801	<0.0001	0.0043[w]	11.77	10.77	12.05	10.25	9.27	
Botrytis decay (%)	0.8522	<0.0001	0.6050	0.54	0.13	0.33	0.16	0.25	
Berry split (%)	<0.0001	<0.0001	0.6919	10.78[a]	3.68[b]	5.81[b]	6.25[b]	5.51[b]	
After 0 weeks storage									
Berry abscission (%)	0.8775			2.45	2.86	2.55	2.28	2.19	2.47[a]
SO_2 damage (%)	0.4375			0.70	0.96	0.35	0.95	0.79	0.75[b]
Botrytis decay (%)	0.4261			0.00	0.00	0.00	0.01	0.00	0.00[c]
Berry split (%)	0.1020			6.12	2.13	1.77	2.68	3.25	3.19[b]
After 5 weeks storage at -0.5 °C									
Berry abscission (%)	0.2147			3.39	2.37	1.75	1.89	3.05	2.49
SO_2 damage (%)	0.0330			19.51[a]	11.84[b]	16.74[ab]	14.33[ab]	13.12[ab]	15.11[a]
Botrytis decay (%)	0.1732			0.28	0.13	0.17	0.07	0.34	0.19[b]
Berry split (%)	0.0032			13.26	3.97	6.44	7.52	4.43	7.13[a]
After 7 weeks storage at -0.5 °C									
Berry abscission (%)	0.8209			3.91	2.79	1.96	3.14	3.46	3.05[a]
SO_2 damage (%)	0.0517			15.10[a]	19.52[a]	19.06[a]	15.46[a]	13.9[a]	16.61[a]
Botrytis decay (%)	0.0339			1.34a	0.26b	0.83ab	0.40ab	0.42ab	0.65[a]
Berry split (%)	0.3783			12.97	4.95	9.23	8.54	8.87	8.91[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 6 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2002/2003 season from Berg River Valley (Trial 3) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.0014	1.67	1.16	1.61	1.44	1.16	
Stem condition[z]	0.2718	1.67	1.94	1.50	1.88	2.00	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.00	1.00	1.00	1.17	1.00	1.03
After 5 weeks storage at -0.5 °C							
Moisture in carton	0.0001	2.00	1.00	1.83	1.67	1.17	1.53
Stem condition	0.0829	2.00	2.83	2.33	2.00	2.17	2.27
After 7 weeks storage at -0.5 °C							
Moisture in carton	0.0110	2.00	1.50	2.00	1.67	1.33	1.70
Stem condition	<0.0001	2.00	2.00	1.17	2.50	2.83	2.10

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 7 Quality disorders of 'Thompson Seedless' table grapes in the 2002/2003 season from Hex River Valley (Trial 4) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.0746	0.1897	0.5301	2.00[a]	1.70[a]	1.80[a]	1.25[a]	1.97[a]	
SO_2 damage (%)	0.1203	<0.0001	0.5359	3.48	2.27	3.12	2.43	2.87	
Botrytis decay (%)	0.2291	<0.0001	0.6871	0.14	0.12	0.31	0.22	0.31	
Berry split (%)	0.1879	<0.0001	0.1933	9.52	6.23	7.52	6.43	5.82	
After 0 weeks storage									
Berry abscission (%)	0.5760			1.61	2.18	2.23	1.29	2.05	1.87[a]
SO_2 damage (%)	0.2645			0.05	0.00	0.00	0.04	0.00	0.02[c]
Botrytis decay (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Berry split (%)	0.2659			0.95	0.46	0.91	0.49	1.17	0.79[c]
After 5 weeks storage at -0.5 °C									
Berry abscission (%)	0.5326			1.68	1.19	1.52	1.26	1.72	1.47[a]
SO_2 damage (%)	0.9086			3.85	2.79	3.04	3.13	3.06	3.17[b]
Botrytis decay (%)	0.6786			0.08	0.17	0.21	0.13	0.20	0.16[b]
Berry split (%)	0.1024			10.16	4.11	11.25	4.19	6.05	7.15[b]
After 7 weeks storage at -0.5 °C									
Berry abscission (%)	0.0339			2.70	1.74	1.64	1.20	2.13	1.88[a]
SO_2 damage (%)	0.0785			6.55	4.02	6.32	4.12	5.54	5.31[a]
Botrytis decay (%)	0.3783			0.33	0.18	0.72	0.55	0.73	0.50[a]
Berry split (%)	0.4644			17.45	14.12	10.39	14.61	10.25	13.36[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 8 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2003 season from Hex River Valley (Trial 4) determined immediately after packing with no storage, and after five or seven weeks of cold storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	1.000	1.67	1.67	1.67	1.67	1.67	
Stem condition[z]	0.9265	2.00	1.94	1.94	1.89	2.11	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.00	1.00	1.00	1.00	1.00	1.00
After 5 weeks storage at -0.5 °C							
Moisture in carton	N/V	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	0.2313	2.50	2.33	2.50	2.00	2.83	2.43
After 7 weeks storage at -0.5 °C							
Moisture in carton	N/V	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	N/V	2.50	2.50	2.33	2.67	2.50	2.50

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 9 Quality disorders of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 1) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.5845	0.0146	0.4914	2.95	2.71	1.99	3.41	3.06	
SO_2 damage (%)	0.4854	<0.0001	0.7587	2.87	3.78	2.01	2.41	3.24	
Botrytis decay (%)	0.7058	0.0006	0.9977	15.07	20.45	25.77	18.47	15.52	
Berry split (%)	0.5299	<0.0001	0.5495	29.24	19.45	26.56	23.89	24.83	
After 1 week at 15 °C									
Berry abscission (%)	0.0821			4.81	4.31	1.89	2.71	4.46	3.64[a]
SO_2 damage (%)	0.0901			0.00	0.00	0.00	0.20	0.00	0.04[b]
Botrytis decay (%)	0.2240			13.34	17.01	24.33	12.94	13.43	16.21[b]
Berry split (%)	0.8454			3.66	9.72	5.43	3.97	4.88	5.53[c]
After 5 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.5443			1.88	2.00	1.97	5.03	1.71	2.52[ab]
SO_2 damage (%)	0.1054			4.28	6.66	3.10	4.52	4.58	4.63[a]
Botrytis decay (%)	0.1799			5.58	6.45	10.97	12.84	5.30	8.23[b]
Berry split (%)	0.3842			48.10	35.17	46.76	45.22	36.56	42.36[a]
After 7 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.8477			2.17	1.83	2.12	2.49	3.01	2.32[b]
SO_2 damage (%)	0.8014			4.33	4.67	2.94	2.51	5.15	3.92[a]
Botrytis decay (%)	0.9574			26.28	37.90	42.02	29.61	27.83	32.73[a]
Berry split (%)	0.5043			35.95	13.45	27.48	22.46	33.05	26.48[b]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 10 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 1) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.0699	1.83	1.33	1.33	1.28	1.44	
Stem condition[z]	0.6336	2.33	2.28	2.39	2.22	2.39	
After 1 week at 15 °C							
Moisture in carton	0.0734	2.50	2.00	2.00	1.83	2.00	2.07
Stem condition	N/V	1.33	1.33	1.50	1.50	1.33	1.40
After 5 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.33	1.00	1.00	1.00	1.00	1.07
Stem condition	N/V	3.17	3.00	2.67	2.67	3.00	2.90
After 7 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.67	1.00	1.00	1.00	1.33	1.20
Stem condition	N/V	2.50	2.50	3.00	2.50	2.83	2.67

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 11 Quality disorders of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 2) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.0155	<0.0001	0.0037[w]	3.07	3.24	3.11	2.62	4.51	
SO_2 damage (%)	0.0095	<0.0001	0.1327	7.40[a]	6.46[ab]	4.67[ab]	4.17[b]	5.59[ab]	
Botrytis decay (%)	0.6796	<0.0001	0.4903	12.11	8.55	16.00	13.94	10.01	
Berry split (%)	0.4562	<0.0001	0.3583	24.55	18.59	22.96	19.41	16.92	
After 1 week at 15 °C									
Berry abscission (%)	0.1830			1.28	1.64	2.70	1.80	1.77	1.84[c]
SO_2 damage (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Botrytis decay (%)	0.3149			28.14	19.67	23.81	17.95	16.32	21.18[a]
Berry split (%)	0.1720			13.83	11.44	8.37	10.48	16.28	12.08[b]
After 5 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.7162			4.66	4.02	4.46	4.50	5.71	4.67[a]
SO_2 damage (%)	0.0017			0.14	0.10	0.08	0.06	0.09	9.52[a]
Botrytis decay (%)	0.3577			2.79	2.72	3.74	1.93	4.75	3.19[b]
Berry split (%)	0.1042			25.69	21.79	23.78	24.56	10.83	21.33[a]
After 7 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.0027			3.27[ab]	4.04[ab]	2.17[b]	1.56[b]	6.10[a]	3.42[b]
SO_2 damage (%)	0.3875			8.07	9.28	5.74	6.37	7.79	7.45[b]
Botrytis decay (%)	0.5821			5.40	3.27	20.44	21.95	8.96	12.00[a]
Berry split (%)	0.6798			34.12	22.53	36.75	23.19	23.65	28.05[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 12 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2001/2002 season from Hex River Valley (Trial 2) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.0190	1.89	1.33	1.44	1.61	1.61	
Stem condition[z]	0.2895	2.00	1.94	1.78	1.72	2.00	
After 1 week at 15 °C							
Moisture in carton	0.5304	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	N/V	1.50	1.17	1.00	1.00	1.00	1.13
After 5 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.83	1.00	1.00	1.00	1.00	1.17
Stem condition	0.0303	2.00	2.33	2.00	1.50	2.17	2.00
After 7 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.83	1.00	1.33	1.83	1.83	1.57
Stem condition	N/V	2.50	2.33	2.33	2.67	2.83	2.53

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 13 Quality disorders of 'Thompson Seedless' table grapes in the 2002/2003 season from Berg River Valley (Trial 3) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.9208	0.0196	0.2299	2.91	2.71	2.76	2.95	2.76	
SO_2 damage (%)	0.3093	<0.0001	0.3839	12.94	14.30	14.91	13.10	12.35	
Botrytis decay (%)	0.2429	0.0008	0.0166[w]	0.90	1.45	1.18	0.96	1.43	
Berry split (%)	0.0118	<0.0001	0.8485	15.11[a]	9.14[b]	11.73[ab]	12.09[ab]	8.31[b]	
After 1 week at 15 °C									
Berry abscission (%)	0.1705			3.50	3.22	3.29	3.74	2.04	3.16[a]
SO_2 damage (%)	0.1637			9.78	9.33	8.06	7.35	5.27	7.96[b]
Botrytis decay (%)	0.2843			1.07	0.82	0.76	0.43	0.79	0.77[b]
Berry split (%)	0.6593			8.78	7.79	4.99	7.05	5.24	6.77[b]
After 5 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.5937			2.36	2.01	1.97	2.67	2.71	2.35[b]
SO_2 damage (%)	0.8403			15.03	17.43	17.67	15.55	16.96	16.53[a]
Botrytis decay (%)	0.0008			0.24[b]	1.15[a]	1.10[a]	1.61[a]	0.81[ab]	0.98[b]
Berry split (%)	0.0645			18.98	9.35	14.74	16.08	9.78	13.78[a]
After 7 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.7647			2.88	2.90	3.04	2.43	3.52	2.95[ab]
SO_2 damage (%)	0.2839			14.00	16.13	19.01	16.39	14.82	16.07[a]
Botrytis decay (%)	0.2533			1.41	2.38	1.68	0.86	2.70	1.80[a]
Berry split (%)	0.3002			17.57	10.28	15.45	13.14	9.92	13.27[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 14 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2002/2003 season from Berg River Valley (Trial 3) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	<0.0001	2.00	1.5	1.72	1.50	1.33	
Stem condition[z]	0.0856	2.28	2.28	2.16	2.22	2.11	
After 1 week at 15 °C							
Moisture in carton	0.1673	2.00	2.00	1.67	2.00	1.83	1.90
Stem condition	N/V	2.00	2.50	1.83	2.67	2.00	2.20
After 5 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	<0.0001	2.00	1.17	2.00	1.00	1.17	1.47
Stem condition	N/V	2.33	3.33	3.17	3.17	3.67	3.13
After 7 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.0018	2.00	1.33	1.50	1.50	1.00	1.47
Stem condition	N/V	2.50	2.50	2.50	2.83	2.50	2.57

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 15 Quality disorders of 'Thompson Seedless' table grapes in the 2002/2003 season from Hex River Valley (Trial 4) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.2806	0.0407	0.3521	1.56	1.37	2.09	1.65	1.58	
SO_2 damage (%)	0.0775	0.0005	0.1382	4.99	4.63	5.65	4.90	3.00	
Botrytis decay (%)	0.4263	0.0233	0.2421	7.56	1.80	3.02	1.66	4.16	
Berry split (%)	0.3575	0.1097	0.4855	23.81	23.21	19.97	17.35	18.96	
After 1 week at 15 °C									
Berry abscission (%)	0.1493			1.97	1.84	3.05	1.47	1.78	2.02[a]
SO_2 damage (%)	0.1442			2.20	3.09	4.97	3.83	1.79	3.17[b]
Botrytis decay (%)	0.1095			1.74	1.96	4.58	1.65	1.74	2.33[ab]
Berry split (%)	0.2548			19.81	16.80	20.04	14.90	12.68	16.84[a]
After 5 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.4167			1.39	1.18	1.54	2.03	1.85	1.60[ab]
SO_2 damage (%)	0.2006			6.97	5.93	3.80	4.56	4.07	5.07[a]
Botrytis decay (%)	0.7730			1.59	1.27	1.24	1.46	2.41	1.59[b]
Berry split (%)	0.3189			22.53	30.08	17.88	22.90	18.17	22.31[a]
After 7 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.7946			1.33	1.09	1.69	1.45	1.12	1.34[b]
SO_2 damage (%)	0.1509			5.78	4.87	8.19	6.30	3.14	5.65[a]
Botrytis decay (%)	0.3342			19.36	2.18	3.24	1.89	8.33	7.00[a]
Berry split (%)	0.5845			29.08	22.76	21.97	14.25	26.05	22.82[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 16 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2002/2003 season from Hex River Valley (Trial 4) determined after one week at 15 °C, and after five or seven weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.2583	1.89	1.94	1.89	1.89	1.89	
Stem condition[z]	0.6336	2.72	2.77	2.72	2.66	2.88	
After 1 week at 15 °C							
Moisture in carton	0.0699	2.00	1.83	1.67	1.67	1.67	1.77
Stem condition	0.2313	2.50	2.67	2.00	2.33	2.83	2.47
After 5 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	1.000	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	0.3093	2.50	2.83	2.83	2.17	2.67	2.60
After 7 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.1673	1.67	2.00	2.00	2.00	2.00	1.93
Stem condition	0.0956	3.17	2.83	3.33	3.50	3.17	3.20

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 17 Quality disorders of 'Red Globe' table grapes in the 2001/2002 season from Berg River Valley (Trial 5) determined immediately after packing with no storage, and after six or eight weeks of cold storage at -0.5 °C.

Parameters	Probability (P≤0.05)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.4866	0.5872	0.8421	0.03	0.13	0.15	0.09	0.08	
SO_2 damage (%)	0.1035	<0.0001	0.2494	5.74	3.26	4.66	3.68	4.11	
Botrytis decay (%)	0.1738	<0.0001	0.7088	0.52	0.38	0.21	0.39	0.14	
Berry split (%)	0.1632	<0.0001	0.3475	0.96	0.79	0.88	0.51	0.37	
After 0 weeks storage									
Berry abscission (%)	0.4583			0.00	0.11	0.07	0.03	0.08	0.06[a]
SO_2 damage (%)	0.0895			0.00	0.00	0.00	0.19	0.00	0.04[c]
Botrytis decay (%)	0.785			0.03	0.04	0.05	0.05	0.00	0.03[b]
Berry split (%)	0.7039			0.22	0.27	0.32	0.37	0.12	0.26[b]
After 6 weeks storage at -0.5 °C									
Berry abscission (%)	0.8554			0.06	0.10	0.13	0.03	0.11	0.09[a]
SO_2 damage (%)	0.5825			7.22	4.82	4.52	4.36	5.42	5.27[b]
Botrytis decay (%)	0.3533			0.42	0.72	0.20	0.27	0.16	0.35[a]
Berry split (%)	0.2216			1.27	0.71	0.54	0.59	0.46	0.71[a]
After 8 weeks storage at -0.5 °C									
Berry abscission (%)	0.6078			0.03	0.17	0.26	0.22	0.04	0.14[a]
SO_2 damage (%)	0.0888			10.01	4.96	9.45	6.50	6.92	7.57[a]
Botrytis decay (%)	0.4435			1.11	0.38	0.37	0.86	0.26	0.60[a]
Berry split (%)	0.2059			1.39	1.39	1.77	0.58	0.51	1.13[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 18 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002 season from Berg River Valley (Trial 5) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.8214	1.56	1.44	1.39	1.39	1.39	
Stem condition[z]	0.9694	2.11	2.06	2.11	2.28	2.22	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.33	1.17	1.33	1.33	1.33	1.30
After 6 weeks storage at -0.5 °C							
Moisture in carton	0.4992	2.00	2.00	1.83	2.00	2.00	1.97
Stem condition	N/V	1.83	2.00	2.00	2.33	2.17	2.07
After 8 weeks storage at -0.5 °C							
Moisture in carton	0.3470	1.67	1.33	1.33	1.17	1.17	1.33
Stem condition	N/V	3.17	3.00	3.00	3.17	3.17	3.10

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 19 Quality disorders of 'Red Globe' table grapes in the 2001/2002 season from Hex River Valley (Trial 6) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.3178	<0.0001	0.0386[w]	0.27	0.35	0.34	0.31	0.49	
SO_2 damage (%)	0.0063	<0.0001	0.0001[w]	6.35	5.16	4.66	5.03	3.08	
Botrytis decay (%)	0.0120	<0.0001	0.0044[w]	0.23	0.14	0.70	0.20	0.13	
Berry split (%)	0.8500	<0.0001	0.0280[w]	1.52	1.60	1.20	1.13	1.22	
After 0 weeks storage									
Berry abscission (%)	0.0212			0.00[b]	0.46[a]	0.09[ab]	0.05[ab]	0.22[ab]	0.16[b]
SO_2 damage (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Botrytis decay (%)	0.7033			0.03	0.00	0.12	0.04	0.11	0.06[b]
Berry split (%)	0.6963			0.06	0.21	0.26	0.41	0.17	0.22[c]
After 6 weeks storage at -0.5 °C									
Berry abscission (%)	0.7414			0.22	0.35	0.32	0.31	0.43	0.33[a]
SO_2 damage (%)	<0.0001			5.51[a]	8.65[a]	6.33[a]	4.67[a]	0.43[b]	5.12[b]
Botrytis decay (%)	0.1388			0.22	0.09	0.02	0.00	0.00	0.07[b]
Berry split (%)	0.0032			3.28[a]	3.36[a]	1.37[b]	1.68[ab]	1.70[ab]	2.28[a]
After 8 weeks storage at -0.5 °C									
Berry abscission (%)	0.1210			0.59	0.25	0.61	0.56	0.83	0.57[a]
SO_2 damage (%)	0.3590			13.49	6.85	7.64	10.41	8.79	9.44[a]
Botrytis decay (%)	0.0108			0.45[ab]	0.33[b]	1.97[a]	0.57[ab]	0.29[b]	0.72[a]
Berry split (%)	0.6924			1.23	1.24	1.97	1.29	1.78	1.50[b]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 20 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2001/2002 season from Hex River Valley (Trial 6) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.0699	1.67	1.39	1.33	1.50	1.22	
Stem condition[z]	0.5663	2.50	2.78	2.44	2.56	2.33	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.17	1.50	1.00	1.00	1.17	1.17
After 6 weeks storage at -0.5 °C							
Moisture in carton	0.0002	2.00	2.00	2.00	2.00	1.17	1.00
Stem condition	N/V	3.00	3.17	2.50	3.00	2.67	2.87
After 8 weeks storage at -0.5 °C							
Moisture in carton	0.0008	2.00	1.17	1.00	1.50	1.50	1.00
Stem condition	N/V	3.33	3.67	3.83	3.67	3.17	3.53

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 21 Quality disorders of 'Red Globe' table grapes in the 2002/2003 season from Hex River Valley (Trial 7) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability (P≤0.05)[x]			Liner type(A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.5032	0.0914	0.5634	0.19	0.23	0.15	0.17	0.22	
SO_2 damage (%)	0.1576	<0.0001	0.8382	1.11	0.80	1.30	1.28	0.95	
Botrytis decay (%)	0.9762	<0.0001	0.3453	0.50	0.55	0.52	0.47	0.59	
Berry split (%)	0.3205	<0.0001	0.9791	0.92	0.46	0.85	0.62	0.74	
After 0 weeks storage									
Berry abscission (%)	0.7538			0.12	0.22	0.15	0.06	0.05	0.12[a]
SO_2 damage (%)	N/V			0.00	0.00	0.00	0.00	0.00	0.00[c]
Botrytis decay (%)	0.8549			0.04	0.07	0.02	0.05	0.02	0.04[b]
Berry split (%)	0.5660			0.39	0.14	0.15	0.21	0.33	0.24[b]
After 6 weeks storage at -0.5 °C									
Berry abscission (%)	0.4735			0.34	0.27	0.07	0.30	0.33	0.26[a]
SO_2 damage (%)	0.3497			1.27	0.73	1.54	1.41	0.79	1.15[b]
Botrytis decay (%)	0.6090			1.02	1.15	0.94	0.59	0.74	0.89[a]
Berry split (%)	0.7549			1.21	0.69	0.93	0.68	0.61	0.82[a]
After 8 weeks storage at -0.5 °C									
Berry abscission (%)	0.3170			0.12	0.20	0.23	0.15	0.29	0.20[a]
SO_2 damage (%)	0.6575			2.06	1.67	2.36	2.43	2.04	2.12[a]
Botrytis decay (%)	0.3425			0.42	0.43	0.61	0.78	1.01	0.65[a]
Berry split (%)	0.6915			1.16	0.54	1.45	0.96	1.29	1.08[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 22 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002/2003 season from Hex River Valley (Trial 7) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.1486	1.89	1.61	1.61	1.72	1.56	
Stem condition[z]	0.6302	1.61	1.94	1.94	2.00	2.33	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.00	1.00	1.00	1.00	1.00	1.00
After 6 weeks storage at -0.5 °C							
Moisture in carton	0.0375	2.67	1.83	1.83	2.17	1.67	2.03
Stem condition	N/V	1.17	1.83	1.83	2.00	2.67	1.90
After 8 weeks storage at -0.5 °C							
Moisture in carton	N/V	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	N/V	2.67	3.00	3.00	3.00	3.33	3.00

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 23 Quality disorders of 'Red Globe' table grapes in the 2002/2003 season from Berg River Valley (Trial 8) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C									
Berry abscission (%)	0.1010	0.829	0.1334	2.20	1.94	2.23	1.45	1.46	
SO_2 damage (%)	0.0428	<0.0001	0.3032	6.52^{a}	4.73^{a}	7.27^{a}	5.63^{a}	4.65^{a}	
Botrytis decay (%)	0.0167	<0.0001	0.1081	0.49^{ab}	0.34^{b}	0.49^{ab}	1.09^{a}	1.55^{a}	
Berry split (%)	<0.0001	<0.0001	0.0007[w]	3.58	2.41	2.84	1.49	0.93	
After 0 weeks storage									
Berry abscission (%)	0.874			1.72	1.81	2.18	1.77	2.13	1.92^{a}
SO_2 damage (%)	0.0705			0.00	0.00	0.09	0.00	0.00	0.02^{b}
Botrytis decay (%)	0.0876			0.00	0.03	0.00	0.00	0.00	0.01^{c}
Berry split (%)	0.5505			0.58	0.75	0.69	0.94	0.57	0.71^{c}
After 6 weeks storage at -0.5 °C									
Berry abscission (%)	0.0933			2.82	2.51	1.96	1.58	0.73	1.92^{a}
SO_2 damage (%)	0.1080			9.17	5.14	12.19	8.37	5.88	8.15^{a}
Botrytis decay (%)	0.1024			0.16	0.10	0.17	1.80	2.24	0.90^{b}
Berry split (%)	0.0743			3.31	3.01	1.95	0.93	1.31	2.10^{b}
After 8 weeks storage at -0.5 °C									
Berry abscission (%)	0.0297			2.05^{ab}	1.50^{ab}	2.55^{a}	0.99^{b}	1.53^{ab}	1.72^{a}
SO_2 damage (%)	0.7715			10.41	9.06	9.52	8.53	8.06	9.11^{a}
Botrytis decay (%)	0.0665			1.32	0.88	1.29	1.46	2.40	1.47^{a}
Berry split (%)	0.0001			6.86^{a}	3.48^{ab}	5.87^{a}	2.59^{ab}	0.91^{b}	3.94^{a}

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 24 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002/2003 season from Berg River Valley (Trial 8) determined immediately after packing with no storage, and after six or eight weeks of storage at -0.5 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C							
Moisture in carton[y]	0.1486	1.39	1.67	1.33	1.27	1.33	
Stem condition[z]	0.2865	2.17	2.27	2.17	2.22	2.11	
After 0 weeks storage							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	1.00	1.00	1.17	1.00	1.50	1.13
After 6 weeks storage at -0.5 °C							
Moisture in carton	0.0289	2.17	2.67	2.00	1.83	1.83	2.10
Stem condition	0.0344	2.50	2.83	2.33	2.83	1.50	2.40
After 8 weeks storage at -0.5 °C							
Moisture in carton	N/V	1.00	1.33	1.00	1.00	1.17	1.10
Stem condition	N/V	3.00	3.00	3.00	2.83	3.33	3.03

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 25 Quality disorders of 'Red Globe' table grapes in the 2001/2002 season from Berg River Valley (Trial 5) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.7395	0.0956	0.8051	0.10	0.14	0.17	0.15	0.18	
SO_2 damage (%)	0.0226	<0.0001	0.0478[w]	6.35	7.01	5.74	5.36	4.11	
Botrytis decay (%)	0.3814	<0.0001	0.4733	3.04	1.92	3.46	3.06	2.83	
Berry split (%)	0.7636	<0.0001	0.0072[w]	1.75	1.18	1.51	1.16	0.97	
After 1 week at 15 °C									
Berry abscission (%)	0.2890			0.00	0.04	0.21	0.16	0.20	0.12[a]
SO_2 damage (%)	0.3883			1.25	1.58	0.85	2.44	1.13	1.45[b]
Botrytis decay (%)	0.7047			0.11	0.18	0.13	0.39	0.25	0.21[c]
Berry split (%)	0.0457			0.00[a]	0.51[a]	0.41[a]	0.85[a]	0.64[a]	0.48[b]
After 6 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.8512			0.16	0.24	0.24	0.23	0.15	0.20[a]
SO_2 damage (%)	0.4478			7.43	8.82	5.32	6.58	6.62	6.96[a]
Botrytis decay (%)	0.2747			2.82	1.52	2.62	3.06	3.31	2.67[b]
Berry split (%)	0.4927			3.12	1.89	1.93	1.21	1.79	1.99[a]
After 8 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.9844			0.15	0.15	0.07	0.08	0.19	0.13[a]
SO_2 damage (%)	0.0052			10.36[a]	10.64[a]	11.04[a]	7.05[ab]	4.58[b]	8.73[a]
Botrytis decay (%)	0.4640			6.20	4.06	7.61	5.72	4.94	5.71[a]
Berry split (%)	0.0269			2.12[ab]	1.15[ab]	2.20[a]	1.42[ab]	0.50[b]	1.48[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 26 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2001/2002 season from Berg River Valley (Trial 5) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.0425	1.72	1.28	1.61	1.39	1.39	
Stem condition[z]	0.0229	3.23	3.06	3.33	3.06	2.89	
After 1 week at 15 °C							
Moisture in carton	0.1302	2.00	1.50	1.50	1.50	1.50	1.60
Stem condition	N/V	2.00	2.17	2.50	1.67	1.17	1.90
After 6 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.0254	1.83	1.33	2.00	1.33	1.67	1.63
Stem condition	N/V	3.67	4.00	3.33	3.33	3.33	3.53
After 8 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.1302	1.33	1.00	1.33	1.33	1.00	1.20
Stem condition	N/V	4.00	3.00	4.17	4.17	4.17	3.90

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 27 Quality disorders of 'Red Globe' table grapes in the 2001/2002 season from Hex River Valley (Trial 6) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.4245	0.0005	0.3804	0.34	0.31	0.65	0.28	0.45	
SO_2 damage (%)	0.2100	<0.0001	0.9652	10.64	6.71	9.05	7.95	8.19	
Botrytis decay (%)	0.6600	<0.0001	0.3188	1.24	0.94	0.94	0.64	0.92	
Berry split (%)	0.0135	<0.0001	0.1187	2.13[a]	2.21[a]	1.29[a]	1.48[a]	1.25[a]	
After 1 week at 15 °C									
Berry abscission (%)	0.7918			0.18	0.09	0.15	0.25	0.13	0.16[b]
SO_2 damage (%)	0.6509			0.95	0.45	0.17	0.41	0.42	0.48[b]
Botrytis decay (%)	0.5270			0.04	0.00	0.06	0.04	0.00	0.03[c]
Berry split (%)	0.1487			1.25	1.41	0.48	1.13	0.30	0.91[b]
After 6 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.0883			0.35	0.45	1.26	0.27	0.83	0.63[a]
SO_2 damage (%)	0.8682			13.19	8.86	12.86	10.76	9.94	11.12[a]
Botrytis decay (%)	0.6589			0.40	0.32	0.65	0.33	0.24	0.39[b]
Berry split (%)	0.0261			2.31[a]	2.24[a]	1.03[ab]	0.83[b]	2.02[a]	1.69[a]
After 8 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.9313			0.50	0.39	0.55	0.32	0.39	0.43[a]
SO_2 damage (%)	0.2428			17.79	10.81	14.12	12.69	14.22	13.93[a]
Botrytis decay (%)	0.3071			3.27	2.51	2.11	1.54	2.53	2.39[a]
Berry split (%)	0.1454			2.83	2.97	2.36	2.49	1.42	2.41[a]

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 28 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2001/2002 season from Hex River Valley (Trial 6) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.8657	1.33	1.33	1.33	1.33	1.33	
Stem condition[z]	0.3314	3.78	3.72	3.33	3.83	4.11	
After 1 week at 15 °C							
Moisture in carton	0.5304	2.00	2.00	2.00	2.00	2.00	1.00
Stem condition	N/V	3.67	3.00	2.83	3.33	3.67	3.30
After 6 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	3.17	3.67	3.33	3.67	3.83	3.53
After 8 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	1.00	1.00	1.00	1.00	1.00	1.00
Stem condition	N/V	4.50	4.50	3.83	4.50	4.83	4.43

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 29 Quality disorders of 'Red Globe' table grapes in the 2002/2003 season from Hex River Valley (Trial 7) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	A x B	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.8693	0.0001	0.0501	0.25	0.43	0.19	0.23	0.29	
SO_2 damage (%)	0.0024	<0.0001	0.6320	2.38[a]	1.42[ab]	2.16[ab]	1.28[b]	1.31[b]	
Botrytis decay (%)	0.5772	0.0001	0.0033[w]	1.73	1.26	1.72	2.17	1.71	
Berry split (%)	0.0056	<0.0001	0.1113	2.43[a]	0.92[b]	1.28[ab]	0.89[b]	0.79[b]	
After 1 week at 15 °C									
Berry abscission (%)	0.8875			0.16	0.16	0.18	0.26	0.16	1.18[b]
SO_2 damage (%)	0.0826			0.38	0.17	0.20	0.17	0.00	0.19[c]
Botrytis decay (%)	0.2656			0.25	0.31	1.87	1.00	0.12	0.71[b]
Berry split (%)	0.9995			0.46	0.48	0.63	0.42	0.53	0.51[b]
After 6 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.1500			0.04	0.05	0.17	0.20	0.18	0.13[b]
SO_2 damage (%)	0.3424			2.09	1.46	2.07	0.92	1.32	1.57[b]
Botrytis decay (%)	0.0728			1.98	2.27	1.89	4.38	1.71	2.44[a]
Berry split (%)	0.0754			2.47	0.89	1.66	1.55	0.77	1.47[a]
After 8 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.1430			0.57	1.09	0.22	0.22	0.52	0.52[a]
SO_2 damage (%)	0.0325			4.01	2.62	4.86	2.75	2.62	3.37[a]
Botrytis decay (%)	0.0052			2.95[a]	1.19[ab]	1.41[ab]	1.12[b]	3.30[a]	1.99[a]
Berry split (%)	0.0178			4.32	1.37	1.55	0.69	1.09	1.81[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 30 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002/2003 season from Hex River Valley (Trial 7) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.1384	2.00	1.83	2.00	1.94	1.94	
Stem condition[z]	0.8925	2.67	2.61	2.78	2.78	2.67	
After 1 week at 15 °C							
Moisture in carton	0.4222	2.00	1.83	2.00	1.83	2.00	1.93
Stem condition	N/V	1.83	1.83	1.83	2.00	2.00	1.90
After 6 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	N/V	2.50	2.83	2.67	3.00	2.50	2.70
After 8 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.1673	2.00	1.67	2.00	2.00	1.83	1.90
Stem condition	N/V	3.67	3.17	3.83	3.33	3.50	3.50

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 31 Quality disorders of 'Red Globe' table grapes in the 2002/2003 season from Berg River Valley (Trial 8) determined after one week at 15 °C, and after six or eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Liner type (A)[y]					Day (B)[z]
	A	B	AxB	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.5353	0.2063	0.4735	1.57	1.26	1.41	1.60	1.35	
SO_2 damage (%)	0.2321	<0.0001	0.4848	7.97	9.50	9.13	7.13	8.57	
Botrytis decay (%)	0.0981	<0.0001	0.3935	4.62	5.82	4.47	3.60	4.46	
Berry split (%)	<0.0001	<0.0001	0.005[w]	6.61	4.68	5.09	2.62	1.94	
After 1 week at 15 °C									
Berry abscission (%)	0.3141			2.18	1.29	1.86	1.56	1.27	1.63[a]
SO_2 damage (%)	0.4072			3.92	2.83	4.28	2.76	2.72	3.30[b]
Botrytis decay (%)	0.7102			0.40	0.45	0.24	0.37	0.34	0.36[c]
Berry split (%)	0.0754			0.75	0.41	1.51	0.65	0.41	0.75[b]
After 6 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.3899			1.10	1.04	1.16	1.76	1.53	1.32[a]
SO_2 damage (%)	0.5579			11.45	11.95	11.27	9.17	11.84	11.14[a]
Botrytis decay (%)	0.1951			6.95	7.60	4.67	4.05	4.43	5.54[b]
Berry split (%)	0.0044			8.17[a]	6.57[a]	5.25[ab]	2.15[b]	3.52[ab]	5.13[a]
After 8 weeks storage at -0.5 °C + 1 week at 15 °C									
Berry abscission (%)	0.8287			1.43	1.45	1.21	1.48	1.26	1.36[a]
SO_2 damage (%)	0.2708			8.53	13.72	11.82	9.45	11.14	10.93[a]
Botrytis decay (%)	0.2799			6.50	9.42	8.49	6.39	8.62	7.88[a]
Berry split (%)	0.0023			10.90[a]	7.06[ab]	8.51[a]	5.07[ab]	1.89[b]	6.69[a]

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Liner type) and factor B (Storage time). Means within a row (Liner type) and within a column (Day) not followed by same letter are significantly different at $P \leq 0.05$ as determined by Bonferroni test.

[y] Liner type data expressed in percentage of the disorder for the overall average and for the three evaluation times.

[z] Day data expressed as percentage of the disorder for all the three evaluation times as it was influenced by storage time.

Table 32 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002/2003 season from Berg River Valley (Trial 8) determined after one week at 15 °C, and after six or after eight weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($\chi^2 \leq 0.05$)[x]	Liner type					Day
	Treatment	Non	Needle	2/3	1/3	0/3	Storage time
Average: storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton[y]	0.1709	2.00	1.83	1.83	1.94	1.83	
Stem condition[z]	0.0622	3.56	3.33	3.83	3.94	3.50	
After 1 week at 15 °C							
Moisture in carton	0.4992	2.00	2.00	1.83	2.00	2.00	1.97
Stem condition	N/V	3.33	2.83	3.50	3.50	3.00	3.23
After 6 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	0.1374	2.00	1.50	1.67	1.83	1.50	1.70
Stem condition	N/V	3.33	2.83	3.33	3.83	3.00	3.27
After 8 weeks storage at -0.5 °C + 1 week at 15 °C							
Moisture in carton	N/V	2.00	2.00	2.00	2.00	2.00	2.00
Stem condition	N/V	4.00	4.33	4.67	4.50	4.50	4.40

[x] Table analysis with the χ^2 test.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

APPENDIX B COMPLETE DATA OF ARTICLE II

Table 1 Quality disorders of 'Thompson Seedless' table grapes in the 2002 season from Hex River Valley (Trial 1) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	AxB	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 5 weeks									
Berry abscission (%)	0.1280	0.425	0.4258	5.97[az]	2.16[a]				
SO_2 damage (%)	0.0490	0.682	0.0647	2.35[b]	3.57[a]				
Botrytis decay (%)	<0.0001	0.872	0.7720	7.70[a]	0.88[b]				
Berry split (%)	<0.0001	0.319	0.0002[w]	11.10	30.18	Non	0.07[b]	41.60[a]	<0.0001
						2/3	14.14[b]	26.53[a]	0.0002
						1/3	21.24[b]	27.96[a]	0.0021
						0/3	10.16[b]	24.63[a]	0.0096
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C									
Berry abscission (%)	0.0053	0.420	0.4086	0.11[b]	2.65[a]				
SO_2 damage (%)	<0.0001	0.191	0.6023	0.31[b]	4.12[a]				
Botrytis decay (%)	<0.0001	0.183	0.5370	95.59[a]	8.67[b]				
Berry split (%)	<0.0001	0.899	0.2731	1.50[b]	44.16[a]				

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test ($t \leq 0.05$) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 2 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2002 season from Hex River Valley (Trial 1) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 5 weeks			
Moisture in carton[y]	0.1614	1.59[ax]	1.47[a]
Stem condition[z]	0.2843	1.50[a]	1.64[a]
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C			
Moisture in carton	0.1136	1.61[a]	1.60[a]
Stem condition	0.0332	1.89[b]	2.15[a]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 3 Quality disorders of 'Thompson Seedless' table grapes in the 2002 season from Hex River Valley (Trial 2) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	A x B	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 5 weeks									
Berry abscission (%)	0.0027	0.589	0.3349	4.81[az]	2.59[b]				
SO_2 damage (%)	<0.0001	0.035	0.9033	4.13[b]	7.17[a]				
Botrytis decay (%)	<0.0001	0.581	0.2805	2.67[a]	0.47[b]				
Berry split (%)	<0.0001	0.213	0.5693	7.37[b]	20.30[a]				
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C									
Berry abscission (%)	<0.0001	0.84	0.5805	0.75[b]	4.83[a]				
SO_2 damage (%)	<0.0001	0.003	0.003[w]	0.77	9.38	Non	0.49[b]	14.15[a]	<0.0001
						2/3	1.38[b]	8.28[a]	<0.0001
						1/3	0.69[b]	6.12[a]	0.0001
						0/3	0.51[b]	8.97[a]	<0.0001
Botrytis decay (%)	<0.0001	0.834	0.8658	77.75[a]	3.31[b]				
Berry split (%)	<0.0001	0.055	0.1382	0.56[b]	21.22[a]				

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test (t ≤ 0.05) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at P ≤ 0.05.

Table 4 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2002 season from Hex River Valley (Trial 2) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 5 weeks			
Moisture in carton[y]	0.0297	1.10[bx]	1.38[a]
Stem condition[z]	0.0013	3.00[a]	2.15[b]
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C			
Moisture in carton	0.9456	1.20[a]	1.20[a]
Stem condition	0.0009	2.65[a]	1.91[b]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 5 Quality disorders of 'Thompson Seedless' table grapes in the 2003 season from Hex River Valley (Trial 3) determined after five weeks of cold storage at -0.5 °C or after five weeks of storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	A x B	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 5 weeks									
Berry abscission (%)	0.5985	0.1659	0.2100	1.93[wz]	1.70[a]				
SO_2 damage (%)	0.3267	0.1366	0.6058	4.36[a]	3.45[a]				
Botrytis decay (%)	<0.0001	0.2949	0.9743	2.42[a]	0.14[b]				
Berry split (%)	0.0043	0.0363	0.9286	3.13[b]	8.11[a]				
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C									
Berry abscission (%)	0.1049	0.1816	0.9756	1.13[a]	1.62[a]				
SO_2 damage (%)	<0.0001	0.8093	0.0259[w]	0.77	5.52	Non	0.57[b]	6.97[a]	<0.0001
						%	0.98[b]	4.07[a]	<0.0001
Botrytis decay (%)	<0.0001	0.6669	0.3525	26.60[a]	2.00[b]				
Berry split (%)	<0.0001	0.0338	0.514	5.13[b]	20.35[a]				

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test ($t \leq 0.05$) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 6 Subjective evaluation of moisture in the carton and stem condition of 'Thompson Seedless' table grapes in the 2003 season from Hex River Valley (Trial 3) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C and one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 5 weeks			
Moisture in carton[y]	<0.0001	1.85[bx]	2.00[a]
Stem condition[z]	0.5985	1.65[a]	2.67[a]
Shelf life: storage at -0.5 °C for 5 weeks and 1 week at 15 °C			
Moisture in carton	0.0003	1.40[b]	2.00[a]
Stem condition	0.0051	1.95[b]	2.58[a]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 7 Quality disorders of 'Red Globe' table grapes in the 2002 season from Berg River Valley (Trial 4) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	A x B	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 6 weeks									
Berry abscission (%)	0.9243	0.4945	0.8385	0.33[az]	0.32[a]				
SO_2 damage (%)	<0.0001	<0.0001	0.0005[w]	1.39	4.23	Non	0.56[b]	5.51[a]	<0.0001
						2/3	2.20[b]	6.33[a]	<0.0001
						1/3	1.59[b]	4.67[a]	0.0021
						0/3	1.22[a]	0.43[a]	0.4000
Botrytis decay (%)	0.2786	0.1570	0.0970	0.02[a]	0.06[a]				
Berry split (%)	<0.0001	0.0287	0.0344[w]	0.17	2.01	Non	0.62[b]	3.28[a]	<0.0001
						2/3	0.51[a]	1.37[a]	0.1052
						1/3	0.59[b]	1.68[a]	0.0441
						0/3	1.11[a]	1.70[a]	0.2587
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C									
Berry abscission (%)	0.0266	0.1154	0.0842	0.68[a]	0.29[b]				
SO_2 damage (%)	<0.0001	0.7599	0.8496	1.82[b]	11.69[a]				
Botrytis decay (%)	0.4831	0.5729	0.0080	0.49[a]	0.40[a]				
Berry split (%)	<0.0001	0.0597	0.0317[w]	0.44	1.55	Non	0.30[b]	2.31[a]	<0.0001
						2/3	0.51[a]	1.03[a]	0.2451
						1/3	0.48[a]	0.83[a]	0.4406
						0/3	0.46[b]	2.02[a]	0.0013

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test ($t \leq 0.05$) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 8 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002 season from Berg River Valley (Trial 4)determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 6 weeks			
Moisture in carton[y]	0.0092	1.50[ax]	1.39[b]
Stem condition[z]	<0.0001	2.59[a]	1.94[b]
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C			
Moisture in carton	N/V	1.55	1.50
Stem condition	<0.0001	3.93[a]	3.44[b]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 9 Quality disorders of 'Red Globe' table grapes in the 2002 season from Hex River Valley (Trial 5) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability ($P \leq 0.05$)[x]			Moisture sheet (A)[y]	
	A	B[w]	AxB		
				Desiccant.	Mam
Average: storage at -0.5 °C for 6 weeks					
Berry abscission (%)	0.3201	0.8629	0.1452	0.13[az]	0.08[a]
SO_2 damage (%)	0.0017	0.2113	0.8523	2.63[b]	5.38[a]
Botrytis decay (%)	0.0899	0.5022	0.7388	0.48[a]	0.26[a]
Berry split (%)	0.0576	0.1986	0.3851	0.71[a]	0.36[a]
Shelf life: storage at –0.5 °C for 6 weeks and 1 week at 15 °C					
Berry abscission (%)	0.5621	0.9658	0.7021	0.20[a]	0.16[a]
SO_2 damage (%)	<0.0001	0.6746	0.7757	0.18[b]	6.49[a]
Botrytis decay (%)	<0.0001	0.5292	0.6623	9.16[a]	2.95[b]
Berry split (%)	<0.0001	0.1611	0.3024	0.22[b]	2.01[a]

[w] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 10 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2002 season from Hex River Valley (Trial 5) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 6 weeks			
Moisture in carton[y]	0.0008	1.25[bx]	1.47[a]
Stem condition[z]	0.1322	1.79[a]	1.71[a]
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C			
Moisture in carton	0.0815	1.45[a]	1.70[a]
Stem condition	0.0242	3.78[a]	3.41[b]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 11 Quality disorders of 'Red Globe' table grapes in the 2003 season from Hex River Valley (Trial 6) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	AxB	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 6 weeks									
Berry abscission (%)	0.6675	0.258	0.5359	0.23[az]	0.33[a]				
SO_2 damage (%)	<0.0001	0.166	0.9463	0.04[b]	1.03[a]				
Botrytis decay (%)	0.7210	0.9597	0.2097	1.67[a]	0.88[a]				
Berry split (%)	0.0010	0.8431	0.2081	0.18[b]	0.91[a]				
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C									
Berry abscission (%)	0.2251	0.8223	0.0189	0.21[a]	0.11[a]				
SO_2 damage (%)	<0.0001	0.0097	0.7906	0.28[b]	1.71[a]				
Botrytis decay (%)	<0.0001	0.5922	0.9021	5.31[a]	1.84[b]				
Berry split (%)	<0.0001	0.0569	0.0179[w]	0.30	1.62	Non	0.32[b]	2.47[a]	0.0060
						%	0.29[a]	0.77[a]	0.1127

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test ($t \leq 0.05$) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 12 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2003 season from Hex River Valley (Trial 6) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 6 weeks			
Moisture in carton[y]	<0.0001	2.00[bx]	2.17[a]
Stem condition[z]	<0.0001	3.90[a]	1.92[b]
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C			
Moisture in carton	0.3274	1.95[a]	2.00[a]
Stem condition	N/V	4.05[a]	2.50[b]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).

Table 13 Quality disorders of 'Red Globe' table grapes in the 2003 season from Berg River Valley (Trial 7) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (P≤0.05)[x]			Moisture sheet (A)[y]		Liner type (B)[v]	Moisture sheet (A)[v]		
	A	B[u]	AxB	Desiccant	Mam		Desiccant	Mam	t-value
Average: storage at -0.5 °C for 6 weeks									
Berry abscission (%)	0.0065	0.7905	0.7248	1.48[bz]	2.54[a]				
SO_2 damage (%)	<0.0001	0.1383	0.7130	7.00[b]	16.00[a]				
Botrytis decay (%)	0.0002	0.0307	0.5342	1.97[a]	0.52[b]				
Berry split (%)	<0.0001	0.0046	0.0060[w]	0.34	14.38	Non	1.17[b]	18.98[a]	<0.0001
						%	20.00[a]	9.78[b]	<0.0001
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at 15 °C									
Berry abscission (%)	0.2006	0.8137	0.2062	1.07[a]	1.32[a]				
SO_2 damage (%)	<0.0001	0.8248	0.9252	4.15[b]	11.64[a]				
Botrytis decay (%)	0.2090	0.3892	0.2706	12.52[a]	5.69[a]				
Berry split (%)	<0.0001	0.0106	0.115	0.54[b]	5.84[a]				

[u] Data pooled across factor A (Moisture sheet type) to show influence of factor B (Liner type) are not shown.

[v] Differences in liner type are explained by the t-test ($t \leq 0.05$) when significant interaction occurred between factor A and B.

[w] Averages of interaction between factor A and B not included.

[x] Two-way ANOVA table with complete randomised factorial design for factor A (Moisture sheet type) and factor B (Liner type).

[y] Data expressed in percentage of the quality disorder after five weeks of storage at -0.5 °C or after five weeks of storage at -0.5 °C and one weeks at 15 °C.

[z] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

Table 14 Subjective evaluation of moisture in the carton and stem condition of 'Red Globe' table grapes in the 2003 season from Berg River Valley (Trial 7) determined after five weeks of cold storage at -0.5 °C or after five weeks of cold storage at -0.5 °C plus one week at 15 °C.

Parameters	Probability (χ^2<0.05)[w]	Moisture sheet	
		Desiccant	Mam
Average: storage at -0.5 °C for 6 weeks			
Moisture in carton[y]	<0.0001	1.95[ax]	1.58[b]
Stem condition[z]	N/V	2.85	3.00
Shelf life: storage at -0.5 °C for 6 weeks and 1 week at -15 °C			
Moisture in carton	0.0920	1.45[a]	1.75[a]
Stem condition	0.1117	3.45[a]	3.17[a]

[w] Table analysis with the χ^2 test.

[x] Means within a row not followed by same letter are significantly different at $P \leq 0.05$.

[y] Moisture in the carton was ranked from 1- 3 (where1 is dry, 2 has condensation and 3 has free water).

[z] Stem condition was ranked from 1-5 (where 1 is green stems and 5 is dry and brown stems).