

Vitis 14, 220—227 (1975)

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Long-term storage of table grape cultivars and the use of liquid-SO₂ and solid -in-package-SO₂ generators¹⁾

by

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Langfristige Lagerung von Tafeltraubensorten unter Verwendung von Flüssig- und Fest-SO₂-Spendern

Zusammenfassung. — Tafeltrauben der Sorten Danugue, Waltham Cross, Alphonse Lavellée und Sultanina wurden mehrere Wochen lang kühl gelagert. Um Fäulnisvorgänge zu unterbinden, wurden den Kartons SO₂-Spender auf flüssiger oder fester Basis beige packt. Die Methode der SO₂-Anwendung muß der jeweiligen Traubensorte angepaßt werden. Von den geprüften Sorten eignete sich Alphonse Lavallée am besten für die langfristige Lagerung. Sultanina war wegen ihrer Anfälligkeit gegen Fäulnis und Schädigung durch SO₂ nur beschränkt lagerungsfähig. Bei Waltham Cross traten in größerem Umfang gebräunte, bei Danugue geplatze Beeren auf.

Introduction

Long-term storage of table grapes requires application of an antifungal material with a prolonged effect. Without such treatment there is no possibility of storing the fruit in marketable condition. Decay in grapes is caused principally by the fungi *Botrytis cinerea*, *Rhizopus nigricans* and *Penicillium* spp. The common practice is to fumigate the storage rooms every 7—10 days with SO₂ (2, 11, 12). Other methods for controlling decay, based on the gradual release of SO₂ from liquid or solid preparations of K₂S₂O₅ or NaHSO₃, have been tried (1, 6, 9, 10). With the liquid-SO₂ generators fruit was packed in closed polyethylene liners (10), whereas with the solid-SO₂ generators mostly unvented coated containers were used (7).

The purpose of this work was to examine the suitability of several table grape cvs. intended for export to Europe after long-term storage and to compare the efficiency of the above-mentioned SO₂ generators. Uncovered wooden trays used for export of grapes in Israel were recently changed to vented cartons and the methods examined had to be applied to this kind of packing.

Materials and Methods

Experiments were carried out on long-term storage of the cultivars Danugue, Alphonse Lavallée, Waltham Cross and Sultanina during five years (1968—1973).

Packaging: The grapes were packed in vented corrugated cartons with lids, containing 5 kg fruit. Perforated polyethylene liners (0.25 mm thick) (3) were used in the cartons in most experiments. The liner was folded over the fruits after they had been cooled to approximately 10 °C. In some trials five containers of fruit were enclosed within a polyethylene pallet cover (0.03 mm thick). Each treatment included five replicates of a tray or carton.

¹⁾ Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel. 1975 Series, No. 152-E.

Storage treatments: a) Liquid-SO₂ generators: A two-stage release of SO₂ was obtained by using polyethylene bags (10 × 15 cm) of two thicknesses — 0.05 mm for the first stage and 0.1 mm for the second stage release. Bags of each thickness, containing 30 ml of 1—2.5 g K₂S₂O₅ solutions, were placed next to each other on top of the fruit. A total of four bags was used in each carton (1.2—1.6 g K₂S₂O₅/kg fruit).

b) Solid-SO₂ generators (manufactured by the Fiberboard Corporation) releasing SO₂ in two stages (9). The SO₂ generator was placed on top of the grapes with a thin paper sheet between the fruit and the generator. The generator was used either in its original form (full length — 20 × 40 cm) or cut to ¾ of its length (20 × 30 cm — shortened generator).

In some of the trials the SO₂ release during the storage period was measured in the polyethylene-pallet-covered cartons by a 'Dräger' multigas detector, calibrated for a range of 1—20 ppm SO₂ in a 100-ml air sample. In the middle carton of a five-carton stack a typon tube was installed between the clusters, so that an air sample could be withdrawn from the carton.

The keeping quality of the fruit was evaluated from the amount of decayed, cracked, and SO₂-bleached berries and its general appearance. The extent of damaged fruit was calculated as an index, as follows:

$$\text{Index} = \frac{\text{si} + 2 \text{md} + 4 \text{hi}}{10}$$

where si = % of clusters with slight decay or bleaching (1—2 berries in a cluster); md = % of clusters with medium injury (3—5 berries in a cluster); and hi = % of clusters with more than 5 injured berries per cluster; maximum index = 40. The stems and pedicels of each cluster were classified as green, partially dry or dry and the percentage for each classification was calculated on the basis of total number of clusters in the container.

The fruit was stored for 3—4 months at 0 °C and examined after 4 days' shelf-life at 20 °C.

Results and Discussion

Danugue: With this cv. only liquid-SO₂ generators were examined (solid-SO₂ generators were not yet available). To control decay, the adequate choice of the release stages in using liquid-SO₂ generators proved to be very important. It was found in previous experiments that to control decay without causing too much bleaching injury, four liquid-SO₂ generators of two release stages have to be used per carton (4, 5). Often, however, although rot was controlled, the appearance of the fruit was impaired by wet and bleached berries, and sometimes even by pedicels covered by mould. In stacks within pallet covers the relative humidity in the cartons was very high (98—100%) and it was thought that reducing humidity would result in better fruit appearance. Experiments were therefore carried out to compare this kind of pack with and without polyethylene pallet covers.

Decay was reduced to a tolerable degree with 1.4 g K₂S₂O₅ per kg fruit only when pallet covers were used. There was no significant difference in the bleaching index between the pallet-covered and non-covered cartons (Table 1). However, even in treatments without polyethylene pallet covers, where the humidity was lower (90% RH), the grapes looked wet and sticky, due to cracking of the berries, which was high in all treatments (Table 1). This is a characteristic of the Danugue variety. It was found in several experiments that the percent of cracking of the Danugue cv.

Table 1

Index of decay, bleaching and cracking of berries of Danugue cv. stored in cartons with liquid-SO₂ generators within polyethylene liners for 4 months at 0 °C, with and without polyethylene pallet covers, and examined after 4 days' shelf-life at 20 °C. (Two release stages in four liquid-SO₂ generators)

Indizes für Fäulnis, Ausbleichen und Platzen bei den Beeren der Sorte Danugue nach 4monatiger Lagerung bei 0 °C unter Verwendung von Flüssig-SO₂-Spendern. Kartons mit Polyäthylenfolie ausgeschlagen, mit oder ohne Polyäthylenüberzug der Paletten. Prüfung nach 4tägiger Verweildauer im Regal bei 20 °C. (SO₂-Freisetzung in zwei Phasen aus insgesamt vier Lösungsbeuteln je Karton)

K ₂ S ₂ O ₅ g/bag		K ₂ S ₂ O ₅ g/kg	Polyethylene pallet covers	Index ¹⁾		
1st stage	2nd stage			Decay	Bleaching	Cracked berries
1.5	1.5	1.2	+	10.7ab ²⁾	10.9	10.6
1.5	1.5	1.2	—	9.1ab	15.8	14.5
1.5	2.0	1.4	+	3.9a	17.0	14.6
1.5	2.0	1.4	—	19.3b	13.6	13.4
					N.S.	N.S.

¹⁾ A waste index of 7–8 is equivalent to approximately 5% loss, which is usually still within the marketing tolerance limit.

²⁾ Means sharing the same letter do not differ at the 5% level of probability (according to Duncan's Multiple Range test).

averaged 15–17% as compared with 2–4% of Alphonse Lavallée cv. and 0.5–2% of Waltham Cross cv. (4, 5).

Alphonse Lavallée and Waltham Cross cvs.: Alphonse Lavallée cv. is susceptible to desiccation, even when packed in polyethylene liners; therefore, the value of using additional polyethylene pallet covers, for improving the keeping quality, was examined. For the Waltham Cross cv., which is less susceptible to stem and pedicel desiccation, packing under pallet covers without polyethylene liners was examined (Table 2). In both cvs. packing in polyethylene liners and pallet covers reduced the percent of desiccation of cluster stems significantly.

Rot incidence was very low in all treatments of Alphonse Lavallée and in most treatments of Waltham Cross. In Waltham Cross the significantly lower incidence of decay in the liquid- and solid-SO₂ generator treatments within liners showed that more SO₂ was present in that case to suppress decay than in the same treatments without polyethylene liners. This was indicated also by a tendency to higher bleaching in these treatments (Table 2), although higher bleaching could also be due to more humid conditions around the fruit. In both cvs., in all experiments, the solid-SO₂ generators were very efficient in reducing decay, but enhanced bleaching even if a shortened generator was used (Fig. 1).

The Waltham Cross cv. was found to be very sensitive to berry browning, which did not impair the taste of the fruit but affected its appearance. Browning became more evident during shelf-life and was probably due to oxidation. The browning was less pronounced in fruit packed with a SO₂ generator in polyethylene liners where the accumulation of SO₂ was higher (bleaching index 10.7, SO₂ content 3.5–4 ppm, browning index 7.9) than in fruit packed without liners (bleaching index 5.1, SO₂ content 1–2.5 ppm, browning index 21.6). It may be assumed that SO₂ had an antioxidant effect.

Table 2

The effect of polyethylene liners and pallet covers on the keeping quality of Alphonse Lavallée and Waltham Cross cvs. after 15 weeks' storage at 0 °C and 4 days' shelf-life at 20 °C (5-kg cartons)

Der Einfluß von Polyäthylenfolien in den Kartons und von Polyäthylenhüllen über den Paletten auf den Erhaltungszustand von Alphonse Lavallée und Waltham Cross nach 15wöchiger Lagerung bei 0 °C und 4tägiger Verweildauer im Regal bei 20 °C (5-kg-Kartons)

Alphonse Lavallée cv. (packed in polyethylene liners)

SO ₂ treatments	Polyethylene pallet covers	Green stems %	Index	
			Bleaching	Decay
Two first-stage and two second-stage liquid-SO ₂ generators (1.5 g K ₂ S ₂ O ₅ in each)	+	63**	4.0	0.6
	—	16	1.6	0.4
Two first-stage (1.5 g K ₂ S ₂ O ₅ each) and two second-stage (2 g K ₂ S ₂ O ₅ each) liquid-SO ₂ generators	+	46**	3.5	0.3
	—	26	1.5	0.1

Waltham Cross cv. (with pallet covers)

SO ₂ treatments	Polyethylene liners	Green stems %	Index	
			Bleaching	Decay
Two first-stage (1.5 g K ₂ S ₂ O ₅ each) and two second-stage (2.5 g K ₂ S ₂ O ₅ each) liquid-SO ₂ generators	+	100**	5.3	1.0*
	—	71	2.3	6.0
	+	92**	10.7*	0
Full-length solid-SO ₂ generator	—	32	5.1	1.1
	+	98**	7.2	3.0*
Shortened (3/4) solid-SO ₂ generator	—	26	5.5	5.1

* and ** indicate significance at the 5% and 1% levels of probability, respectively, from corresponding treatment without liners or pallet covers (according to Duncan's Multiple Range test).

It is possible that browning could be partly controlled by higher SO₂ dosages, but then the fruit would be damaged by bleaching.

Sultana: This cultivar has been found susceptible to decay under local conditions (3).

The amount of decay of fruit stored for up to 12 weeks increased with extension of the storage period. Decay was satisfactorily controlled by solid-SO₂ generators of both lengths, even after 12 weeks' storage. Nevertheless, at that time the fruit, although marketable, looked dull and less attractive than after shorter storage periods. Bleaching was generally much higher with the full-length generator. The least bleaching occurred with the liquid-SO₂ generators (four two-stage bags, 1.6 g K₂S₂O₅/kg fruit), but decay control was less efficient (Fig. 2).

These results correspond to the SO₂ content as measured in the fruit cartons during storage (Fig. 3). Within one week after harvest (6 days after treatment) there was a marked difference in SO₂ concentration between the fruit cartons with the full length solid-SO₂ generator and those with the shortened solid-SO₂ or the liquid-SO₂ generator (where the concentration of SO₂ was similar). After 6 weeks' storage

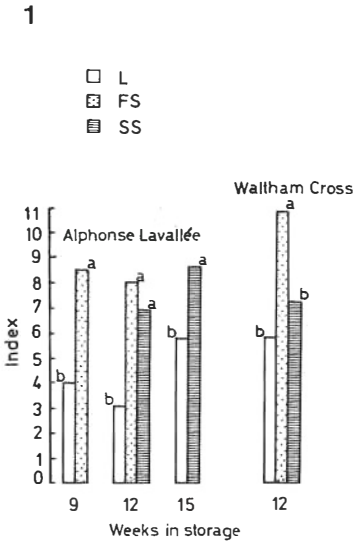


Fig. 1: Effect of liquid- and solid-SO₂ generators on bleaching index of Alphonse Lavallée and Waltham Cross cvs. after cold storage and shelf-life. Columns bearing the same letter do not differ significantly at the 5% level. L = Liquid-SO₂ generator, FS = Full length, solid-SO₂ generator, SS = Shortened, solid-SO₂ generator.

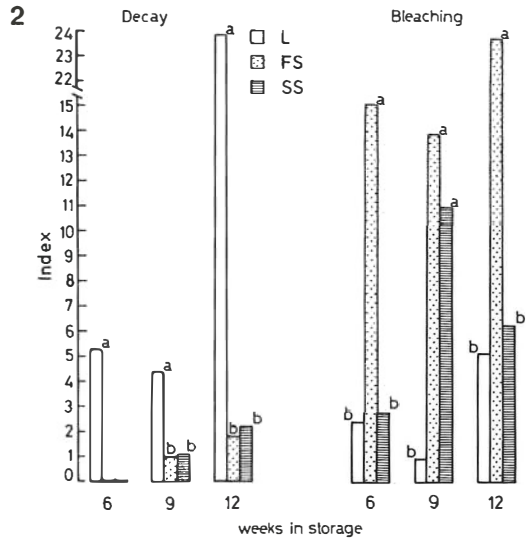


Fig. 2: Effect of liquid- and solid-SO₂ generators on decay index and bleaching index of Sultanina cv. after cold storage and shelf-life. Further explanations see Fig. 1.

Abb. 1: Der Einfluß von Flüssig- und Fest-SO₂-Spendern auf den Ausbleichungsindex der Sorten Alphonse Lavallée und Waltham Cross nach Kühlagerung und Regalaufenthalt. Säulen mit demselben Buchstaben unterscheiden sich nicht signifikant bei einer Irrtumswahrscheinlichkeit von 5%. L = Flüssig-SO₂-Spender, FS = Fest-SO₂-Spender — volle Länge, SS = Fest-SO₂-Spender — gekürzt.

Abb. 2: Der Einfluß von Flüssig- und Fest-SO₂-Spendern auf den Fäulnis- und Ausbleichungsindex der Sorte Sultanina nach Kühlagerung und Regalaufenthalt. Weitere Erläuterungen s. Abb. 1.

there was a peak of SO₂ concentration in all treatments, the solid-SO₂ full-length generator producing the highest peak and the liquid-SO₂ generator the lowest. It can be assumed that by that time the SO₂ had evolved from the second-stage generators. After 6 weeks there was a general reduction in SO₂ concentration (probably only second-stage evolution), which was especially marked in the treatments with liquid-SO₂ generators (1 ppm after 12 weeks' storage, Fig. 3). At that time the amount of decay in fruit from this treatment was high (Fig. 2).

The SO₂ concentration pattern in the polyethylene pallet covers was similar to that in unvented containers with polyethylene curtains as mentioned by NELSON and AHMEDULLA (6); only that in our case the rise of SO₂ concentration was much slower, which was certainly due to the fact that the SO₂ generators were put on the fruit when already cooled. The differences in the SO₂ concentration between the treatments can be ascribed to the dose of NaHSO₃ or K₂S₂O₅ in the generators (9).

When vented cartons are used for packing (as in Israel), a polyethylene pallet cover is obligatory to retain the SO₂ released from the generators and to preserve

Table 3

Effect of different SO₂ generators on decay and bleaching index of Sultanina cv. after cold storage and 4 days' shelf-life at 20 °C (5-kg cartons)

Der Einfluß verschiedener SO₂-Spender auf die Indizes für Fäulnis und Ausbleichung der Sorte Sultanina nach Kühlung und 4tägiger Verweildauer im Regal bei 20 °C (5-kg-Kartons)

Treatment	Weeks in storage					
	6		9		12	
	Decay	Bleaching	Decay	Bleaching	Decay	Bleaching
Four liquid-SO ₂ generators, two stages (1.6 g K ₂ S ₂ O ₅ /kg)	6.3	3.4a**	5.4a	1.9a*	24.8b	6.1a**
Full-length solid-SO ₂ generator	0	16.0b	2.0a	14.8b	2.7a	24.6b
Shortened (3/4) solid-SO ₂ generator	0	3.8a	2.1a	11.9b	3.1a	7.2a

* and ** indicate significance at the 5% and 1% levels of probability, respectively (according to Duncan's Multiple Range test).

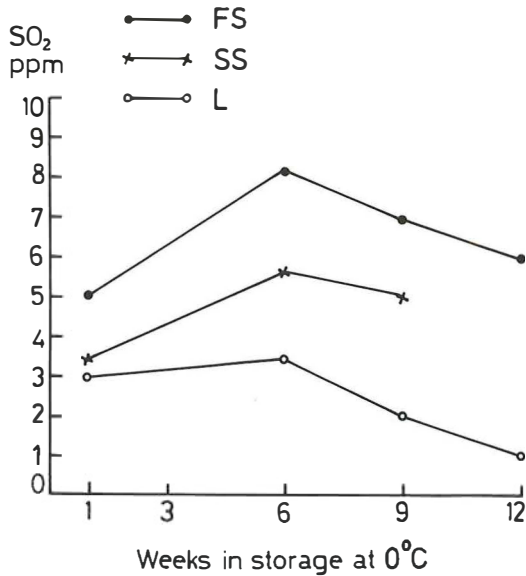


Fig. 3: Changes in SO₂ content during storage in cartons of Sultanina cv. treated with liquid- and solid-SO₂ generators. FS = Full length solid-SO₂ generator, SS = Shortened solid-SO₂ generator, L = Liquid-SO₂ generator.

Veränderung des SO₂-Gehaltes während der Lagerung von Sultanina-Trauben in Kartons bei Verwendung von Flüssig- und Fest-SO₂-Spendern. FS = Fest-SO₂-Spender — volle Länge, SS = Fest-SO₂-Spender — gekürzt, L = Flüssig-SO₂-Spender.

the stem freshness during storage, instead of the unvented packaging recommended elsewhere (6, 10). The use of polyethylene liners alone was not sufficient, especially as perforation of the liners is necessary to avoid excess moisture, when the fruit is transferred from storage to the higher ambient temperature of shelf-life. When perforated polyethylene liners and pallet covers are used in combination, the latter can be easily removed for the period of shelf-life and, thus, the excessive bleaching caused by high temperature and humidity can be prevented, while the liners continue to protect the freshness of the fruit.

Conclusions

The keeping quality of the stored table grapes varied with the cultivar and the SO₂ application method.

The solid-SO₂ generators were very convenient for use and very efficient in controlling decay, but, as they increased bleaching, they should be used only with cvs. where the liquid-SO₂ generators cannot control decay sufficiently. This was the case with Sultanina, where solid-SO₂ generators were more effective. However, due to excessive bleaching, the shortened generator is recommended for 5 kg of fruit. For the other cvs. — Danugue, Alphonse Lavallée and Waltham Cross — 1.4—1.6 g K₂S₂O₈/kg fruit in liquid-SO₂ generators gave satisfactory results. In this case, two-stage SO₂-release bags (0.05 mm and 0.1 mm thick) should be used.

Not all of the cvs. examined can be recommended for export after long-term storage even if decay can be satisfactorily controlled. The storage life of Waltham Cross is limited, because of berry browning; the tendency of the Danugue cv. to split berries increased bleaching injury and affected the general appearance of the fruit. Alphonse Lavallée was found to be the most suitable cultivar for long-term storage (4 months) under Israeli conditions and for export. The desiccation of stems and pedicels, to which this cv. is susceptible, can be reduced by packing the fruit in polyethylene liners and pallet covers. For the Sultanina cv., with the methods used, 9 weeks of storage before export can be recommended.

Summary

Danugue, Waltham Cross, Alphonse Lavallée and Sultanina cvs. of table grapes were kept for several weeks in cold storage. To control rots, liquid- or solid-SO₂ generators were used. The appropriate method of SO₂ application has to be chosen according to the cultivar. Of the cvs. examined, Alphonse Lavallée was the most suitable for long-term storage. Sultanina had a more restricted storage period because of its susceptibility to decay and SO₂ injury, Waltham Cross suffered from berry browning, and Danugue from split berries.

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Eingegangen am 26. 5. 1975

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