Post-harvest conservation of "Benitaka" table grapes with different SO_2-generating pads and plastic liners under cold storage

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Abstract. This work aimed at evaluating the post-harvest conservation of "Benitaka" table grape by using different types of SO_2-generating pads and perforated plastic liners under cold storage. The grapes were harvested from off-season crop 2018 in a commercial vineyard located at Cambira, PR, Brazil. The completely randomized design was used with four replications in a 2-factor arrangement with an additional treatment [(4 × 3) + 1], and the following factors were evaluated: a) SO_2-generating pads (slow release containing 7 g of active ingredient – a.i.; slow release containing 4 g of a.i.; dual release containing 5 g of a.i.; and dual release containing 8 g of a.i.); and b) perforated plastic liners (0.3%, 0.9% and 1.0% of ventilation areas). The additional treatment did not contain any type of SO_2-generating pad, only standard microperforated plastic liner (1% of ventilation area). The bunches were packed in 0.5 kg-capacity plastic clamshells, which were placed in a corrugated carton box with the different combinations of SO_2-generating pads and plastic liners under cold storage at 1 °C with high relative humidity (>90%). The treatments were evaluated at 30 and 45 days after the beginning of the cold storage, recording the incidence of gray mold, shattered berries, stem browning, mass loss and berry firmness. The data were submitted to analysis of variance and the means were compared by Tukey's test at 5%. The use of dual release SO_2-generating pads containing 5 g or 8 g of a.i., as well the slow release pads with 7 g of a.i., are efficient to control the incidence of gray mold in "Benitaka" table grapes packaged in plastic clamshells and kept under cold storage at 1 °C up to 45 days. In these storage conditions, the use of perforated plastic liners with 0.3% of ventilation area or the micro perforated with 1.0% of ventilation area, result in the lowest bunch mass loss and shattered berries.

1. Introduction

Viticulture is an important economic activity in Brazil. In the recent years, it has also become important in generating employment in large enterprises for production of table grapes, mainly the seedless types. The worldwide trend for the consumption of seedless grapes has increased the competition between producers, which direct efforts to meet a more demanding consumer market [1,2].

The northern region of Parana State is a consolidated area in table grape production, and it is based on seeded grapes such as "Benitaka" (*Vitis vinifera* L.). In order to meet the demands of the market and also to ensure the trade of grapes throughout the year, it is necessary to use techniques that enable the supply of quality fruits to the consumers. In this sense, cold storage is the most used technique among post-harvest practices, demonstrating that it is efficient in increasing fruit longevity, considerably reducing the loss of mass and controlling the development of pathogens such as gray mold caused by *Botrytis cinerea*. The use of sulfur dioxide (SO_2) generating pads has shown good results in the control of this and other post-harvest diseases in cold chamber, making it an alternative of easy application and good performance. In order to improve the efficiency of the use of SO2-generating pads in the refrigerated preservation of table grapes, it is necessary to use them in combination with perforated plastic liners, in order to facilitate their circulation of gas in the box, as well as to avoid mass loss of the fruits [3–6].

However, it is still not well known about the interaction of the different types of SO_2-generating pads and perforated plastic liners for the post-harvest refrigerated conservation of the "Benitaka" table grape, mainly in relation to the incidence of gray mold. In view of these aspects, the objective of this work was to evaluate the post-harvest conservation of "Benitaka" table grapes individually packaged in clamshells, combining different types of SO_2-generating pads and perforated plastic liners in a cold chamber.

2. Materials and methods

The "Benitaka" bunches were obtained in a commercial vineyard located at Cambira, PR (23° 35′S, 51° 34′O, elevation of 1,017 m), with a history of gray mold occurrence.

The completely randomized design was used with four replications in a 2-factor arrangement with an additional treatment [(4 × 3) + 1], and the following factors were evaluated: a) SO_2-generating pads (slow release containing 7 g of active ingredient – a.i.; slow release containing 4 g of a.i.; dual release containing 5 g of a.i.; and dual release containing 8 g of a.i.); and b) perforated plastic liners (0.3%, 0.9% and 1.0% of ventilation areas). The

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Table 1. Incidence of gray mold (% of diseased berries) of "Benitaka" table grape at 30 and 45 of cold storage individually packaged in clamshells with different SO_2-generating pads and perforated plastic liners.

Release type and amount of SO_2 of pads (A)	**Incidence of gray mold (% of diseased berries)**	
	At 30 days of cold storage	At 45 days of cold storage
Slow – 7 g	0.03 b	0.35 b
Slow – 4 g	0.31 a	0.92 a
Dual – 5 g	0.00 b	0.04 b
Dual – 8 g	0.00 b	0.00 b
Ventilation area of liners (B)		
0.3%	0.10	0.37
0.9%	0.03	0.26
1.0%	0.12	0.35
Additional treatment × factorial		
Additional treatment	0.59 a	1.45 a
Factorial	0.08 b	0.32 b
F (A)	5.41*	11.19*
F (B)	0.65^{ns}	0.16^{ns}
F (A × B)	0.66^{ns}	0.85^{ns}
F (Additional treatment × factorial)	17.43*	18.96*
CV %	19.74	32.44

Means within columns followed by the same letters are not statistically different by Tukey´s test ($P \leq 0.05$). ns: not significant; *: significant at 5%. Original data transformed in $\sqrt{x + 0.5}$.

Table 2. Shattered berries (%) of "Benitaka" table grape at 30 and 45 of cold storage individually packaged in clamshells with different SO_2-generating pads and perforated plastic liners.

Release type and amount of SO_2 of pads (A)	**Shattered berries (%)**	
	At 30 days of cold storage	At 45 days of cold storage
Slow – 7 g	0.34	0.50
Slow – 4 g	0.22	0.65
Dual – 5 g	0.28	0.55
Dual – 8 g	0.20	0.43
Ventilation area of liners (B)		
0.3%	0.15	0.34 b
0.9%	0.36	0.81 a
1.0%	0.27	0.45 ab
Additional treatment × factorial		
Additional treatment	0.38	0.11
Factorial	0.26	0.53
F (A)	0.43^{ns}	1.04^{ns}
F (B)	1.53^{ns}	3.61*
F (A × B)	0.30^{ns}	0.18^{ns}
F (Additional treatment × factorial)	0.07^{ns}	2.23^{ns}
CV %	21.86	2.76

Means within columns followed by the same letters are not statistically different by Tukey´s test ($P \leq 0.05$). ns: not significant; *: significant at 5%. Original data transformed in $\sqrt{x + 0.5}$.

additional treatment did not contain any type of SO_2-generating pad, only standard microperforated plastic liner (1% of ventilated area – VA). The bunches were packed in 0.5 kg-capacity plastic clamshells, which were placed in a corrugated carton box with the different combinations of SO_2-generating pads and plastic liners under cold storage at 1 °C with high relative humidity (>90%). The treatments were evaluated at 30 and 45 days after the beginning of the cold storage, recording the incidence of gray mold, shattered berries, stem browning, mass loss and berry firmness [7–9]. The data were submitted to analysis of variance and the means were compared by Tukey's test at 5%.

3. Results and discussion

The high efficiency observed in the control of gray mold (Table 1) by the dual release pads is due to the fact that, from the contact with the humidity of the air, they release a higher amount of the gas in the first 48 hours of storage (1 g of the a.i.), thus eliminating any *B. cinerea* spores. After that period, the gas emission becomes slow and constant.

Table 3. Stem browning of "Benitaka" table grape at 30 and 45 of cold storage individually packaged in clamshells with different SO_2-generating pads and perforated plastic liners.

Release type and amount of SO_2 of pads (A)	**Stem browing[a]**	
	At 30 days of cold storage	At 45 days of cold storage
Slow – 7 g	1.00	1.28 ab
Slow – 4 g	1.00	1.30 a
Dual – 5 g	1.00	1.11 ab
Dual – 8 g	1.05	1.05 b
Ventilation area of liners (B)		
0.3%	1.00	1.31
0.9%	1.00	1.12
1.0%	1.00	1.12
Additional treatment × factorial		
Additional treatment	1.05	1.20
Factorial	1.00	1.18
F (A)	0.14^{ns}	3.51*
F (B)	1.08^{ns}	0.80^{ns}
F (A × B)	0.07^{ns}	1.59^{ns}
F (Additional treatment × factorial)	12.00^{ns}	0.01^{ns}
CV %	27.41	21.95

Means within columns followed by the same letters are not statistically different by Tukey´s test ($P \leq 0.05$). *: significant at 5%. ns: not significant. [a]: 1: fresh and green; 2: light browning; 3: moderate browning; and 4: severe browning (Ngcobo et al., 2013).

Table 4. Mass loss (%) and berry firmness (N) of "Benitaka" table grape at 30 and 45 of cold storage individually packaged in clamshells with different SO_2-generating pads and perforated plastic liners.

Release type and amount of SO_2 of pads (A)	**Mass loss(%)**		**Firmness(N)**
	At 30 days of cold storage	At 45 days of cold storage	At 45 days of cold storage
Slow – 7 g	0.79	1.53	8.71
Slow – 4 g	0.75	1.53	8.28
Dual – 5 g	0.58	1.08	8.56
Dual – 8 g	0.56	1.30	8.25
Ventilation area of liners (B)			
0.3%	0.51 b	0.99 b	8.60
0.9%	0.86 a	1.81 a	8.14
1.0%	0.63 ab	1.27 b	8.61
Additional treatment × factorial			
Additional treatment	0.91	1.57	8.73
Factorial	0.67	1.36	8.45
F (A)	1.09^{ns}	2.93^{ns}	1.57^{ns}
F (B)	3.25*	13.16*	3.28^{ns}
F (A × B)	1.68^{ns}	1.95^{ns}	1.77^{ns}
F (Additional treatment × factorial)	1.34^{ns}	0.92^{ns}	0.82^{ns}
CV %	19.22	17.10	7.92

Means within columns followed by the same letters are not statistically different by Tukey´s test ($P \leq 0.05$). ns: not significant; *: significant at 5%. Original data transformed in $\sqrt{x + 0.5}$.

Although there were no significant differences between the two types of dual release pads tested, at 45 days of cold storage, a small incidence of gray mold was observed when the dual pad containing 5 g of a.i., which did not occur when the dual release pad with 8 g of a.i. was used. In this case, the highest SO_2 concentration in this last pad was decisive to keep the "Benitaka" bunches completely free of the disease during this storage period.

The different plastic liners evaluated did not influence this characteristic in the evaluated periods, however, it was verified that the bunches submitted to the combination of the factors showed lower averages of gray mold incidence when compared to the additional treatment. It confirms the need for the use of SO_2-generating pads in the control of the gray mold of "Benitaka" table grape during the cold storage period.

Regarding the shattered berries and stem browning, there were differences only at 45 days of refrigerated storage (Tables 2 and 3). The highest mean of shattered berries was observed when the liner with 0.9%

of VA, followed by the pockets with 1.0 and 0.3% of VA.

This is due to the relationship between the VA and a possible reduction of humidity inside the boxes, leading to a greater dehydration, loss of mass and concomitantly, greater shattered berries incidence. However, no differences were observed among the different SO_2 generating pads.

For the mass loss and berry firmness, there was no significant difference in the use of the different SO_2 generating pads in both cold storage periods evaluated (Table 4).

However, in relation to perforated plastic liners, the highest mass loss means occurred when the liner with 0.9% of VA was used, being more evident at 45 days of cold storage. Increasing liner VA can result in reduced humidity inside the box and increased SO_2 gas dispersion, which explains the greater dehydration of the bunches.

4. Conclusion

The use of dual release SO_2-generating pads containing 5 g or 8 g a.i. as well as a slow release with 7 g of a.i. is efficient to control the incidence of gray mold in "Benitaka" table grapes individually packaged in plastic clamshells and kept in a cold storage at 1 °C for up to 45 days. In these storage conditions, the use of a perforated plastic liners with 0.3% of ventilation area or microperforated with 1.0% of ventilation area, results in lower mass loss and shattered berries.

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