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Quality of 'Taify' Table Grapes Fumigated with Carbon Dioxide and Sulfur Dioxide

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Abstract. This investigation was initiated to study the effect of fumigation treatments after harvest on 'Taify' table grape fruit quality properties during storage periods. Grape was hand harvested in 2007 and stored at 2°C. Fumigation treatments were applied with 30% carbon dioxide (CO_2) and 200 ppm. sulfur dioxide (SO_2) besides control treatment. Fruits treated with 30% CO_2 and 200 ppm SO_2 developed less decay. Firmness was reduced as time of storage increased for all treatments, however, fruit fumigated with 30% CO_2 showed high firmness. Juice pH, soluble solid concentration (SSC), and soluble solid concentration to titratable acidity ratio (SSC/TA) increased over the storage periods and was lowest under 30% CO_2 and 200 ppm SO_2 treatments. Titratable acidity increased as storage time increased for all treatments. Weight loss varied with time of storage. Fruit appearance score was significantly high for fruit treated with 30% CO_2 and 200 ppm SO_2. Fruit exhibited skin toughness score of 4.22 at 7 days of storage at 200 ppm SO_2 treatment and was above average for all treatments. Overall acceptance score was significantly high when fruits were treated with 30% CO_2 and 200 ppm SO_2.. Fumigation of grape with 30% CO_2 and 200 ppm SO_2 had a beneficial effect in preserving fruit quality.

Introduction

Grape (*Vitis vinifera* L.) is widely grown for raisins or fresh consumption and on a commercial scale, is considered the world's second most grown fruit crop. The hectarage of planted fruit crops in Saudi Arabia has increased by 13 percent from 191323ha. in 2001 to 217451ha. in 2005, and grapes represent 8.5 % of this area producing 132175 tons. The most cultivated regions are Medinah and Tabouk which produce about 33.4 and 14.9 % of the total grape production, respectively (ARDA, 2006). This increasing in hectarage and production of fruits in Saudi Arabia appears promising for further development in the future. Therefore, scientific information is required for selecting varieties, proper production practices, and optimum postharvest handling strategies.

Grape is one of the important summer fruits in Taif area. During the season of grape harvesting and transporting, fruits often do not go through postharvest handling steps such as fast cooling after harvest or fumigation and refrigeration and it is hard to find a way that accurately quantifies these losses. Therefore, a significant portion of the harvested production never reaches the consumer. Also, inappropriate handling methods are the main reason that may weaken the natural defenses of fresh production and making it more susceptible to decay and consequently deterioration (Boyette *et al*., 1992). Thus, correct steps of handling and storage methods of fresh grapes are needed.

Grapes are non-climacteric fruits with a relatively low physiological activity, and are subject to serious water loss and softening after harvest, which can result in stem browning, berry shatter, wilting, shriveling of berries (Crisosto and Smilanick, 2007).

Gray mold, caused by the fungus *Botrytis cinerea*, and Botrytis rot are the most common cause of postharvest decay of table grapes worldwide (Crisosto *et al.*, 1998). Thus, practices such as postharvest fumigation with sulfur dioxide (SO_2) and carbon dioxide (CO_2) have a beneficial effect in preserving quality attribute for table grape (Mitcham and Leesch, 2004).

Quality and shelf life are important in grapes intended for table use. Decreased quality during postharvest handling of table grapes is usually associated with water loss, softening, and decay. There are beneficial effects of elevated CO_2 fumigation on the shelf life of horticultural produce (Wang, 1993). The response to application of CO_2 depends on the crop, CO_2 concentration and time of application. Short-term applications of gas have shown beneficial effects to many fruits during storage (Higashio *et al*., 1980 and Herner, 1987). Under high CO_2 storage, the internal amount of succinic acid increases, reducing respiration. The activity of many enzymes is also reduced (Kader, 1986).

Kubo *et al.* (1990) stated that high CO_2 storage decreases respiration only in climacteric fruits and vegetables. In non climacteric fruits and vegetables, including grapes, high CO_2 had little effect on respiration. However, storing grapes at 10-15 % CO_2 can be used to control grey mold for 2-4 weeks depending on cultivar (Crisosto and Smilanick, 2007). Crisosto *et al.* (1998) stated that controlled atmosphere at combination of 15% CO_2 with 3-12% O_2 is effective in decay control without detrimental effects on quality, especially when late harvested table grapes were used.

Hriber *et al.* (1994) reported that fruit quality was better preserved by initial high CO_2 treatments. Short exposure to high CO_2 before storage at low temperatures has been shown to decrease the development of chilling injury in several commodities (Bertolini *et al*., 1991) and reduce green color loss of CA stored apple (Hriber *et al*., 1994).

Storing grapes in non perforated polypropylene packages at 1˚C for 53 days had the highest CO_2 and lowest O_2 contents, with reduced weight losses, increased berry and skin firmness, and were effective in maintaining skin color (Martinez-Romero *et al*., 2003). Treating grapes immediately after harvest for 24 hours every 15 days during cold storage with application of 96-98% CO_2 was found to be effective in transport and storage (Magomedov *et al*., 1998).

Fumigation with SO_2 has been used to control fruit decay organisms in grapes (Snowdon, 1990). Nelson and Richardson (1967) stated that SO_2 was a very effective fumigation for retarding the spread of decay in table grapes by *Botrytis vinerea*. Table grapes 'Thompson seedless' packed in vented 27lb- containers and stored at 31, 35, and 39º F were fumigated weekly with 0.2, 0.1, 0.05 or 0.025% SO_2 for 30 minutes to retard the spread of decay from berries infected with *Botrytis cinerea*.

Marois *et al*. (1986) indicated that 200 ppm of SO_2 stopped the spread of disease. Complete control was only obtained with 800 ppm dose and repeated fumigation (three time/week) with 200 ppm significantly lowered the infection 30 %. Rossello *et al*. (1994) found that treated dried apricots with high SO_2 at different temperatures or low SO_2 with refrigeration maintained quality and met market requirement at the end of 9 months- storage.

Pretel *et al*. (2006) reported that a slightly CO_2 enriched atmosphere, SO_2 fumigation and their combination extended the storage life of late-harvested 'Aledo' table grapes without relatively affecting their quality. The objective of this study was to investigate the effects of CO_2 and SO_2 fumigation on Taify grapes quality attributes.

Materials and Methods

Table grape 'Taify' were harvested from private controlled farm at Taif area, Saudi Arabia. The grapes were hand harvested, placed in cardboard boxes (50 x 30 x 15cm), and transported to King Abdulaziz University Horticultural Lab on the same day.

Fruits were stored in the same boxes overnight at 2˚C. Next day, decayed, overripe and damaged berries with dull appearance were detached. The remaining fruits were divided among two treatments and control with four replicates. The treatments consisted of fumigation with 30% carbon dioxide (CO_2) in 70 % nitrogen (N_2) and 200 ppm sulfur dioxide (SO_2). Control fruits were untreated. Statistical design was applied according to El-Nakhlawy (2008). Split plot design with four replicates was used in this study. Main plots were occupied with three storage gases treatment (30% $CO_{2,}$ 200 ppm. $SO_{2,}$ and control), while the sub plot treatments were seven storage periods (0, 7, 14, 28, 35, and 42 days) for the trait of decay (%), firmness (%), pH, soluble solid contents (SSC), titratable acidity (TA), and SSC/TA. For the trait of weight loss, appearance, skin toughness, sweetness, flavors, and overall acceptance, the storage periods were six periods (all previous periods except the 0 period). Fifteen gallon plastic containers sealed with special metal rings were used for fumigation purposes. After placing the grape boxes in containers for refrigeration, required amounts of gas were released inside the containers from a gas cylinder. The control fruits were also placed in the same containers used for the fumigation under normal air. The samples were fumigated for six hours, and clusters were raped in 0.1mm polyethylene bags with holes and stored at 2˚C. Samples were taken at 0, 7, 14, 21, 28, 35, and 42 days of storage. Data were recorded for weight loss in grams, by placing 2 fruit clusters in each of four clusters (each cluster was replicated) per treatment giving a total of eight clusters per treatment. The same four bags were used through the experiment. The initial weight of each cluster was recorded, and percentage weight loss was obtained by subtracting the final weight from the initial weight and multiplying by 100.

Percentage decay was scored as visible fungal appearance by evaluating 2 fruit clusters randomly selected per replication per treatment at weekly intervals. Firmness was measured by using Chatillon dfm-100in (N); a total of four fruits per replication per treatment per sampling date were tasted. To determine the quality parameter, about 200grams of fruits were homogenized using a blender, and the juice was filtered. The pH of the juice was determined with the Inolab pH meter 720. Kruss dr6200/2 refractometer was used to measure soluble solid concentration (SSC). Titratable acidity (TA), expressed as mg tartaric acid/ml juice, was measured using 0.1 N NaOH to titrate 5 ml of juice diluted with 95 ml of distilled water to the end point of pH 8.2. Soluble solid concentration to titratable ratio (SSC/TA) was obtained by dividing SSC/TA.

Sensory analysis with scaling was conducted by seven panelists and the analysis included appearance, skin toughness, sweetness, flavor, and the overall acceptance. In the sensory analysis questionnaire, fruits were categorized on scale of 0 to 12. Numerical values for the variables were obtained by measuring the distance of the judges' marks from the left end of the line in a unit of 1cm. Data were statistically analyzed according to El-Nakhlawy (2008) using the general linear models (GLM) procedure of SAS (SAS, 2000). Means were separated using least significant difference test (LSD) at $P \leq 0.05$.

Results and Discussion

Data of analysis of variance of the studied traits under the effects of storage gases treatments, storage periods, and their interaction are summarized in Tables 1 and 2. The significant levels of mean squares of the studied traits are summarized in (Table 1). They showed significant effects for storage gases on decay, firmness, pH, soluble solids concentration, and soluble solids concentration to titratable acidity ratio at $p \leq 0.01$, but no significant effects were shown on titratable acidity. Storage periods significantly affected decay, firmness, pH, soluble solids concentration, titratable acidity and soluble solids concentration to titratable acidity ratio at $p \leq 0.01$ as shown in Table 1. Concerning the interaction between the storage gases and storage periods effects, analysis of variance data revealed significant effects at $p \leq 0.01$ on traits of decay and soluble solids concentration to titratable acidity ratio, while the other traits were significantly affected at $p \leq 0.05$ level of probability.

Analysis of variance results regarding weight loss, appearance, skin toughness, sweetness, flavors, and overall acceptance mean squares values are presented in Table 2. Significant effects for storage gases on appearance only are shown, but the other traits were not significantly affected at $p \leq 0.05$. Storage periods significantly affected the previous six grape traits. Also, the interaction between the storage gases and storage periods significantly affected the previous six grape traits. The results of analysis of variance for all studied grape traits (Table 1 and 2) concerning with the significant effects of storage gases and storage periods interaction were in agreement with the results obtained by Pretel *et al.* (2006) and Magomedov *et al.* (1998).

According to the analysis of variance, and the significance of the interaction effects on all studied traits, means of the studied traits under the interaction effects were statistically compared using LSD at 0.05 level of probability as shown in Tables 3 and 4. Decay percentage increased as storage time increased for all treatments (Table 3). At 35 and 42 days of storage, grapes treated with 200 ppm SO_2 and 30 % CO_2 had less decay compared to control at the same times of storage. Results of this experiment support previous findings that grapes fumigated with SO_2 and CO_2 have beneficial effects in suppressing decay during the storage time (Marois *et al.*, 1986 and Crisosto and Smilanick, 2007).

Significant reduction in fruit firmness over the storage time for all the treatments has been shown (Table 3). Comparing the control *vs*. the two other treatments, no differences were found after 7 and 28 days of storage. However, at 14, 21, 45, and 42 days of storage, fruits stored at 30% CO_2 treatment were significantly firmer than control treatment but did not significantly differ from 200ppm SO_2 treatment.

Juice pH significantly increased as the storage time increased, however, it varied between treatments (Table 3). This variability was within a narrow range of 0.27 pH units. At 28, 35 and 42 days of storage, juice pH was significantly higher in control than others treatments. At 42 days of storage, no significant difference on juice pH between treatments was detected.

Table 1. Mean squares of decay (%), firmness, pH, soluble solids concentration (SCC), titratable acidity (TA), and (SCC /TA) ratio of Taify table grapes stored at 2°C under the effects of storage gases, storage period and the interaction between them.

Source of Variation	df	MS					
		Decay (%)	Firmness (%)	pH	Soluble solids conc. (SSC)	Titrable acidity (TA)	SCC/TA
Replicate	3						
Storage gases (T)	2	39.82**	134.0 **	0.02 **	6.21 **	0.007NS	45.57**
Error "a"	6	2.02	0.48	0.005	0.52	0.003	9.53
Storage periods (D)	6	146.73**	24.22 **	0.052 **	13.75 **	0.042**	69.21**
T X D	12	11.91**	1.95 *	0.002 *	0.74 *	0.002*	8.58**
Error "b"	54	1.57	0.95	0.001	0.50	0.001	3.38

NS : not significant at 0.05 level of probability **, * : Significant at 0.01 and 0.05 levels of probability respectively

Table 2. Mean squares of weight loss, appearance, skin toughness, sweetness, flavors and overall acceptance of Taify table grapes stored at 2°C under the effects of storage gases, storage period and the interaction between them.

Source of Variation	df	MS					
		Weight loss	Appearance	Skin Toughness	Sweetness	Flavors	Overall acceptance
Replicate	3						
Storage gases (T)	2	0.07 NS	66.82 **	6.32 NS	6.96 NS	11.46 NS	24.63 NS
Error "a"	6	0.04	6.38	8.01	4.51	12.67	9.52
Storage periods (D)	5	0.24 **	13.55 **	15.23 *	36.62**	11.83 **	19.29 **
T X D	10	0.03 **	7.30**	10.08 *	4.63**	5.64*	6.63 **
Error "b"	45	0.01	3.30	5.93	2.21	3.71	3.34

NS : not significant at 0.05 level of probability **, * : Significant at 0.01 and 0.05 levels of probability respectively

Table 3. Means of decay (%), firmness, pH, soluble solids concentration (SCC), titratable acidity (TA), and (SCC /TA) ratio of Taify table grapes stored at 2°C under the effects of storage gases, storage period, and the interaction between them.

Storage gases (T)	Storage periods (D)	Decay (%)	Firmness	pH	Soluble solids concentration (SSC)	Titratable acidity (TA)	SCC/TA
SO_2 (200ppm)	0	0.00	10.66	3.54	17.29	0.57	22.61
	7	0.00	9.16	3.64	18.10	0.67	23.91
	14	0.33	8.83	3.68	18.03	0.65	24.54
	21	1.33	8.66	3.68	18.41	0.73	28.12
	28	2.66	8.00	3.70	18.86	0.72	28.16
	35	5.00	7.50	3.70	20.40	0.75	26.85
	42	8.66	5.50	3.76	20.57	0.77	31.65
C O_2 (30%)	0	0.00	10.66	3.54	17. 29	0.57	22.61
	7	0.00	10.33	3.58	16.71	0.73	23.67
	14	0.66	9.00	3.60	18.08	0.70	24.11
	21	1.00	8.16	3.61	18.61	0.75	27.18
	28	1. 66	7.83	3.65	18.68	0.76	24.34
	35	3.33	8.33	3.64	19.89	0.77	28.28
	42	7.33	6.83	3.76	20.04	0.79	29.30
Control	0	0.00	10.66	3.54	17. 29	0.57	22.61
	7	0.00	8.73	3.62	18.67	0.61	25.77
	14	0.00	7.46	3.62	19.05	0.68	29.56
	21	1.66	6.86	3.71	19.63	0.68	33.15
	28	5.00	6.80	3.75	20.13	0.73	30.49
	35	9.00	5.43	3.77	20.55	0.76	27.35
	42	16.66	4.40	3.81	21.44	0.76	30.73
$LSD_{0.05}$ (TiDi-TjDi)		2.22	1.85	0.07	1.38	0.20	3.93
$LSD_{0.05}$ (TiDi-TiDj)		2.01	1.38	0.05	1.29	0.07	3.85
$LSD_{0.05}$ (TiDi-TjDj)		2.01	1.38	0.05	1.29	0.07	3.85

Soluble solid concentration (SSC) increased over the storage time for all treatments, with the highest being (21.44) for the control treatment by the end of the storage periods (Table 3). Differences in soluble solid concentration between treatments and the control were shown in approximately 28, and 42 days of storage, in which soluble solid concentration was significantly higher in the control treatment than under the 30% CO_2 treatment but not significantly differ from 200 ppm. SO_2 treatment.

Titratable acidity (TA) increased with storage duration for all treatments (Table 3). The differences in treatments showed an increase in titratable acidity in 30% CO_2 treatment at 7 and 21 days compared to control, but did not differ from 200ppm SO_2 treatment.

Table 4. Means of weight loss, appearance, skin toughness, sweetness, flavors, and overall acceptance of Taify table grapes stored at 2°C under the effects of storage gases, storage period and the interaction between them.

Storage gases (T)	Storage periods (D)	Weight loss	Appearance	Skin Toughness	Sweetness	Flavors	Overall acceptance
SO_2 (200ppm)	7	0.49	8.87	4.22	6.04	8.14	8.50
	14	0.67	8.72	6.21	5.94	8.62	9.07
	21	0.37	7.24	6.94	7.45	8.52	8.32
	28	0.55	7.71	8.20	7.75	7.90	7.55
	35	0.51	7.97	7.87	8.33	7.25	8.14
	42	0.36	7.10	7.82	9.24	7.02	7.27
CO_2 (30%)	7	0.55	9.17	5.68	4.54	6.27	9.07
	14	0.32	8.55	5.98	5.94	8.35	7.92
	21	0.33	9.11	6.45	7.41	7.41	7.44
	28	0.31	7.98	7.05	6.42	6.78	7.77
	35	0.36	7.87	6.07	8.11	7.20	7.25
	42	0.28	7.17	7.77	8.78	6.78	6.42
Control	7	0.52	6.74	6.41	6.32	8.40	8.47
	14	0.57	7.50	7.10	6.24	8.00	7.87
	21	0.35	6.68	7.40	8.37	6.48	7.14
	28	0.32	5.38	7.40	7.82	6.94	6.38
	35	0.37	4.98	7.62	7.61	6.61	5.77
	42	0.51	4.48	7.74	9.72	5.04	4.25
$LSD_{0.05}$ (TiDi-TjDi)		0.30	2.29	2.84	2.05	2.62	2.37
$LSD_{0.05}$ (TiDi-TiDj)		0.23	2.10	2.73	1.98	2.37	2.13
$LSD_{0.05}$ (TiDi-TjDj)		0.23	2.10	2.73	1.98	2.37	2.13

Fruits from all treatments showed an increase in soluble solid concentration to titratable acid ratio (SSC/TA) with time in storage (Table 3). Comparing control treatment with the other treatments, at 14, and 21 days of storage, soluble solid concentration to titratable acid ratio was significantly the highest at the control treatment compared to 200ppm SO_2 and 30 % CO_2. At 28 days of storage, 30% CO_2 had lower soluble solid concentration to titratable acid ratio compared to other treatments.

Weight loss varied across the time of storage. At 7 days of storage, weight loss was significantly high when compared with 21 and 42 days of storage at 200ppm SO_2 treatment (Table 4). Under 30 % CO_2 treatment, weight loss decreased as storage time increased. In the control treatment, weight loss was the greatest at 7 and 42 days of storage time when compared with 28 days of storage.

Percentage weight loss ranged from 0.28% to 0.67% by comparing other treatments with control. At 14 days of storage, weight loss was significantly lower at 30 % CO_2 treatment than under other treatments. At 28 days of storage, 30% CO_2 treatment had a significantly lower weight loss compared to 200ppm SO_2 treatment, but did not differ significantly from control. At 42 days of storage, weight loss was higher for control treatment compared to 30 % CO_2, but did not differ from 200ppm SO_2 treatment. Total weight loss was highest when fruits were fumigated with 200ppm SO_2 treatment compared to other treatments.

Appearance means showed no significant changes with storage time in 200ppm SO_2 and 30 % CO_2 treatments (Table 4). In control treatment, appearance decreased over the storage duration. Comparing other treatments to control, at 7 days of storage, appearance received a lower score (6.74) at the control treatment compared to 30% CO_2 treatment, but did not differ significantly from 200 ppm SO_2 treatment. At 21 days of storage, 200 ppm SO_2 treatment had significantly higher score of appearance when compared to control treatment. At 28, 35, and 42 days of storage, fruits of control treatment had significantly lower score of appearance compared to other treatments. The results of this experiment support findings in that storage of berries fruits in CO_2 treatment leads to better sensory rating (Smittle and Miller, 1988).

Skin toughness was not significantly different over the storage periods under the fumigation with 30% CO_2 and the control (Table 4). Under 200ppm SO_2 treatment, fruits exhibited tough skin scores (4.22) and showed a consistent score above average with time in storage through 42 days. Comparing other treatments to control, skin toughness was not significantly different.

Another quality attribute evaluated by sensory panels was sweetness. Sweetness score increased over the storage duration for all treatments tested in the experiments (Table 4). However, sweetness was not significantly different between treatments.

Flavor score was not significantly different over the storage time when fruits were treated with 200ppm SO_2 and 30% CO_2 (Table 4). Under control treatment, flavor varied significantly with time in storage, but fruits did not receive a flavor score below average except in the last sampling date where the score was 5.04. When comparing the treatments, flavor was not significantly different and the flavor score ranged from 8.62 to 5.04.

The overall acceptance was not significantly affected by storage time when fruits were treated by 200 ppm SO_2 (Table 4). In fruits treated with 30% CO_2 and control, the overall acceptance score decreased significantly with storage time. The greatest decrease in overall acceptance score occurred at 42 days of storage with 6.42 and 4.25 for 30% CO_2 and control, respectively. Comparing treatments at 35 and 42 days of storage, overall acceptance scores were significantly lower among fruits stored as control compared to 200 ppm SO_2, but not significantly different from fruits treated with 30% CO_2.

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جودة عنب المائدة الطائفي المعامل بالتبخير بغازي ثاني أكسيد الكربون وثاني أكسيد الكبريت

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المستخلص. تهدف هذه الدراسة إلى معرفة تأثير التبخير بالغاز على ثمار عنب المائدة الطائفي بعد الحصاد، ودوره في حفظ جودة الثمار وإطالة فترة التخزين، حيث تم حصاد الثمار يدوياً، ثم خزنت على درجة حرارة ٢°م، وكانت معاملات التبخير ٣٠٪ غاز ثاني أكسيد الكربون (CO_2) و٢٠٠ جزء في المليون غاز ثاني أكسيد الكبريت (SO_2) خلال فترات تخزين من صفر يوم وحتى ٤٢ يوماً، بفترة فاصلة ٧ أيام بين كل فترتين للتخزين. والثمار التي لم يتم عليها أي من عمليات التبخير، استخدمت كمعاملة مقارنة. وأعطت الثمار التى تم تبخيرها باستخدام ٣٠٪ من غاز ثاني أكسيد الكربون و٢٠٠ جزء في المليون من غاز ثاني أكسيد الكبريت أقل نسبة من الثمار التالفة، وقد انخفضت صلابة الثمار مع طول فترة التخزين لجميع المعاملات، ولكن مع التبخير بـ٣٠٪ CO_2 أظهرت أعلى صلابة، ورقم الحموضة، وتركيزات المواد الصلبة الذائبة (SSC)، ونسبة تركيز المواد الصلبة الذائبة إلى معدل معيار الحموضة (SSC/TA)زادت مع طول فترة التخزين، وكانت الأقل عند ما عوملت الثمار باستخدام ٣٠ ٪ من (CO_2) و٢٠٠ جزء في المليون من (SO_2)، وزادت الحموضة مع طوال فترة التخزين لجميع المعاملات. وظهر اختلاف في الفاقد فى وزن الثمار مع طول فترة

التخزين. وكانت أعلى قيم للمظهر العام للثمـــار عنـــدما عوملـــت باستخدام ٣٠٪ (CO_2) و٢٠٠ جزء في المليون (SO_2). وقد أظهرت الثمار قيمة (٤،٢٢) لصلابة جلد الثمرة عند اليـــوم الـــسابع مـــن التخزين، وظلت فوق المعدل لجميـــع المعـــاملات طـــوال فتـــرة التخزين. وأوضحت نتائج قيم صفات القبول الكلية أن أعلى قيمة تم الحصول عليها عندما عوملت الثمار باستخدام ٣٠ ٪ (CO_2) و٢٠٠ جزء في المليون (SO_2). وعند تبخير العنب بواســـطة ٣٠٪ (CO_2) و٢٠٠ جزء في المليون (SO_2) كان هناك تاثير مفيد فـــي الحفـــاظ على جودة الثمار.