Post-Harvest Weight Loss of Flame Seedless Clusters

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This research was conducted to determine cluster weight loss and the rate of water loss under controlled conditions for eight days. Rachis represented *ca.* 4% of total cluster biomass, and its water content was almost the same as that of berries. Respiration rates at 4°C for clusters, berries, and rachis were 9, 7, and 211 mL CO_2/kg • h. This finding demonstrates a high respiratory activity in rachis, although no differences in metabolic heat were observed in rachis components with values around 3.6 ± 0.3 μJ/sec•mg dry weight. Therefore, rachis susceptibility to dehydration is both a physical and a metabolic phenomenon. Weight loss rate was five times faster at 25°C than at 5°C. As the dehydration symptoms became evident, cluster dehydration decreased from 4 to 0.2 mL/day/mg fresh weight. Cluster weight showed a constant decline in time, while its rate loss followed an almost normal distribution, peaking between the fifth and sixth day. Our results suggest the importance of appropriate management conditions immediately after harvest to avoid the onset of irreversible processes leading to senescence.

Table grape production is an important component of the Sonoran economy. Seedless grapes grown in the desert are of excellent quality. Keeping such quality represents an important task in an economic context, where efficiency and competitive levels are essential. Therefore, a top quality product in the market is merely a factor of survival. Such cultivars require a very careful postharvest management.

This research was conducted because of the scarce information on Flame Seedless post-harvest physiology, which in turn dictates its management requirements. Our objectives were to characterize several physiological events defining its post-harvest behavior, which includes respiration rates of clusters and cluster components, dehydration rates, and weight losses.

Materials and Methods

Sample description: All clusters were harvested at 16° Brix from mature Flame Seedless vines grown in a commercial vineyard near Pesqueira, Sonora, México. Samples were immediately transported to the laboratory in ice boxes. The experiments were conducted either in a cold chamber (4°C ± 1°C, 90% RH), or at room temperature (25°C ± 3°C, 30% RH).

Cluster biomass partitioning: Individual clusters were weighed on a precision balance, 5000 ± 1 g (Sartorius, Germany). Berries were excised, and berries and stem weights were separately recorded. Samples were dried to constant weight in an oven at 70°C for a week. Their respective dry weights were obtained, and the water contents were calculated as the differences between fresh and dry weights. Sample size was four clusters.

Metabolic heat of stem components: The heat of metabolism of pedicels, lateral branches, and rachis was obtained using a differential scanning calorimeter (Hart Scientific, Pleasant Grove, Utah). Samples from the three components mentioned above were weighed, randomized, and assigned to each of the three available ampules in the instrument. The calorimeter was operated in the isothermal mode at 25°C for 45 minutes with data acquisition at 10-second intervals. The last 10 observations were averaged, base-line corrected, and expressed on a dry weight basis. A total of ten replications was considered.

Respiration of cluster and cluster components: Respiration rates were assessed at 4°C. Five replications were followed in a flow board for 30 days, with samplings at irregular intervals. Clusters, stems, and berries were enclosed in sealed jars, and on every sampling, 1 mL of gas was extracted with a 1-mL insulin syringe. Measurements of CO_2 production were obtained with a Horiba PIR-2000 infrared gas analyzer (Horiba Instruments, Irving, CA.)

Quality loss: Quality losses were estimated based on cluster weight loss and dehydration rate as a function of storage temperature (4 or 25°C) for 192 hours. Weight loss was calculated gravimetrically as above, while dehydration rates were estimated as follows: Peduncle's proximal end was cut immersed in water, and clusters were weighed and connected with flexible tubing to a 10-mL pipet partially filled with water. Connections were sealed with parafilm, and water level was adjusted to zero. Total weight (apparatus, water and cluster) was recorded. On every sampling, water consumed was measured, then levels were zeroed, and weights were recorded. Number of replications was five, and the experiment was performed twice.

Storage potential under modified atmo-

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spheres: Individual clusters were suspended within one-gallon containers. Direct contact of berries and container was prevented to avoid condensation areas. The flask mouth was covered with the 0.6-mm plastic film Cryovac SSD-310 (Cryovac Division W. R. Grace & Co., Duncan, SC). This film has a relatively high gas permeability; at 5°C its transmission is 4291 and 22104 cc/day/m²/atm for 0_2 and CO_2, respectively. The mouth was sealed with tape so that the effective area for gas exchange was adjusted to either 25 or 75 mm². Changes in atmosphere composition were monitored periodically. Carbon dioxide concentration was measured as described earlier, while O_2 was determined with a Mocon LC-700F oxygen analyzer (Toray Engineering Co. Ltd., Japan). At the same time, changes in cluster weights were followed in the four replications.

Statistical analyses: All experiments were analyzed by ANOVA, and mean separation was done by FPLSD ($p \leq 0.05$). In the quality loss experiment, a factorial arrangement of treatments was considered for storage conditions and evaluation period, while effective gas exchange area and evaluation period were used in the modified atmosphere assay. Where relative values were used, analyses were done with arc-sin converted data (9).

Results and Discussion

Cluster biomass partitioning: A cluster is composed primarily of berries and the stem structure. At harvest, 96% of cluster fresh weight corresponded to berries and only 4% to stems. Table 1 shows such proportions, as well as water contents and dry weights for both components. In this assay, clusters with an average weight of 450 g were used. Water content on a fresh weight basis was 88% in berries and only 72% in stems. These water contents, expressed as a function of the whole cluster fresh weight, represent 85% for berries and only 3% for stems.

Berries seem to be the main target for water loss, as suggested by their succulence. However, they have a somewhat thick epidermis, covered with cuticular waxes acting as an important barrier against dehydration (1,6). Stems, on the other hand, lack such protective structures, and they are more prone to dehydration (1,4,5). This condition is aggravated in early cultivars. These are typically harvested when the soluble solid content reaches the minimum required for marketing, if color development is not a problem. Early season clusters have tender stems, which are not lignified and are still too succulent. Lignification is an important aging factor leading to more resistant and less hydrated stems, consequently preserving cluster integrity (5). In the early 1910s, the knowledge of this characteristic was one of the factors that made possible the export of Spanish grapes to America (8).

Table 1. Biomass partitioning of Flame Seedless clusters as a function of their fresh and dry weights and their water contents.

Component	Berry weight		Stem weight	
	g	%	g	%
Fresh weight	429.5 ± 42.8	96	17.7 ± 1.5	4
Dry weight	50.8 ± 4.9	11	4.7 ± 0.4	1
Water content	378.7 ± 37.9	85	13.0 ± 1.0	3

Means ± Standard deviation of four replications.

Table 2. Metabolic heat production (qmet) of stem components measured isothermically at 25°C and expressed on a dry weight basis.

Component	qmet (μJ/sec•mg)
Rachis	3.65
Lateral	3.76
Pedicel	3.66

Standard error, 0.34.

Metabolic heat of stem components. No significant differences in metabolic heat were found among stem components. Heat production was close to 3.6 μJ/sec•mg dry weight with a standard error of 0.34 (Table 2). This suggests that senescence gradients observed during stem deterioration are not caused by a differential in metabolic activity, but possibly by different dehydration rates, although this would require further testing.

Respiration of cluster and cluster components. This is the physiological event resembling more closely the metabolic activity in fruits. Respiration rate strongly determines post-harvest life by triggering senescence processes (3). Grapes are non-climacteric, slow respiring fruits. In fact, their respiration rates are just slightly higher than those of dry fruits (*e.g.*, dates and nuts), while other species respire at considerably faster rates

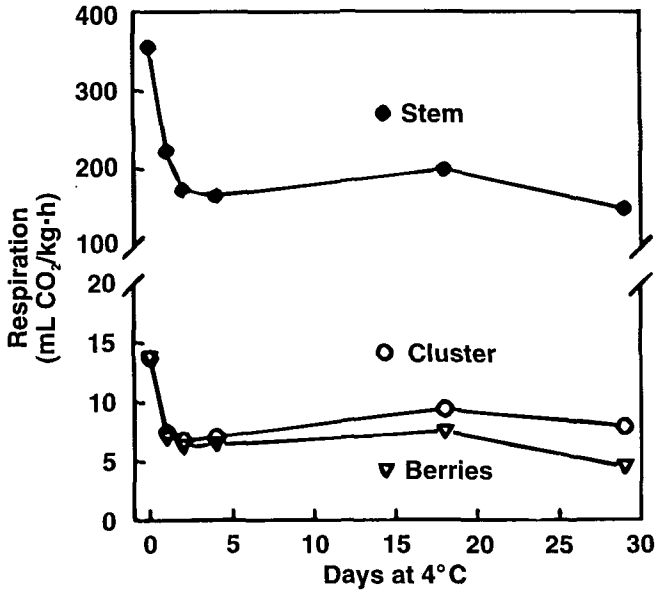

Fig. 1. Flame Seedless respiration at 4°C for a month. Characterizing rates of berries, stems, and whole clusters.

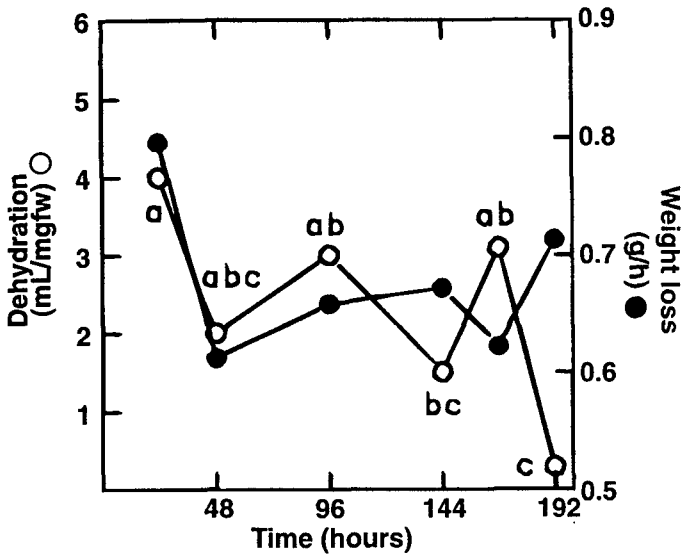

Fig. 2. Quality loss of clusters in a simulated shelf-life study of seven days. Changes in dehydration rates expressed as water consumed on fresh weight basis, open figures. Hourly weight loss, closed figures. Means followed by the same letter are not significantly different ($p \leq 0.05$) according to FPLSD.

such as in avocados, bananas, and strawberries (4). Our results confirmed such characteristics, also showing that different cluster components have different metabolic activities. Figure 1 shows the respiration rate of Flame Seedless clusters kept at 4°C for 30 days. A notable decrease in respiration rate was observed during the first 24 hours, because fruit entering the cold chamber was at the higher field temperature and respired faster. During the evaluation period, the average respiration rates of complete clusters, berries, and stems were 8.7, 7.5, and 211.1 mL CO_2/kg/h, respectively. This confirms that the cluster, as a whole, respires at a slow pace, following the same pattern shown by berries.

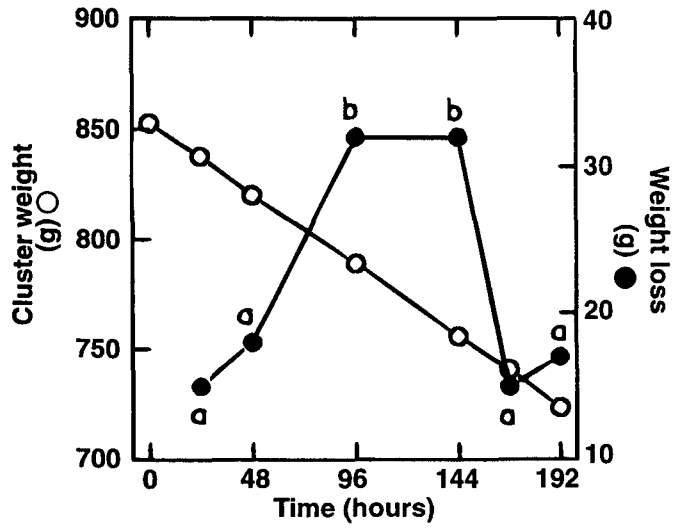

Fig. 3. Cluster weight and weight losses during shelf-life. The relationship between cluster weight and evaluation period was determined by the algorithm $Y_{es} = 851.8 - 0.662 + e$ with a determination coefficient of 0.9997. Means followed by the same letter are not significantly different ($p \leq 0.05$) according to FPLSD.

However, on a fresh weight basis, stems respired at the highest rate and accounted for the difference between whole clusters and berries. Considering that CO_2 production is concomitantly followed by water hydrolysis from carbohydrates (7), then we can assume that such water becomes available for the dehydration process which, coupled with the lowest hydration levels found in stems, would explain why stem deterioration is a major limitation of cluster's post-harvest life.

Quality loss: Cluster dehydration has been considered the most important physiological limitation to post-harvest life of grapes (5). Water losses on the order of 1.2% not only have a noticeable effect on appearance (2), but also cause berry drop (5).

Cluster weight loss during shelf life is mainly caused by dehydration and substrate oxidation to maintain the respiratory process. Berry drop, which obviously affects cluster weight, is partly an effect of these two causes. Also, extreme environmental conditions act as catalysts of such processes (5).

Figure 2 shows changes in dehydration rates of Flame Seedless clusters kept at 25°C and 30% RH in a seven-day shelf-life simulation assay. Despite high variability among clusters, significant differences were found during the study. This variability was caused by different sample physiological conditions. Although berries may have the same amounts of sugars, we believe that stems may be ontogenetically different. This in turn affects both succulence and degree of lignification, and as a consequence, susceptibility to dehydration. During the first 48 hours, dehydration rates were 2 mL/mg fresh weight, and dehydration symptoms were already visible, affecting sample's marketability. At 120 hours, dehydration rates were minimum; however, the stems were completely deteriorated.

Weight loss for the same set of samples is presented in Figure 3. Initial average cluster weight was 855 g, and the 10.8 g loss recorded after 24 hours represents a decrease in weight of 1.2%, which according to other reports is enough to affect cluster marketability (2,3). This loss increased in time as expected. Appropriate postharvest handling is essential because it determines deterioration rate.

Temperature is undoubtedly the single most important factor catalyzing weight losses. Table 3 shows the cumulative weight loss for clusters stored for 168 hours under two conditions: *(a)* 4°C ± 1°C and 90% RH and *(b)*

Table 3. Effect of storage for 192 hours under two conditions on cluster weight loss and loss rate.

Storage (°C, % RH)	Loss (g)	Loss rate (g/h)
4 ± 1, 90	7.37 a	0.23 a
25 ± 3, 30	29.4 b	0.93 b

Within columns, means followed by the same letter are not significantly different ($p \leq 0.05$) according to FPLSD.

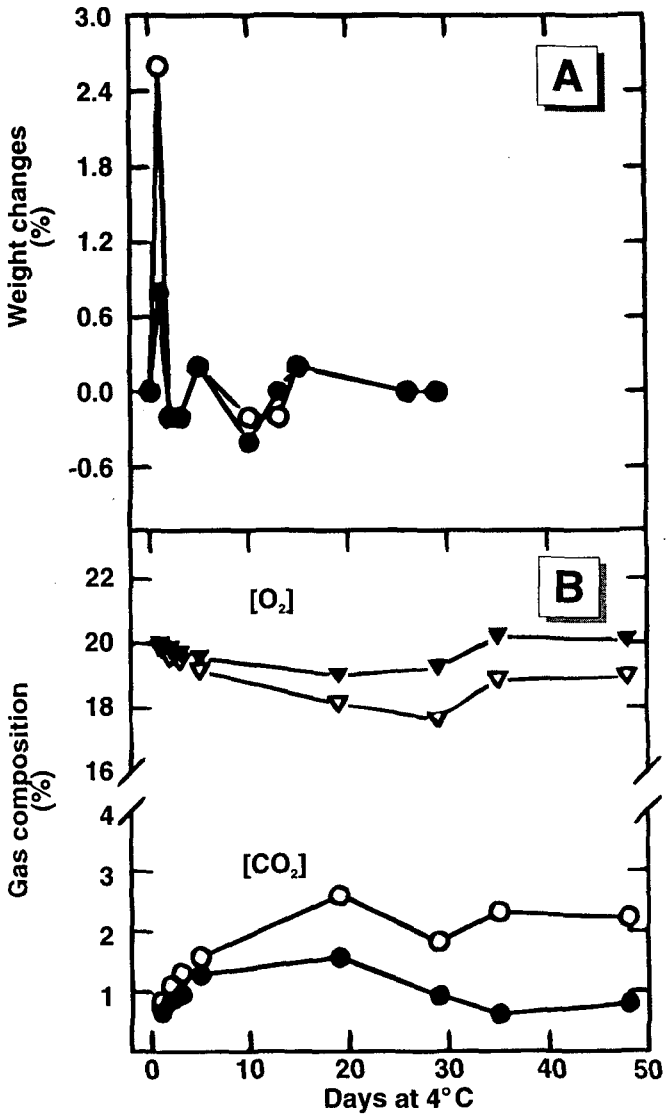

Fig. 4. Changes in grape clusters during a modified atmosphere storage. (A) Effect on weight changes, standard error 0.26 %. (B) Changes in atmosphere gas composition, standard errors of 0.23% for oxygen and 0.19 % for carbon bioxide, respectively. Effective gas exchange areas of 25- and 75-mm² are represented by open and closed figures, respectively.

25°C ± 5°C and 30% RH. A low temperature combined with a high relative humidity had a synergistic effect in preventing weight loss, which increased four-fold in the hot, dry storage. Temperature regulates not only respiration, but also dehydration, by directly affecting evapotranspiration rates and consequent water loss (3). Indirectly, temperature plays a role by influencing air relative humidity; at lower temperatures, RH rises, decreasing the gradient between RH in the fruit and its surrounding environment. Another factor is wind speed, since water extraction from tissues is directly proportional to it (2).

Storage potential under modified atmospheres. Cluster weight was affected by a significant interaction between gas exchange surface and time (Fig. 4a), although weights were generally very stable. The biggest change was detected after the first 24 hours, when the flasks increased their weights, because of internal condensation. After 30 days, no visual changes in quality were noticed, and cluster weight was practically the same.

As far as atmosphere composition, the analysis also shows a significant interaction between those factors mentioned above (Fig. 4b). As expected, a 25-mm² opening was more restrictive to gas exchange. This was expressed as a high accumulation of CO_2, and a depletion of O_2. The 75-mm² area had an opposite effect, which at any given moment was significantly different in the two treatments. Despite these results, we consider that slow respiration rates cause a very slow change in gas composition, which is particularly important in a commercial operation. As a consequence, fungi developed by the end of the experiment.

Conclusions

Post-harvest physiology of grape clusters calls for a special handling system. Although respiration rate is very slow, the susceptibility of clusters to dehydration requires quick and careful handling. Berries represent most of the cluster biomass; however, stems are the weakest link in the chain because of their high susceptibility to dehydration. Dehydration and weight loss rates are strongly determined by temperature and humidity. Therefore, efforts should be made to avoid cluster exposure to high temperatures, diminishing the amount of field heat to be eliminated by cooling. Modified atmosphere storage shows potential to maintain grape quality for significant periods, if sanitation treatments are included.

Literature Cited

1. Elboudwarej, A. F., A. Shirazi, A. Cameron, and R. C. Herner. Measurements of transpiration of different parts of grape clusters. Presented at the 41st Annual Meeting of the American Society for Enology and Viticulture. Los Angeles, CA (June, 1990).

2. Hardenburg, R. E., A. E. Watada, and C. Y. Wang. The commercial storage of fruits, vegetables, and florist and nursery stocks. US Department of Agriculture. Agriculture Handbook No. 66 (revised). 136 pp. (1986).

3. Kader, A. L. Postharvest biology and technology: An overview. *In:* Postharvest technology of horticultural crops. A. L. Kader, R. F. Kasmire, F. G. Mitchell, M. S. Reid, N. F. Sommer, and J. F. Thompson (Eds.). pp 3-7. ANR Publications, Oakland, CA (1985).

4. Mitchell, F. G. Postharvest handling systems: Table grapes. *In:* Postharvest technology of horticultural Crops. A. L. Kader, R. F. Kasmire, F. G. Mitchell, M. S. Reid, N. F. Sommer, and J. F. Thompson (Eds.). pp 149-151. ANR Publications, Oakland, CA (1985).

5. Nelson, K. E. Harvesting and handling California table grapes for market. Bulletin 1913. pp 3-9. ANR Publications, Oakland CA. (1985).

6. Rosenquist, J. K., and J. C. Morrison. Causes of variability in wax and cuticle development on grape berries. Am. J. Enol. Vitic. 40:241-244 (1989).

7. Stryer, L. Biochemistry (3rd ed.). 1089 pp. W. H. Freeman and Co., New York (1988).

8. Stubenrauch, A. V., and C. W. Mann. Factors governing the successful storage of California table grapes. USDA Bulletin No. 35 (1913).

9. Zar, J. Biostatistical analysis (2nd ed.). 718 pp. Prentice-Hall, Englewood Cliffs (1984).