



Packaging California Table Grapes

UNIVERSITY OF CALIFORNIA
DIVISION OF AGRICULTURE
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Packaging California Table Grapes

The authors are

Donald A. Luvisi, UC Cooperative Extension, Kern County

Harry H. Shorey, Department of Entomology, UC Davis

James F. Thompson, Biological and Agricultural Engineering Department, UC
Davis

Tom Hinsch, USDA, Marketing Specialist, retired

David C. Slaughter, Biological and Agricultural Engineering Department, UC
Davis

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CONTENTS

Introduction	2
Research	4
Packing the Boxes	5
Box Material and Construction	5
Cultivar and Pack Volume	6
Cultivar	6
Growing region	7
Package volume and soluble solids content	7
Depth of pack	7
Overpacking	8
Box dimensions	8
Inner packaging	8
Palletizing and Transporting Boxes to Cold Storage	9
Forced-air Cooling	9
Initial Fumigation	11
Cold Storage	12
Storage Room Fumigation	13
Transportation	13
References	15

Cover and back cover photos by Don Luvisi

Introduction

The present practice of field-packing table grapes directly into the boxes used to store, ship, and distribute them has evolved from an earlier method of packing. In early shipments table grapes, tree fruits, and other types of fresh produce were packed naked or in sawdust in containers that measured 35 by 42 inches, designed to fit into refrigerated railroad cars.

In the 1950s, shippers began to experiment with banding smaller, wooden table-grape boxes together on 35-by 42-inch pallets that fit the same floor configuration as the earlier containers. The standard wooden-box dimension that evolved was 14 by 17.5 inches, and it came to be known as the “LA lug.” These boxes were stacked, six per layer, on 35-by 42-inch pallets. This pallet size has persisted in the northern San Joaquin Valley and the Coachella Valley where it has been used to ship tree fruit and table grapes. However, in the southern San Joaquin Valley, a larger pallet of 53 by 42 inches was adopted to accommodate LA lugs stacked in layers of nine boxes each.

Initially, grape boxes were constructed entirely of wood with wood-slat lids nailed in place. The inside depth of LA lug boxes became standardized at 5.5 inches, based on the availability and economics of using 5.5-inch-wide lumber rather than on the optimal depth for best grape quality during handling and shipment. Later, the Technical Kraft Veneer (TKV) box was developed, made from thin strips of wood sandwiched between layers of Kraft paper. Although the table-grape industry still refers to all boxes with wood at each end as TKV boxes, this designation is specific to the type of manufactured box mentioned above. In this publication we will use the generic designation of “wood-end box” for any box with ends made of solid wood or particle board.

In the 1950s corrugated fiberboard boxes were developed for packing and shipping horticultural crops. Corrugated boxes gained favor for packing table grapes when long-term storage is not required. The corrugated box is relatively easy to recycle and is the least costly box to purchase. During the 1970s boxes made of

TABLE 1. Advantages and disadvantages of corrugated, wood-end, or foam boxes for packing table grapes.

Attribute	Type of box		
	Wood-end	Corrugated	Foam
Historical identification as a grape box	+++ ¹	+ ³	+
Pleasant appearance and presentation of the fruit	+++	+	+++
Most favorable cost	+	+++	++ ²
Ease of storing empty boxes and logistics of transporting to field	+	+++	+
Ease of packing	+	+	+
Protection against heat gain in the field	+	+	++
Protection of the fruit against shatter	+	+	+++
Protection of the fruit against bruising and splitting	+	+	+++
Stability of columns of boxes prior to palletizing	+++	+	++
Firmness of interlock for stability in the pallet	+	+	+++
Penetrability of palletized boxes to circulating air and fumigant	++	+	+++
Light weight during handling and shipping	+	++	+++
Conservation of storage and shipping space due to small bulk of box	+++	+++	+
Stability of the box in multiple pallet stacks	+++	+	++
Stability of the box during high humidity cold storage	+++	. ⁴	+++
Perceived (by receivers and public):			
Environmental acceptability	++	+++	-
Potential for recycling	+++	+++	+++
Actual amount of recycling (1995)	-	+++	-

¹+++ - most or best attribute
²++ = intermediate attribute
³+ = average attribute
⁴. = negative attribute

expanded polystyrene were specifically produced for packing, storing, and shipping table grapes. These boxes were commonly called “Styrofoam,” “EPS,” or “foam” boxes, and in this publication we will refer to them as foam boxes. In the last 20 years foam boxes have improved, and they are now used for 12 to 15 percent of the grape crop. The use of corrugated boxes has also increased, especially for early-season fruit and fruit that is not stored for long periods. Advantages and disadvantages of wood-end, corrugated, and foam boxes are listed in Table 1.

Through the early 1960s most fruit was loaded by hand into railroad cars. But in the mid-1960s shippers began using trucks for long-distance transport and started loading produce on pallets using forklifts. A loaded pallet could hold 70 to 90 boxes (depending on box type) held together by steel or plastic straps.

Pallet loading made for efficient handling of produce from the field to the market, but it introduced a new range of problems in terms of matching box size to pallet size. The range of box sizes had already expanded well beyond the standard LA lug dimensions as new box materials were developed. When shippers began to use pallets for loading, box sizes had to conform to various pallet sizes. In the early 1970s there were 18 sizes of containers; by 1993 there were more than 90 box-and-pallet combinations in use.

Little research has been conducted on table grape packaging since the mid 1970s, when pioneering work by R. Hinsch and R. E. Rij (1970); F. G. Mitchell, R. Guillou, and R. A. Parsons (1972); Nelson (1985); and F. G. Mitchell, D. A. Luvisi, and G. Mayer (1985) focused on factors that cause damage to the grapes after harvest. From these early studies the following conclusions were drawn.

- Most shatter (the breaking of individual berries from their stems on the bunch) occurs when table grapes are packed into the box.
- When various weights of Thompson Seedless grapes were packed into a standard 1,210-cubic-inch LA lug, packing 23 pounds of grapes resulted in more shatter than packing fewer pounds of grapes.

- 4
- In the late 1960s, the use of newly developed foam boxes reduced bruising and shatter of packed Thompson Seedless grapes that occurred in corrugated and wood-end boxes.
 - Shatter tends to increase as cold-storage time for Thompson Seedless grapes increases.

In 1993 the California Table Grape Industry initiated an extensive research project to evaluate containers for table grapes. The project initially evaluated most of the different box sizes, pallets, and materials available to the industry for the following reasons.

- Packers have had to stock a large inventory of materials to satisfy the wishes of different receivers because of the varied number of box and pallet sizes.
- Despite the wide range of box designs, types of inner packaging materials, and methods for cooling and fumigating packed table grapes, there has not been a systematic study of table grape packaging since the 1970s.
- Although the wood-end box is the primary packing container used, there are indications that corrugated and foam boxes may be used more often in the future.
- The industry standard (the wood-end box, 14 by 17.5 inches) can be severely overpacked when filled with 23 pounds of fruit.
- The produce industry has been moving toward using a standard grocery -industry pallet measuring 48 by 40 inches, but these dimensions will not accommodate the standard wood-end box of 14 by 17.5 inches.
- Increasing environmental concerns (and regulation in some markets) have emphasized the use of packing materials that can be easily recycled.
- The poor structural integrity of some table-grape boxes has led to breakage and fruit loss during long-term cold storage and transportation.
- Cost effectiveness and competitiveness of packaging types and materials must be balanced with the economic needs of the industry.

Research

The research objective was to determine how table grapes can be moved from the field to the consumer in the best possible condition. The research was conducted during the 1993 and 1994 seasons. The 1993 effort was directed toward evaluation of individual boxes. Over 4,000 boxes were packed with table grapes in more than 1,000 experimental combinations of the following variables.

Cultivar—Thompson Seedless, Perlette, Flame Seedless, Ruby Seedless, and Redglobe (the only seeded cultivar)

Growing regions—the Coachella Valley and the San Joaquin Valley

Box construction materials—wood-end, corrugated, and foam

Box dimensions (outside width and length)—

- a) 14 by 17.5 inches (the LA lug), which fits on pallets that are 35 by 42 or 53 by 42 inches
- b) 13.3 by 16 inches (sometimes called the “MUM box”), which fits a 48 by 40-inch pallet
- c) 12 by 20 inches (sometimes called the “shoe box”), which fits on a 48 by 40-inch pallet
- d) 16 by 20 inches (sometimes called the “metric box”), which fits on a 48 by 40-inch pallet

Box depths—Depths in 1/2-inch increments for weights between 18 and 25 pounds of packed fruit

Inner packaging—plain-packed and poly-bagged

Level or pack volume—quantity of fruit packed in the box was calculated to bring the height of fruit in each box to level-full, versus 10% overpacked (above level-full) and 10% underpacked (below level-full).

The 1994 effort was directed toward evaluating how the most promising boxes, identified during the 1993 research, would protect the quality of grapes as they were moved through normal marketing channels in palletized units. Fruit was packed, palletized, and evaluated as it went through the normal cycle of initial fumigation, precooling, storage, storage-room fumigation, shipping by truck, and receiving at a distant terminal market.

Packing the Boxes

The method used for packing table grapes is generally the same among most growers. Grape clusters are placed either directly into the box (plain pack) or into bags (bagged) by hand. In each packing system clusters are transferred twice—first from the vine into a field box by the picker, then from the field box into a shipping box by the packer.

The picker selects clusters for quality and maturity, removing undersized, decayed, immature, and other damaged berries before placing clusters in the field box. Field boxes are sometimes moved to a central location for packing (shed pack), but the majority of California table grapes are packed in the field. The packer works either on the ground or beside a wheeled stand that accommodates the field box of clean fruit carried to the packer by the picker. The stand can be equipped with a scale and additional boxes for packing. As each box is packed, clusters are selected or trimmed to fill the box to its correct volume and final weight.

In these studies, high quality was defined as lack of damage to the fruit caused by shatter, splitting, and bruising. Most shatter occurs during packing of the grapes, probably due to the sideways pressure from the packers' hands, the sides of the box, and cluster-to-cluster contact. Most splitting and bruising results from compression when too many grapes are placed in a box so that the fruit mounds above an imaginary line between the tops of the opposing box ends. When a box lid is forced into place over mounded fruit, splitting and bruising result, mainly on berries that are touching the lid or the bottom of the box.

A box is "plain packed" when fruit is placed cluster to cluster in the box until the appropriate net weight is obtained. Net weight of the standard plain-packed, wood-end box in 1970 was 26 pounds; through 1995 that weight is 23 pounds in the San Joaquin Valley and 22 pounds in the Coachella Valley. However, it has been recognized for some time that even these reduced weights often result in overfilled boxes with lids that must be forced into place, causing considerable bruising and splitting of the berries.

Box Material and Construction

Choice of box material is often influenced by factors other than maintaining the quality of the packed fruit (Table 1). The preferences of the receiver and environmental (recycling) considerations are more important in some markets than in others, and these factors may dictate the type of box to be used. In addition, cost considerations can be very important; corrugated boxes are usually lower in price than wood-end or foam boxes. The humidity of the storage room and the length of storage time will also affect the selection of box material. Wood-end and foam boxes maintain their structural integrity in high-humidity storage better than corrugated boxes. Waxing corrugated boxes can improve their strength, but it reduces their recycling potential, and is rarely used. Foam boxes are preferred by some exporters, since more product can be shipped due to their light weight.

Box materials can have a noticeable effect on fruit quality immediately after harvest, both early in the harvest season when the sugar content of the fruit is lower, and later when the fruit is at full maturity. Thompson Seedless grapes that were packed into foam boxes in Delano, Calif., during the summer of 1993 had about 30 percent less shatter than those packed into corrugated or wood-end boxes (Table 2). No consistent differences in the amount of shatter were detected among grapes packed in corrugated or wood-end boxes. However, after six weeks of cold storage, shatter in the foam boxes increased to a level that was equal to shatter in all types of boxes.

Non-stored Thompson Seedless grapes packed in foam boxes displayed less splitting and bruising than those packed in corrugated or wood-end boxes (Table 2). Foam box lids are less flexible than wood or corrugated lids, and this discourages overpacking of foam boxes. A bulging lid is often considered acceptable on a wood-end or corrugated box but not on a foam box. Another practice that leads to increased shatter and bruising is overfilling a box to provide a bonus product for the buyer.

The typical wood-end table-grape box has all four corners of each end panel "clipped." The clipped-corner

TABLE 2. Percentage of shattered, bruised and split berries of Thompson Seedless grapes harvested at two maturity levels in Delano, Calif., 1993

Box Dimensions (inches)	Box construction					
	Corrugated Inner pack		Wood-end Inner pack		Foam Inner pack	
	Plain	Bags	Plain	Bags	Plain	Bags
EARLY HARVEST (NOT STORED)						
Shatter (%)						
13.3 x 16	7.5	6.7	8.0	6.7	—	—
14 x 17.5	7.4	7.2	7.5	6.6	5.6	3.8
16 x 20	7.9	8.8	8.7	8.8	5.1	4.8
12 x 20	8.8	5.4	5.9	6.2	—	—
Split and Bruised (%)						
13.3 x 16	0.4	0.5	0.8	1.0	—	—
14 x 17.5	1.4	0.9	1.0	1.4	0.3	0.2
16 x 20	0.8	1.4	1.2	1.7	0.9	1.1
12 x 20	1.0	0.8	0.7	0.6	—	—
MATURE HARVEST (NOT STORED)						
Shatter (%)						
13.3 x 16	8.7	7.5	9.3	8.0	—	—
14 x 17.5	7.8	5.9	7.6	7.1	6.5	3.7
16 x 20	8.5	8.2	8.1	9.4	5.5	6.3
12 x 20	7.8	6.2	7.9	8.7	—	—
Split and Bruised (%)						
13.3 x 16	0.5	0.8	1.0	0.2	—	—
14 x 17.5	2.2	1.1	0.8	0.2	0.2	1.2
16 x 20	0.4	0.6	0.6	0.6	0.9	0.6
12 x 20	1.2	0.8	0.4	0.2	—	—
MATURE HARVEST (STORED)*						
Shatter (%)						
13.3 x 16	11.9	10.6	10.8	9.7	—	—
14 x 17.5	10.7	9.4	9.7	8.3	11.5	10.8
16 x 20	10.0	12.0	9.4	10.0	9.9	11.0
12 x 20	10.1	8.4	7.9	9.3	—	—
Split and Bruised (%)						
13.3 x 16	3.1	3.8	1.8	1.4	—	—
14 x 17.5	3.9	3.3	2.8	1.6	5.9	1.8
16 x 20	3.0	2.8	3.4	2.6	2.8	2.1
12 x 20	2.4	1.3	3.6	1.3	—	—

*Mature harvest "stored fruit" was harvested on the same date and from the same field as mature harvest fruit but was held in cold storage for 6 weeks before evaluation.

design was developed to facilitate the circulation of air during cooling and storage. The clipped corners provide channels for air to flow through the pallet, improving cooling and fumigation. However, clipped corners are not necessary for efficient forced-air methods of initial fumigation or precooling when air is actively drawn through the boxes. Avoid the orientation of pallets during cooling and fumigation so that the air channels through the pallets are at right angles to the direction of air flow.

Manufacturers have designed corrugated boxes with clipped corners, but clipped corners are probably not needed on corrugated boxes that are subjected to forced-air fumigation and precooling, provided they are not stored for more than a few weeks. Corrugated, clipped-corner boxes do lack end-panel structural stability, so that those on the bottom of a pallet load tend to tip to one side, or move out-of-square because the stacking tabs that engage with slots into the box above (for stability) become misaligned. When this happens whole columns of boxes may collapse.

If grapes are stored in corrugated boxes for more than a few weeks, they require storage-room fumigation with sulfur dioxide under non-forced air conditions; in this case, clipped-corner boxes would probably enhance the penetration of gas into the boxes. However, the structural weakness imparted to corrugated boxes by clipped corners often outweighs the advantages gained through greater cooling and fumigation efficiency. Consequently, a value judgment must be made by the facility management concerning the use of corrugated boxes constructed with or without clipped corners.

Cultivar and Pack Volume

The pack volume refers to cubic inches per pound of (cu in/lb) of fruit and depends on the following factors.

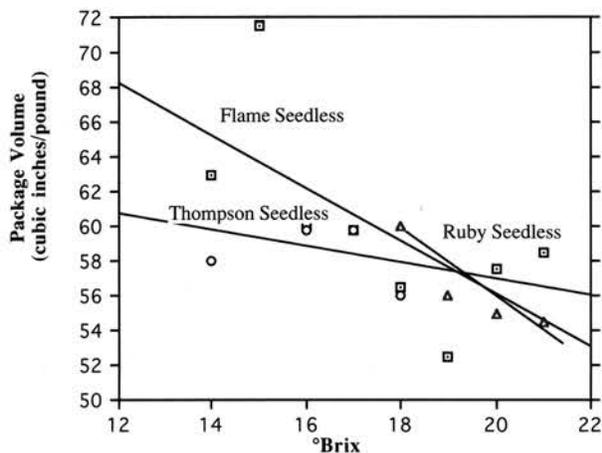
Cultivar

Tested seedless cultivars, picked during 1993 at normal harvest maturity, had densities ranging from 56 to 63 cubic inches per pound of fruit (Table 3). The one seeded variety, Redglobe, had a higher pack volume (53 cu in/lb). The pack volume varied with the maturity of the fruit.

Table 3. Effect of table grape cultivar and production area on fruit package volume 1993

	Density Lb/cu in	Package volume Cu in/lb	Pounds to level-fill a 1,210-cu in box
<u>Coachella Valley</u>			
Perlette	0.0161	62.1	19.5
Flame Seedless	0.0158	63.3	19.1
Thompson Seedless	0.0159	62.9	19.2
<u>San Joaquin Valley</u>			
Flame Seedless	0.0164	61.0	19.8
Thompson Seedless (early harvest)	0.0166	60.2	20.1
Thompson Seedless (mature)	0.0180	55.6	21.8
Ruby Seedless	0.0162	61.7	19.6
Redglobe	0.0187	53.5	22.6

Figure 1. Relationship between soluble solids content and package volume for three cultivars of plain-pack table grapes.



Growing region

Grapes grown in the Coachella Valley mature during a short period of time and tend to be harvested at minimum maturity. The soluble solids content ($^{\circ}$ Brix) of these grapes tends to be lower than it is for the same cultivars harvested later in the season in the San Joaquin Valley.

Package volume and soluble solids content

The package volume decreases as the soluble solids content ($^{\circ}$ Brix) increases (Fig. 1 and Table 3). In 1994, this relationship was experimentally determined for three cultivars—Flame Seedless, Ruby Seedless, and Thompson Seedless—in the Coachella and San Joaquin valleys. Each cultivar was packed at several ranches on different dates into boxes with inner volumes of 1,210 cubic inches. Packers were instructed to pack each box to level-full (level with the box ends and sides). The net weight of each box and $^{\circ}$ Brix was determined. For each of the three cultivars, the relation between $^{\circ}$ Brix and pack volume of the fruit is shown in Figure 1. Although there is some variation between samples, consistent relationships are evident. Grapes packed at 15 $^{\circ}$ Brix had a pack volume of about 61 cubic inches per pound; those packed at 17.5 $^{\circ}$ Brix about 58 cubic inches per pound; and those at 20 $^{\circ}$ Brix had a pack volume of 55 cubic inches per pound. The following pounds of fruit at various Brix levels can be level packed into a 1,210 cubic inch box: 15 $^{\circ}$ Brix = 19.8 pounds, 17.5 $^{\circ}$ Brix = 20.9 pounds, and 20 $^{\circ}$ Brix = 22.0 pounds. Since the normal range of soluble solids content found in table grapes during the harvest season is 15 to 20 $^{\circ}$ Brix, 19.8 to 22 pounds of fruit can be level-packed into a 1,210 cubic inch box. This weight variation presents a challenge to the packer, who packs the same net weight of fruit into a box regardless of maturity ($^{\circ}$ Brix) while trying to maintain a level pack.

Depth of pack

As the depth of fruit packed into a box increases, the pack volume also increases because the vertical weight of the fruit causes compaction at the bottom of the box. The relationship between depth and pack volume was determined for Perlette and Flame Seedless grapes in the Coachella Valley in 1993. Experimental 8-inch-deep boxes of 13.3 by 16, 14 by 17.5 and 12 by 20 inches

Figure 2. Relationship between pack depth and pack volume of Perlette grapes in a 13.3-by 16-inch box.

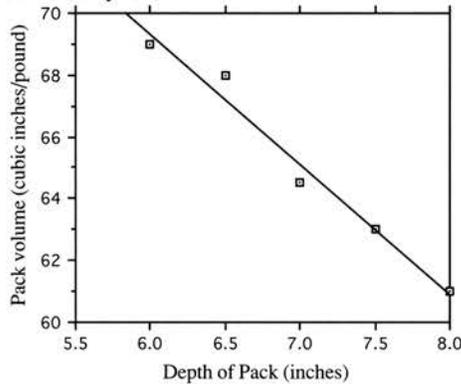


Figure 3. Depth of pack and damage in Thompson Seedless, Perlette and Redglobe table grapes.

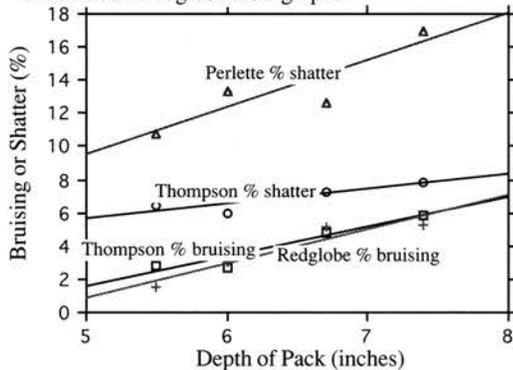


Table 4. Relationship between depth and weight of Perlette Grapes packed in corrugated boxes of three different lengths and widths, Coachella Valley, CA, 1993

Box external Dimensions (inches)	Net weight (pounds)	Pack depth (inches)	Pack volume (cu. in./lb)
13.3 x 16 (213 in ²)	16	5.8	69
	18	6.4	68
	20	6.7	64
	22	7.2	63
	24	7.6	60
14 x 17.5 (245 in ²)	16	5.1	71
	18	5.7	70
	20	6.0	67
	22	6.4	65
	24	6.9	64
12 x 20 (245 in ²)	16	5.1	70
	18	5.5	67
	20	5.7	63
	22	6.2	61
	24	6.9	62

were packed without lids with 16, 18, 20, 22, or 24 pounds of fruit. The depth of the fruit in each box was then determined (Table 4). The greater the depth of pack, the more dense was the fruit in that pack, and this could be described by a linear relationship for Perlette grapes (Fig. 2). This relationship was also present in other cultivars (data not presented). Increased pack depths are directly related to increased fruit damage, as demonstrated in several experiments. Shatter in Thompson Seedless and Perlette grapes, and bruising in Thompson Seedless and Redglobe grapes, increased as the depth of pack increased from 5.5 to 7.5 inches (Fig. 3). Packing to a depth of 6.4 inches did not usually cause excessive damage, but damage increased at depths greater than 6.4 inches. Depths less than 5.5 inches also were associated with increased fruit damage. Increased damage was noted when the largest box (16 by 20 in) and the shallowest depth (4.5 in) was filled to level-full. Increased shatter and bruising was observed, compared to similar boxes of 5.5-inch depth. Increased damage in shallow boxes may be caused by the geometry of individual bunches. Clusters with lengths or diameters larger than the depth of the box would suffer damage when forced into the box during packing.

Overpacking

Overpacking is defined as mounding and box more than 1/4 inch above level-full and usually increases fruit damage, especially bruising. Bruising was observed at box weights over 20 to 21 pounds in Thompson Seedless grapes in the Coachella Valley and if Flame Seedless, Thompson Seedless, Ruby Seedless and Redglobe grapes grown in the San Joaquin Valley (Fig 4 and 5)

Box dimension

Tests showed that box dimension did not affect fruit damage, with the exception of small-dimension boxes deeper than 6.4 inches and large dimension boxes that were less than 4.5 inches deep

Inner packaging

The use of poly bags greatly reduces fruit damage. In evaluating 4,000 boxes packed during the 1993 and 1994 seasons, fruit bruising was reduced by 50 to 90 percent when fruit was bagged, as compared to plain-

Figure 4. Effect of weight of pack on bruising and splitting on the top and bottom surfaces of Thompson Seedless grapes in 5.5-inch-deep corrugated or wood-end LA lugs upon arrival in Dallas, Texas 1 week after packing in Coachella Valley, Calif.

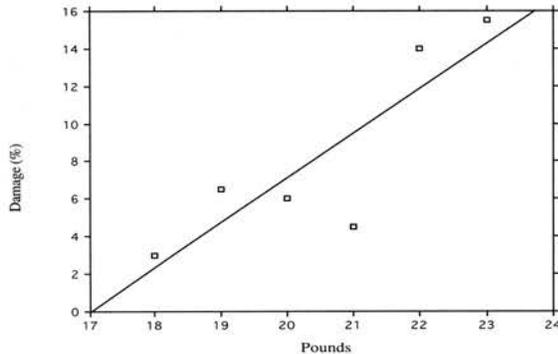


Figure 5. Relation between net weight of four cultivars of table grapes packed in 1,210-cubic-inch-boxes and the amount of fruit bruising at the upper and lower box surfaces.

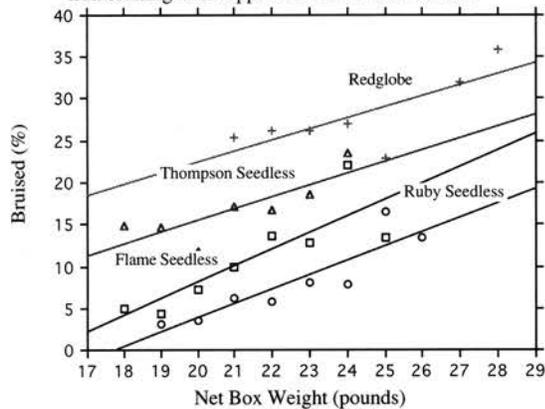


Table 5. Average bruising of table grapes bagged or plain packed in corrugated, wood-end, or foam boxes in the San Joaquin Valley, 1994.

Packing method	Percentage of Bruising by Cultivar		
	Flame Seedless	Thompson Seedless	Ruby Seedless
Grapes not stored, plain pack			
Corrugated	8.5	11.4	6.9
Wood-end	7.5	5.7	7.3
Foam	6.3	6.6	3.0
Grapes not stored, bagged			
Corrugated	1.6	4.0	3.7
Wood-end	0.7	1.2	1.3
Foam	2.0	0.7	1.4
Grapes stored, plain pack			
Corrugated	17.3	10.8	9.3
Wood-end	15.2	19.1	6.4
Foam	8.8	11.4	3.4
Grapes stored, bagged			
Corrugated	1.1	4.2	2.4
Wood-end	2.8	4.9	1.5
Foam	1.7	3.6	1.7

-packed fruit (Tables 2 and 5). When packers were instructed to place the maximum amount of fruit into a box and pack the box level-full, the plain-packed were 1.0 to 2.4 pounds heavier than poly-bagged boxes (Table 6).

Palletizing and Transporting Boxes to Cold Storage

After table grapes have been field packed, the boxes are stacked in columns (about ten boxes each) on the ground adjacent to the packing area to await loading onto trucks for transport to cold storage. The narrow 12-by 20-inch box is unstable in this type of stack, and extra attention is often needed to ensure that these boxes do not fall over in the field or on the truck during transport. Clipped corners on corrugated boxes also greatly reduces stacking stability. Handling stability improves when boxes are strapped immediately after loading. However, this is an extra operation and is not required when using the larger, more stable LA lug box (14 by 17.5 in), which is strapped at the cold storage plant.

Fruit damage can occur when boxes are moved from the stacks on the ground to pallets on the bed of the truck. A worker standing on the ground throws a box of grapes to another worker standing on the truck bed who places it on the pallet. Boxes are sometimes slammed into position on the pallet, and this may increase the amount of shatter, bruising, or splitting of the grapes inside the box.

Forced-air Cooling

The calculated cooling times for 15 combinations of box material, dimension, and inner packaging are listed in Table 7. The standard 14- by 17.5-inch wood box cools quickly because it has a large vent area, but cooling may be slower if vents are restricted by misaligned box liners or other packing materials. Cooling is also slower for grapes packed in poly bags, particularly at low air-flow rates (Fig. 6). It is important to design boxes with adequate venting to ensure fast cooling. Box dimension does not appear to influence forced-air cooling times.

Figure 6 is a plot of cooling time versus the air-flow rate data presented in Table 7. It shows that bagged

Table 6. Weights of three-table grape cultivars packed in bags or plain-packed in corrugated, wood-end or foam boxes in the San Joaquin Valley, 1994

Packing method	Pounds of packed grapes		
	Flame Seedless	Thompson Seedless	Ruby Seedless
Grapes plain packed			
Corrugated	20.9	20.6	21.6
Wood-end	21.3	20.5	22.3
Foam	21.5	20.8	20.3
Grapes bagged			
Corrugated	19.5	18.6	21.7
Wood-end	20.2	18.7	21.2
Foam	19.7	17.2	18.4
Means: Plain packed	21.2	20.6	21.4
Bagged	20.1	18.2	20.4
% Less in bags	5.2%	11.7%	4.7%

Table 7. Forced-air cooling times and air flow through pallet-loads of table grapes packed in various boxes

Construction material	Box dimension (inches)	Inner Packaging	7/8 th * Cooling (hr.)	Air flow (cfm/lb @ 1" w.c. pressure)
foam	14 x 17.5	plain	1.80	0.92
foam	16 x 20	plain	1.90	1.13
wood	14 x 17.5	bag	1.90	1.24
foam	14 x 17.5	bag	2.05	1.09
corrugated	14 x 17.5	plain	2.25	0.68
foam	12 x 20	plain	2.30	0.92
wood	12 x 20	bag	2.50	0.96
wood	12 x 20	plain	2.50	0.92
corrugated	12 x 20	bag	2.50	-
wood	13.3 x 16	plain	2.55	0.83
corrugated	12 x 20	plain	2.80	0.44
corrugated	13.3 x 16	plain	3.00	0.64
corrugated	13.3 x 16	bag	3.00	0.65
foam	12 x 20	bag	3.40	0.77
corrugated	14 x 17.5	bag	3.60	0.78

* Time to cool from 70°F to 35°F using 30°F air temperature. The data in the table are mathematically adjusted to account for differing initial fruit temperatures encountered in the tests. All test were conducted with a 1" w.c. static pressure across the simulated test pallet.

grapes take longer to cool at low air-flow rates than plain-packed fruit. At air-flow rates of 1.0 cubic foot per minute per pound of gross box weight (cfm/lb), cooling is accomplished in about 2 hours for both bagged and plain-packed grapes. But when that air flow is cut in half, cooling time increases by one hour for plain-packed grapes and by about two hours for bagged grapes. The data also indicates that, while bagging does not restrict air flow through the box, it probably causes air to channel around the fruit.

Forced-air coolers are most effective when operated at air-flow rates of at least 1.0 cfm/lb. These high rates are important for coolers that routinely cool bagged and plain packed fruit at the same time. Pressure difference across pallets to produce 1.0 cfm/lb depends on the box type. Palletized wood boxes with box and liner vents aligned have pressure differences of 1.0 cfm/lb at about 0.5 inches of water column (w.c.) static pressure. Foam boxes need about 1.0 inches w.c. and poorly vented corrugated boxes need almost 2.0 inches w.c. to achieve the same air-flow rate of 1.0 cfm/lb of fruit. Commercial coolers should have fans sized to produce 1 cfm/lb at 2.0 inches w.c. Fan output can be reduced using variable frequency motor speed controls if an entire load of wood or foam boxes are within the cooler. A pressure gauge should be installed at each cooling position. If at all possible, grapes packed in corrugated boxes should be cooled separately from those in wood and foam boxes.

The 13.3 by 16 inch and the 16 by 20 inch foam box can be designed to allow air to flow perpendicular to the pallet stringers, parallel to the 40-inch dimension on a 48- by 40-inch pallet (Fig. 7). This allows easy loading on a tunnel-type, forced air-cooler. The 12- by 20-inch box requires that the pallet be turned 90 degrees and the pallet lifted through the stringer notches. This orientation also causes a 6 inch loss of free space between the columns of pallets on a cooler. In some coolers this may restrict air flow in the air supply and return channels causing pallets near the fan to get less air and cool more slowly than those farthest from the fan. The 12- by 20-inch box on pallets also require that the fork lift entry be sealed to prevent cooling air from bypassing the grapes.

FIGURE 6. Effect of air flow rate and fruit bagging on forced-air cooling times, based on a laboratory simulation of pallet loads of grapes in various types of boxes.

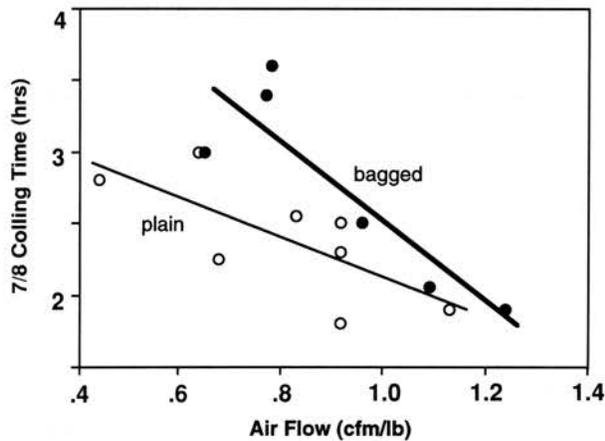
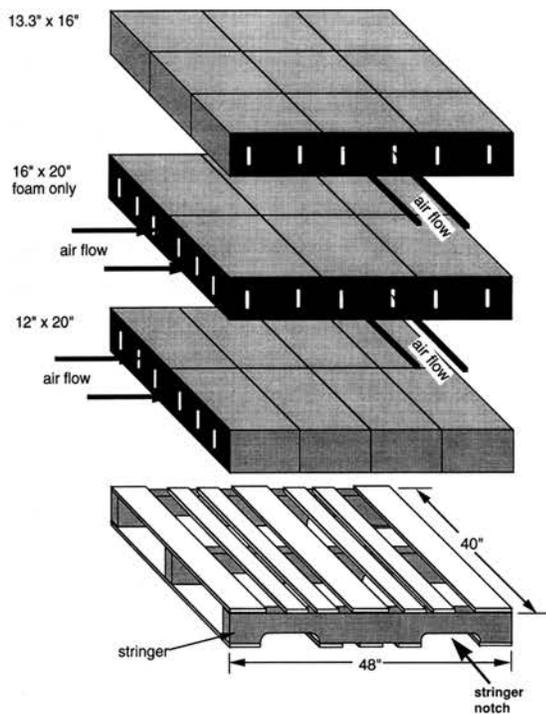


FIGURE 7. Box placement on a 48 by 40 inch pallet.



Initial Fumigation

Except for a few situations in which boxes of table grapes are packed, cooled, and shipped immediately to nearby markets, fumigation with sulfur dioxide is used to control spores and early infections of *Botrytis cinerea* Pers that can cause severe decay. Most important is the initial fumigation, which destroys the spores of *Botrytis cinerea*. (For further information see University of California Division of Agriculture and Natural Resources Bulletin 1932 *Sulfur Dioxide Fumigation of Table Grapes*.) Until recent years initial fumigation was primarily accomplished in separate "gas houses" with high doses (5,000 to 10,000 ppm) of sulfur dioxide circulated among the palletized boxes. In this style of initial fumigation, excess gas in the circulating air is exhausted from the room atmosphere after 30 minutes.

Recently, a new procedure was developed to combine initial fumigation with forced-air cooling (Luvisi et al. 1992) It uses lower doses of gas (600 to 1,250 ppm) in the atmosphere of forced-air coolers. The amount of gas is adjusted so that it is totally absorbed by the boxes and fruit by the end of the cooling cycle.

Under forced-air conditions there are no significant differences in penetration of sulfur dioxide among any of the box types (corrugated, wood-end, or foam) or between inner packaging methods (plain-pack or poly bags). All boxes and packaging styles received essentially the same amount of sulfur dioxide, and this was adequate for protection of the fruit against *Botrytis cinerea*.

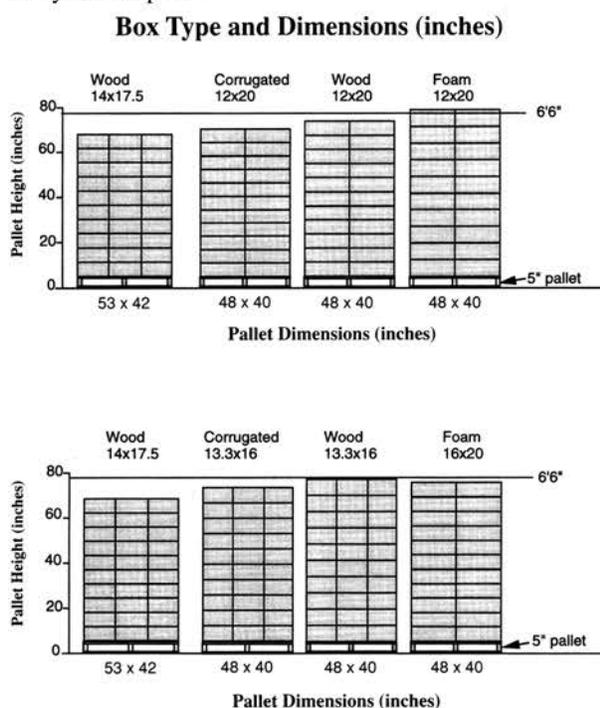
Box type and packaging methods did affect gas penetration when boxes of Ruby Seedless grapes were fumigated in a circulating-air initial fumigation room. Sulfur dioxide penetrated foam boxes the best, providing adequate protection against *Botrytis cinerea*. However, corrugated and wood-end boxes lacked consistent penetration. The problem was more severe in the center boxes of the pallet. Polybags also impeded the penetration of gas into wood-end and corrugated boxes in this circulating-air gas house. These findings suggest that the biggest difference in sulfur dioxide penetration into the boxes is due to the type of fumigation room.

Table 8. Box capacity and pallet height during storage for pallet dimensions of 53 by 42 inch, 35 by 42 inch, and 48 by 40 inch*.

Box Dimensions	Pallet size	Boxes/layer	Foam		Corrugated		Wood	
			box no.	Height	box no.	Height	box no.	Height
14" x 17.5"	53" x 42"	9	90	6'8"	90	5'4"	90	5'8"
14" x 17.5"	35" x 42"	6	60	6'8"	60	5'4"	60	5'8"
12" x 20"	48" x 40"	8	80	6'7"	88	5'10"	88	6'2"
13.3" x 16"	48" x 40"	9	-	-	90	6'2"	90	6'6"
16" x 20"	48" x 40"	6	72	7'2"	-	-	-	-

*includes height of a 5" pallet

FIGURE 8. Pallet load height for various box sizes that fit a 48 by 40 inch pallet.



Cold Storage

After grapes are received, precooled, and initially fumigated, a period of storage may be required, ranging from a few days to as long as 16 weeks. Table grapes are usually stored at a temperature just below 32°F (0°C) and at relative humidities of 90 percent or above.

Pallets of wood-end boxes may be stacked two- to three-pallets high, depending on the height of the storage room ceiling. Foam boxes are usually stacked two-pallets high, partly because each box requires more vertical space than a wood-end box, so loaded pallets are taller. Also, foam boxes stacked three-pallets high have a tendency to lean more than pallets of wood boxes stacked three-pallets high. Pallets of corrugated boxes usually are not stacked because their clipped corners reduce stability and because corrugated boxes stored under high humidity tend to gain moisture and weaken. Occasionally, pallets of corrugated boxes will be stacked two high, and, when pallet racks are used, they can be stacked two- or three-pallets high.

Table-grape storage-life depends on storage temperature, the number of sulfur dioxide fumigations, and the concentration of sulfur dioxide used. The objective of packaging, fumigation, and storage management is to minimize losses in fruit quality. Some indicators of reduced quality, such as shatter, splitting, and bruising, become more pronounced as storage time increases. For example, bruising was distinctly less in foam and wood-end boxes than in corrugated boxes when grapes were evaluated immediately after packing; however, after a 4- to 8-week storage period these differences disappeared due to the fairly high level of damage in all lots (Table 5). This phenomenon was also seen in 1993, when the amount of shatter, splitting, and bruising in Thompson Seedless grapes increased as the storage season progressed (Table 2). Cultivar differences also occur; loss of quality induced by length of storage is less pronounced in Ruby Seedless than in Thompson Seedless grapes (Table 5).

The 48- by 40-inch pallet (1,920 sq in) has about 14 percent less surface area than the 53- by 42-inch pallet (2,226 sq in), so pallet loads on the former are usually taller to compensate for reduced surface area. Figure 8

Table 9. Pallet weights in pounds including a 50-lb pallet

Box Dimensions	Pallet size	Foam	Corrugated	Wood
14" x 17.5"	53" x 42"	2210	2300	2390
14" x 17.5"	35" x 42"	1490	1550	1643
12" x 20"	48" x 40"	1865	1945	2025
13.3" x 16"	48" x 40"	—	2120	2210
16" x 20"	48" x 40"	1502	—	—

Table based on 21 lb. net grape weight for 48" x 40" pallets and 23 lb net weight for 53" x 42" and 35" x 42" pallets. An empty foam box weighs 1 lb, a corrugated box weighs 2 lb and a wood box weighs 3 lb.

compares the height of loads stacked on these pallets using various boxes. Foam boxes are so tall that it is not possible to stack them ten high on a 48- by 40-inch pallet (to get 90 boxes per pallet) and have a pallet height less than about 6.5 feet. Most storage rooms are not tall enough to stack pallets three high if they are this tall. Table 8 lists the box configurations and pallet heights for the 48- by 40-inch and 53- by 42-inch pallets.

Box depth limits for the boxes that fit the 48- by 40-inch pallet have also reduced the total weight of the 48-inch by 40-inch pallet loads (Table 9). Pallets with foam boxes are lighter because foam is the lightest box material available and the height limit may reduce the maximum number of boxes on a pallet.

Storage Room Fumigation

All tested grape cultivars were subjected to total-utilization storage-room fumigation under circulating-air conditions, using 400- to 1250-ppm sulfur dioxide. Foam boxes were more easily penetrated by the gas than were wood-end boxes, and wood-end boxes were more easily penetrated than corrugated ones. Even at low levels of gas concentration, enough gas penetrated the foam boxes to provide adequate control for *Botrytis cinerea*. Wood-end and corrugated boxes were sometimes not adequately penetrated and had considerably more variability in penetration than did foam boxes. Poly-bags did not retard gas penetration.

Transportation

A full trailer load of wood or corrugated boxes weighs 45,000 pounds and will fit into a 48-foot-long trailer on 48- by 40-inch pallets. A full load of the 12- by 20-inch foam boxes would require a 53-foot-long trailer. If 16- by 20-inch foam boxes are used in a 53-foot-long trailer, the load weight would be less than 45,000 pounds (Table 10). Pallet weights can be increased prior to shipping by adding one to two layers of boxes to a storage pallet. These capacities assume that the pallets are pin-wheel loaded, as in Figure 9. If pallets are loaded with the 48-inch dimension across a 102-inch-wide trailer, product would be placed against the interior walls of the trailer, blocking the flow of refrigerated air. Pinwheel loading allows an air space between the load and the trailer walls to help prevent product warming during transit.

Table 10. Truck capacity with 42 by 53 inch, 35 by 42 inch and 40 by 48 inch grape pallets using pinwheel loading pattern.

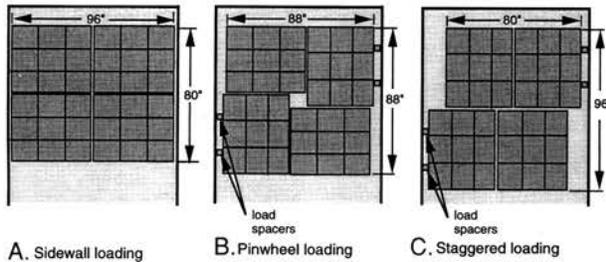
Box Dimensions	Pallet size	Pallets per 45,000 lb load		
		Foam	Corrugated	Wood
14" x 17.5"	53" x 42"	20	19	18
14" x 17.5"	35" x 42"	30*	30*	27
12" x 20"	48" x 40"	24*	23	22
13.3" x 16"	48" x 40"	—	20	19
16" x 20"	48" x 40"	24*	—	—

Table based on 21 lb. net grape weight for 48" x 40" pallets and 23 lb net weight for 53"x 42" and 35" x 42" pallets.

* maximum capacity of a pinwheel loaded 48' trailer is 24 pallets 48" x 40". Foam boxes can be stacked 12-13 layers high to increase pallet weight for transport.

† straight loaded

FIGURE 9. Top view of loading patterns for 48 by 40 inch pallets in 102-inch-wide trailers.



Wood boxes are heavy enough to reach the full load limit of 45,000 pounds before filling the space in a 48-foot trailer. In this case, 48- by 40-inch pallets can be loaded with their 40-inch dimension across the trailer width and can be side-shifted against curb- or road-side walls (using load spacers) to prevent contact between boxes and interior trailer walls (Fig. 9c).

Evaluations of table grapes before shipment from California and then arrival at a market 2,000 to 3,000 miles away indicates that the fruit settles about 1/4 inch in the box. Shattering caused by vibration occurs occasionally in highway shipment. When transit-shatter damage does occur, it can be distinguished from other types of shatter by the following symptoms: damage is mostly confined to the top few layers of boxes, and damage is more prevalent in boxes on the last one or two pallet positions near the rear doors. Transit-shatter damage usually occurs on trailers with steel spring suspension, rarely on air-suspension trailers. Vibration is amplified as it is transmitted through boxes on a pallet; only the top one or two layers are subjected to critical levels of vibration. The rear of the trailer has the most vibration and the center of the trailer has least. Vibration levels are also low in the front of the trailer because it is supported by the air-ride suspension common on most long-haul tractors.

These findings can be applied when loading grapes for transport by truck to minimize fruit damage. If plain-packed and poly-bagged fruit are to be carried on the same trailer, the bagged fruit should be carried in the rear of spring-suspension trailers where vibration is worse because the bagging will help protect the fruit against vibration damage. Plain-packed grapes carried at the rear of spring-suspension trailers will suffer the most damage from vibration. Transport on trailers equipped with air-ride suspension will improve the chances of fruit arriving in good condition at distant markets.

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NOTES



A



B

1

2

3

Packs and Boxes

A. Typical packing stand with position for boxes and scale.

B. Three common containers: (1) wood-end box; (2) corrugated box; (3) EPS or foam box.



C



C. *Left:* Plain or naked pack of Thompson Seedless grapes in a wood end box; *Right:* lower right corner of box



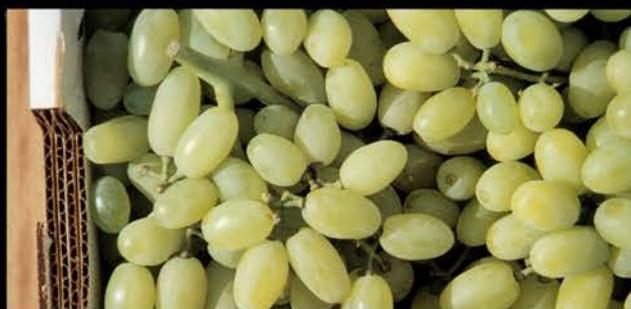
D



D. *Left:* Bagged Thompson Seedless grapes in an EPS (expanded polystyrene) box. *Right:* Lower right hand corner of box.



E



E. *Left:* Plain or naked pack of Thompson Seedless grapes in a corrugated box. *Right:* Lower right hand corner of box.

F. Fiberboard container with clipped corners to improve air circulation. The resulting air passage lines up from box to box along the full length of the pallet.



F



G

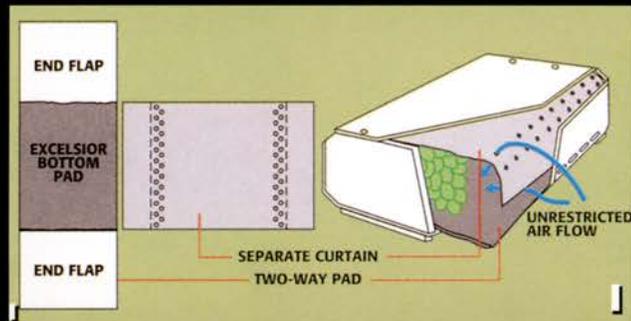
G. TKV box with crowned center. The box's vent holes are plugged by misalignment of liners and the top curtain restricting air flow through the container.

H. Wood-end boxes on a pallet being strapped for handling by forklift and shipping

I. Diagram of vents and air flow in a TKV box with a two-way pad and separate curtain.



H



I



From the Orchard Below
PREMIER QUALITY TABLE GRAPES

From the Orchard Below
PREMIER QUALITY TABLE GRAPES