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SOME PHYSICAL CHARACTERISTICS OF BELL PEPPERS IN RELATION TO CAPACITIES OF STANDARD AND POTENTIAL SHIPPING CONTAINERS

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Abstract. **Bioyield points were determined for bell peppers (*Capsicum annuum*). The stem end shoulders are more sensitive to mechanical injury than the blossom end lobes; this location should serve as the indicator of injury for studies seeking to identify problem points during pepper handling. Florida bell pepper packers in this study generally met or exceeded USDA count recommendations and overcame variability in pepper shape by adjusting fruit diameter ranges to fit the 0.039 m³ (1 1/9 bushel) cartons. Highest counts were obtained using jumble fill plus place pack of the top layer; 50 cm x 30 cm cartons had greater capacity than 40 cm x 30 cm cartons with 0.035 m³ volume. Adoption of a carton with standard dimensions meeting MUM specifications would facilitate rapid, careful handling of bell peppers.**

Introduction

During commercial harvest, handling and packing operations, vegetables and fruits pass several transfer points, each of which has potential to reduce quality by inflicting mechanical injuries such as bruises, cuts, punctures and abrasions. Injured tissues have greater tendency for water loss and are more likely to serve as entry sites for decay than uninjured tissues. Bell peppers are quite susceptible to mechanical injury. Thus, whether field-packed or packed in a packinghouse, primary goals of Florida packers are minimizing injury during handling and removing injured peppers during packing in order to reduce losses during shipping. Also, many packing line manufacturers attempt to minimize impacts at transfer points at the design and installation stages. Previous studies have measured some physical properties of bell peppers (Showalter, 1973; Hampshire, et al., 1987).

The selection and use of appropriate shipping containers has long been a concern to fresh produce shippers. Besides serving as a measure of product quantity, a properly designed container also performs several functions during handling, including protection, ventilation, and identification (Hanlon, 1971). The container must protect the product from injury due to external forces such as shock during handling and compression while bearing the load of other containers on the pallet during shipping. It must also provide protection from injury due to internal factors such as abrasion from the product resting against the container inner surfaces and jostling of loosely packed product within the container during handling. Ventilation within the container is also important for efficient removal of field heat during precooling and for maintenance of product temperature during handling and storage. Additionally, the container must be identified as to the contents, size, weight, grade and shipper. There is an increasing trend to use containers as marketing tools at wholesale and retail level through the use of consumer packages and color graphics.

With the proliferation of many sizes of shipping containers, adoption of base container dimensions recommended by the Organization for Economic Cooperation was pursued by the United Fresh Fruit and Vegetable Association and the U.S.D.A. as Project MUM, which stands for Modularization, Unitization and Metrification (Turczyn and Anthony, undated). The goal of this project was to substitute for the dozens of shipping container sizes, 5 container sizes which would completely utilize the surface of a standard pallet (100 cm x 120 cm) and permit the use of more than one container size on a pallet, when necessary, while maximizing surface coverage and maintaining stability of the load. Cartons which extend over the pallet side have weaker stacking strength than those which are properly stacked. Unitizing cartons reduces the number of handling steps the containers are subjected to and hastens loading/unloading operations.

Several years ago Florida tomato shippers, through the leadership of the Florida Tomato Committee, adopted two carton sizes with MUM dimensions containing 9.1 and 11.3 kg, and limited sales to pallet size quantities only. Tomatoes were shipped to the northeast in non-MUM and MUM containers and arrived with excellent quality with no differences in postharvest quality upon arrival (Sherman et al., 1982). The Florida bell pepper industry currently has a single volume container of 0.039 m³ (known in the industry as a "1 1/9 bushel container"), but there are no standard dimensions. Bell peppers are packed according to count in the 1 1/9 bushel container following USDA guidelines (Table 1). Also, peppers are generally sold on a container basis with the result that only a small portion of the crop is shipped on pallets.

With these considerations in mind, the following research objectives were developed: 1) to determine the sensitivity of pepper fruits to mechanical injury as affected by

Table 1. Average Counts for Bell Peppers Shipped in Bushel Baskets, Cartons or 1 1/9 Bushel Crates or Cartons (USDA/AMS).[z]

Size	Count
Jumbo	50 or less
Extra Large	55-65
Large	70-80
Medium	85-95
Small	100-110
Very Small	111 or more

[z]W. Whatley, Federal Supervisor - Florida, personal communication.

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location on the pepper fruit and as affected by different environmental and handling conditions; and 2) to evaluate alternative carton sizes as to feasibility for adoption by Florida shippers as a standard shipping container for bell peppers. In this report we will discuss recent research related to determination of the most sensitive location on the pepper and development of a database on capacities of two prototype cartons with MUM dimensions and several cartons currently used by Florida pepper shippers.

Materials and Methods

Bioyield Tests

Many bruises occur in peppers without breaking the epidermis; the inner fruit walls normally rupture first with sufficient impact. Bell peppers (cv. Jupiter) were commercially harvested in Immokalee, Florida on December 1, 1988 and returned to Gainesville the same day. The following day, the fruits were selected for uniform size (large size, about 75 mm diameter) and freedom from defects, then randomized. Forty peppers were selected for bioyield tests; of these, 20 each had 3 and 4 lobes at the blossom end. These fruits were at room temperature (about 20°C). The fruits were sliced through the equator and deformed in three locations each on the shoulders at the stem end and at the blossom end using an Instron universal testing machine (Instron Corp., Canton MA). The deformations were made by a convex-tip probe (14.3 mm diameter) which caused a bruise similar to that noted on peppers injured during commercial handling. The crosshead speed was 50 mm/min. The probe pressed against the tissue until the bioyield point was reached (that point at which the tissue is permanently deformed, Mohsenin, 1970). The bioyield point was determined when tissue fracture was audible during deformation, at which point the peak force was recorded.

Container Capacity Tests

Two prototype, fiberboard cartons (regular slotted container style, RSC) were tested for weight and count using commercially-sized bell peppers at three packinghouses during the spring and fall seasons of 1990. The cartons were slightly smaller than the currently used 1 1/9 bushel carton, had 0.036 m^3 (1.0 bu) capacity and were constructed of waxed, corrugated fiberboard. Respective lengths, widths and heights were 40 cm x 30 cm x 30 cm and 50 cm x 30 cm x 24 cm. The 40 x 30 carton stacks 10 cartons/pallet layer, and the 50 x 30 carton stacks 8 cartons/layer. The cartons were filled utilizing commercial volume filling equipment. Each packinghouse had somewhat different packing conditions (Table 2). At each packinghouse the packer's carton and the 2 MUM cartons were filled with each of three sizes. Net weights and pepper counts were recorded for each carton. The diameters of 30 peppers were measured at the equators for each of the 3 sizes; this procedure was replicated 3, 5 and 4 times for packinghouses 1, 2 and 3, respectively.

Results and Discussion

Bioyield Tests

Results from the deformation tests revealed that the stem end shoulders were significantly more sensitive to mechanical injury than the blossom end lobes (Table 3). The shoulders required about 57% of the force to reach the bioyield point that the lobes required. Most likely, the shoulder region is structurally weaker because it is has a small radius and is attached to the placental tissue, causing it to be relatively rigid. The lobe, in contrast, has a larger radius and is not attached to the placenta, therefore it can flex under load. Thus, when determining the effects of different handling systems on bell pepper quality, incidence of mechanical injury at the stem end shoulder should serve as the indicator of sensitivity to the particular procedure. There was no significant difference in the bioyield points of 3-lobed vs. 4-lobed blossom ends.

Container Capacity Tests

Fruit diameters for the three packinghouses were generally similar for the respective sizes (Tables 4-6). The only

Table 3. Resistance of bell pepper fruits to deformation.[z]

Location	n	Bioyield Force (Newtons)	Pr > F[y]
Stem end	40	39.9	0.0001
Blossom end	40	69.1	
Number of lobes on blossom end			
3 lobes	20	68.9	n.s.
4 lobes	20	69.2	

[z]Fruit halves were deformed three times each using a 14.3 mm blunt tip mounted on the compression cell of an Instron universal testing machine. Cultivar: Jupiter.
[y]Analysis of variance using SAS/PC. SAS Institute, Cary, NC.

Table 2. Packing conditions for carton capacity measurements performed during spring and fall seasons, 1990.

Packinghouse	Date of Test	Packing Method	1 1/9 Bushel[z] Carton Dimensions L	W	H	Vol.	Reps	Cultivar
			cm	cm	cm	m^3		
1	June 14	Mechanical size, place pack	45.3	30.7	29.6	0.039	3	unknown
2	Nov. 15	Manual size, jumble fill	45.0	30.7	31.0	0.040	5	Bellmont
3	Dec. 7	Mechanical size, jumble fill	45.0	30.3	31.0	0.038	4	Jupiter

[z]1 1/9 bushel = 0.039 m^3

Table 4. Capacities of bell pepper shipping containers. Packinghouse 1.[z]

Size	CONTAINER TYPE 40 x 30 cm[y]	50 x 30 cm	1 1/9 Standard
SMALL			
(64.0 mm dia.; 4.00 std. dev.)			
Net wt. (kg)	9.7 (0.81)[x]	10.3 (0.68)	10.9 (0.26)
Count	123 (6.93)	128 (4.58)	131.7 (7.09)
MEDIUM			
(71.2 mm dia.; 0.60 std. dev.)			
Net wt. (kg)	9.6 (0.21)	10.0 (0.35)	10.6 (0.76)
Count	87.7 (3.21)	91.7 (3.06)	96 (4.36)
LARGE			
(81.9 mm dia.; 3.14 std. dev.)			
Net wt. (kg)	9.3 (0.32)	9.4 (0.25)	9.6 (0.21)
Count	59.3 (1.15)	61.7 (1.15)	61.7 (4.04)

[z]Mechanically sized, place packed. Cultivar: unknown.
[y]Outside carton dimensions (volumes): '40x30': 39.9 cm (L) x 29.7 cm (W)x 33.0 cm (H), (0.036m³); '50x30': 49.9 cm (L) x 29.8 cm (W) x 26.8 cm (H), (0.036m³); 'Standard': 45.3 m (L) x 30.7 m (W) x 29.6 cm (H), (0.039m³).
[x]First value is mean, second value is standard deviation.

Table 5. Capacities of bell pepper shipping containers. Packinghouse 2.[z]

Size	CONTAINER TYPE 40 x 30 cm[y]	50 x 30 cm	1 1/9 Standard
SMALL			
(63.7 mm dia.; 3.27 std. dev.)			
Net wt. (kg)	9.9 (0.18)[x]	10.2 (0.16)	11.1 (0.26)
Count	97.8 (1.17)	98.8 (0.75)	112.8 (8.38)
MEDIUM			
(71.2 mm dia.; 1.60 std. dev.)			
Net wt. (kg)	9.9 (0.26)	9.9 (0.16)	11.1 (0.14)
Count	75.6 (2.15)	77.0 (2.10)	85.4 (2.42)
LARGE			
(76.8 mm dia.; 1.60 std. dev.)			
Net wt. (kg)	10.0 (0.26)	10.2 (0.18)	10.9 (0.31)
Count	69.2 (1.17)	68.8 (1.47)	75.4 (2.42)

[z]Manually sized, jumble filled. Cultivar: Bellmont.
[y]Outside carton dimensions (volumes): '40x30': 39.9 cm (L) x 29.7 cm (W) x 33.0 cm (H), (0.036m³); '50x30': 49.9 cm (L) x 29.8 cm (W) x 26.8 cm (H), (0.036m³);' Standard': 45.0 cm (L) x 30.7 cm (W) x 31.0 cm (H), (0.04m³).
[x]First value is mean, second value is standard deviation.

deviation was the Large size for Packinghouse 1, which was 81.9 mm and the size of Extra Large packed by Packinghouse 3.

Peppers at Packinghouse 1 were machine sized and hand packed into the MUM cartons; this resulted in the highest count per carton for each size classification as compared to the pepper sizes packed by the other two packinghouses (Tables 4-6). For example, Medium size peppers had mean diameters of 71.2 mm, 71.2 mm and 70.0 mm for Packinghouses 1, 2 and 3, respectively. Mean counts for the 40 x 30 carton were 87.7, 75.6 and 79.3, respectively, and mean counts for the 50 x 30 carton were 91.7, 77.0 and 79.8, respectively. Peppers packed by packinghouse personnel into 1 1/9 cartons resulted in mean counts of 96.0, 85.4 and 89.0 for these houses, respectively. Peppers from Packinghouses 1 and 3 were jumble filled into the 1 1/9 cartons with some orientation of the fruits on the top layer prior to carton closure, while peppers from Packinghouse 2 were jumble filled with little orientation of the top layer.

Table 6. Capacities of bell pepper shipping containers. Packinghouse 3.[z]

Size	CONTAINER TYPE 40 x 30 cm[y]	50 x 30 cm	1 1/9 Standard
MEDIUM			
(70.0 mm dia.; 3.30 std. dev.)			
Net wt. (kg)	10.4 (0.21)[x]	10.6 (0.06)	11.4 (0.18)
Count	79.3 (4.57)	79.8 (3.50)	89.0 (0.82)
LARGE			
(75.6 mm dia.; 5.24 std. dev.)			
Net wt. (kg)	10.1 (0.43)	10.2 (0.63)	11.4 (0.52)
Count	60.8 (1.71)	58.0 (2.45)	69.0 (5.35)
X-LARGE			
(81.1 mm dia.; 16.0 std. dev.)			
Net wt. (kg)	10.2 (0.32)	11.1 (0.60)	11.5 (0.36)
Count	49.3 (3.30)	52.3 (2.36)	55.3 (2.99)

[z]Mechanically sized, jumble filled, top layer place packed. Cultivar: Jupiter.
[y]Outside carton dimensions (volumes): '40x30': 39.9 cm (L) x 29.7 cm (W) x 33.0 cm (H), (0.036m³); '50x30': 49.9 cm (L) x 29.8 cm (W) x 26.8 cm (H), (0.04m³); Standard: 45.0 m (L) x 30.3 cm (W) x 31.0 cm (H), (0.038m³).
[x]First value is mean, second value is standard deviation.

Although pepper counts were higher at Packinghouse 1, carton net weights were generally less for this packinghouse than the other packinghouses. This was due to a substantial amount of variation in capacities between carton replicates, as indicated by standard deviations of the net weights and pepper counts for each of the treatments (Tables 4-6). Some of the variation can be attributed to the inherent diversity in fruit shape such as number of lobes on the blossom end; 3-lobed fruits tend to be pointed while 4-lobed fruits tend to have a blocky shape. Other sources of variation were the ratio of the equatorial diameter to the length, and wall thickness; the thicker the wall, the more dense the pepper and the heavier the net carton weight.

Although not statistically significant due to the variability between replicates, average counts and net weights of peppers packed in the 50 x 30 carton for Packinghouses 1 and 3 tended to be higher than peppers of the same size which were packed in the 40 x 30 carton (Tables 4-6).

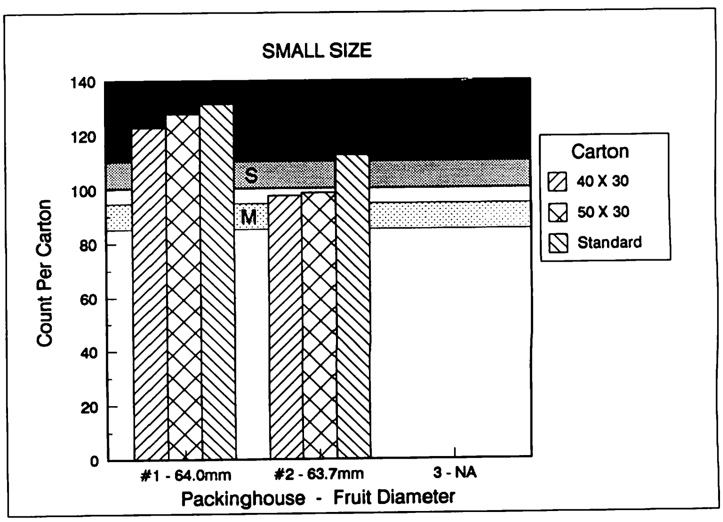

Figure 1. Effect of carton style on pepper count at three packinghouses. (VS, S, M = Very Small, Small and Medium sizes with normal count ranges in shaded areas.)

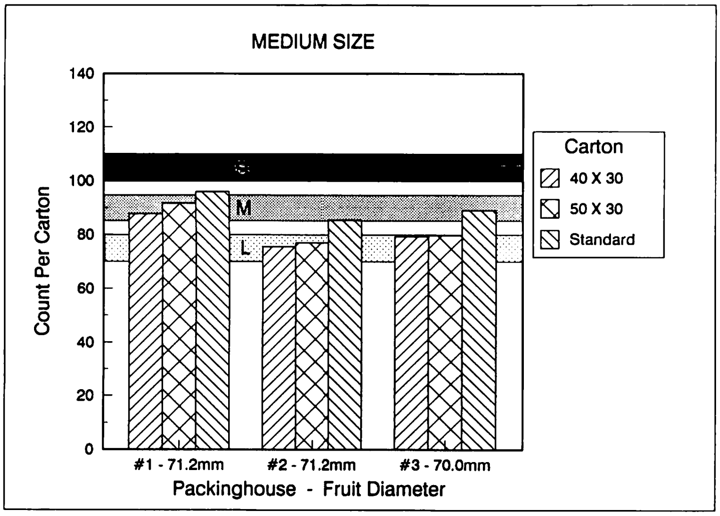

Figure 2. Effect of carton style on pepper count at three packinghouses. (S, M, L = Small, Medium and Large sizes with normal count ranges in shaded areas.)

Peppers packed at Packinghouse 2 were not place packed on the top layer which may have accounted for the counts being similar for the two MUM carton types. Conversations with packinghouse managers have confirmed that shorter cartons have higher counts than higher cartons with the same volume.

For each fruit size, pepper counts were plotted by packinghouse and container type, and USDA count guidelines were superimposed on the graph (Figures 1-4). The pepper counts for the two MUM cartons were less than those for the 1 1/9 cartons used in the three packinghouses. However, the differences in count were not sufficient to change the size designation except for Medium size peppers from Packinghouses 2 and 3 (Figure 2). Count ranges for Medium size peppers from these packinghouses were in the count range for Large size.

Although measurements made for these carton sizes were based on relatively small sample sizes, it appears that the 50 x 30 carton has greater capacity than the 40 x 30 carton. Possibly the longer length and lower height of the 50 x 30 carton conforms better to the shape of peppers than the shorter length, higher 40 x 30 carton. The 50 x 30 carton may also reduce compression injury during handling and shipping, since there should be less weight bearing on the peppers on the bottom layer in this carton. There was less deformation of exported grapefruits which were shipped in 50 x 30 cartons on pallets than those which were shipped in conventional 4/5 bushel cartons (43.2 L x 27.0 W x 25.7 cm H) (Hale, et al., 1976).

The adoption of a standard carton conforming to MUM standards in conjunction with palletized shipping by the Florida pepper industry should prove beneficial by reducing mechanical injury during handling and by permitting more uniform marketing.

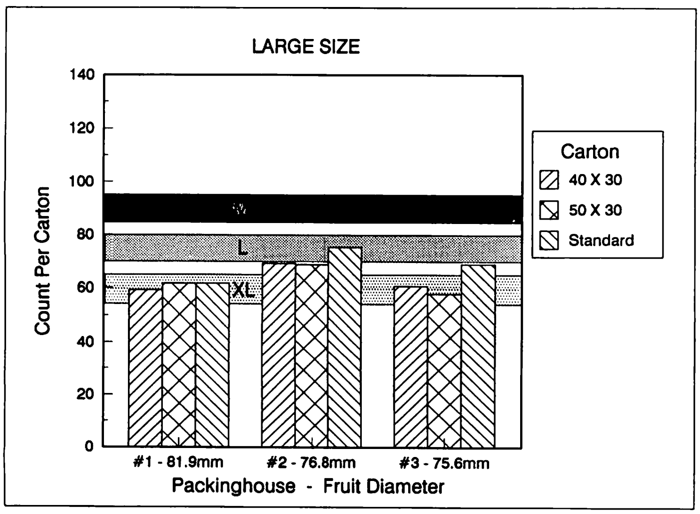

Figure 3. Effect of carton style on pepper count at three packinghouses. (M, L, XL = Medium, Large and Extra Large sizes with normal count ranges in shaded areas.)

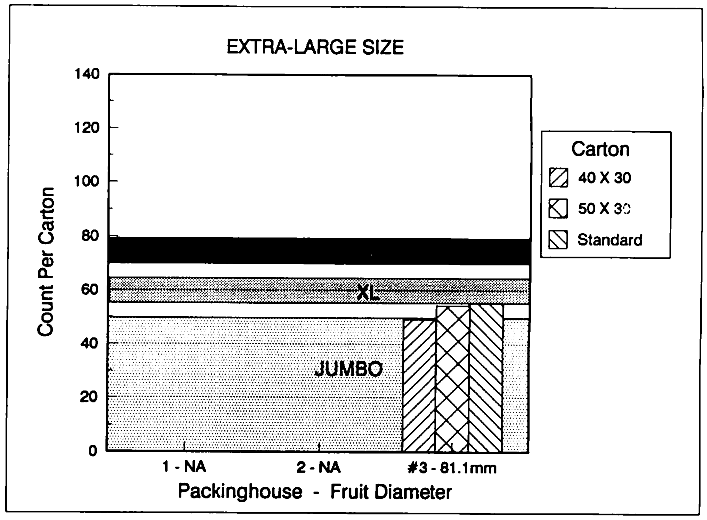

Figure 4. Effect of carton style on pepper count at three packinghouses. (L, XL, Jumbo = Large, Extra Large and Jumbo sizes with normal count ranges in shaded areas.)

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