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A Performance Evaluation of Five Sweetpotato* Shipping Containers**

by

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Abstract

Using a six x six latin square experimental design, five box types in two different markets were evaluated over a six-week period in 1986 to determine if sweetpotato arrival damage could be reduced through use of alternative shipping containers. Findings indicated that skinning, cut and break damage, and bruising could be reduced through use of either a 40-pound container or the 45-pound MUM box rather than using the current 50-pound box. Economic considerations, receiver preferences, and the actions of shippers resulted in the selection of a 40-pound shipping carton as the new standard for the North Carolina sweetpotato industry.

Introduction

Fruit and vegetable growers expend a great deal of resources and effort each year to produce high quality, farm fresh produce. Much of this effort can be lost, however, if ineffective post-harvest handling practices are used by shippers, handlers, and retailers. Despite the existence of a sophisticated and efficient domestic produce distribution system, it is estimated that post-harvest losses for perishable fruits and vegetables exceed $6 billion annually (Ashby, et al., 1987). In general, a large proportion of produce losses result from the interaction of a variety of causes including inadequate temperature and humidity management, improper and excessive handling, poor field quality or disease infestation, inadequate

*In 1989 the Sweetpotato Collaborators of the United States voted to change the official spelling of "sweet potato" to "sweetpotato." The one-word spelling is used in this article.

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shipping container strength, and excessive delivery time from the field to the retail store.

The contribution of poor packaging to poor shelf quality and system-wide losses is complex because many indirect factors can contribute to shipping container failure during transport. These include harsh handling or dropping, improper stacking on a pallet, and containers that are weakened by excessive moisture. However, the basic function of a package is to protect the produce during the course of normal handling and to maintain initial quality during transport. Improvements in individual package strengths and design can assist in reducing post-harvest losses. Historically, transport loss rates for perishable crops are highest for lettuce, tomatoes, apples, potatoes, and sweetpotatoes (Pierson, Allen, McLaughlin).

As part of an overall effort to assist the North Carolina Yam Commission (now called the North Carolina Sweetpotato Commission) improve the arrival appearance of locally grown sweetpotatoes in supermarkets, a sweetpotato shipping container study was initiated in the spring of 1986. Five alternative design shipping containers were compared to determine if the type of box design had an effect on reducing weight loss, bruising, skinning, cut and break injury, and total arrival damage for sweetpotatoes.

Sweetpotatoes are an important horticultural crop to southern U.S. producers as measured by planted acreage and farm income criteria. In 1988, southern producers planted approximately 87,000 acres which resulted in an estimated gross farm value of $145 million to producers (*Agricultural Statistics*, 1989). Currently, U.S. consumers eat approximately 4.4 pounds of sweetpotatoes and industry promotion efforts have stressed that sweetpotatoes are an important source for beta carotene (vitamin A).

The specific purposes of this study were to identify, assess, and compare the extent and level of scorable damage incurred by sweetpotatoes during normal shipment for five different box types and to obtain retail produce managers' preferences for each type of shipping container. In addition, economic considerations associated with a switch from the current container to an alternate design which offers better protection are discussed. Finally, some implications of reduced losses for retailers are offered.

Project Design and Research Methods

The experimental test design was a 6 x 6 latin square which was configured to control for possible time and store location variation among loads of sweetpotatoes. In particular, the amount of damage sustained by sweetpotatoes in transit from the packing shed to six local retail stores and six distant store locations over a six-week period during March and April of 1986 was measured. Thus, column headings in the local market latin square matrix were the individual local stores while the rows were test week 1 through week 6. Matrix entries were the predetermined set of three boxes distributed to each store. Although only five box designs were investigated in this study, multiple use of the current box provided symmetry for the 6 x 6 latin square. A similar 6 x 6 matrix was constructed for the distant market stores.

The amount of damage sustained by the sweetpotatoes for each box design was the primary measurement tool used to evaluate the performance of each box design. Damage assessment evaluations were conducted by the same interdisciplinary team of researchers for the local market and the distant market. Seminal research work in latin square experimental design was conducted by Brunk and Federer (1952) in their study of apple bruising and subsequent researchers have found this approach to be a very effective experimental design for marketing research studies (Steel and Torrie, 1960; Cochran and Cox, 1957). At a cooperator packing facility located in southeastern North Carolina, all test boxes of sweetpotatoes were graded, packed, and standardized such that preshipment damage levels for each box were similar. At the shipping point, every attempt was made to pack sweetpotatoes that were uniform with respect to harvest date, growing conditions, variety, storage conditions, quality, location on the shipping pallet, and placement within a transport truck. Thus, standardization of initial packing quality provided some assurance that changes in arrival damage levels occurred primarily during the transport and distribution phases and the initial quality in all boxes were similar. In addition, one box of each design and its contents was set aside each week to serve as an experimental control box.

Test boxes were transported by truck to the central warehouse facility of the Raleigh Division of Winn-Dixie Food Stores. At the central warehouse, test boxes were then incorporated into the normal handling and distribution scheme used by Winn-Dixie to ship grocery and produce items to individual retail stores in

their division. The twelve cooperating retail stores in the two market areas were selected randomly by the head produce buyer for the Raleigh division of Winn-Dixie. The designated six local stores were located in the cities of Durham, Cary, Garner, and Raleigh, N.C., while the distant market stores were located in the cities of Williamsburg, Norfolk, and Suffolk, Virginia.

The five shipping containers examined in the study were: (1) the standard, two-piece, telescope style, North Carolina shipping container holding 50 pounds of product, identified as box design number 1; (2) an experimental one-piece, fold-over flap box holding 50 pounds of sweetpotatoes (box design 2); (3) a two-piece box (number 3) configured to match the dimensions developed by the American National Standards Institute (commonly referred to as Project Metrification, Unitization and Modularization [MUM] specifications) holding 45 pounds; (4) a two-piece box (number 4) frequently used by sweetpotato shippers in California and Texas containing 40 pounds of product; and (5) box type 5 holding 32 pounds of product and used primarily by shippers for export sales to Europe. All boxes were void of external markings except for the 32-pound export box which was obtained from a cooperating shipper and displayed his company name.

Each local and distant store received a predetermined set of three boxes of sweetpotatoes per week over the six-week test period. The order in which each store received each box set was selected randomly. Immediately upon the box set arrival at the test store, the condition of the boxes was noted and manager preference data were collected. The arrival appearance and structural integrity of each box (excluding contents) was evaluated and the boxes were assigned a numerical rating ranging from 1.0 to 5.0 by the evaluation team. Then, each produce department manager was asked to rank numerically his or her preference for each box using a 7-point semantic differential scale ranging from 0.0 to 6.0. After the box condition and manager preference data were collected, all boxes of sweetpotatoes were opened and inspected for visible signs of bruising, skinning, and cut and break damage prior to their display on the retail shelf. Over the test period, approximately 10,800 pounds of sweetpotatoes were inspected in the combined markets.

Each weekly shipment of sweetpotatoes to a test store always consisted of product packed in the standard 50-pound container plus two of the other four box designs. Thus, over the six-week period, each store received the following box groupings (within set order is disregarded): (1) box designs 1, 2, and 3; (2) box designs 1, 2, and 4; (3) box designs 1, 2, and 5; (4) box designs 1, 3, and 4; (5) box designs 1, 3, and 5; and (6) box designs 1, 4, and 5. Store shipments always included the standard 50-pound container so it could serve as a standard reference for the produce managers to assist them in expressing their preference for or dislike of the other boxes relative to box design 1.

As stated previously, managers were asked to express their preference for a box design using a semantic differential rating scale. Each manager was instructed to assume that a value of 3.0 was assigned to box design 1 and then assign ratings to other boxes relative to this value. By obtaining manager rankings for each box prior to showing them the box contents, their preferences provided an independent evaluation of each box design without consideration of the arrival quality of the sweetpotatoes. Dislike of a box design and its contents resulted in a ranking between 0.0 and 2.9, while preference for a box resulted in selection of a value between 3.1 and 6.0, depending on the degree of preference. Indifference between the current box and an alternative design was expressed by selecting a value of 3.0. In addition to the appearance, preference, and damage data, all boxes were weighed prior to shipment and after their arrival in the store and these figures were recorded.

Damage was determined through visual inspection of all sweetpotatoes in each box and by counting the number of sweetpotatoes that were cut or broken as well as the number that sustained unacceptable surface skinning (more than 10% of the total surface area). It should be noted, however, that the total damage count in this study does not include problems attributable to field conditions such as insect punctures or diseases. Therefore, the percentage damaged was not necessarily the same as the percentage that were unmarketable. However, all box contents met USDA No. 1 minimum grade standards.

Standard analysis of variance tests (ANOVA) were performed on all damage data to determine if differences were observed in damage levels by alternative box type in comparison with the current 50-pound box. ANOVA two-tail tests were conducted for local market, distant market, and combined market data. Protected LSD procedures (alpha=.05 and alpha=.01) were used to determine if overall damage levels differed among all box designs.

ANOVA tests for the model indicated that there were differences among box designs in the amount of damage sustained at the 5 percent level and therefore, additional analysis of results were conducted. In addition, interactions among and between time, market location, and type of container were examined to ascertain if the time and market variables remained constant over the test period. Manager preference evaluations for each box type were computed as simple averages of all responses for both the local and distant markets.

Results

ANOVA tests revealed that total damage levels differed significantly by the type of shipping container used and the week shipped (alpha=.05). The average mean proportion of arriving sweetpotatoes that were cut, bruised, or skinned by container design is reported in Table 1. Box designs which differed from each other are noted through the use of different superscripts in Table 1.

Approximately 13.7 percent of the sweetpotatoes shipped in the 45-pound MUM box (design 3) arrived with unacceptable levels of damage. Total damage levels were higher for the other box designs with the proportion of unacceptable damage ranging from 14.2 percent for the 40-pound box to 20.8 percent for the one-piece box. Use of the current container resulted in an average of 19.4 percent damage to the sweetpotatoes. Use of either the 40- or 45-pound box reduced total damage when compared with the current container while there was no significant reduction in total damage levels observed by using the other two designs. The most common type of damage sustained by the sweetpotatoes was surface skinning and nicking.

Although attempts were made to pack and ship similar quality sweetpotatoes over the entire six-week period, ANOVA results suggest that damage levels differed from week to week (F,week = 8.81; Pr > .0001). Ex-post analysis of data suggests that poorer quality sweetpotatoes arrived in all stores during the first three weeks of the test when compared with the last three weeks. Per box count data from the first three weeks reveals that slightly smaller sweetpotatoes were packed during this period. Smaller sizes may increase the possibility of product shifting within all boxes and thus may result in an increase in skinning damage.

Cut and break damage (CBD) was related to the type of shipping container used only in the distant market stores (Table 2). Again, the 40- and 45-pound containers reduced CBD substantially when compared with the current box. An interesting result was that use of the export box in distant market shipments more than doubled the average amount of CBD when compared with the standard 50-pound box.

Table 2

Average percentage of unacceptable sweetpotatoes arriving at six distant retail market stores with cut damage in 1986, by box type[1]

Box type	Distant Market (%)
Current (50 lbs)	3.69[a]
One-Piece	3.84[a]
MUM (45 lbs)	.49**[b]
40 Pounds	.36**[b]
Export (32 lbs)	8.41**[c]

** Significantly different from current box at 5% level.

[1]Average mean values having a common superscript are not different from each other at the 5% level.

Arrival weight for product packed in the one-piece 50-pound box was 2.5 percent less than the shipping weight. All other designs resulted in a weight loss of less than 1 percent (Table 3). Excess weight loss for the one-piece design likely resulted from excessive open space between the top fold-over flaps on the box which allowed some sweetpotatoes to fall out of the box during transport. It was noted that there were several loose sweetpotatoes in several of the Winn-Dixie distribution trucks. If future design modifications narrowed the fold-over flap opening, then this problem would likely be corrected. With this adjustment, it is anticipated that weight loss would be unrelated to the type of shipping container used.

An expert evaluation team rated the arrival appearance and integrity of all boxes. If boxes were torn, excessively crushed, or had flaps unstapled, then they were rated as poor or fair depending on the degree of damage. A

Table 1

Average Percentage of Unacceptable Total Damage on Sweetpotatoes Arriving at Six Local and Six Distant Retail Stores in 1986, by Box Type[1]

Box Type	Local (%)	Distant (%)	Total (%)
Current (50 lbs)	19.4[a]	19.6[a]	19.5[a]
One-Piece (50 lbs)	19.6[a]	22.0[a]	20.8[a]
MUM (45 lbs)	13.6*[b]	13.8*[b]	13.7*[b]
40 lbs	14.1**[b]	14.3**[b]	14.2**[b]
Export	18.8[a]	21.6[a]	20.2[a]

**Significantly different from current box at 1% level.
* Significantly different from current box at 5% level. F(model) = 4.51; Pr > F = .0001

Table 3

Average Percentage Difference in Shipping Weight and Arrival For Sweetpotatoes Transported to Local and Distant Markets, By Box Design, in 1986[2]

Box Type	Shipping Weight (lbs)	Tare Weight of Box (lbs)	% Wt. Loss at Arrival (%)
Current (50 lbs)	50.0	2.1	.2[a]
One-Piece (50 lbs)	50.0	2.0	2.5*[b]
MUM (45 lbs)	45.0	2.1	.2[a]
40 Pounds	40.0	2.0	.7[a]
Export (32 lbs)	32.0	1.6	.3[a]

* Significantly different from the current container at 5% level.

[1]Average percentage means having a common superscript in the same column are not different from each other at the 5% significance level.

[2]Average mean values having the same superscript are not different from each other at the 5% level.

Table 4

Average Percentage of Boxes Rated as Poor, Fair, Good and Excellent
In Both Local and Distant Markets in 1986 by Box Type

Container	Poor (%)	Fair (%)	Good (%)	Excellent (%)
Current (50 lbs)	19	51	15	15
One-Piece (50 lbs)	10	20	60	10
MUM (45 lbs)	11	15	36	38
40-pound	0	20	36	44
Export (32 lbs)	9	25	33	33

Table 5

Manager Preference Rating for Each Box Design
Using a Scale Ranging from 0 to 6, By Market Location, and Box Type, 1986[1]

Container	Local	Distant	Overall
Current (50 lbs)	3.00	3.00	3.00
One-Piece (50 lbs)	2.30	2.40	2.35
MUM (45 lbs)	2.80	2.40	2.60
40-pound	3.70	3.60	3.65
Export (32 lbs)	3.20	2.70	2.95

[1]Ratings of above 3.0 indicate a preference for a design while ratings below 3.0 indicate dislike of a design relative to the current box.

summary of local and distant market ratings is reported in Table 4. The combined good and excellent ratings for the one-piece, MUM, and 40-pound containers all exceeded the combined average good-excellent rating of 66 percent received by the current box. In addition, the current box received the largest poor rating with 15 percent of the boxes identified as arriving in the worst condition. The major reason for the high unacceptable rating for the current box was that an unacceptable number of flaps became unstapled during transit. Casual observation suggested that an insufficient number of staples were used at the packing shed prior to shipment.

Finally, managers expressed a clear preference for the 40-pound box over the other boxes (Table 5). Their reasons for preferring the 40-pound box may be summarized best by the statement that "the 50 pound boxes were a bit too heavy to lift but 40 pounds seemed about right." Several managers also stated that the side bulge was less with a 40-pound box and there seemed to be less tendency to over-pack the 40-pound box. The box-was-too-heavy attitude was not a surprising comment since some managers and clerks had obvious difficulty in lifting the 50-pound boxes. Two managers also thought that less weight might reduce damage, but they did not seem to consider this factor as particularly important. In general, the remaining three box designs were considered less desirable than the standard container or the 40-pound box. Particular dissatisfaction with the 50-pound one-piece box was evident as it received an overall rating of 2.35. Several managers thought a one-piece 40-pound box would be a good idea, but the present design configuration and weight of the one-piece box was not an improvement over the current box. The 32-pound export box was thought to contain too few sweetpotatoes but was otherwise fine. Among the group of managers who expressed a dislike for the MUM box, the most frequently cited reason was the high side risers. In their opinion, the higher risers would increase box storage and stacking problems. Most would find the MUM box acceptable if the box corners were reinforced to make them less susceptible to crushing.

Damage assessment data suggest that a switch from the current 50-pound container to either the 45-pound or 40-pound container would probably reduce total skinning, cut, and break damage. Arrival box integrity for the 40-pound box was rated as good or excellent for 80 percent of the boxes, the highest level among the five box designs examined. In addition, retail produce managers expressed a preference for the 40-pound box over the alternative designs. Thus, two independent measures of box performance (damage reduction and manager preference) suggest that retailer losses might be less and receiver satisfaction greater if shippers used the 40-pound shipping container. The MUM box also seemed to offer a reasonable alternative container design which would reduce total damage. However, the poor preference rating it received from the surveyed produce managers is of some concern and may suggest that it is a slightly inferior choice when compared with the 40-pound alternative. Data and preference ratings for the current box suggest it performs adequately but reductions in bruising and skinning damage seem likely through use of either the 40- or 45-pound box. The one-piece and export boxes do not seem to reduce total damage levels when compared with the other alternatives and are considered inferior alternatives by the managers.

A decision to switch from the current box design to the 40-pound alternative, however, would involve additional considerations beyond the issues of damage reduction and manager preferences. A 20 percent reduction in per unit box capacity (from 50 to 40 pounds) would increase container expenditures approximately 25 percent for an equivalent volume shipped. The reduction in per box capacity and the concomitant increase in box expenditures are not equivalent proportions because of the assumption that an equivalent season long volume is shipped. For example, if a shipper were currently shipping 100,000 pounds of sweetpotatoes per season, then the shipper would need to use 2,000 boxes of the current 50-pound containers. However, for an equivalent 100,000-pound volume of sweetpotatoes using a 40-pound box, then 2,500 boxes would be needed, or an increase of 500 boxes. This represents an increase of 25 percent over the current box requirements. Thus, box expenditures would increase approximately 25 percent if a switch from a 50-pound box to a 40-pound container were to occur.

Of particular importance is the economic issue of comparing the benefit gained by reducing damage incidence with the increase in box expenditures. For example, if the current 50-pound box costs a shipper $.70 per box or $1.40 per cwt, then a 25 percent increase in the number of boxes needed to ship an equivalent amount of sweetpotatoes would result in an additional expenditure of $.35 per cwt using the smaller capacity 40-pound boxes. Increased labor use, handling time, box assembly, glue,

and staples are estimated to add approximately $.07 per cwt based on time and motion information that we collected at the cooperating shippers' packing facility. The additional cost of $.42 per cwt may be offset slightly by the fact that a shipper may pay less for the 40-pound box relative to a 50-pound container. However, in order to value the cost of switching conservatively, this possible cost savings is ignored and it is assumed that shippers will pay the same price per box for the 40-pound container as is paid for the 50-pound box. Thus, a marginal gain of at least $.42 per cwt in benefits is needed to offset the additional cost. Since an equivalent volume shipped is assumed, for the purposes of this analysis, any additional transport and capacity costs for the industry are irrelevant. However, for an individual shipper, differences in volume shipped, truck capacity, and the need for additional trips to a market will likely change their breakeven switching costs and careful examination of their true costs for switching containers is warranted.

From 1983 through 1988 the season average grower price for sweetpotatoes was $12.80 per cwt. If an average lower damage level was realized through the use of a 40-pound box, then there would be a corresponding reduction in the number of unmarketable sweetpotatoes arriving at supermarkets. The value of this benefit to the industry could be estimated by multiplying the average damage reduction times the average value of the product. Equivalently expressed, this means that a reduction in total damage levels of at least 3.3 percent ($.42 divided by $12.80) would offset the additional box and handling costs. Study data indicate that the average loss rate would be reduced by 5.3 percent (from 19.5% to 14.2%) by switching from the current container to the 40-pound container. Since this amount exceeds the breakeven estimate of 3.3 percent, the average gain from switching exceeds the average cost. Examination of the confidence interval range around the 40-pound box damage reduction estimates reveals a 95 percent probability that, on average, a damage reduction level of 5.3 percent is expected. Using average sweetpotato prices, the savings in damage reduction exceeds the cost of switching. Possible undervalued or omitted switching costs for retailers plus changes in box cost differentials would have to exceed an additional $.26 per cwt before the marginal cost to the industry of switching is greater than the marginal benefit gained under the assumptions and findings of this study. An unvalued benefit from better quality sweetpotatoes could include also the gain in reputation that a local grower or region could acquire through delivery of a higher quality product. In addition, the higher quality product may result in some buyer substitution of 40-pound box users for current 50-pound box users. To the extent this occurs, shippers may expand market share and realize a price premium for their sweetpotatoes relative to shippers who continue to use the 50-pound box. Since the primary benefit of switching containers is realized through reducing arrival damage, an alternative strategy would be to strengthen the current 50-pound box so that it protects the product to the same degree that a 40-pound container does. However, this study did not specifically examine this alternative, so conclusions concerning the advisability of this option cannot be made. To the extent that this alternative would represent a lower cost alternative than a switch to the 40-pound container, specific examination of this alternative is one area for future research. The box company cooperator on this project hypothesized that a strengthening charge for the current box would range from 5 to 8 percent above the current box cost, much less than the additional cost of packing and handling 25 percent more boxes. However, this alternative does present a slight problem for shippers, in that they must inform buyers that they are using a stronger box than usual. To the extent this communication problem can be overcome, strengthening the current box would seem to be another alternative to reducing in-transit damage. Specific research which compares damage levels between a stronger 50-pound box and the 40-pound box is needed before any recommendations can be made.

Other Observations and Implications

The principle objective of this study was to investigate ways to improve the appearance and arrival quality of sweetpotatoes offered for sale in supermarkets. Reduction of transit damage through better protection of the product and improved box design can contribute significantly to reduced losses and offer greater opportunities to sell more sweetpotatoes. However, casual observation of retailer produce display shelves during this study suggests that there are additional opportunities for retailers to reduce shrinkage. In seven of the twelve stores used in this study, internal pulp temperatures for displayed sweetpotatoes were measured under 50°F (10°C), considerably below the recommended holding temperature of 55°F (13°C). Indeed, pulp temperatures in three of the test stores were below 32°F (0°C). Excessively cold temperatures for sweetpotatoes induces shriveling, causes flesh discoloration, contributes to internal breakdown, and causes a

sweetpotato to develop an off-flavor when cooked (Hardenburg, 1986). Proper display temperatures for sweetpotatoes are similar to requirements for bananas, with placement in a refrigerated display unit unadvisable unless the cold air delivery unit is partially blocked. When asked why sweetpotatoes were placed in refrigerated cases, most managers stated that they were simply following the suggested produce schematic plan developed by the central office. System-wide losses for sweetpotatoes can be reduced through the use of smaller capacity shipping containers and adherence to the correct handling practices and display temperatures for sweetpotatoes after they arrive in the supermarket. In general, it would appear that better training of store personnel would contribute substantially to an improvement in sweetpotato display appearance.

A second implication from this study focuses on an opportunity for shippers to improve sweetpotato arrival appearance while satisfying manager preferences for a smaller, less bulky box. The number of women employees in produce departments is increasing, and many individuals feel uncomfortable asking certain women (and some men) to move or carry 50-pound boxes. A 40-pound container presents less of a problem in this area. For many of the sample produce managers, the additional damage protection afforded by the smaller 40-pound box was of secondary importance compared with the greater ease in handling that it offered.

Conclusions

On the basis of loss reduction findings and partial benefit and cost considerations, it seems reasonable to conclude that additional net benefits would be realized by sweetpotato producers, shippers, and retailers if the industry were to switch from the current container to a 40-pound shipping box. Potential savings associated with using a stronger 50-pound box should also be explored. Indirect benefits from either alternative would likely include improved shelf appearance, increased retail sales of local sweetpotatoes, and fewer sweetpotatoes discarded at retail stores.

In late fall of 1987, study findings and recommendations were presented to representatives of growers, packers, and shippers of North Carolina sweetpotatoes. North Carolina growers produced 40 percent of the U.S. sweetpotato crop in 1987 and shipped most product in 50-pound cartons. At subsequent meetings, the North Carolina Sweetpotato Commission recommended to its membership that they use a 40-pound shipping container. For the 1988-89 crop year, this recommendation was adopted and implemented by a majority of North Carolina shippers. At present, a majority of shippers in other major sweetpotato producing states have switched to a 40-pound box. Telephone conversations with selected shippers indicate general buyer acceptance and satisfaction with the new box.

A comparison of North Carolina season average prices reveals that 1988 prices were 35 percent higher than 1987 prices for an equivalent amount of production shipped ($13.50 per cwt in 1988 versus $10.00 per cwt in 1987). Although overall supply conditions and other considerations likely contributed to higher prices received in 1988, this evidence supports the notion that additional gains realized were sufficient to offset the additional box costs incurred by shippers. Subsequent research is needed to determine overall industry gains and costs associated with the shipping container switch.

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