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SHIPMENT OF CELERY IN CORRUGATED FIBERBOARD BOXES TREATED WITH WAX WHILE UNDER VACUUM[1]

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Abstract. **In two separate tests, celery packed in experimentally waxed corrugated fiberboard boxes was shipped under commercial conditions from Belle Glade, FL to Woodbridge, NJ. Deformation of the experimental boxes was compared with that of regular commercially waxed celery boxes included in the same shipment. Experimental boxes in the first shipment were made from standard weight fiberboard normally used in the manufacture of celery boxes. The second shipment included experimental boxes made from lighter weight fiberboard. In both cases, although not significantly different, deformation of the experimental boxes was slightly less than the regular boxes. Crush tests conducted in the laboratory showed the compression strength of the experimental boxes to be greater than that of the commercial boxes.**

A general trend has developed in the produce industry toward the use of more corrugated fiberboard shipping containers. One of the main reasons is the cost advantage these containers have over wooden wirebound crates. This has created some problems with products which are normally hydrocooled because the fiberboard boxes are not as strong as wirebound crates when wet. Some shippers use forced-air precooling or vacuum cooling with fiberboard boxes, but vacuum cooling is more costly, both in equipment requirements and energy use, and neither system is completely compatible with some of the products. Other shippers use a heavily waxed corrugated fiberboard box for hydrocooling, but the boxes do not always hold up well during shipment and storage, resulting in damage to the product. A new precooling technique has been developed (5) which requires only 10% to 20% as much water circulation as hydrocoolers, and has potential for cooling a wide range of products, but also requires the use of a heavily waxed box.

Most corrugated shipping containers used in the produce industry are manufactured from single wall fiberboard consisting of inner and outer liner-boards and the corrugated medium. Wax treatment is accomplished by several methods and the method used depends on the intended use of the box.

Lightly waxed boxes are used for dry or damp products where the box will not come in contact with water for extended periods of time. In one such light treatment, known as wax impregnation, the fiberboard has one or more of its components (linerboards and corrugated medium) infused with wax. This is accomplished during manufacture of the components and results in a wax add-on of 5% to 15% of the weight of the untreated material. The components are later glued together to form the fiberboard from which the box is constructed. Another light treatment is surface coating either or both sides of the fiberboard with wax. Surface coating can either be used alone or in combination with wax impregnation.

Heavily treated boxes are dipped in hot wax or wax is cascaded over the boxes when stacked with the flutes of the corrugated medium in a vertical position. The resultant wax add-on is usually 40% or more of the weight of the box prior to treatment. Boxes receiving this treatment are usually much stronger than the lightly waxed boxes and are used for products which are hydrocooled or top-iced during shipment and storage.

The ultimate strength of a fiberboard box is dependent on several factors: the weight of the linerboards and the corrugated medium expressed in terms of weight per unit area, the height and width of the corrugations or flutes, and the type of wax treatment used. The term "bursting strength" is used in connection with corrugated fiberboard strength and measures the resistance of the material to bursting when pressure is applied perpendicular to the surface of the fiberboard. The result is expressed in pounds per square inch. Another test used in determining corrugated fiberboard strength is column compression. This measures the edgewise strength of a short column of corrugated fiberboard when force is applied parallel to the flutes. This test is a better measure of the stacking strength of fiberboard boxes than the bursting strength.

Size of the corrugations most commonly used in the produce industry are designated as either A, B, or C-flute (2). The number of flutes per linear foot are 36, 50, and 42 respectively. Approximate heights are: A-flute–0.2 in. (4.8 mm), B-flute–0.1 in. (2.4 mm), and C-flute–0.14 in. (3.6 mm). Moody (6) reported the edgewise compressive strength of B-flute samples to be greater than either A or C-flute samples.

Relative humidity of the storage environment is also a factor in corrugated fiberboard strength. Benson (1) reported that for untreated samples, moisture content of the fiberboard increased and the strength decreased as the relative humidity increased. Peleg and Smolinski (7) showed that the yield compressive force of apple boxes conditioned at 92% RH was only 40 to 60% of that of boxes conditioned at 50% RH.

One of the most important considerations in the ultimate wet strength of corrugated fiberboard is the method used in treating the board with wax. Henry (3, 4) has shown that the wet strength of fiberboard boxes is increased when they are treated with wax while under vacuum. In his experiments, the vacuum was released while the boxes were submerged in melted wax, causing the wax to penetrate into the cellular structure of the fiberboard.

The objective of the research reported here was to compare the strength of experimentally waxed fiberboard boxes with that of regular boxes under commercial handling and shipping conditions.

Materials and Methods

Corrugated fiberboard boxes packed with celery were hydrocooled and shipped from Belle Glade, FL to Woodbridge, NJ in 2 test shipments during April and May, 1981. Boxes used in both shipments were single wall, "C" flute, regular slotted containers with inside dimensions of 20 inches (50.8 cm) x 14 inches (35.6 cm) x 11.25 inches (28.6 cm). Eleven ventilation holes 2.75 inches (7 cm) x 0.63 inches (1.6 cm) were cut in each side of the boxes. The first shipment consisted of 128 boxes, half of which were commercially waxed using the cascade method. The other half were dipped in melted wax while under a vacuum of 20 in.

[1]Appreciation is expressed to A. Duda and Sons, Inc. Oviedo, FL and to Supermarket General, Inc., Woodbridge, NJ for making their facilities available for this research.

hg. (68 kpa). Both boxes were manufactured from corrugated fiberboard (275 lb. test) normally used for celery boxes. The second shipment was made up of commercial boxes similar to those in the first shipment and experimental boxes manufactured from lighter weight fiberboard (250 lb. test). The commercial boxes, again, were waxed using the cascade method and the experimental boxes were treated while under vacuum.

The experimental boxes were treated with wax in a specially designed vacuum chamber equipped with a steam coil for regulating the wax temperature and a mechanism for lowering the boxes into the melted wax. The steps involved in treating boxes with wax in the vacuum chamber were as follows:

1. Load boxes into rack suspended above melted wax.
2. Pull vacuum.
3. Lower boxes into melted wax and leave for 15 sec.
4. Break vacuum.
5. Soak boxes in melted wax for 30 sec.
6. Raise boxes and allow excess wax to drain.

The temperature of the wax during these experiments was 210° F (93.3 C). Wax was drained from the boxes in the vacuum chamber suspended above the melted wax at a temperature of approximately 175° F (79.4 C). This was well above the melting temperature of the wax [135° F (57.2 C)].

Wax add-on was determined by weighing each box before and after wax treatment. Dimensions of the boxes were recorded immediately after they were packed with celery and again when they were unloaded from the truck at the terminal point. Side and end bulge and top to bottom compression were then calculated from these measurements. Compression tests were conducted on empty boxes identical to the 3 types in the shipments. The boxes were first sprayed with water for 1 hour at a rate of 5.4 gpm (20.3 l/m) per box to simulate hydrocooling. Then the boxes were placed in a hydraulic press and force was applied until the sidewalls failed.

Results and Discussion

Results of the different wax treatment methods in terms of the average amount of wax added to the boxes are shown in Table 1. Wax add-on was greatest for the 275 lb. test experimental box (treated while under vacuum). Although the actual weight of wax added to the 250 lb. test experimental box was smaller than that added to the other boxes, when expressed as a percentage of the weight before wax application, wax add-on was equal to that of the 275-lb. test experimental box. It was obvious from examination of the boxes that more wax adhered to the surfaces of the commercial boxes than the experimental boxes. This was probably due to the lower temperature wax used to treat the commercial boxes (180-190° F vs 210° F). The wax temperature was purposely increased for the experimental boxes in order to drain off as much of the surface wax as possible. The greater wax add-on for the experimental boxes is attributed to the vacuum process where the wax replaced the evacuated air within the cellular structure of the fiberboard when the vacuum was broken.

Deformation of the boxes after the test shipments is shown in Table 2. Although the deformation of the commercial boxes in both shipments appears to be slightly greater than that of either of the experimental boxes, the difference is not significant. Celery packed in all of the boxes arrived in Woodbridge, NJ in excellent condition.

Compression tests conducted in the laboratory showed the 275 lb. test experimental box to be stronger than the other two when subjected to a 1 hour water spray. There was no difference in the wet strength of the 250 lb. test experimental box and the 275 lb. test commercial box (Table 3).

Table 1. Wax add-on of corrugated fiberboard celery boxes during wax treatment.

Type box[z]	Wax add-on lb	Wax add-on g	Wax add-on %
Experimental—275 lb. test	1.15 a[y]	520 a	51.1 a
Commercial —275 lb. test	0.99 b	447 b	43.9 b
Experimental—250 lb. test	0.95 c	430 c	50.5 a

[z]Experimental boxes were dipped in wax while under vacuum. Wax was cascaded over commercial boxes under atmosphere conditions.
[y]Values within a column followed by the same letter are not significantly different at the 1% level.

Table 2. Deformation of corrugated fiberboard boxes packed with celery during shipment from Belle Glade, FL to Woodbridge, NJ.

	top to bottom compression[z]		side to side bulge[z]		end to end bulge[z]	
	in	mm	in	mm	in	mm
First shipment						
Experimental—275 lb. test	0.44[y]	11.3[y]	0.30[y]	7.5[y]	0.32	8.1[y]
Commercial —275 lb. test	0.45	11.4	0.45	11.4	0.58	14.7
Second shipment						
Experimental—250 lb. test	0.44	11.1	0.34	8.6	0.25	6.4
Commercial —275 lb. test	0.66	16.7	0.42	10.6	0.15	3.9

[z]Values are total deformation of both surfaces of the box.
[y]Values within a column for each shipment were not significantly different at the 1% level.

Table 3. Compressive force required to cause corrugated fiberboard celery box to fail after a 1 hour water spray at 5.4 gpm (20.3 l/m).

Type box	Force lb	Force N
Experimental—275 lb. test	1255 a[z]	5583 a
Commercial —275 lb. test	1162 b	5169 b
Experimental—250 lb. test	1170 b	5204 b

[z]Values followed by the same letter are not significantly different at the 1% level.

However, the fact that the 250 lb. test experimental box was as strong as the commercial box is noteworthy, because less wax was used in treating the 250 lb. test box. Wax is a petroleum based product and is expected to continue to rise in price. It is estimated that if celery boxes were manufactured from 250 lb. test instead of 275 lb. test fiberboard, a savings of approximately $0.06 per box could be realized in material costs.

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STORAGE QUALITY OF FLORIDA CRISPHEAD LETTUCE

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Abstract. **In 8 laboratory storage tests, Florida crisphead iceberg lettuce** (Lactuca sativa) **was stored at 36°F (2.2°C) for 7 and 14 days followed by 50°F (10°C) for 3 and 5 days to simulate domestic and export shipment and retail handling. After storage, the lettuce was weighed and evaluated for weight loss, firmness, bruising, rib discoloration, decay, and percentage of trim. Decay was minimal after 7 or 14 days' storage at 36°F, but generally increased following simulated retail handling at 50°F. Preharvest conditions, packing, and bruising were related to amount of decay and percentage of trim loss after storage. Results indicate that good-quality Florida lettuce can be delivered to market with minimal decay if: 1, growing and preharvest weather conditions are ideal, 2, lettuce is harvested and packed carefully, and 3, lettuce is promptly vacuum-cooled and held at a temperature of 34-36°F (1.1-2.2°C).**

The production of Florida crisphead iceberg lettuce (henceforth, crisphead iceberg lettuce is referred to as "lettuce") has increased rapidly in the last 10 years (3). During the 1979-80 season, almost 10,000 acres (4,047 ha) of lettuce, valued at ca. $25 million, were planted in the Belle Glade area of Florida (3). Florida is the third leading state in production of lettuce. Florida lettuce is vacuum-cooled to 36-40°F (2.2-4.4°C) immediately after harvest and stored in cold rooms until shipment. Most shipments terminate east of the Mississippi River. Exports of U.S. lettuce have been increasing and currently total $38.1 million per year (13). At least 5 van-container shipments of Florida lettuce have been sent to Europe during the past 2 years. Three of the shipments arrived in excellent condition, and the other 2 shipments arrived in poor condition with high incidence of decay.

The postharvest quality of western lettuce has been studied for many years (4, 5, 6, 7, 9, 11, 12). However, very little research has been published on the postharvest quality of Florida lettuce. In this study, the quality of Florida-grown lettuce was studied under simulated domestic and export conditions, and retail handling. Lutz (10) stated that, ideally, lettuce should be stored at 32°F (0°C); but for practical purposes, most storage and transit vehicles maintain somewhat higher temperatures. Therefore, 36°F (2.2°C) was the storage temperature selected for simulated transit, and 50°F (10°C) was selected as a retail handling temperature. The lettuce was stored for 7 and 14 days to simulate domestic and export transit times.

The objective of this research was to evaluate the storage quality of Florida lettuce under simulated conditions for domestic and export shipments.

Materials and Methods

Eight tests were conducted at ca. 2-week intervals from early February through late April 1980. The tests were made with naked or unwrapped heads of lettuce grown in the Belle Glade, Florida, area and were packed 24 heads per corrugated, regular-slotted fiberboard box. The predominant cultivar grown in Florida, 'Montello', was used in these tests. The fiberboard box was the conventional box which the industry uses, with inside dimensions of 21 1/2 x 16 x 10 1/2 inches (54.6 x 40.6 x 26.7 cm). The lettuce was harvested, packed, and vacuum-cooled commercially. For each test, 1 to 5 samples were collected such that the total number of samples for the 8 tests was 22. Each sample consisted of 4 randomly selected boxes of lettuce. Test samples were transported by air-conditioned automobile to the Horticultural Research Laboratory at Orlando.

On arrival at Orlando, ca. 4 hr after vacuum cooling, the boxes of lettuce were immediately weighed and placed in rooms held at 36°F (2.2°C) and 85 to 90% relative humidity. Two of the 4 boxes of lettuce per sample were removed from storage after 7 days. The boxes were weighed, and 8 heads of lettuce were removed from each box, weighed, and evaluated. The remaining 16 heads in each box were then stored at 50°F (10°C). At the end of 3 days' storage at 50°F, 8 heads were removed, weighed, and evaluated. At the end of 5 days' storage, the remaining 8 heads were weighed and evaluated. The same procedure was used with the 2 boxes which remained in storage for 14 days at 36°F.

At each evaluation, the total weight of 8 heads was recorded and each head was then evaluated on a rating scale developed by Kader et al. (8) for the following factors:

Appearance	Firmness	Crushing and Bruising
9—Excellent	1—Soft	1—None
7—Good	2—Fairly firm	3—Slight
5—Fair	3—Firm	5—Moderate
3—Poor	4—Hard	7—Severe
1—Not salable	5—Extra hard	9—Extreme

Butt discoloration, crushing and bruising, and decay were the main defects evaluated. Most unwrapped lettuce is trimmed at the wholesale or retail level to remove wrapper leaves and damaged or decayed leaves. In this test, the lettuce heads were rated for appearance, firmness, and defects, and then trimmed as a retail produce clerk would do to make them presentable for sale. These trimmings were weighed and referred to as "retail trim loss." After trimming to salable condition, the lettuce heads were cut in half and

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