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THE EFFECT OF STORAGE CONDITIONS AND WAX TREATMENT ON THE COMPRESSIVE STRENGTH OF CORRUGATED FIBERBOARD PEACH BOXES

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Abstract. **Empty corrugated fiberboard boxes and boxes packed with peaches were stored for 7 wk under various humidity conditions. After the storage period, the empty boxes showed more compressive strength than boxes which were packed during storage. Humidity in the storage room and the degree of wax treatment received by the boxes during manufacture also affected compressive box strength.**

A number of types and grades of corrugated fiberboard boxes are used for shipping peaches from the production areas of the southeastern United States. Each shipper, working with a box manufacturer, has developed specifications for a box which he feels best suits his needs. These specifications have been adequate in most cases, but some shippers have experienced box failures due to insufficient strength. The initial strength of the boxes depends primarily on the components from which they are made, the type of construction, and the degree of wax treatment they receive. The paper used to make the corrugated fiberboard may be of various weights. The corrugated fiberboard may be single or double thickness. Treatments of corrugated boxes may range from no treatment at all to complete immersion of the boxes in melted wax. All of these factors have a direct bearing on the strength of the box and also determine their final cost. The ultimate strength of the box also depends on handling and storage conditions.

Some of the more important factors which should be considered when boxes are purchased are: (1) the length of time the peaches will be in storage; (2) the humidity in the storage room; (3) the distance between the shipping point and the terminal market; and (4) the overhead force exerted on the boxes during storage and shipping.

Unwaxed or lightly waxed boxes may provide adequate protection for peaches that will be in storage for only a short time. However, several researchers have reported an increase in moisture content and a decrease in the compressive strength of boxes stored in a high humidity environment (2, 4). Pelig and Smolinski (8) showed that the yield compressive force of apple boxes conditioned at 92% relative humidity was only 40 to 60% of that of boxes conditioned at 50% relative humidity. Unwaxed boxes are especially susceptible to increased moisture content when exposed to water. Henry (5) reported water absorption of 1% by weight for heavily waxed samples of corrugated fiberboard and 117% for unwaxed samples when soaked in water for 1 hr.

The research reported here was conducted to investigate the compressive strength of boxes commonly used in the peach industry after several weeks in storage at different humidity levels.

Box Construction

Shipping boxes used in the peach industry are constructed from either single wall or double wall corrugated fiberboard. Single wall fiberboard is made of an outer facing, the corrugated medium and an inner facing. For double wall fiberboard, another corrugated medium and facing are added. The facings and corrugated medium are made from paper of various thicknesses expressed in terms of weight per unit area (lb./1000 ft^2), and the strength of the corrugated fiberboard usually increases as the weight of the paper increases. Boxes constructed from double wall fiberboard are stronger than those made from single wall fiberboard.

The number and size of the flutes in the corrugated medium also have a bearing on box strength. The most commonly used sizes are designated as A-, B-, or C-flute. The number of flutes per lineal foot are 36, 50, and 42 respectively. Approximate heights are: A-flute—3/16 inch, B-flute—3/32 inch, and C-flute—9/64 inch (3). Moody (7) reported the edgewise compressive strength of B-flute samples to be greater than either A- or C-flute samples.

Treatment of the boxes to retard moisture absorption is important if the boxes will be subjected to high moisture storage conditions. This can range from spraying the facings with a moisture retarding chemical (sizing) to dipping the boxes into melted wax. Intermediate treatments are wax impregnation where wax is lightly applied to one or more of the components during manufacture of the corrugated fiberboard and surface coating where a coating or film of wax is applied to the completed box. Surface coating can be used alone or in combination with sizing or wax impregnation. Heavily waxed boxes dipped in melted wax absorb less moisture and are stronger than boxes receiving the other treatments, especially in high moisture storage conditions (6).

Experimental Procedure

Containers used in these experiments were design-style, double-wall boxes made from the following components: outer facing—42 lb., corrugated medium—33 lb, B-flute; middle facing—69 lb., corrugated medium—33 lb., C-flute; and inner facing—42 lb. (42/33/69/33/42). The ends of the sidewalls were folded inward behind the ends of the box to provide a double thickness of corrugated fiberboard and the boxes were fitted with 3-inch deep partial telescopic covers. Inside dimensions of the boxes were 18 inches x 12 inches x 11 inches. Two 5/8 inch x 3-inch ventilation slots were located in each end panel and three 5/8 inch x 3 1/2 inch slots in each side panel. The inner facings of all boxes were sized to retard moisture transfer from the peaches to the fiberboard material. One third of the boxes received no additional treatment. One third were surface coated with wax and the remainder were dipped in melted wax.

Four boxes of each treatment (i.e. inner facings sized only, sizing plus surface coating, and sizing plus dipping) were packed with peaches and placed in each of the three storage rooms for three consecutive weeks. The boxes were stacked 4-high in direct vertical alignment. In addition, three empty boxes of each treatment were placed in each of the storage rooms and three were held under ambient conditions. The three storage rooms, described in detail by Bennett *et al.* (1) were constructed as follows:

Room 1—Conventional storage with overhead-mounted direct expansion cooling coil.
Room 2—Combined forced-air precooling and storage in which a coil-type water-to-air heat exchanger chills the circulating air.
Room 3—Combined forced-air precooling and storage in which a direct-contact heat and water vapor transfer unit (Filacell) chills and controls the humidity of the circulating air.

The temperature in all three rooms was maintained at 37°F during the 7-wk storage period. Relative humidity averaged 90% in room 1, 96% in room 2, and 97% in room 3. Ambient relative humidity averaged about 60%. Room 2 was designed to operate at a lower relative humidity, but a leak in the duct system caused warm saturated air to be pulled into the room.

At the end of the storage period, the boxes were first unpacked where applicable and then placed in a hydraulic press where force was applied until the boxes failed. Boxes were considered to have failed when further downward movement of the top loading plate did not require increased force and the box collapsed in one or more areas. The total sidewall bulge at the point of failure was also measured.

Results and Discussion

Results of the compressive strength tests for boxes which were empty during storage are shown in Table 1. As expected, the boxes left in storage in ambient conditions displayed the greatest compressive strength. Boxes in room 1, which had the lowest humidity, were stronger than boxes in either of the other two rooms. Data for rooms 2 and 3, although not significantly different, indicate a slight difference in compressive strength in favor of room 3 even though the relative humidity in room 2 was lower. This was due to the leak in the duct system in room 2 causing warm saturated air to be pulled into the room and condense on the surface of the boxes. Rooms 1 and 3 remained free of condensate at all times.

Table 1. Compressive strength of corrugated fiberboard peach boxes stored under 4 different conditions for 7 wk.

Treatments	Storage room 1	Storage room 2	Storage room 3	Ambient Conditions
	lb.			
Inner facings sized	889 b[z]	599 a	696 ab	1432 d
Inner facings sized plus wax surface coated	909 bc	843 b	823 b	1381 d
Inner facings sized plus wax dipped	1477 d	1113 c	1263 cd	1905 e

[z]Mean separation by Duncan's multiple range test, 5% level.

The wax dipped boxes were stronger than the surface coated or unwaxed boxes in all 3 storage rooms. Surface coated boxes were slightly stronger than unwaxed boxes (15%) although the difference was not always significant. The average strength of the surface coated boxes was 67% of that of the dipped boxes. The dipped boxes stored in the 3 rooms also retained more of their strength when compared to boxes stored in ambient conditions. The unwaxed boxes were only 51% as strong as like boxes stored in ambient conditions compared to 62% for surface coated boxes and 68% for dipped boxes (Table 2).

Table 2. Percent of compressive strength retained by empty peach boxes after a 7-wk high humidity storage period compared to boxes stored under ambient conditions.

Treatments	%
Inner facings sized	51
Inner facings sized plus wax surface coated	62
Inner facings sized plus wax dipped	68

Compressive strength data for boxes which were packed with peaches during the storage period (Table 3) are similar to data for the empty boxes. However, in all cases the compressive strength of the boxes which had been packed was not as great as the strength of the empty boxes.

Table 3. Compressive strength of corrugated fiberboard boxes packed with peaches and stored under 3 diffrent conditions for 7 wk.

Treatments	Storage room 1	Storage room 2	Storage room 3
	lb.		
Inner facings sized	639 d[z]	437 a	568 bc
Inner facings sized plus wax surface coated	676 d	542 b	607 cd
Inner facings sized plus wax dipped	1199 g	946 e	1081 f

[z]Mean separation by Duncan's multiple range test, 5% level.

The unwaxed and surface coated boxes which were packed during storage also were not as strong in relation to the dipped boxes as were the empty boxes. Empty box data showed the average strength of the unwaxed and surface coated boxes to be 57% and 67%, respectively, of that of the dipped boxes. With packed boxes, unwaxed and surface coated boxes were only 51% and 57% as strong as the dipped boxes (Table 4).

The amount of sidewall bulge was measured at the point of box failure during the compressive strength tests for the empty boxes. These data are shown in Table 5. There is no correlation between box strength and sidewall bulge within

Table 4. Percent of compressive strength retained by unwaxed and lightly waxed peach boxes after a 7-wk storage period compared to boxes dipped in melted wax.

Treatments	Empty (%)	Packed (%)
Inner facings sized	57	51
Inner facings sized plus wax surface coated	67	57

Table 5. Side wall bulge at force required to cause failure in empty peach boxes stored under 4 different conditions for 7 wk.

Treatments	Storage room 1	Storage room 2	Storage room 3	Ambient Conditions
	inches			
Inner facings sized	2.0	1.8	1.8	2.4
Inner facings sized plus wax surface coated	1.4	1.7	1.3	1.5
Inner facings sized plus wax dipped	1.6	1.5	1.3	1.2

any storage condition or wax treatment, but the bulge of the surface coated and dipped boxes was less than that of the unwaxed boxes. The average bulge was 2 inches for the unwaxed boxes, 1.5 inches for the surface coated boxes and 1.4 inches for the dipped boxes. This indicates that the surface coated and dipped boxes retained more of their rigidity during the storage period than did the unwaxed boxes.

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MOISTURE LOSS AND JUICE QUALITY FROM WAXED AND INDIVIDUALLY SEAL-PACKAGED CITRUS FRUITS[1]

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Abstract. **Seal-packaging of individual fruit was effective in reducing moisture loss from oranges and grapefruit stored at 21°C and 5°C. During storage, the major change in internal quality observed for oranges and grapefruit was a reduction in acidity with the consequent increase in Brix:acid ratio. Acidity reduction was greater at 21°C than at 5°C and seal-packaging did not alter acidity reduction when compared to waxing. Although seal-packaging in polyethylene maintains the fresh appearance of citrus fruits during long-term storage at room temperature, it does not alter the rate at which internal acidity decreases. Thus, a problem with long-term storage of seal-packaged low acid citrus fruits may be the development of insipid flavors resulting from acidity reduction. The problem of acidity reduction may not be as apparent with waxed fruit because of the generally shorter shelf life.**

Transpiration (moisture loss) and respiration are processes which contribute most to the physiological deterioration of citrus fruits after harvest. Because moisture loss results in a rapid deterioration in the appearance of the fruit, more attention has been given to controlling transpiration than respiration. Waxes, along with high humidity and refrigeration, have traditionally been used to reduce moisture loss from fresh citrus fruits during transit and storage. Additional benefits are derived from refrigeration, such as reduced respiratory activity of the fruit as well as reduced invasion and growth of fungal pathogens. Sealing fruit individually in polyethylene film has been shown to be more effective than waxes in reducing moisture loss, especially under conditions of low humidity and nonrefrigerated temperatures (2, 3, 5, 7, 10). Thus, with longer storage periods at nonrefrigerated temperatures, respiration may contribute more than transpiration to the deterioration of seal-packaged fresh citrus fruits. In previous studies, sealing fruit in polyethylene film had no apparent effect on juice quality of 'Marsh' grapefruit (2, 10) and 'Shamouti' oranges (2) compared to waxed fruit stored at 20 to 21°C. The study reported here compares to effects of waxing and sealing in polyethylene film on moisture loss and juice quality of 'Marsh' grapefruit and 'Hamlin' oranges stored at 5°C and 21°C.

[1]Florida Agricultural Experiment Stations Journal Series No. 5173.

Materials and Methods

'Hamlin' oranges and 'Marsh' grapefruit were harvested from the groves of the Citrus Research and Education Center at Lake Alfred. The fruit were prepared for storage within 2 to 4 hr after harvest. All fruit were washed, dipped in a 600 ppm benomyl [methyl 1-(butylcarbomoyl)-2-benzimidazole-carbamate] suspension to minimize decay during storage and air dried. The fruit were randomized into lots and half were waxed with a solvent-type wax (Flavorseal, FMC). The remaining fruit were individually seal-packaged in 21.1 μm polyethylene film (Cryovac D-925) with a Cryovac Magna-Lok Edgeseal Machine (Cryovac Division, W. R. Grace & Co., Duncan, SC 29334) and the film was shrunk in a Cryovac Shrink Tunnel. Ten fruit from each treatment and storage temperature were numbered with a felt-tip pen and weighed at the start of each experiment and at predetermined intervals during the storage period. Storage room temperatures were maintained at 5°C $\pm$ 1°C and 21°C $\pm$ 1°C for the entire time. Relative humidity of the storage rooms ranged from 85 to 95%. All weighings were completed within 0.5 hr after the fruit were removed from storage and the fruit were returned to the storage rooms immediately after weighings. Weight loss is presented on a surface area and weight basis. Since most of the weight loss from fruit during storage can be accounted for by water loss (2), weight loss and transpiration here were considered synonymous. Surface area was calculated from polar and equatorial diameters.

At the end of the storage experiment, the juice was extracted from individual fruit of each treatment, weighed, and analyzed for °Brix with an Abbe refractometer (American Optical Corp., Buffalo, NY 14215) and for total acids by titration with standard NaOH using phenolphthalein indicator.