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Effect of Packing on Rot and Fruit Damage in Rio Red Grapefruit

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ABSTRACT

Citrus shippers receive complaints about poor fruit quality, referred to as 'delivery problems', that include any bruising, rots, or combinations of problems, which are seen on arrival, and result in unmarketable fruit. This fruit damage is not visible at time of shipping. The character of, or initial cause of fruit damage is not clear since shippers do not inspect the delivered fruit. To determine the source of damage to grapefruit, a packing and shipping interaction study, and additional packing studies were conducted. Unwashed fruit placed directly in boxes after harvest (field packed), without handling at a packinghouse, incurred less bruising and had equal or less incidence of green mold, caused by *Penicillium digitatum*, than fruit handled in packinghouses. Incidence of bruising did not differ significantly among the four packinghouses tested, but bruising was significantly lower in field packed control fruit. Differences in green mold incidence in fruit handled at different packinghouses were significant and became more apparent when fruit were shipped greater shipping distances. Bruising increased if fruit were shipped, but did not increase with distance. These results quantify the effects of fruit handling and demonstrate the importance of implementing recommended packinghouse practices in controlling delivery problems in citrus fruit. The results demonstrate that fruit damage occurs in the packinghouse, but is not visible until days later at market. Two follow-up studies conducted in 2003 confirmed the difference in fruit rot occurrence between packinghouse handled and control fruit.

RESUMEN

Las compañías empacadoras de cítricos reciben quejas sobre el arribo de frutos de pobre calidad, que presentan daños conocidos como 'problemas de envío' que incluyen golpes, pudriciones, o combinaciones de problemas y que son detectados al momento del arribo, y vuelven incomercializable a la fruta. Estos daños a la fruta no son visibles al tiempo del empaque. La naturaleza, o causa inicial del daño a la fruta no es clara ya que los empacadores no inspeccionan la fruta enviada. Para determinar el origen del daño de la fruta, se realizaron un estudio sobre la interacción entre empacado y transporte, y otros estudios adicionales sobre el empacado de la fruta. La fruta no lavada, colocada en cajas directamente después de la cosecha, sin procesarse en la empacadora (empacada en campo), presentó menos golpes y tuvo una incidencia similar o menor de moho verde, causado por *Penicillium digitatum*, que la fruta procesada en la empacadora. La incidencia de golpes no varió significativamente entre las cuatro empacadoras estudiadas, pero el maltrato fue significativamente menor en las frutas testigo empacadas en campo. Las diferencias en la incidencia del moho verde en la fruta procesada en las diferentes empacadoras fueron significativas y se volvieron mas aparentes cuando la fruta se envío a distancias mas lejanas. El maltrato aumentó cuando la fruta fue transportada, pero no se incrementó con la distancia. Estos resultados cuantifican los efectos de la manipulación de la fruta y demuestran la importancia de la implementación de prácticas recomendables en las empacadoras para controlar los problemas de transporte en frutos de cítricos. Estos resultados demuestran que el daño a la fruta ocurre en la empacadora pero no es visible hasta días mas tarde en el mercado. Dos estudios posteriores realizados en el 2003 confirmaron la diferencia en la incidencia de la pudrición de la fruta entre la fruta procesada en la empacadora y la fruta control.

Additional keywords: Grapefruit, citrus, green mold, Penicillium digitatum

Citrus growers and packers are concerned with unspecified fruit quality problems at delivery, that is, complaints about the condition of fruit on arrival at distant grocery stores or to gift fruit recipients. Fruit suffering a bruise, cut, or infection, during harvest or packing may, over the course of shipping, deteriorate to a level that the buyer can not readily define or describe the cause of the problem. When shippers receive complaints about the condition of fruit on arrival, there is no practical way to know the cause of the problem without inspecting samples of the delivered fruit. Fruit

may have been improperly handled, or receivers may complain in hopes of getting a reduced price. Since the shipper or grower can not see the fruit, they can not know the cause of the problem, and in fact, sometimes question if the fruit is really damaged. Grapefruit (*Citrus paradisi* Macf.) for the gift market bring premium prices, and it is beneficial to growers and shippers to maintain the quality and reputation of Texas grapefruit.

The predominant postharvest problems in citrus are: green mold, caused by *Penicillium digitatum* (Pers.:Fr.) Sacc.; sour rot, caused by *Galactomyces citri-aurantii* E. E. Butler (anamorph *Geotricum citri-aurantii* (Ferraris) Butler); blue mold caused by *P. italicum* Wehmer, and physical handling injury, including oleocellosis. *P. digitatum* is the most widespread and most serious postharvest fungal problem in citrus (Brown and Eckert, 2000, Snowdown, 1990). Infection occurs through injuries, more readily through cuts and cracks than abrasions (Snowdown, 1990). Incidence of green mold on one fruit in a box can degrade the quality of the entire box due to soiling and ethylene production. In the case of blue mold, nesting occurs, and infection of one fruit spreads to other fruit, again increasing losses (Snowdon, 1990). Postharvest disease control relies heavily on fungicide use in the packing shed (Snowdon, 1990). The influence of packinghouse design on disease incidence and fruit quality has been reported (Bancroft et al., 1984). Disease incidence is a function of inoculum density and number of wounds per fruit (Bancroft et al., 1984).

The objectives of this research were to characterize the problems that occur in shipped fruit and to determine the effects of packinghouse handling on fruit quality of 'Rio Red' Grapefruit.

MATERIALS AND METHODS

Experimental design was a split plot test, with packinghouses as main plot treatments, and outbound shipping destinations as sub plots. The outbound destinations differed in distance shipped, and length of time before fruit were observed. Control fruit were included for both packing and shipping. For comparison with the packinghouse treatments, control fruit were field packed without washing or fungicide treatment. For comparison with shipped fruit, control fruit from each packinghouse and the field packed control were held without shipping.

'Rio Red' grapefruit were harvested from the Texas A & M University-Kingsville Citrus Center in Weslaco, TX (Citrus Center). Control fruit were harvested and placed directly into forty-four 1/2 standard cardboard boxes designed to hold 18.1 kg of fruit. Remaining fruit were taken by truck in wooden fruit bins (61 x 119 x 119 cm) to one of four packinghouses. At the packinghouses, fruit were washed, graded, treated with commercial fungicides including thiabendazole (TBZ) and sodium *o*-phenylphenate (SOPP), and packed into 1/2 standard boxes, following the usual procedures for each packinghouse. Both packinghouse handled and field packed control fruit were then shipped to one of 10 cities, or as a control, not shipped. Fruit were shipped to destination cities and returned to Weslaco by a commercial package delivery service. Each treatment had four replications, that is there were four boxes of fruit for each combination of packinghouses, or field packed control and destinations and non- shipped control. This study was conducted in March and April, 1995.

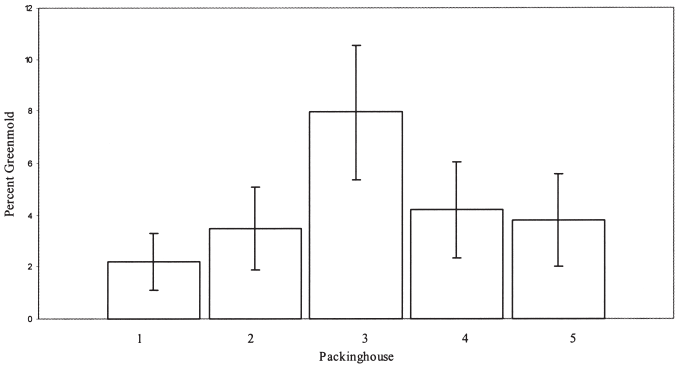

Fig. 1. Effect of Packinghouses 1 to 4 and field packed control, 5, on percent of fruit with green mold. Vertical lines represent 95% confidence intervals. Packinghouse 3 had higher green mold than field pack control fruit mean ($p=0.0504$), and was significantly higher than two of the other packinghouses, 1 and 2 ($p<0.05$).

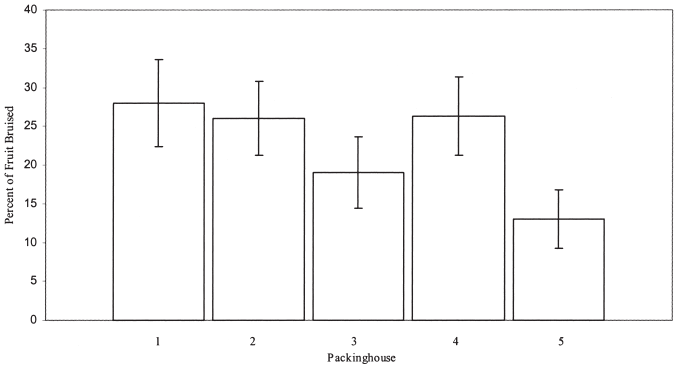

Fig. 2. Effect of packinghouses 1 to 4 and fieldpacked control, 5, on percent of fruit bruised. Vertical lines represent 95% confidence intervals. All of the packinghouses had significantly more bruising than the field packed control fruit at the 5% level using SAS PROC GENMOD. In the trials conducted in 2003, green mold was significantly less at the 5% level in control fruit than in fruit handled at Packinghouse 4 and held for an equal length of time ($Pr>F = 0.0392$, $Pr>ChiSq = 0.0329$).

Upon return, fruit were observed for incidence of green mold, sour rot, button damage, bruising, and dehydration within 24 hrs of return to the Citrus Center. Fruit with green, sporulating fungal infection, characteristic of *P. digitatum*, was considered infected with green mold. Fruit with water soaked bruising with no visible infection were considered bruised. Control fruit were observed 15 days after harvest, when fruit were returning from the most distant destinations. Fruit were held at ambient temperature.

Statistical analysis was performed on percentage of fruit with green mold, and percentage of fruit with bruising. Statistical analysis was conducted by a generalized, linear models approach with SAS PROC GENMOD to model a binomial response with a logit link function (Littell et al.,

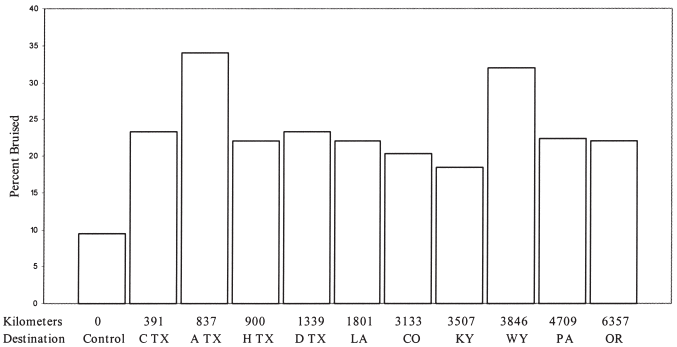

Fig. 3. Effect of shipping distance and destination on percent of fruit bruised. CNTL = control, not shipped, A TX = Austin, C TX = Corpus Christi, H TX = Houston, D TX= Dallas, WY= Casper, WY; CO = Commerce City, CO; PA = Harrisburg, PA; KY Louisville, KY; LA = New Orleans, LA; and OR = Portland, OR. Control fruit suffered significantly less bruising than shipped fruit.

2002). The presented means and 95% confidence intervals have been transformed back to the original scale of measurement for percent green mold or percent bruising. Paired comparisons were made among the packinghouse, least squares means using the PDIFF option.

To confirm the effects of the packinghouse handling, two additional studies of the effect of packinghouse on fruit decay were conducted in 2003. In the first study, Rio Red grapefruit from an orchard in Brownsville, TX were harvested on April 10, 2003 into wooden fruit bins (61 x 119 x 119 cm), transported to packinghouse 3, and packed in ½ standard boxes after the standard packinghouse handling that include washing, disinfecting, waxing and treating the fruit with fungicide. Control fruit were field packed in similar boxes but was not handled in the packinghouse. All boxes were stored at 21º C in a room at the Citrus Center. The number of total rotten fruit was counted over a period of four weeks. In the second study, Rio Red grapefruit from a Citrus Center orchard were harvested on May 5, 2003 into field boxes. In this case fruit were handled at packinghouse 2, and the assessment was the same as described above.

RESULTS

Packinghouse 3 had higher green mold than field pack control fruit mean ($p=0.01$) and was significantly higher than two of the other packinghouses, 1 and 2 ($p<0.01$), (Fig. 1). Packinghouses 1, 2, and 4 did not have significantly different green mold incidence than the field packed control fruit.

In the additional trials conducted in 2003, only packinghouse handling effects were considered. In both trials, green mold was significantly higher in packinghouse-handled fruit than in nontreated control fruit. Green mold was significantly less at the 5% level in control fruit than in fruit handled at Packinghouses 4 and 6 and held for an equal length of time ($Pr>F = 0.0392$, $Pr>ChiSq = 0.0329$). Grapefruit handled at all of the packinghouses had significantly more bruising than the field packed control fruit, (Fig. 2).

No significant interactions between packinghouse and outbound destination cities were found. Shipped fruit had more bruising than non-shipped, but distance shipped, or length of time in transit, did not have an effect on percent bruising, (Fig. 3).

Even after shipping, the field packed fruit remained in better condition than fruit handled in packinghouses. This was consistent for all shipping destinations, the non-shipped control fruit, and the additional trials conducted in 2003. Fruit handled at packinghouse 3 had especially high incidence of green mold decay (Fig. 1). This difference became more evident in boxes shipped to more distant locations, as would be expected as incipient infections became manifest with time.

Climate and length of time in transit account for the effect of shipping destination on green mold. Fruit shipped 2179 miles in temperate climate to and from Kentucky had 10% green mold, while fruit shipped 1947 miles in colder climate to and from Colorado had 4% green mold, and fruit shipped 832 miles to and from Dallas had 3% green mold. Non-shipped control fruit held at ambient temperature in Weslaco for the duration of the shipping trial had 18% green mold.

The gift fruit industry ships from south Texas via a combination of commercial trucks and UPS. When a truck loaded with gift fruit for the region arrives at a distribution node, the boxes go into the regular delivery routes. Use of commercial package delivery service in this study is representative of this form of commercial shipping.

DISCUSSION

These studies demonstrate that some fruit injuries and infections that occur during handling are not visible at time of shipment, and become manifest during shipping. Many preharvest factors, including rootstock, rainfall, fertilization, fungicide applications, and inoculum density in the field influence levels of postharvest disease in citrus (Eckert and Eaks, 1989). In each of these trials, all fruit were from the same field location and handled in the same manner, so differences in postharvest quality were due to handling at the packinghouses. The significant difference in quality in fruit handled at packinghouse 3 demonstrates the importance of packinghouse practices in achieving high fruit quality at delivery. The most important issues are avoiding wounding, and avoiding re-circulating *P. digitatum* and *P. italicum* spores from discarded fruit to fruit on the packing line, and sanitation on the packing lines, floors, storage areas. *Penicillium* infects wounds sustained during harvest and handling (Eckert and Brown, 1986). Others have shown that *Penicillium* decay in oranges is directly related to injury during harvest and packing (Christ, 1966).

From these results, it is clear that packinghouse practices strongly impact the quality of fruit on arrival at retail outlets. It is also evident that fruit were becoming infected with green mold at packinghouse 3 in particular. In South Texas, *P. digitatum* is abundant, and a continual problem. However, the volume of losses due to infection can be reduced by improved packinghouse practices. Recommended practices include prompt removal and burial of culled fruit, and avoidance of puncture wounds.

This study was originally designed to characterize and verify the type of arrival problems; specific packinghouse practices were not studied. The differences in quality of fruit handled by different packinghouses point to a need for better application of recommended practices by the industry. Good packinghouse design and packing line practices have been studied and reviewed by Eckert and Eaks (1989), and Miller et al. (2001) and specific packinghouse design and practices were studied by Bancroft et al. (1984) and Gardener et al. (1986). Our results are consistent with those reports and emphasize the importance of packinghouse practices in reducing delivery problems. Good practices include prompt removal of culled fruit, thorough and frequent cleaning of all equipment, floors and cold rooms, requiring workers to maintain short fingernails, or wear clean cotton gloves, and padding or removing sharp and hard surfaces that may damage fruit. In preliminary investigations prior to this study, one of the investigators observed workers mishandling fruit when they were not supervised.

Miller et al. (2001) discuss factors such as the speed of the packing line, removal of rotted fruit from the packing line early in the process, and wetting fruit before contact with brushes to reduce surface injury. Damage from brushes may not be visible during grading, but shows up days later at delivery. Another practice noted in this study and mentioned by Miller (Miller et al., 2001) is overfilling boxes. When too many fruit are forced into a box, the fruit become flattened on one side and bruised. When additional boxes are stacked on top of an over filled box, additional damage occurs. Boxes are over-filled to avoid an appearance of a deficient amount of fruit. It was also evident that too many fruit have been forced into the $^1/_2$ standard size boxes, causing bruising, and avoidable damage. Frequently, fruit were flattened on one side against the side of the box. This was significant in control fruit that were handled at packinghouses, but not shipped. In comparison, the field packed control fruit were not misshaped and bruised.

Since field packed fruit received no fungicide, these results also demonstrate that use of fungicides is a less effective green mold control than careful handling. In addition to the wounding and damage that occurs with handling, washing may remove some natural biological competitors. An integrated approach to postharvest disease control including conscientious fruit handling, meticulous sanitation, judicious fungicide use, and biological control agents should result in greatly improved fruit quality at delivery and fewer complaints.

Bruising was increased by shipping, but not influenced by distance shipped. The effect of shipping destination on green mold can be explained by time en route and climate of the destination. Fruit held at Weslaco at ambient temperature for the duration of the trial showed the highest percentage of green mold. This was most obvious in fruit from packinghouse 3. Fruit shipped to Kentucky developed green mold on many fruit compared to fruit shipped to other destinations. This was likely due to warmer temperatures en route than to Colorado, Wyoming or Oregon, and the longer distance than to Louisiana and Texas destinations. Fruit handled at packinghouse 3 were the most vulnerable to these shipping effects.

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