EVALUATION OF MECHANICAL DAMAGE TO CITRUS

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INTRODUCTION

Mechanical injury is one of the major causes of losses in fresh citrus harvesting and packing operations. Brown (1), in a review of fruit handling and decay control techniques, emphasized the importance of careful handling of citrus fruit to ensure good keeping quality. Injuries caused by rough handling provide ports of entry for decay-causing organisms resulting in fruit decay in marketing and distribution channels

When producing citrus fruit for the fresh fruit market, pack-out is extremely important in determining grower and packer returns (4). Pack-out can be maximized by reducing defects and blemishes caused by insects, diseases, green color, wind scars, plugging, chemical peel injury and any other factor which may detract from acceptable fruit quality. These factors may be controlled in the grove during fruit growth and development using appropriate cultural practices to improve fruit appearance, and thereby increase pack-out. Mechanical damage to fruit during harvesting and on the packinghouse line can be more serious than grove-induced blemishes and defects. The impact of the latter is usually manifested as decay at wholesale and retai outlets or in the hands of the consumer. This usually lowers grower and packer returns due to price adjustment, reduced sales and loss of customers, which is difficult to measure and more difficult to overcome. It is, therefore, important that fruit injury caused by abrasion, dropping or shearing of fruit during harvesting and in the packinghouse be minimized to reduce decay and assure good arrival quality. The key to such reduction is careful evaluation of harvesting, handling and packing procedures. This must be followed by taking the necessary corrective measures to ameliorate those conditions which lead to fruit injury

In the previous presentation on packinghouse design and machinery considerations, various causes of fruit injury during packing were discussed. This presentation is aimed at introducing methods of detection and evaluation of mechanical injury to citrus fruit. Greater emphasis will be placed on fruit staining procedures, especially that using 2,3,4-triphenyl-2H-tetrazolium chloride (TTC).

Predicting Mechanical Damage During Harvest

One of the most common problems encountered by fresh citrus packers is spotting due to mechanical injury of early-season fruit. 'Navel' orange and lemons are susceptible to oi spotting also known as oleocellosis, when harvested in wet conditions created by rain, overhead irrigation dew or fog

Oleocellosis is caused by release of oil from ruptured oil glands resulting in irregular shaped spots. The spots are green or brown depending on fruit maturity. If fruit must be picked when wet, extreme care should be exercised during harvest to minimize mechanical damage. Humidity during degreening must also be maintained above 95%, to reduce enlargement and discoloration of injured spots

To assess the potential for mechanical injury to navel orange or lemons during harvest, a preharvest pressure test (10) may be conducted using a spring-loaded tester with a 3/8 inch cylindrical tip. The tip is pressed gently against the peel until peel oil is released. A small piece of absorbent tissue paper is placed near the tip to indicate the release of oil If the oil glands are ruptured and oil.is released at less than 3 pounds of pressure, harvesting will lead to severe oil spotting. f rupture of oil glands occurs at 3-7 pounds, extreme care must be exercised during harvesting to reduce fruit damage. Normal harvesting procedures are followed if the force required to rupture oil cells exceeds 7 pounds.

Methods of Mechanical Injury Assessment

The ultimate method of evaluating harvesting, packing and shipping operations for damage to citrus fruit is by monitoring fruit quality in the marketplace. Fruit must not be excessively bruised, deformed or decayed. Simulated shipping tests may be conducted in the packinghouse by holding samples of packed fruit at $70^{o}F$ for 1-2 weeks and examined for appearance, shape and the type and extent of decay. This method, however, is lengthy, not too specific and requires relatively large temperature controlled storage facilities.

Other specific methods of citrus fruit injury assessment include

1. Measuring CO_2 production.
2. Weight loss measurement.
3. Staining of injured surfaces.

CO_2 Production As An Indicator of Mechanical Injury

Mechanical injury to citrus fruit increases the rate of respiration Both oxygen consumption and CO_2 production are increased in injured fruit as compared to sound fruit. Parker et al. (7) assessed the damage incurred by citrus fruit in a Florida packinghouse by measuring CO_2 production of fruit taken off various points of the line using a portable infrared analyzer. Tl procedure involves weighing fruit samples and holding them in sealed plastic containers at constant temperature (approximately 68^{o}F). Readings are taken over a period of 10 hours and expressed in terms of mg/kg fruit/hour. An increase in CO_2 production over that of control samples is an indication of increased mechanical injury. A copy of Parker's paper is included in this shortcourse proceedings

Specific Weight Loss As An Indicator of Mechanical Damage

This method is based on the principle that severely injured fruit will lose weight and, thus, dehydrate at a faster rate than slightly injured or sound fruit. A high correlation between specific weight loss (grams per cm^2) and the degree of mechanical damage was reported

Sampling points along the packinghouse line are chosen where mechanical damage needs to be evaluated. These may include the dumper, before washing, after washing, after drying or color adding... etc. Twelve to fifteen fruit, taken at each sampling station, are stored for 24 hours at 21^{o}C (70^{o}F) and 70% rh. This initial period stabilizes the rate of moisture loss by the fruit at the above standard storage conditions. The surface area of eight generally wholesome fruits, chosen from the sample of 12 to 15 fruit is then measured and calculated, assuming ellipsoidal fruit shape. Each fruit is then weighed by a precision scale and the ratio of its weight to surface area is computed. After a holding period of 24 hours, the fruit is weighed and the difference between the weight-to-surface area ratios after 24 hours is recorded for each sampling station. Greater specific weight loss indicates higher incidence of mechanical injury.

Although the specific weight procedure appear simple, it is time consuming and requires a temperature and humidity controlled room and an accurate and expensive scale. Errors may also be generated in the surface area measurement due to the odd shape of citrus fruits. The data must also be statistically analyzed to assure correct interpretation of results.

Staining Procedures for Detection of Mechanical Injury

Use of chemical dyes and pH indicators for detection of surface injuries is usually easy to perform and can provide objective evaluation of harvesting and packing practices in a relatively short time. Severe damage, e.g., crushing of fruit during harvesting and hauling may be evaluated using sheets of filter paper saturated with alkaline solution of methyl red (3). The paper changes color from yellow to red when it contacts citrus juice. This method is suitable for assessment of fruit damage which may occur in pallet boxes or semitrailer. Less severe injury can be evaluated using filter paper treated with alkaline alcoholic solution of phenolphthalin. When the paper comes in contact with peel oil from injured fruit, its color changes from red to lemon yellow. Details of these two procedures have been described by W. Grierson in circular S-102. A copy of the circular is included in the shortcourse proceedings

Another procedure which is easily adaptable in the packinghouse for evaluation of mechanical injury to citrus fruit is by using triphenyl tetrazolium chloride. TTC is a water soluble powdery substance which becomes insoluble and turns bright red when it comes in contact with living tissue. Bruises and minute surface scratches can be detected by this procedure. It was first used on citrus fruit for surface injury detection by Roistacher et al. (9) and later on by McCornack (6). It is easily carried out at room temperature (75-80°F) and does not require expensive or sophisticated equipment. We have used it repeatedly on 'Robinson' tangerines with good results and it is routinely used by Sunkist Growers, Inc. for evaluation of California citrus packinghouse machinery. The only difficulty which may be encountered using the TTC method is the need for statistical evaluation of the data using the analysis of variance (ANOVA) procedure. However, with the availability of sophisticated hand held calculators and desk top personal computers, it should not be difficult to apply the ANOVA to the data for objective interpretation of results.

The following is a description of the TTC procedure.

1. In a clean plastic jug, prepare 0.5% TTC[1] solution by dissolving 19 g (approximately 13 level teaspoons) in a gallon of water.
2. Collect four samples of 15-25 fruit off the packinghouse line at points where damage evaluation is needed. These points may include the degreening room, the dumper, before washing, after washing and rinsing, after color-adding, after drying, but before waxing (wax seals injured surfaces and interferes with reaction of TTC with injured tissue). Unwashed fruit must be gently washed with a sponge or rag.
3. Place fruit in plastic dish pan, approximately 10 x 12 inch.
4. Fill dishpan with TTC solution to cover fruit.
5. Submerge fruit for 30 minutes.
6. Pour TTC dye back into container.
7. Refill dishpan with tap water to cover fruit and hold for 5 minutes.

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1 2,3,5-Triphenyl-2H-tetrazolium chloride may be obtianed from Aldrich Chemical Company, Inc., 940 West Saint Paul Avenue, Milwaukee, Wisconsin 53233.

8. Place fruit in double layers of brown paper bags for a minimum of 8 hours at room temperature (approximately 75-85^{o}F). Label each bag with sample code or location off the packing line
9. Evaluate amount of stained injuries on fruit, placing them in sound, slight, moderate, or severely injured categories. Calculate percentage of fruit in each category.
10. Analyze data statistically using analysis of variance (ANOVA).

If the calculated F value for a given level of injury caused by a specific harvesting or packing point exceeds that of the F table at the 95% level, the injury caused by this particular handling or packing step is considered statistically significant. If the F value is lower than the table value, the injury is not significant.

Staining with TTC should be conducted at least twice a year and following installation of new equipment or modification of the packing line and when different varieties are being packed. Results should be saved for future reference.

Conclusion

Preservation of quality of fresh citrus fruits is best achieved through gentle harvesting and packing. Mechanical injury can be objectively evaluated using different procedures, one of which is staining with triphenyl tetrazolium chloride. This procedure should be conducted at least twice a year on various segments of the packinghouse line when various varieties of fruit are being packed.

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Circular S-102 February 1958

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Indicator Papers for Detecting Damage To Citrus Fruit

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A constant problem in fruit handling is the detection and elimination of mechanical damage. Mechanical damage invariably results in increased losses from decay, causing marketing problems with fresh fruit and serious quality control problems in juice and concentrate plants.

The usual method of locating the points at which mechanical damage occurs is by taking successive samples throughout the various stages of the fruit handling operation. Such samples have to be carefully examined for mechanical lesions and/or held for decay studies. A method recently developed in California (*3*) has provided a valuable tool for the detection of injuries on such fruit samples. In this method the fruits to be examined are soaked in a very dilute solution of 2, 3, 5-triphenyl-2H-tetrazolium chloride for approximately 15 hours. "TTC" is a colorless solution that stains a deep red wherever it encounters the enzymes of a living cell. Thus every lesion, no matter how small, becomes clearly visible.

The "TTC" method is cumbersome in that a large number of samples have to be taken and treated in order to locate even the major source of injury. In studies such as led to the recently developed bulk handling methods for fresh citrus (*1*, *2*) this can be very onerous. A quick method of locating the general areas of fruit damage would greatly facilitate such studies by limiting the detailed sampling to those areas or operations in which the damage is known to occur. Such a method has been developed in connection with bulk harvesting operations, although its possible applications extend to any operation in which citrus fruit is handled in quantity.

In the new method, indicator papers are used that change color when in contact with citrus juice or peel oil. Papers that will react colorimetrically with juice are easily devised since citrus juice is invariably acid. In the first study of this nature, the interior of a bulk fruit truck was covered with a pattern of indicator papers, principally filter papers soaked in an alkaline solution of methyl red. Such papers turn from brilliant yellow to red when moistened with juice. The results of this study are shown in Figure 1. It had been conjectured that the damage was occurring against the sides of the truck, against the front end of the truck body and at the bottom of the load behind the rear axle as the load jolted some twenty-five miles along an uneven concrete road. As examination of the results in Figure 1 shows these conjectures were almost entirely faulty. The stains

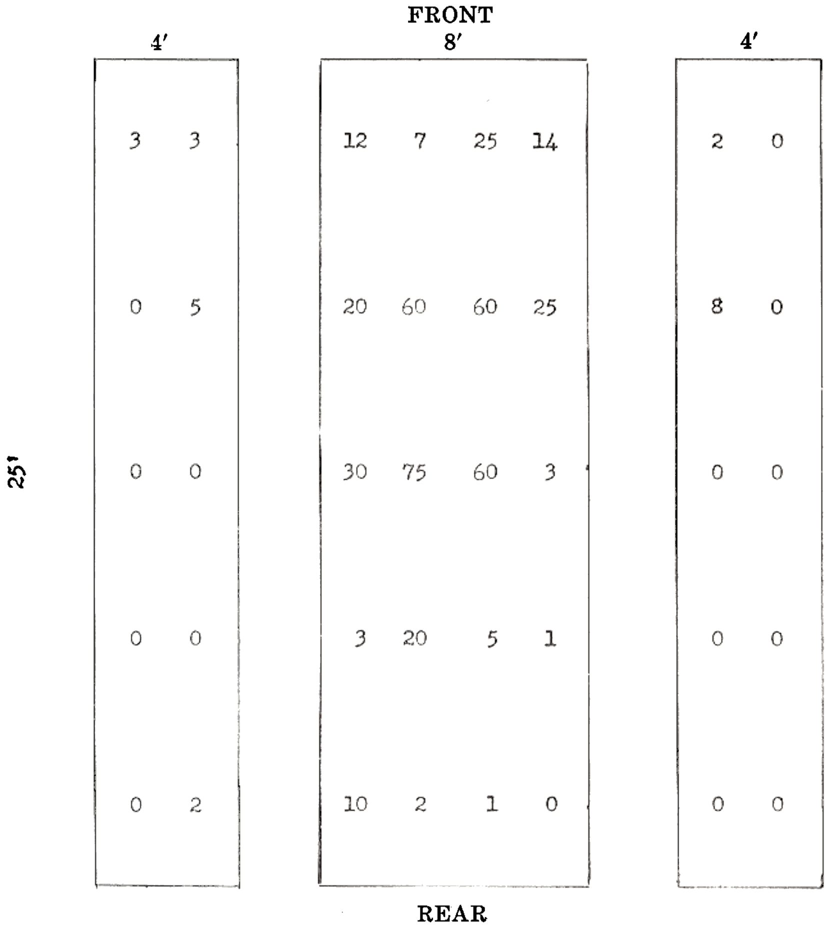

Fig. 1.—Fruit damage in a bulk truck as indicated by pH sensitive indicator papers. The rectangles represent the two sides and bottom of the truck. The numerals indicate the area of each indicator paper (expressed as percent) showing a juice reaction. This truck body was a double axle semi-trailer.

on the indicator papers indicated that fruit was being crushed at the forward end where loading started and down the center of the load where fruit was piled much deeper than at the sides. These troubles are being corrected with re-designed baffles to break the fall of the fruit in the initial loading and an improved loader chute to distribute the load more evenly across the truck (*4*).

Only gross damage can be detected by indicator papers depending on pH reaction alone. More subtle damage to citrus fruit takes the form of oleocellosis due to injury by peel oil released in the rupturing of the epidermal oil cells. Hence it became necessary to find a colorimetric reaction for peel oil. Such a reaction became available when it was found that freshly extruded peel oil turns filter paper treated with alkaline alcoholic solution of phenolphthalein from red to lemon yellow. The reaction is virtually instantaneous and the color contrast is excellent. However, the paper also reacts to juice, turning white, and the lemon yellow areas become difficult to detect. This becomes less of a problem if the paper is also treated with an oil soluble blue dye. In this case contact with peel oil turns the indicator paper from purple to green or chartreuse while contact with juice changes it from purple to pale blue and a reasonable contrast still prevails.

The following method of preparing indicator papers may be quoted as typical, although a variety of dyes and solvents can be used:

Preparation of Indicator Papers

Solutions "A" and "B" are first prepared and then combined with water to form the final dye solution, "C".

Solution A

Phenolphthalein powder	1.5 grams
Sodium hydroxide	1.5 grams
Isopropanol	150 ml.

Solution B

Oil Soluble Victoria Blue	.25 0.~~75~~ grams
Acetone	100 ml.

Solution C

Solution A	150 ml.
Solution B	100 ml.
Water	250 ml.
	500 ml.

Soak filter papers or chromatography paper for five minutes and then hang up to dry. These indicator papers are not perfectly stable and hence should not be prepared more than three months prior to use and should be stored in a light-tight container.

Bond paper, mimeograph paper, newsprint etc., cannot be used without pretreatment. Soaking in one percent sodium hydroxide and air drying will condition such papers so that they will take up the indicator solution without color change, but the result is not as satisfactory as when filter paper is used.

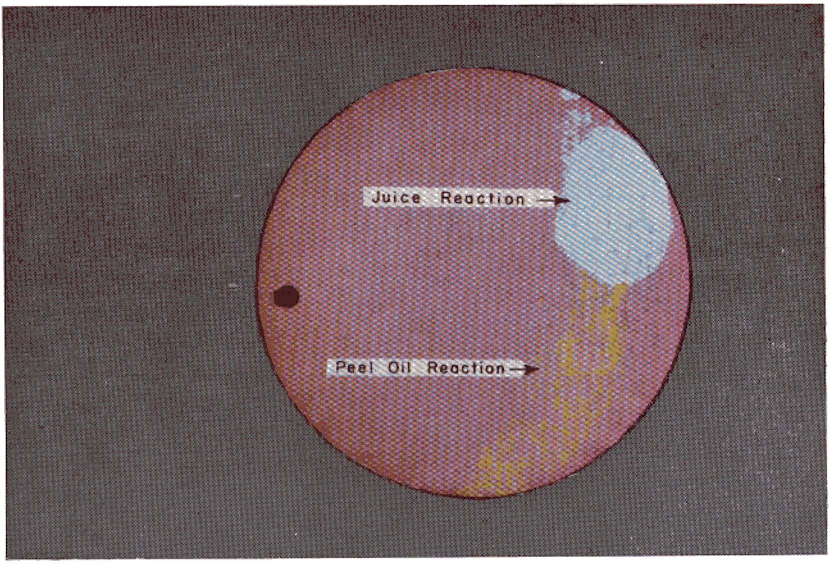

Fig. 2.—Typical color reactions on a two-way indicator paper. (Photograph by Harriet Long.)

Figure 2 shows peel oil and juice reactions on one of these indicator papers. The two types of reaction can be discerned both in terms of color and of pattern. The typical pattern for extruded peel oil is a series of small dots where individual oil cells have been ruptured. Juice tends to form larger blotchy areas. Conditions when juice is released are comparatively rare, so it is felt that the peel oil reaction is by far the most valuable attribute of this method.

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