thus avoided extensive freeze damage as would have been expected of temp in the upper teens and low twenties. LFP were not as low in Tavares and Bartow as in Gainesville but trees at Tavares and Bartow did acquire greater cold acclimation during the 1976-77 winter as indicated by lower LFP values this winter than in previous studies using similar location (9). Furthermore, no leaf damage occurred at any location, even though min temp of −5°C (23°F) to −7.2°C (18°F) were frequent during the coldest nights of the winter.

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A NEW APPROACH TO JUICE YIELD LOSS IN ORANGES FOLLOWING FREEZING WEATHER

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Additional index words. citrus, freeze damage calculation, crop insurance.

Abstract. **A new objective method of calculating yield loss in crops of oranges due to drying is presented. The method utilizes test house extraction data and historical non-freeze year yield data for the crops. Yield loss calculations by the new method are compared to yield loss values determined by USDA Federal Crop Insurance Crop adjusters using the dryness cut method. This study covers a total of 375,866 90 lb (40.9 kg) boxes of early midseason and late varieties harvested and delivered to Florida processing plants after the January 1977 freeze.**

The new method may overcome 4 limitations of the dryness cut method. When variability of the dryness cut losses were compared to the variability of the calculated losses for the same crops, the dryness cut method showed significantly more variability at the 99.9% level.

Citrus fruit left on the tree exhibit loss of juice by drying as a result of freezing weather. Consequently, freezing weather can result in serious economic losses to the grower. The equivalent of approx 1/3 of Florida's citrus crops were lost due to the 1977 freeze. The USDA administers the Federal Crop Insurance Corp. (FCIC) to alleviate these losses for participating growers. FCIC adjusters are responsible for evaluating crop losses due to freezing. Freeze damage and crop loss has long been estimated by the dryness cut method (1) although its exact origin is unknown. Westbrook (6) lists an excellent bibliography of early work on frozen citrus fruit. The dryness cut method of evaluating frozen fruit is specified for use by USDA-FCIC adjusters (5) and also for use by Florida Department of Agriculture Inspectors (3, 7) in determining U.S. grades of oranges (4) for shipment to the fresh fruit markets. The dryness cut method has the following serious limitations:

1. It is open to subjective errors such as: (a) visual estimation of depth of cut, 1/4, 1/2, or 2/3 of the distance from the stem end to the blossom end or 1/4, 1/2, or 3/4 inch at the stem end, and (b) visual estimation of the extent of internal dryness at the cut surfaces (2, 4).
2. Required manual contact and visual appraisal of each fruit is time consuming and fatiguing.
3. Sampling is often done in the grove under widely varying conditions which precludes the more representative mechanically drawn sample associated with the test house analysis.
4. Training of new personnel and retraining old personnel at the occurrence of an infrequent freeze is a problem

[1]Cooperative research of the Florida Department of Citrus and the University of Florida, IFAS, Agricultural Research and Education Center, Lake Alfred, Florida.

[2]The authors acknowledge the helpful review suggestions of Dr. B. A. Eagerman in simplification of the equation.

because accelerated harvesting increases demands on the time of personnel.

Cognizant of the above limitations, the USDA-FCIC in April 1977 commissioned an internal research group to investigate alternative methods of determining juice loss in Florida citrus. Members of this research group subsequently met with representatives of the Florida Department of Citrus and the Univerity of Florida, Institute of Food and Agricultural Sciences, Agricultural Research and Education Center at Lake Alfred. As a result of this meeting, the basis of the equation (Fig. 1) was conceived and the authors initiated this study. The purpose of this paper is to describe a new and improved approach to determining crop or juice yield loss from freezing. This approach utilizes an equation and requires only data from test house load certificates to calculate the percent juice yield loss due to freezing.

PERCENT JUICE YIELD LOSS EQUATION

$$C = 100\left(\frac{90\,(B - A)}{B\,(90 - A)}\right)$$

Where:
A = Pounds of pulp and peel in 90 lbs prefreeze fruit.
B = Pounds of pulp and peel in 90 lbs postfreeze fruit.
C = % juice yield loss, calculated.

Fig. 1. Percent juice yield loss equation.

Materials and Methods

Scope of the study. This study covers 375,866 boxes of early, midseason, and late season oranges from crops insured by the FCIC. The fruit was grown in 9 Florida counties by 57 growers and harvested, during a period beginning with the January 20 freeze and continuing to July 1977, for delivery to various processing plants in the state. Within a few days prior to harvest of each crop covered in this study, a FCIC adjuster evaluated the crop for percent yield loss using the traditional dryness cut method (5). A total of 17 adjusters were used to evaluate the crops in this study. When the crops were delivered to the processing plants, samples were drawn mechanically from each load and analyzed as required by law (3). This analysis includes determining the lbs. of juice per 90 lb. box (lbs. of pulp and peel = 90 lbs. minus lbs. of juice). Crop sizes and the mean are shown in Table 1.

The equation. The authors developed the equation to arrive at an estimate of juice yield percent loss due to freezing when only post-freeze total fruit wt and yield data are known together with an historical non-freeze yield record of one or more of the previous 4 seasons for a particular grove.

Comparison shows the December 1976 pre-freeze USDA estimated yield of the study season to be normal to the December estimated yields for the 4 previous seasons (2). It is thus presumed that only the January 1977 freeze produced the loss of yield measured in the study.

A problem with test house yield information on freeze damaged oranges is that it is based on a 90 lb. "equivalent box" (3). Of course, 90 lbs. of moderately dry freeze damaged oranges will occupy more vol than the 2.23 bu (4800 cu in)[3] of the "equivalent box." If a freeze damaged crop weighs 90,000 lbs., the certificates of inspection list the number of boxes at 1,000 even though the fruit may actually fill 1,200 or more "equivalent boxes." The authors have assumed these 1,200 boxes occupy about the same vol as before freezing and drying. Likewise, the pulp and peel in an individual orange weigh about the same after freezing and juice loss by drying as before freeze damage. Only juice wt is presumed to change significantly (this is the basis of the equation). Thus by use of two values (1) an historical yield value for the grove, typical of the wt of pulp and peel in 90 lbs. of non-frozen fruit and (2) the wt of pulp and peel in 90 lbs. of frozen fruit from the same grove. The percent loss of juice yield in a crop received for processing can then be objectively determined by using the equation (Fig. 1). The derivation of the equation is shown below.

Table 1. Statistical analysis of data.

Adjuster	No. of crops	% Cal/% Dry ratio* Mean	SD	CV%	90 lb Boxes freeze damaged fruit
E	4	.619	.146	23.6	65,978
P	3	.743	.206	27.7	9,528
F	5	.572	.096	16.8	10,828
D	15	.749	.227	30.3	79,074
J	2	.915	.134	14.7	3,817
K	2	1.477	.810	55.1	12,079
S	3	.858	.207	24.2	11,072
T	4	.898	.488	54.3	29,160
G	5	.907	.119	13.1	20,865
N	5	.961	.188	19.5	18,855
V	2	.739	.086	10.9	5,326
W	2	.783	.147	18.8	40,448
I	1	.742	—	—	6,254
B	1	.404	—	—	40,947
L	1	.708	—	—	10,624
M	1	.476	—	—	10,910
R	1	.709	—	—	101
Mean —	—	.742	0.291	39.2	22,109
Total 17	57	—	—	—	375,866

*% Cal/% Dry ratio found by dividing the mean of the values calculated by the equation by the mean of the values obtained by the dryness cut method for each adjuster. A ratio of 1.000 would indicate perfect agreement between the means of all calculated values and dryness cut values for an adjuster. A ratio of .749 indicates that the calculated loss percent is about 75% of the dryness cut loss percent.

Derivation of the Equation

Desired: An equation to calculate juice yield loss due to freezing.

(1) $$\% \text{ Loss} = 100\,\frac{x}{y}$$

Where:
x = Wt of juice loss from pre-freeze total wt of 90 lbs. post-freeze fruit.
y = Pre-freeze juice wt of 90 lbs. of post-freeze fruit.
Let: A = Pounds of pulp and peel in 90 lbs. pre-freeze fruit.
B = Pounds of pulp and peel in 90 lbs. post-freeze fruit.
c = % juice yield loss, calculated
Then:

(2) $\frac{B}{A}$ = Ratio of pulp and peel in 90 lbs. post-freeze fruit to pulp and peel in 90 lbs. pre-freeze fruit

and

(3) $90\frac{B}{A}$ = Pre-freeze equivalent wt of 90 lbs. post-freeze fruit

and

(4) $90 - B$ = Juice yield from 90 lbs. post-freeze fruit

(5) $\frac{90 - A}{90}$ = Pre-freeze juice fraction

and

[3]For metric conversions see Table near the front of this volume. Ed.

(6) $$y = \left(90\frac{B}{A}\right)\left(\frac{90-A}{90}\right)$$

and

x is expressed in terms of (3), (4), & (5),

(7) $$x = \left[\left(90\frac{B}{A}\right)\left(\frac{90-A}{90}\right)\right] - (90-B)$$

Substituting (6) & (7) in (1),

(8) $$C = 100\left[\frac{\left(\frac{B}{A}(90-A)\right)-(90-B)}{\frac{B}{A}(90-A)}\right]$$

Simplifying:

(9) $$C = 100\left[\frac{\left(\frac{90B-AB}{A}\right)-90+B}{\frac{90B-AB}{A}}\right]$$

Multiplying by $\frac{A}{A}$:

(10) $$C = 100\left(\frac{90B-AB-90A+AB}{90B-AB}\right)$$

Simplifying:

(11) $$C = 100\left(\frac{90B-90A}{90B-AB}\right)$$ and

(12) $$C = 100\left(\frac{90(B-A)}{B(90-A)}\right)$$

Results and Discussion

Using historical test house yield data from one or more of the previous 4 seasons and the test house yield data for fruit harvested after damage by the January 1977 freeze, the equation was applied to all crops of this study. A ratio of the mean percent calculated juice yield loss to the mean percent juice loss using the drynes cut method is presented in Table 1 for the crops evaluated by each FICI adjuster together with a statistical comparison of values among adjusters.

The mean of the ratios for all crops was 0.742 which indicates the calculated losses averaged 74% of the dryness cut losses. Another way of expressing this is to say the dryness cut losses averaged 35% greater than the calculated losses.

This study points up the variability of averages among adjusters using the subjective dryness cut method as compared to the objective calculation using the equation. For example, some adjusters' dryness cut values closely approximated the loss values calculated by the equation. Calculated values for 5 adjusters representing 23% of the fruit in the study averaged 86 to 96% of their reported dryness cut losses averages.

Calculated values for 4 other adjusters representing 36% of the fruit in the study averaged 40 to 62% of their reported dryness cut loss averages.

In an example of extreme variation, calculated values for one adjuster representing 3% of the fruit in the study averaged 148% of his reported dryness cut loss.

Coefficients of variability (CV%), the standard deviation divided by the mean X 100%, of ratios among adjusters ranged from a low of 10.9 for one adjuster of 2 crops to a high of 55.1 for an adjuster also of 2 crops.

To compare the variability of the calculated values and the dryness cut values, the values for both methods were analyzed statistically for all crops evaluated by each adjuster. Coefficients of variability for the dryness cut values were significantly greater at the 99.9% level than the coefficients for the calculated values of the same crops. Thus, it is apparent that the dryness cut method used by adjusters was more erratic or varied more widely than the calculation by the equation.

Conclusion

The equation offers an improved objective method of calculating yield loss because it is based on juice actually squeezed from a mechanically drawn random sample, approx 0.1% from each load harvested. Using the wt of pulp and peel in the samples of frozen fruit and a multi-year average yield for the grower, the post-freeze sample wt can be compared to the pre-freeze wt of each sample by use of the equation. Use of the equation avoids 4 serious limitations of the subjective dryness cut method of yield loss evaluation. However, losses of fruit fallen to the ground would still require limited on site evaluations.

This study shows this new approach to determining juice loss has practical application for Florida oranges. An expanded field testing program will be initiated by the FCIC for the 1977-78 crop year in the event freezing conditions occur. The dryness cut method and the new approach will be compared directly for accuracy and efficiency in a selected county. Continued confidence in the results of the field trials would result in a pilot program in 2 or more counties the following crop year.

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