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A DAMAGE TEST FOR ORANGES IN A COMMERCIAL PACKINGHOUSE LINE[1]

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Abstract. **A relatively rapid means for assessing physical damage to apples developed at Michigan State University was examined as a possible means for determining the sources of damage to oranges in a commercial citrus packinghouse line. The procedure utilizes increases in carbon dioxide (CO_2) evolution during the first few hours following injury as an indication of damage level. Very mature 'Pineapple' oranges harvested in February, 1984 had up to a 25% increase in CO_2 as a result of passing over the packinghouse line. 'Valencia' fruit placed on the beginning and removed at the end of various line operations during a commercial run of 'Marsh' grapefruit yielded a damage response during all operations except waxing. The CO_2 increases ranged from 24 to 59% over nontreated fruit for the dumping, washing, sorting, drying after waxing, transferring, conveying and sizing operations.**

Although much of the physical damage that occurs to citrus fruit during handling and marketing is not readily visible, it may result in considerable degradation of market quality and loss of economic value by the time the fruit reaches the consumer. Damage evident as surface lesions and/or leakage of peel oil and juice can be evaluated by time-consuming visual examinations with the use of detector papers (2) and 2,3,5-triphenyl-tetrazolium chloride (TTC) (4). A physiological test for damage was suggested by Eaks (1) in 1961 whereby bruising caused by dropping or compression is measured by a stimulation in CO_2 production by the fruit. This procedure has not been utilized in a commercial application, probably due to the complexity of the CO_2 collection process. A simplified procedure for measuring the CO_2 response of damaged apples (unpublished results by D. H. Dewey, J. D. Klein and M. L. Parker, Michigan State University) consists of holding small samples of fruit within airtight plastic containers at room temperature for several hours. Then the accumulation of CO_2 in the atmosphere of the airtight containers is quickly analyzed by means of a portable CO_2 analyzer. The CO_2 evolved by damaged fruit, relative to that of nondamaged fruit, provides an indication of the occurrence and extent of damage. The purpose of this study was to evaluate possible applications of this procedure for detecting sources of fruit damage in a commercial citrus packinghouse line.

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[2]Retired

Materials and Methods

A preliminary trial was made with very mature 'Pineapple' oranges (harvested February 1984) by random removal of fruit from a packinghouse line during a commercial run. Nontreated samples of fruit taken from the bins prior to dumping served as the control. Fruit were removed from the line as they passed through various line operations throughout the system for the first experimental run. In subsequent experiments individual line operations were examined using preselected February and March harvested 'Valencia' orange fruit inserted before an operation and removed immediately after the operation during commercial runs of 'Marsh' grapefruit. The control or nontreated fruit were handled similarly to the treated in every respect except for insertion and removal at the line operation being evaluated. Some of the characteristics of the operations are listed in Table 1. In the first test with 'Valencia' oranges, the fruit were selectively harvested by clipping on the previous day and carefully handled. In the second, the fruit were carefully selected from the upper portion of commercially harvested bins in the holding yard, just prior to the experiment.

Table 1. Observed characteristics of the citrus packinghouse line operations examined for their effect on the evolution of CO_2 by 'Pineapple' and 'Valencia' oranges.

				Drops	
Line operation	Duration of travel (sec)	Distance of travel (m)	Directional transfers (no.)	Less than 15 cm (no.)	15 cm and greater (no.)
Dumper	35	9.1	1	0	1
Washer	46	11.9	0	3	1
Grader A	18	10.1	1	0	1
Grader B[z]	198	56.7	9	2	7
Waxer	33	3.4	0	0	0
Dryer	96	13.7	0	0	2
Post-dryer drop	5	2.4	1	0	1
Master sizer	15	6.1	0	0	1

[z]Grader B is similar to Grader A plus lengthy conveying attachments and a water type frozen fruit separator (5).

Following treatment, always within 1 hr of starting a test, 8 fruit were placed in each of 4 plastic freezer containers of 6-liter capacity and immediately sealed with airtight snap-on lids. The closed containers were carefully transported to a laboratory where they were weighed and placed at 20±1°C. Analysis of CO_2 in the container headspace was made 6 hr (selected as representative from preliminary data not shown, but taken as a time course over a 10-hr period) after closure using gas samples drawn through fitted needles of the intake and exhaust lines of the analyzer (A.D.C. Carbon Dioxide Analyser, The Analytical Development Co. Ltd., England) inserted into the containers through electrical tape covering two 1-cm holes in each lid. The atmosphere was recirculated through the analyzer and container until a constant reading was obtained, typically in 20 sec.

The percentages of CO_2 read from the analyzer were converted to ml CO_2 evolved by each kg of fruit per hour, taking into account airspace of the container. To help offset any underestimate of experimental error due to the sampling procedure, the conservative HSD test was utilized to statistically compare treatment differences. Index values were calculated (quotient of treated $CO_2 \div$ nontreated CO_2) to demonstrate the response of fruit damaged by the individual line operations to that of the nondamaged control fruit.

Results and Discussion

Highly significant increases in CO_2 evolution occurred as a result of passage of the fruit through the packinghouse line for both 'Pineapple' and 'Valencia' oranges. Previous studies with apples and oranges, as well as the results of Eaks (1) with California lemons and oranges, have shown that physical damage to fruit causes an increase in CO_2 evolution, with degree of response reflecting extent of the damage. Klein (3) reported that CO_2 increase for apples resulted from decarboxylation of the malic acid spilled from the damaged cells rather than from an increase in respiration. Although Eaks (1) attributed the citrus response to respiration, further evidence is needed to ascertain the actual cause of the increased CO_2 in citrus fruits.

There was a greater CO_2 response to packinghouse line operations for 'Valencia' than for 'Pineapple' oranges. Whether this difference is due to varietal differences, maturity or fruit handling procedures was not determined.

The results in Table 2 show that the dumping operation of 'Pineapple' oranges during a normal run did not cause a significant increase in CO_2 evolution over the control fruit selected from the bin prior to dumping. However, fruit removed from the line at the next site, just prior to washing, and at all other points thereafter, except after waxing, showed significant increases in CO_2 evolution of up to 25% greater than the control. There was no significant difference in CO_2 production between the various line operations (Table 2). An additive effect from each successive operation was not evident. The decrease as a result of waxing was likely a result of the wax coating acting as a barrier to the movement of CO_2 from the fruit. A similar effect was noted by Eaks (1) for lemons and oranges. The decrease in CO_2 evolution from waxing was not permanent in that the CO_2 evolved by fruit removed at the next step after a 90 cm drop to the belt was significantly greater than for the control fruit. The wax coating was likely broken sufficiently to permit gas exchange.

'Valencia' oranges which had been carefully clipped and handled for use in testing individual line operations had significant increases in CO_2 evolution as a result of each operation except waxing where there was a significant decrease in CO_2 evolution (Table 3, Experiment A). The greatest increase, 50% above the control, resulted from grader B which includes an exceptionally long conveying process and many directional transfers. This increase was significantly larger than all of the other operations except the dumper.

Table 2. CO_2 evolution by 'Pineapple' oranges removed at various sequential sites from a packinghouse line during a commercial run.

Sites of removal of fruit from packinghouse line	CO_2 evolved ml/kg·hr	CO_2 evolved Index
Prior to dumper (control)	12.5	1.00
After dumper	13.9	1.12
Prior to washer	15.3	1.23**z
After washer, prior to rinse brusher	14.7	1.18**
Prior to graders	15.3	1.23**
After graders, prior to waxer	14.6	1.17**
After waxer and dryer	13.5	1.08
After 90 cm drop to belt	14.7	1.18**
After master sizer	15.5	1.25**
Prior to packer station	14.8	1.19**
HSD .05	1.6	
HSD .01	1.9	

z** significantly different from the control at $P \leq 0.01$.

Table 3. CO_2 evolution by 'Valencia' oranges following passage through individual line operations of a citrus packinghouse line during a commercial run of 'Marsh' grapefruit. Fruit for Experiment A were carefully harvested by clipping; fruit for Experiment B were commercially harvested.

Line operation	Experiment A CO_2 evolved ml/kg·hr	Experiment A Index	Experiment B CO_2 evolved ml/kg·hr	Experiment B Index
Control (nontreated)	13.0	1.00	13.5	1.00
Dumper	18.9	1.45**z	20.5	1.52**
Washer	17.4	1.34**	19.1	1.41**
Grader A	17.5	1.35**	17.9	1.33**
Grader B	20.2	1.55**	21.4	1.59**
Waxer for 6 sec	—	—	13.2	.98
Waxer for 30 sec	10.4	.80**	12.1	.90
Dryer	17.5	1.35**	17.7	1.31**
Post-dryer drop	16.8	1.29**	16.7	1.24*
Master sizer	17.4	1.34**	18.5	1.37**
HSD, 5%	1.8		3.1	
HSD, 1%	2.1		3.7	

zSignificantly different from control by HSD at $P \leq 0.05$ (*) or $P \leq 0.01$ (**).

The line responses for 'Valencia' fruit selected from bins of commercial fruit are summarized in Table 3 (Experiment B). Again, each operation except waxing resulted in a significant increase in CO_2 evolution relative to that of the nontreated fruit. The amount evolved from fruit that passed over grader B did not significantly exceed that caused by dumping, washing and the master sizer as in Experiment A with fruit that was carefully clip-harvested. Intermediate responses occurred upon passing through grader A, the dryer and the post-dryer drop.

Based on the increased evolution of CO_2, it is evident that fruit damage occurs in most packinghouse line operations. Since the greatest damage apparently occurred at grader B, dumper, washer and master sizer in the line examined, modifications in these operations should be initially considered for reduction of fruit damage. These tests demonstrated that fruit selected from commercially harvested bins for insertion into an operating line of grapefruit would provide information suitable for diagnosing and correcting possible sources and causes of damage. The relatively simple procedure of measuring CO_2 accumulating from small samples of fruit enclosed in plastic containers with a portable CO_2 analyzer could be readily used without need for sophisticated laboratory equipment.

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