Journal American Pomological Society 55(2):76-81 2001

Stone Fruit Critical Bruising Thresholds

CARLOS H. CRISOSTO,[1] DAVID SLAUGHTER,[2] DAVID GARNER,[1] AND JOAN BOYD[1]

Abstract

The critical bruising thresholds varied among stone fruit cultivars. In general, plums tolerated more physical abuse than yellow flesh peach and nectarine cultivars. Impact location on the fruit was an important factor in the determination of critical bruising thresholds. Potential sources of bruising damage during fruit packing were located using an instrumental sphere (IS-100).

Introduction

In recent years, total production of stone fruits has increased rapidly, but fruit consumption has remained steady at approximately 2.0, 4.5 and 2.5 (pounds/per capita/per year) for nectarines, peaches and plums, respectively. Surveys indicate that consumer complaints primarily focus on a lack of eating quality and that they are willing to pay for higher quality. Consequently, there is a demand for high quality fresh stone fruits (2). Immature fruit at harvest will be of inferior quality and incapable of ripening to their highest potential eating quality. Over mature fruit at harvest will have high quality initially, but will be incapable of withstanding the rigors of postharvest handling and distribution (4, 5, 6). During the past 10 years, increased emphasis has been placed on developing new peach, plum, and nectarine cultivars with darker skin color. Unfortunately, early red or dark color development masks the ground color, making it impossible to determine optimum fruit maturity.

We have developed a method of determining maximum maturity indices for stone fruit cultivars using bruising susceptibility measurements based on fruit firmness at the weakest point on the fruit. These critical bruising thresholds were calculated for different levels of fruit firmness and expressed as G's (acceleration). These thresholds predict how much physical abuse fruit will tolerate at different firmness levels during packinghouse operations. The use of these thresholds will allow us to decide how late we can pick without inducing bruising, thereby maximizing the quality potential of stone fruit from different orchards.

Materials and Methods

During two seasons, an evaluation of the impact bruising susceptibility of several plum, yellow flesh peach and nectarine cultivars was carried out at the F. Gordon Mitchell Postharvest Laboratory (University of California, Kearney Agricultural Center).

Bruising Potential Survey

A survey of the bruising potential (G levels) for different packingline operations was conducted using an instrumental sphere (IS-100) (TECHMARK, E. Lansing, MI) device according to Brown's recommendation (1, 7). The IS-100 uses a triaxial accelerometer to measure acceleration, but includes an A/D converter and a programmable microcontroller imbedded into beeswax and covered with urethane. The microcontroller stores accelerometer data in memory. The number of impacts stored is determined by the A/D sample rate. The IS-100 has a cable connection to connect a computer to download data collected for analysis. Each transfer point within each packingline was repeated 10 times.

[1]Department of Pomology, University of California, Davis, One Shields Avenue, Davis, CA 95616 located at the Kearney Agricultural Center, 9240 South Riverbend Avenue, Parlier, CA 93648.
[2]Department of Biological and Agricultural Engineering, University of California, Davis, One Shields Avenue, University of California, Davis, CA 95616-5294.

Table 1. Survey of impact forces (G) measured by using the instrumental sphere (IS-100) at different transfer points in three typical stone fruit packinglines.

Transfer points	Impact Forces		Range (min-max)
	Mean[z] (G's)	SD[y]	
Packingline A			
Bin Dumper	90.7	48.6	24-180
Bin Dumper To Pony Sizer	110.4	12.1	105-131
Pony Sizer	70.6	13.3	54-84
To Washer/Brusher	80.0	16.8	75-98
To Sorting Tables	102.0	31.6	66-145
To Sizers	88.9	9.5	74-97
Sizer Cups	67.6	5.3	59-72
Sizer Kick Out	57.0	21.3	25-78
Boxing Line	71.0	10.2	55-82
Boxing Machine	65.0	19.8	46-94
Box Volume Fill	47.0	24.1	28-89
Box Tray Pack	60.6	18.5	33-78
Packingline B			
Bin Dumper	94.3	47.3	38-177
Elevator to Pony Sizer	121.8	50.3	72-187
Pony Sizer to Washer/Brusher	83.4	10.4	71-98
Brusher to Sorting Tables	130.9	29.7	58-180
Sorting to Sizers	94.2	13.7	72-117
Sizer to Sizer Cups	61.0	10.3	38-74
Sizer Cups Kick Out		Not detectable	
Drop Down to Packing Belt	94.9	56.9	30-165
Box Volume Fill	103.8	32.8	70-146
Packingline C			
Bin Dumper	82.8	16.5	73-107
Dumper to Elevator	57.9	26.2	25-114
Conveyor to Washer	68.4	21.4	42-106
Washer to Waxer	24.5	4.4	19-33
Waxer to Sorting Tables	25.1	3.5	21-32
Sorting to Sizers	90.6	11.6	72-110
Sizers to Conveyor	71.6	50.8	23-170
Conveyor to Packing Tables	97.5	14.7	83-126
Box Tray Pack	61.5	31.9	27-117
Box Volume Fill	143.0	28.1	111-206

[z]Means were calculated using the peak impact measured during each of the 10 trips of the instrumental sphere across each transfer point.
[y]Indicates standard deviation.

Fruit Bruising Susceptibility

Bruising susceptibility was determined by subjecting fruit with different firmness to three bruising energy levels (G). Impact bruising potential was created by dropping fruit from different heights onto a surface of known characteristics. The impact bruising energy was measured with an IS-100 device in different packingline situations (1, 3, 7).

In California at the packinghouse fruit are dumped (mostly using dry bin dumps) and cleaned. Sorting is done to eliminate fruit with visual defects and sometimes to divert fruit of high surface color to a high-maturity pack. Sizing segregates fruit by either weight or dimension. Some Califor-

Table 2. Minimum flesh firmness (measured at the weakest point on the fruit) necessary to avoid commercial bruising at three levels of physical fruit handling during packaging.

Cultivar	Drop Height[z] (1 cm) ~66 G[y]	(5 cm) ~185 G	(10 cm) ~246 G	Weakest position
	Minimum Firmness (lbs)			
Plums				
Blackamber	0	0	3[x]	Tip
Fortune	0	0	0	Shoulder
Royal Diamond	0	0	0	Shoulder
Angeleno	0	0	0	Shoulder
Peaches (yellow flesh)				
Queencrest	0	4	9	Tip
Rich May	0	0	9	Tip
Kern Sun	2	6	9	Tip
Flavorcrest	3	5	6-9	Tip
Rich Lady	6	10	11	Shoulder
Fancy Lady	3	7	11	Shoulder
Diamond Princess	0	0	9	Shoulder
Elegant Lady	3	5	6-9	Shoulder
Summer Lady	0	0	8	Shoulder
O'Henry	3	5	6-9	Shoulder
August Sun	3	4	9	Shoulder
Ryan Sun	0	0	10	Shoulder
September Sun	0	4	9	Shoulder
Nectarines (yellow flesh)				
Mayglo	4	8	11	Tip
Rose Diamond	6	7	8	Suture/Shoulder
Royal Glo	0	9	11	Shoulder/Tip
Spring Bright	6	10	10	Shoulder
Red Diamond	6	7	11	Shoulder
Ruby Diamond	4	9	9	Shoulder
Summer Grand	2	5	6	Shoulder
Flavortop	3	6	6	Tip
Summer Bright	0	6	8	Shoulder
Summer Fire	0	0	9	Shoulder
August Red	2	12	12	Shoulder
September Red	0	0	10	Shoulder

[z]Dropped on 1/8" PVC belt. Damaged areas with a diameter equal to or greater than 2.5 mm were measured as bruises.
[y]Impact bruising forces measured with the instrumental sphere (IS-100) and expressed as acceleration (G).
[x]Fruit firmness measured with an 8 mm tip penetrometer and expressed as lbs-force.

nia stone fruits are volume filled with the fruit automatically filled by weight into shipping containers, or are packed into trays. Mechanical place-packing units use hand-assisted fillers where the operator can control the belt speed to match the flow of fruit into plastic trays.

Limited volumes of stone fruits are "ranch packed" at point of production. In a typical operation, fruit are picked into buckets, which are carried by trailer to the packing area. Packers may work directly from the buckets to select, grade, size, and pack fruit into plastic trays. Some ranch pack operations have a mechanized tote and/or basket dumper onto the packing line.

The three impact bruising levels were selected based on our previous packing-house bruising potential servey (3). A

packingline with a gentle basket and/or tote automatic dumpers revealed one or more impacts of ~66 G's. A standard automatic gentle packing operation had at least one or more impacts of ~185 G's; and a standard automatic rough packing operation had one or more impacts of ~245 G's. Bruising susceptibility was expressed as size of the bruise (mm^2) in relation to fruit firmness at a given bruising potential level.

The softest firmness at which a given cultivar did not develop bruising when exposed to three different bruising potential levels (66, 185, 245 G) was defined as the critical bruising thresholds. These critical bruising thresholds were calculated for each cultivar by using a 99% confident limit from the relationship between bruising versus firmness at a given bruising potential level of energy.

Results and Discussion

Bruising Potential Survey

Average bruising potentials (G's) varied from 24 to 143 G's among packinghouses (Table 1). In general, the bin dumping and transfer points at the small size eliminator, and at the end of the packingline (package filling) had the highest G values. Small size elimination is carried immediately after bin dumping on the packing line. There was a large difference between the three different bin dumpers evaluated. A reading of approximately 175 G's was detected in two bin dumpers and 107 G's in the "improved" bin dumper. During dumping, a high value of 220 G's was measured in standard size bins that were only half full when dumped. Similar values were measured on fruit over the pony sizers. Bruising potentials of 47, 104 and 143 G's were measured on three types of volume fillers. The highest value corresponded to a hand volume filling operation. Bruising potentials were lower in the tray pack operations surveyed. During dumping with automatic tote or basket dumpers, we measured approximately 60 G's.

Reductions in these bruising potential values were accomplished by adding padding material to the packingline, minimizing height differences at transfer points, synchronizing timing between components, and reducing the operating speed (1, 3).

Bruising Susceptibility

Critical bruising thresholds were developed for different stone fruit cultivars (Table 2). The minimum fruit firmness (critical bruising threshold) able to tolerate impact bruising and the number of fruit bruised at a given impact intensity (bruising probability) varied among stone fruit cultivars. In general, plums tolerated more physical abuse than yellow flesh peach, nectarine and white flesh peach cultivars.

The relationship between bruising and firmness varied according to bruising energy level and cultivar. In general, when fruit were exposed to 245 G, 'Blackamber' plums started to show bruises when firmess went below 3 pounds (Fig. 1C). 'Summer Bright' nectarines and 'Elegant Lady' peaches expressed bruises when they soften below 10 pounds (Fig. 1B) and 8 pounds (Fig. 1A), respectively.

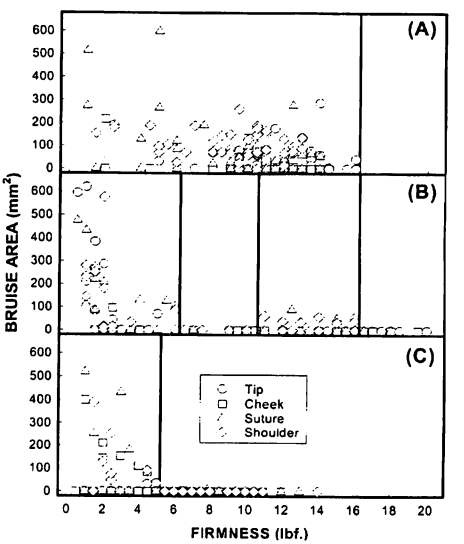

Figure 1. Relationship between area of bruises and fruit firmness measured at different fruit positions (tip, cheek, suture, and shoulder) for (A) 'Summer Bright' nectarines (B) 'Elegant Lady' peaches, and (C) 'Blackamber' plums. Vertical lines indicate a 99% confident limit.

Table 3. Effect of multiple drops on fruit bruising expressed as bruising percentage and size of the bruises for nectarine, apple, and pear.

Drop height[z] (cm.)	Nectarine		Apple		Pear	
	Bruising					
	%	Size (mm^2)	%	Size (mm^2)	%	Size (mm^2)
1	0	0	70	83.6	30	17.1
5	30	31.3	100	332.8	45	19.2
10	60	32.3	100	455.2	50	35.2
15	80	79.4	100	559.8	—	—
1 (5x)[y]	80	112.7	100	215.2	70	32.3
5 (2x)	70	124.7	100	424.5	35	32.6
1 (10x)	90	195.7	100	527.5	40	34.7
5+1 (5x)	60	108.0	100	411.8	50	37.8
10+5	80	93.1	100	538.6	—	—
5 (3x)	60	98.7	100	548.2	—	—
1 (10x) + 5[x]	90	251.4	100	717.5	—	—
1 (5x) + 10	100	189.4	100	512.4	—	—
1 (5x) + 5 + 5	80	152.3	100	624.2	—	—

[z]Fifty fruit were dropped onto a 1/8" PVC belt for each drop treatment.
[y]1 (5x) means that fruit were dropped 1 cm. five times on the same spot.
[x]1 (10x) + 5 means that fruit were dropped 1 cm. ten times plus one 5 cm. drop on the same spot.

The location of the impact on the fruit was an important factor in the calculation of these critical bruising thresholds. In general, soft fruit were more susceptible to impact bruising than hard fruit except in a few peach cultivars in which we found a "safe window" for a high impact damage between 6-9 lbf. Among the cultivars evaluated, soft plums tolerated impact damage much better than soft nectarines and peaches. 'Blackamber' plum showed higher bruising susceptibility than other plum cultivars when exposed to approximately 246 G.

Among the peach cultivars evaluated 'Fancy Lady' and 'Rich Lady' were less tolerant of impact damage than the other peach cultivars evaluated when exposed to 185 G. Among the nectarine cultivars evaluated 'Spring Bright' and 'August Red' were less tolerant of impact damage (185 G) than the other tested cultivars.

The position of the weakest spot on the fruit varied among cultivars. In general, early season cultivars softened faster at the tips and late cultivars at the shoulders/sutures (Table 2). The tip was the softest position for 'Blackamber,' 'Rich May,' 'Queencrest,' 'Flavorcrest,' 'Kern Sun,' 'Snow Brite,' 'White Lady,' 'Flavortop,' 'Royal Glo,' and 'May Glo.' The shoulder was the softest position for 'Royal Diamond,' 'Fortune,' 'Angeleno,' 'Diamond Princess,' 'Elegant Lady,' 'O'Henry,' 'Fancy Lady,' 'Summer Lady,' 'August Sun,' 'September Sun,' 'Rich Lady,' 'Ryan Sun,' 'Royal Glo,' 'Red Diamond,' 'Rose Diamond,' 'Ruby Diamond,' 'Spring Bright,' 'Summer Fire,' 'Summer Bright,' 'Summer Grand,' 'August Red,' and 'September Red.' The suture was also the softest spot for 'Rose Diamond.'

We also determined that fruit impact bruising damage is cumulative. For example, if a 10 cm. drop induces bruising on a nectarine, then 10 drops of 1 cm. each on the same spot on the fruit will induce equal or higher damage (Table 3). Similar situations occurred on apples and pears. The probability of a fruit dropping on the same spot 10 times during packing is very low, however it may be important during transportation where vibration may occur repeatedly.

The use of the thresholds will allow us to pick later without inducing bruising, thereby maximizing potential fruit quality. Under specific conditions, the comparison of fruit damage susceptibility (G's)

and packingline G's will help to decide how late fruit can be harvested and packed without causing bruising. Maximizing fruit quality potential depends on the cultivars and/or orchard conditions. Our previous work (4, 5) indicated that in most stone fruit cultivars, delaying harvest beyond "California Well Matured" increased fruit size. In some cultivars fruit red color also increased and, in a few, there was the perception of an improvement in flavor on ripe fruit.

The California well mature is a maturity stage based on ground color changes. For most of the cultivars, the California well mature is a more advanced maturity than minimum physiological maturity. Thus, fruit that meet the California well mature stage will ripen properly and end with more quality attributes such as color, SSC and size than some fruit picked at the minimum physiological maturity. The well mature fruit is generally well formed in the shoulders, cuts easily, flesh color is mainly yellow, and some juice is present in the flesh.

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Early Season Temperature Effects on Apple Maturity

Temperature during the 6 weeks after bloom affected ethylene production, back ground color, starch content, firmness and red blush with these variables responding at different degrees. Acid content at ripening was lower at the higher post-bloom temperatures. Irrespective of the post bloom temperature acid content was reduced by higher temperatures during the maturation period. The content of soluble solids showed no consistent pattern. From Tromp. 1997. J. Hort. Sci. 72(5):811-819.