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HANDLING AND STORAGE CONDITIONS THAT AFFECT BLOSSOM END CLEARING DEVELOPMENT IN GRAPEFRUIT

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Abstract. **The studies on Blossom End Clearing (BEC) in grapefruit described in this communication demonstrate that BEC develops as a result of rough handling practices more likely at the packinghouse and not as the result of picking. In addition, the data establish a direct relationship between high temperature and the incidence of BEC and an indirect relationship between humidity and BEC. Mature fruit with a weak internal anatomy developed higher % of BEC at 100°F than at 60°F. When warm fruit was allowed to cool, % BEC was reduced significantly during regular packinghouse operations as well as in controlled studies at the Citrus Research Center. Fruit harvested in the morning developed less BEC than fruit harvested later in the day, with smaller fruit showing the greatest % of BEC.**

Blossom end clearing (BEC) is a physiological disorder most commonly observed, but not limited, to late harvested, thin-peeled colored grapefruit. BEC generally appears as a wet translucent area at the blossom end; however, it can be frequently seen anywhere on the fruit. The formation of the translucent wet area on the fruit's surface is the result of juice leaking out of the vesicles into the peel (Goell et al., 1988). Once the juice soaks the peel, the appearance is blemished, the fruit develops off flavors, and the area becomes susceptible to invading pathogens. The prevalent belief is that visible symptoms can develop soon or several days after harvest. This condition is very similar to the stylar end breakdown of Tahiti limes (Davenport and Campbell, 1977a, 1977b).

The occurrence of BEC in harvested grapefruit increases throughout the growing season, with many growers and packers contending that its onset coincides with the spring flowering period. Factors such as rough handling are known to increase the incidence of BEC (McCormack, 1966). It is also suspected that environmental conditions and cultural practices, in addition to anatomical characteristics, may also have direct influence over the development of BEC.

The experiments herein were designed to gain further information on the factors that augment the incidence of BEC. The results indicate that fruit handling as well as temperature and humidity play a decisive role in the development of BEC.

Materials and Methods

Temperature experiments. Fruit was collected from groves located in the Fort Pierce area during three different seasons and brought to the Citrus Research and Education Center at Lake Alfred. Upon arrival, the fruit was placed in a refrigerated room at 70°F and 95% RH until the next morning. At this time, fruit was divided into 4 groups of 10 boxes of 50 lbs each. Two sets of 10 boxes were transferred to a 100°F storage room. Of the remaining 20 boxes, 10 were placed at 60° and the rest at 80°F (unless otherwise indicated). Humidity was maintained at or above 95°RH.

After 24 hr, fruit at 60°, 80°, and one set of 100°F were passed through the packingline and stored at 70°F for 4 additional days. The remaining set of 100°F fruit was transferred to 60°F for another 24 hr and then passed through the packingline as indicated above. To simulate dumping procedures, the fruit was dropped from a height of 4 ft at the start of the packingline. After 4 days, fruit was examined for BEC and internal damage.

BEC vs time of day. The following experiments were carried out at Sun Citrus Packinghouse in Fort Pierce, Florida. A pallet of fruit was harvested every 2 hr by commercial pickers starting at 9:00 am and ending at 3:00 pm. The fruit was immediately taken to the packinghouse and commercially packed. Four days later, the fruit was examined for BEC and internal bruising.

In a separate experiment, 2 sets of fruit were collected at 2:00 pm. Fruit was transported to the packinghouse and 1 set immediately packed. At the same time, the second set was transferred to a storage room equipped with a mist system under continuous operation. The following morning the fruit were removed and commercially packed. Both sets of fruit were examined 3 days after packing.

Humidity experiments. Fruit was collected from commercial groves as described above, transferred to the CREC facilities, and upon arrival, divided into 2 equal groups. One group was stored at 90°F and 95% RH whereas the other was stored at the same temperature but 40% RH. After two days, the fruit was passed through the packingline and stored for 3 days at 70°F.

Controlled impact experiments. Two 50 lb boxes of fruit were dropped from 0, 1, 2, 3, and 4 ft onto a wooden platform prior to washing at the packinghouse. The impact of each drop was measured by the use of the instrumented sphere dropped from the same heights. Fruit was stored for 3 days and BEC evaluated.

Results and Discussion

The data of Table 1 illustrates the association of BEC with higher temperatures. Data from different experiments could not be combined since the response to BEC was variable from year to year and from grove to grove. However, despite these differences, trends in BEC were always similar. The warmer the fruit at the time of packingline operations, the higher the incidence of BEC. It is noteworthy that cooling warm fruit reduces % BEC significantly (Table 1). The effect of temperature on BEC is also apparent in Table 3 where % BEC in all fruit sizes increased with a rise in temperature.

From our controlled packinghouse experiments, it was clear that humidity had an effect on the incidence of BEC.

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Table 1. Relationship between fruit temperature and development of blossom end clearing.

Temperature °F	Sound fruit	BEC Fruit	% BEC
60°	164	81	32.9
80°	142	92	39.3
100°	142	124	46.8
100 - 60°	165	70	29.8

Fruit stored at high humidity followed by rough handling at the packingline was more resistant to the development of BEC than fruit stored at low humidities and handled in the same way (Table 2).

During the course of the day, temperatures rise as humidity falls, creating conditions which are favorable for BEC formation under regulated experiments. The results of field experiments (where fruit was harvested at different times of the day and immediately packed) are consistent with the results of controlled experiments. BEC increased throughout the day, reaching a maximum sometime in mid afternoon (Table 3). However, keeping fruit (harvested during the time of maximum BEC development) overnight under constant mist prior to packing reduced the levels of BEC to those obtained during the previous morning (Table 3). It is noteworthy that, after the overnight treatment of high humidity in the dark at ambient temperature, the fruit was firmer than when harvested the previous afternoon. In addition, smaller fruit developed higher % of BEC than larger fruit. A similar size/stylar-end breakdown ratio was found by Davenport in "Tahiti" limes (Davenport and Campbell, 1977b).

The potential effect of rough handling of the fruit during harvest was investigated by comparing fruit commercially picked to fruit purposely picked in a gentle way (Table 4). All fruit samples were cautiously passed through the packingline and BEC development determined 3 days later. Fruit picked by commercial personnel developed negligible levels of BEC as was the case of fruit carefully picked by the researchers (Table 4). However, fruit gently harvested but roughly handled through the packingline showed high levels of BEC (Table 4).

Table 2. Development of blossom end clearing in grapefruit stored at different humidities and 100°F. Fruit was roughly handled through the packingline.

% humidity	% BEC
> 95	11.7
≈ 40	22.2

Table 3. Percentage development of blossom end clearing in grapefruit harvested at different times of the day. Fruit were commercially handled and packed.

	Fruit size			
Time of day	Small	Medium	Large	Average
9:00 am	12.5	8.2	4.7	9.0
11:00 am	18.1	13.3	11.7	16.0
1:00 pm	26.8	25.4	12.6	28.9
3:00 pm	34.1	27.4	11.2	25.5
3:00 pm and stored overnight under mist				9.3

Table 4. Comparison of fruit commercially harvested with fruit carefully picked and packed under 2 conditions.

Harvesters	Handling	% BEC
Researchers	Gentle[z]	0.5
Commercial pickers	—	0.7
Researchers	Rough[y]	18.7

[z]Gentle handling: Fruit individually picked and placed carefully in bins prior to transport to the Citrus Research and Education Center. At the packingline, the fruit was placed onto the initial conveyor belt and later placed carefully into storage boxes.
[y]Rough handling: Fruit picked as above but dropped 4 ft onto the initial conveyor belt and 1.5 ft into the storage boxes.

Table 5. Relationship between drop height, g-force, and blossom end clearing.

Drop height (ft)	g-force	% BEC
0	0	0
1	71.9	5.0
2	183.7	13.3
3	232.0	36.7
4	374.5	42.9

We observed that all affected fruit showed advanced degrees of deterioration of the internal spongy core. Most segments were open towards the center where juice vesicles protrude into the cavity. It becomes apparent from these observations that the segment walls and the juice vesicle membranes have become too fragile to withstand additional pressure. Young healthy and sound fruit (up until about the time of flowering) did not develop BEC despite rough treatment.

In addition, we noticed that a high percentage of fruit treated under conditions known to induce BEC had severe internal bruising as evidenced by a juice soaked albedo but unaffected flavedo and thus no external symptoms. This condition has been referred to as "wet core" and can result in the development of off flavors.

The relationship between impact severity and incidence of BEC was determined in controlled drop experiments (Table 5). As impact severity increased, BEC increased. At impacts of greater than approximately 150g, the number of fruit affected increased substantially. Miller and Wagner (1991) earlier recommended that packinghouses reduce their impacts to less than 150g to reduce mechanical damage to the fruit.

From the data presented in this communication, we conclude:

1. BEC is the result of high impact damage. Under normal conditions, BEC occurs as the result of packinghouse handling and not a result of picking.

2. Temperature has a direct effect on BEC, with warmer fruit temperatures increasing the incidence for BEC.

3. Smaller fruit are more susceptible to development of BEC than larger fruit.

4. Fruit harvested early in the day hours developed less BEC than later harvested fruit.

5. BEC occurs almost exclusively in aging fruit with a weak internal structure as reflected by a disintegrated internal core and open segments.

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EDIBLE FILMS REDUCE SURFACE DRYING OF PEELED CARROTS

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Abstract. **Although peeled, ready-to-eat carrots have gained a significant market share in recent years, consumers tend to associate the appearance of a white surface with senescence. This color change develops during handling, as a consequence of an abrasion peeling process which removes the epidermal layer, but leaves macerated cell walls that later desiccate. Five formulations of edible films (carboxymethylcellulose-based) were tested as a means of minimizing the surface drying of commercially peeled carrots. The carrots were immersed for 3-min in the viscous film solution, blotted and stored in microperforated plastic bags at 4C. Coated carrots had significantly less surface drying and more acceptable appearance than noncoated carrots throughout 30 days of storage. Surfaces of coated carrots remained quite tacky up to 26 days of storage. Films which dried more rapidly during storage hastened the appearance of surface whitening. There were no differences in decay or moisture content for any treatments.**

Consumers and the food service industry continue to approve the concept of lightly processed, or precut, fresh fruits and vegetables, as evidenced by the increasing number and variety of products which are being prepared and marketed in these sectors. These products add to the convenience and efficiency of on-site meal preparation, not to mention the reduction in food waste. The main drawback with lightly processed products is compromised storage life due to the wounding which normally occurs during preparation. The products are sliced, diced, chopped or peeled, injuries which enhance senescent processes by stimulating stress metabolism as evidenced by increased respiration rate (Priepke et al., 1976) and the evolution of ethylene. Typical quality losses include degradation of chlorophyl (yellowing) and other pigments, enzymatic browning at cut surfaces, accelerated softening of tissues and off flavors (Varoquaux and Wiley, 1994). Also, water loss is enhanced and natural barriers to decay pathogens are compromised.

Extension of postharvest quality of lightly processed fruits and vegetables requires diligence during all handling stages, and begins at the processing facility. Techniques include the avoidance of mechanical injuries during handling, constant maintenance of sanitary conditions in handling areas, rapid and thorough cooling to the recommended storage temperature, appropriate packaging which protects the product while minimizing water loss, and maintenance of the storage temperature throughout subsequent handling operations. Currently, several commercial products are available, notably salad mixes, which employ modified atmosphere packaging. At retail level, the lack of proper temperature control on the display racks can accelerate senescence and decay.

Quality of abrasion-peeled carrots is limited by water loss, development of decay organisms and whitening of the surface. Surface whitening has been attributed to two factors: the desiccation of macerated cell walls (Tatsumi et al., 1991) and lignin synthesis (Bolin and Huxsoll, 1991; L. Howard, personal communication). Bruemmer (1987) found no quality extension beyond two weeks storage after infusing peeled carrot sticks with antimicrobial agents or ascorbic + citric acids; rather, most treatments negatively affected flavor. In a separate study, he found no benefits to infusion of metabolites, cofactors or growth regulators, nor storage in low permeability film (Bruemmer, 1988). *Leuconostoc mesenteroides,* a species of lactic acid bacteria, was identified as the chief cause of decay in grated carrots in France (Carlin et al., 1989).

Several companies recently developed edible coatings for use on fruits and vegetables. Mitsubishi Kasei is one such company which offers a sucrose ester product. Several labs are currently developing edible films (coatings) for use on lightly processed fruits and vegetables using a variety of materials (Baldwin et al., 1995). The USDA labs at Albany, California, are experimenting with an alginate-lipid bilayer coating (Wong et al., 1994) that reduces respiration in cut apple, and the University of California developed a casein-based coating that reduces whitening of peeled carrots (Avena-Bustillos and

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