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Susceptibility of avocado fruit to mechanical damage as influenced by variety, maturity and stage of ripeness

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SYNOPSIS
The susceptibility of the avocado to both vibration and impaction as influenced by cultivar, maturity and flesh firmness was studied. Emphasis was placed on the Hass variety since it comprises about 70 per cent of the total California acreage. External vibration injury (1,1 x g for 20, 40 or 60 min) is easily discernible in Fuerte, Pinkerton and early-season Hass fruit as surface discolouration. As the Hass variety darkens either during ripening or with maturity, the external symptoms of injury are masked. As flesh firmness decreases during ripening (< 2,7 kgf), internal darkening and epidermal flesh adhesion occurs as a result of vibration. The response to impaction is also dependent upon flesh firmness at the time of injury. When the fruit is firm (> 6,8 kgf), prior to extensive softening, no appreciable damage is observed as a result of impaction (23, 46 or 92 cm). As flesh softening occurs, bruising due to impaction increases. Bruising is characterised by flesh discolouration sometimes extending into the seed cavity in soft fruit and occurred in all evaluated varieties.

INTRODUCTION

The quality of produce is influenced by the appearance, shape and textural characteristics of the commodity. Both external and internal appearance can greatly influence the consumer's purchasing decision. Mechanical damage can detract from fresh fruit quality since appearance may be affected. Williams (1961) evaluated consumer preference for avocados with varying degrees of surface blemishes over a range of prices. At equal prices, unblemished fruit was preferred by a 2:1 margin. Evaluation of consumer preferences has indicated ripe, ready to eat avocados are also preferred (Williams, 1961; Lee & Coggins, 1982). Current marketing efforts in the United States are focused on the enhancement of sales through the delivery of ripe avocados at the retail level by using ethylene to promote ripening. Softening resulting from ethylene treatments may increase susceptibility to mechanical damage (Young, 1979; Lee & Coggins, 1982).

This study evaluates the susceptibility of the avocado to two forms of mechanical damage, vibration and impaction. The influence of cultivar, fruit maturity (based on percentage dry weight) and flesh firmness of susceptibility to vibration and impaction was monitored. Emphasis was placed upon the Hass variety since it comprises

approximately 70 per cent of the total California acreage.

MATERIALS AND METHODS

Hass fruit were harvested' at approximately six-week intervals between March and September 1985, from an eight-year-old, drip irrigated orchard near Santa Paula, California. Harvest occurred between 6 and 8 am when pulp temperatures were coolest. Avocados were returned to the UC Davis post-harvest lab, a six-hour drive. Pulp temperature during transit never exceeded 15°C. Fruit were placed at 10°C overnight. The following day, fruit were sorted for size, uniformity and colour. Initial quality measurements were made on 15 fruit and included skin and flesh colour, flesh firmness and dry matter content. Fruit were randomly selected for seven treatments. Each treatment included three subtreatments: no injury (control); a 20-minute vibration treatment; and a group subjected to impaction. Injuries were applied according to the following schedule:

Treatment sequence

1 Harvest - injure - C_2H_4-trt[a] - ripen[b].
2 Harvest - injure - store 10 days - C_2H_4-trt - ripen.
3 Harvest - injure - store 20 days - C_2H_4-trt - ripen.
4 Harvest - C_2H_4-trt - injure - ripen.
5 Harvest - C_2H_4-trt - ripen - injure.
6 Harvest - store 10 days - injure - C_2H_4-trt - ripen.
7 Harvest - store 10 days - C_2H_4-trt - injure - ripen.

a = 100 ppm C_2H_4 for 24 hrs at 20°C.
b = Ripening temperature= 20°C.
c = Storage temperature = 5°C.

Periodic evaluations were made on 15 fruit samples from each subtreatment, following removal from storage (if applicable), after ethylene treatment and after ripening. Final evaluations also included monitoring the days to ripen following ethylene treatment.

Vibration injury was produced by accelerating avocados 1,1 - 1,2 x g for 20 minutes in a smooth-sided container. Vibration damage to the epidermis was evaluated for both unripe and ripe fruit on a 0 to 5 scale: 0 = no injury; 1 =1-20 per cent; 2 = 21-40 per cent; 3 = 41-60 per cent; 4=61-80 per cent; and 5 = 81-100 per cent surface discolouration. Epidermal flesh adhesion was observed in some vibrated fruit after ripening. Epidermal skin adhesion was evaluated using a rating scale of 0 to 3, where 0 = no adhesion; 1 = slight; 2 = moderate; and 3 =severe adhesion.

Impact injury was produced by holding fruit stationary on a flat surface while dropping a 2,5 cm, 82 g steel ball 23, 46 or 92 cm through a guiding tube onto different locations on each fruit. Evaluation of impacted fruit included measurement of bruise volume and bruise colour on a 0 to 3 basis where 0 = no colour; 1 = slight; 2 = moderate; and 3 = severe discolouration after fruit ripening.

A Gardner Colour Difference Meter (Model XL-23) was used to measure skin and flesh colour. Flesh firmness was determined on opposite sides of each fruit after skin removal using a UC Firmness Tester (Claypool *et al,* 1966) with a 6,4 mm plunger. Maturity of the fruit was monitored using dry matter determination (Anonymous, 1985).

To evaluate the influence of flesh firmness on susceptibility to impact bruising, individual fruit were impacted from 23, 46 and 92 cm at varying flesh firmnesses. After impaction, the fruit were returned to 20°C for ripening and then evaluated as described previously. In a similar study, the influence of flesh firmness on vibration injury susceptibility was evaluated. Six lots of 45 fruit each were treated with C_2H_4 (20 ppm) and softened to varying levels of flesh firmness (approximately 13,6; 11,3; 9,1; 4,5; 2,3 and 0,5 kgf). Each lot was divided into three 15-fruit subtreatments. Each subtreatment was vibrated at 20, 40 or 60 minutes at 1,1 - 1,2 x g, then ripened for evaluation.

To compare the response of Hass to mechanical damage in relation to flesh firmness to other avocados cultivars, a single harvest of Fuerte (July, 1985) and Pinkerton (March, 1986) avocados was made. The fruit were treated at varying flesh firmnesses as outlined above.

RESULTS AND DISCUSSIONS

Physical and visual response to vibration injury

There were no significant differences in external or internal colour or flesh firmness between control and vibrated (20 minutes) fruit, whether examined immediately following removal from storage after 24 hours exposure to 100 ppm ethylene, or following ripening. Although vibration injury has been reported to increase the rate of ripening for some deciduous fruits (Sommer et al, 1960), such a response was not observed in Hass avocado. The authors also monitored fruit respiration and ethylene production (data not presented). No differences between control or vibrated fruit were detected from any harvest or storage treatment.

A comparison of the effects of 0, 20, 40 and 60 minutes vibration at flesh firmness levels of 0,45 to 13,6 kgf indicated a progressive increase in surface injury with increasing exposure time to vibration and a variable response to decreasing fruit flesh firmness. There was a decrease noted in surface injury between 2,0 and 4,0 kgf firmness which could be due to an observed tendency of softening fruit to revolve less about their vertical axes than firmer fruit during vibration treatments. External surface injury was more readily detected on the Pinkerton and Fuerte varieties and early season Hass than on the dark-skinned late season Hass fruit. Vibration injury remained noticeable upon ripening for the Pinkerton and Fuerte avocado since the epidermis remains green as the fruit matures and ripens. Vibration (20, 40 or 60 minutes) of both cultivars at flesh firmnesses of 0,45 to 13,6 kgf produced similar surface injury.

The epidermal structure of the Hass avocado fruit affected the expression of surface injury. Vibration injury occurred primarily on elevated portions of the epidermis. The injured tissue appeared brown in colour. Once surface browning occurred, no

regreening of the injured tissue was observed. Increasing the duration of vibration produced an aggregation of injured tissue into larger spots or patches. Depending on the severity of the injury, the external quality of Hass fruit may be severely impaired. This could be important for Hass avocados marketed early in the season when the epidermal colour is still primarily green. Although surface injury on ripened fruit could still be detected in the laboratory, it is doubtful that it would be noticed by the average consumer.

When firm Hass avocado fruit were vibrated (flesh firmness > 2,7 kgf), internal injury was barely detectable, even after ripening. When injury occurred at firmness levels of < 2,7 kgf, epidermal flesh adhesion was regularly detected. There was only slight internal injury after 20 minutes vibration with fruit flesh firmness > 2,7 kgf, although differences between 0 and 20 minutes vibration were significant (P=0,05). Below 2,7 kgf, flesh firmness internal injury increased dramatically. Treatments of 40 and 60 minutes produced significantly higher (P = 0,05) amounts of internal injury compared to 0 or 20 minutes vibration at flesh firmness levels of 4,5 to 13,6 kgf. At flesh firmness levels < 11,3 kgf, Fuerte avocado exhibited greater internal injury from 20 minutes vibration than Hass or Pinkerton. At flesh firmness levels of 0,45 kgf, all fruit exhibited severe injury after 20 minutes vibration. Location of internal injury in all cultivars was always adjacent to an external injury symptom. Internal injury consisted of flesh adhering to the inner epidermis, darkening of the injured tissue and a reduction in textural consistency. Regardless of storage and ripening treatment, 20 minutes vibration produced no flesh adhesion in Hass fruit from any harvest when flesh firmness was greater than 4,5 kgf at the time of injury.

The results of these vibration injury studies indicate that avocado fruit is susceptible to mechanical injury at all stages of ripeness. The detection of external injury for the Hass variety, however, becomes more difficult as fruit ripeness increases due to skin darkening. The results of this study indicate a similar pattern of internal response to vibration injury for all cultivars evaluated.

Physical and visual response to impact injury

No differences in the rate of external colour changes between impact injured and control fruit were observed throughout the season for the Hass variety. Fruit that were injured prior to storage exhibited similar surface colour when removed from storage after ethylene treatment, following ripening. Changes in flesh firmness in impacted and control fruit were similar. There were no significant differences in flesh firmness related to impact treatment upon removal from 10 or 20 days storage at 5°C, following 24 hours of ethylene treatment at 20°C, or after ripening. Impact injury did not appear to affect the rate of avocado fruit ripening as measured by either changes in surface colour, flesh firmness or respiration and ethylene production (unpublished data). Hass fruit maturity, however, appeared to influence the amount of impact bruising. Early season Hass were more susceptible to impact bruising than mid to late season fruit.

Unlike vibration injury, impact injury is primarily an internal response to external forces. When injured at high flesh firmnesses, fruit from the three cultivars exhibited little

external evidence of injury. A surface blemish, such as a slight flattening of the raised portion of the epidermis could occasionally be detected. Impact injury at a low flesh firmness was often readily detected as a surface depression. Response to impaction was dependent on both height of impact and flesh firmness at time of injury. When flesh firmness was 11,3 kgf or above, virtually no internal injury was detectable from any of the impact heights used. Between 6,8 and 11,3 kgf flesh firmness, fruit occasionally developed a small volume (0,25 cm3) of injured tissue. Bruising appeared as a light to dark brown approximately spherical area located about half the distance from the seed to the epidermis in Hass and Pinkerton avocado fruit. Injury colour was similar in all cultivars, although injury location differed somewhat in Fuerte avocado fruit, appearing usually as a flattened disc below the epidermis. The softer the flesh at the time of injury, the darker the bruise colour in all cultivars.

Below 6,8 kgf flesh firmness, 23 and 46 cm impacts produced internal injuries similar to the 92 cm impact on fruit of higher flesh firmness. Following impacts of fruit between 4,5 and 6,8 kgf flesh firmness, a small plug of distinctly brown mesocarp tissue would adhere inside the epidermis when the ripened fruit was peeled for examination. This phenomenon was not observed in either softer or firmer fruit. When all cultivars were injured at flesh firmnesses below 4,5 kgf, an air pocket near the centre of the bruised tissue frequently developed. The air pockets were sometimes circular in form and with striation which radiated throughout the injured tissue. In soft fruit, injured tissue began at the inner epidermis, radiated out into the mesocarp, and often reached the seed in the Hass and Pinkerton fruit.

The difference in apparent impact injury response between Hass, Pinkerton and Fuerte may be due in part to specific cultivar differences in levels of phenolic substrates or phenolic enzyme activity, although this was not studied here. Golan *et al* (1977) measured substantial differences in the phenolic activity of the Fuerte and Lerman cultivars. Avocado cultivars may also be distinguished on the basis of thick or thin skins. The Hass variety is characterised by a thick, bumpy skin, whereas the Fuerte is a thin-skinned fruit. The Pinkerton has a skin texture similar to Hass, but somewhat thinner. The amount of sclerenchyma cells within the exocarp may have a direct bearing on resistance to mechanical injury (Biale & Young, 1971).

The results of these impaction tests indicate that the response to impact bruising is dependent on flesh firmness and on the height of the impact. No internal injury is likely if fruit is injured at a flesh firmness greater than 6,8 kgf.

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