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MEASURING AVOCADO FIRMNESS: ASSESSMENT OF VARIOUS METHODS

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SUMMARY

Firmness is an important characteristic of avocado fruit as it is the most reliable method of determining if the fruit is ripe to eat. A range of different methods are available to assess firmness of avocados; Firmometer, 2 mm deformation of whole fruit, puncture tests using Effegi probes and conical probes (Chatillon), and gentle hand squeezing of the fruit. The Firmometer, originally developed in South Africa and modernised in N.Z. (called the Anderson Firmometer), is increasingly being used by the N.Z. avocado industry as a tool to measure firmness. The aim of this study was to identify the most appropriate method of measuring 'Hass' avocado firmness at both the firm (at harvest) and soft (eating ripe) stages. As squeezing the fruit by hand is the most common method employed to measure avocado firmness, all the tests were compared to this. The Firmometer had the closest relationship with hand firmness (R^2 = 0.93) across the entire firmness range. Use of a 200 g weight rather than a 300 g weight on the Firmometer allowed greater measurement sensitivity of softer fruit.

KEY WORDS: Firmometer, ripeness, postharvest, *Persea americana* (Mill.), 'Hass'

INTRODUCTION

Firmness is an important characteristic of avocado as it is the most reliable method of determining if the fruit is ripe to eat. The firmness at which a fruit is consumed or assessed for quality is very important since rots and internal disorders of 'Hass' avocado develop rapidly during the latter stages of fruit ripening (Hopkirk *et al*., 1994). Research groups have used a range of different methods to assess firmness of avocados. For example; Firmometer (Swarts, 1981), whole fruit compression (Hoffmann, pers comm), puncture tests using Effegi probes (Arpaia *et al*., 1987) and conical probes (Meir *et al*., 1995), and tactile assessment (Hopkirk *et al*., 1994).

The Firmometer was developed in South Africa and is specifically designed for whole fruit compression testing of avocado fruit. The Firmometer has been modified in New Zealand (precision engineering and digitalisation) and named the Anderson Firmometer. It is increasingly being used by the N.Z. avocado industry as a tool to measure firmness.

A puncture (or penetrometer) test using a probe with a convex tip (e.g. Effegi) is the most widely used method of measuring firmness in a range of fruit (Harker et al., 1997). With avocado, a probe with a conical tip (e.g. Chatillon) is often used during puncture tests. An advantage of using a conical probe is that fruit firmness can be measured without needing to remove the skin (Fuchs and Zauberman, 1987). The other widespread method for measuring avocado firmness which is used by industry personnel, researchers and consumers is gentle hand squeezing of the fruit (Harker *et al*., 1997).

The aim of this study was to investigate relationships between instrumental methods of measuring avocado firmness and hand assessments. The methods investigated are currently used in various parts of the world by either industry or researchers.

MATERIALS AND METHODS

Approximately 160 ‘Hass’ avocado fruit were held at 15°C without storage, and at regular intervals during ripening a sample of fruit was assessed for firmness using the following methods; hand firmness, Firmometer, whole fruit compression (WFC), Chatillon puncture and Effegi puncture. Half of each fruit was marked into quarters and four instrumental tests were made at these points around the equator.

Preliminary tests confirmed our ability to carry out four tests in adjacent quarters of the fruit without one test influencing another. The location for the first test Firmometer) was varied systematically from position ‘1’ to position ‘2’ etc, with each subsequent fruit. This ensured that measurements on the flat side of the fruit were not constantly associated with one type of test. Tests were carried out according to protocols described in literature (see below) for probe size and shape, as well as test speed and measurement criteria.

Hand firmness

Two experienced assessors undertook tactile assessments of each fruit. The fruit was held in the palm of the hand and squeezed with the fingers when fruit were firm, or with the whole hand when softer. An eight category scale, ranging from 0 (very hard, no “give” in the fruit) to 7 (over-ripe, flesh feels almost liquid) was used. A value of 5 (whole fruit deforms with moderate hand pressure) corresponded with our definition of fully ripe. The scores of both assessors were averaged.

Firmometer

The Anderson Firmometer measures deformation over a 10 second period after a force has been applied to a 17 mm diameter convex probe. The deformation in mm is multiplied by 10 to give the ‘Firmometer value’. A typical value obtained immediately after harvest is approximately 10-15 and as fruit soften the Firmometer values increase to a maximum of 110.

Tests applied using a food testing machine

An Instron model 4301 materials testing machine (Instron, Canton, Mass. USA) fitted with a 5 KN or 100 N load cell was used to apply the following tests. Maximum force was determined.

Whole fruit compression

An 8 mm diameter probe with a hemispherical tip deformed fruit (skin intact) 2 mm at a speed of 20 mm·min^{-1} (Hoffman, pers comm; ASAE standard, 1984).

Puncture using conical probe (Chatillon)

A 6 mm diameter probe tapering to a conical tip in 4 mm was driven 8 mm into the fruit (skin intact) at a speed of 180 mm/min (Pesis, pers comm).

Effegi puncture

A portion of skin (approximately 2 mm thick) was removed from the fruit. An 11.1 mm diameter Effegi probe was driven 8 mm into the flesh at a speed of 240 mm·min^{-1} (Harker *et al*., 1996).

Modifications to the Firmometer

The Firmometer was modified in an attempt to increase sensitivity of measurement of soft fruit. The 300 g weight used to provide constant force during deformation measurement was replaced with 100 and 200 g weights. A total of 120 fruit were assessed during ripening at 20^{o}C over a period of 7 days until fruit were over-ripe. Fruit were ethylene treated (100 mg·liter^{-1} for 48 hours at 20^{o}C) so that fruit would ripen in a more uniform manner. A sub-sample of fruit was measured daily on the Firmometer using each of the three weights on each individual fruit. Fruit firmness was also assessed by hand.

Statistical analysis

Relationships between hand and mechanical device firmness measurements were examined with scatter plots. A data driven smoothed curve using the loess smoothing function in S-PLUS (Statistical Sciences Inc, 1991) was fitted through the points to examine relationships further. There appeared to be a multiplicative error relationship between hand firmness measurements and the Instron applied tests. A $\log_e$ transformation was applied to the mechanical devices to make relationships simpler and stabilise the variation present. R^2 measurements about the smoothed curve were calculated.

RESULTS AND DISCUSSION

Relationship of tests to hand firmness

Measurements made using the Firmometer provided an almost linear relationship to hand assessment of fruit firmness when plotted on untransformed scales (Figure 1). The other three objective test methods exhibited a curvilinear relationship with hand assessments. These instrumental measurements were able to discriminate differences between very hard fruit that tactile assessment was unable to perceive, but hand assessment was able to discriminate differences between soft fruit when the instrumental measurements were unable to measure differences. This curvilinear relationship is typical of the psychophysical basis of human perception of texture (Harker *et al*., 1997). All devices provided reasonable predictions of hand firmness when the datasets were transformed (Figure 1).

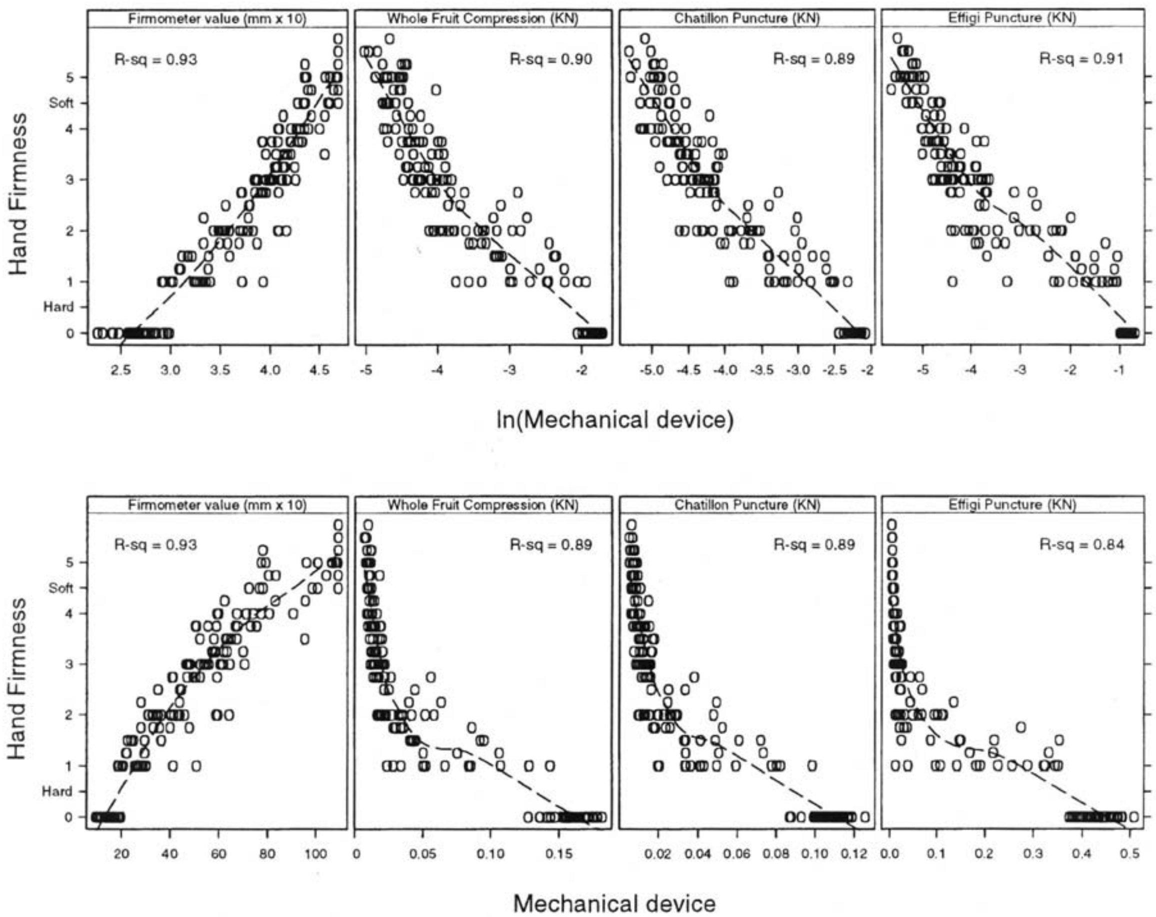

Figure. 1. The relationship between the firmness of the same individual avocado measured by hand (averaged rating of two experienced assessors, 0=hard, 5=fully ripe) and by various mechanical devices (untransformed and Log_e transformed data). R^2 was calculated about the smoothed curve.

Overall, the Firmometer was the most convenient device to use since the data did not need to be transformed. The Firmometer mimicked the hand at being relatively insensitive to very firm fruit and more sensitive to soft fruit. For Instron based measurements, there appears to be a misclassification in hand firmness readings at the firm end.

The different firmness tests all used different speeds, reflecting the methods used by various international groups. Fruit, however, are viscoelastic and thus the speed that a test is conducted will influence the measurement. The importance of this effect was investigated with the whole fruit compression and puncture tests (data not shown). Findings confirmed that the speed at which a firmness test is carried out influences the maximum force value. Therefore firmness values generated using a particular method and speed cannot be compared to values generated using the same method but carried out at a different speed.

Modifications to the Firmometer

The relationship between Firmometer values and hand assessment rating was fairly linear for the 100 and 200 g weights but was curvilinear for the 300 g weight (Figure 2). The 300 g weight was unable to differentiate between fruit that had a hand firmness rating of more than about 4.5 i.e. ripe to over-ripe. The 100 and 200 g weights were more sensitive and were able to differentiate fruit which were rated as ripe to over-ripe by hand firmness.

These results suggest that it is more appropriate to use a 200 g weight on the Firmometer rather than a 300 g weight when measuring fruit firmness as fruit approach eating ripeness. Using a 300 g weight is appropriate if fruit which are to be tested are firm, as would usually be the case when used by industry to monitor quality prior to marketing and consumption. However, for researchers and the retail industry, use of the 200 g weight would be more appropriate as fruit tested would be approaching, or at eating ripe. It should be noted that values generated on the Firmometer using the 200 g weight cannot be directly compared to values generated using the 300 g weight.

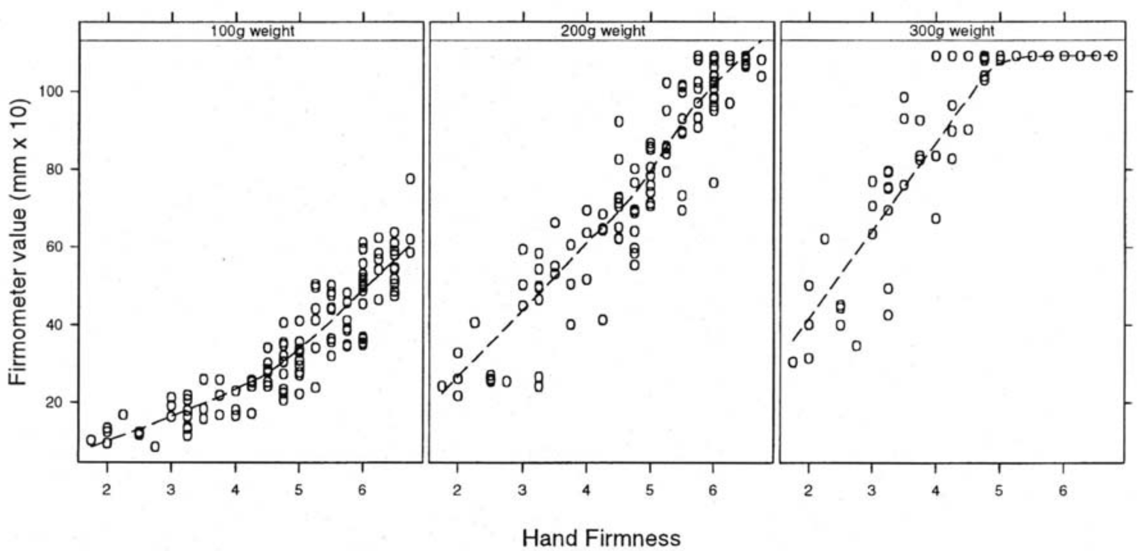

Figure 2. The relationship between the firmness of the same individual avocado measured by hand (averaged rating of two experienced assessors, on a scale of 0=hard to 7=over ripe) and by the Firmometer, using either a 100, 200 or 300 g weight to provide the force A.

Having assessed four objective methods of measuring avocado firmness, we conclude that the Firmometer appears to be the most accurate, practical method and, with slight modifications, is able to discriminate between fruit over the entire firmness spectrum.

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