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THE ELECTRONIC FIRMOMETER

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Abstract

The rate of ripening, which may be measured by changes in fruit firmness, is a key variable to be understood in the handling and sale of quality 'Hass' avocados. However, currently there is no generally accepted technique for objectively measuring avocado firmness in New Zealand.

A new version of the South African analogue firmometer was developed and called the Anderson firmometer. Although it uses the same principle as the South African firmometer, the Anderson firmometer employs an electronic timer and digital displacement meter. The aims of this research were to describe and calibrate the Anderson firmometer, and relate the softening of 'Hass' avocados using the Anderson firmometer to other subjective measures of fruit ripening such as; skin colour, hand firmness, button and stone removal and taste.

Aside from slight changes made to the calibration point (which allowed softer fruit to be measured), the Anderson firmometer produced similar firmness values to those obtained using the South African firmometer. The Anderson firmometer reduced user variability and increased speed and ease of use compared to the South African firmometer. The firmometer provides an objective measure of fruit firmness which can be related to subjective descriptions of softening used by industry and consumers. Firmometer values can therefore be used for standardisation and unambiguous communication within the avocado industry.

Introduction

Firmness is an important characteristic of avocado as it is the most reliable method of determining if the fruit is ripe to eat. Change in skin colour from green to black, which is also an indicator of ripening in 'Hass', can be very inaccurate, as fruit which is ripened at lower temperatures can be ready to eat while the skin colour is still green (Hopkirk *et al*, 1992). A widespread method for measuring firmness used by both industry personnel and researchers in N.Z. is gentle hand squeezing of the fruit. This method, while being subjective, is valid as it is a rapid technique which does not damage the fruit and the consumer is likely to use such a method to determine fruit ripeness.

Researchers overseas use a number of methods to determine avocado fruit firmness, generally either compression by hand or machine (skin intact e.g. firmometer or Instron), or a puncture method (skin removed e.g. penetrometer). As fruit approach eating ripeness, researchers widely believe that the skin must be removed from 'Hass' avocados to obtain a precise measurement of firmness as both skin thickness and skin elasticity can result in false readings using a compression test, i.e. soft flesh can be masked by a hard skin.

The firmometer is a device developed in South Africa to objectively measure avocado fruit firmness as the resistance to compression of the whole fruit (skin intact) when a force is applied through a 17 mm diameter button over a 10 second period (Swarts, 1981). The displacement of the button gives the firmometer value which increases as fruit soften. This is opposite to other firmness devices where values decrease towards zero as the fruit soften. As a tool to objectively measure firmness, the firmometer is portable, easy to operate, relatively non-destructive, and reasonably affordable. In addition, there is a large base of historical data and experience from South Africa where standards have been set for handling and exporting fruit based on maximum firmometer values. For example, export lines are routinely sampled at the packhouse to ensure that fruit are less than a standard value (Pers. com., Colin Partridge). In addition, on arrival in Europe, fruit should not be above a firmometer value of 30 (Vorster *et al*, 1991).

The aims of this research were i) to describe the new Anderson firmometer, ii) calibrate the Anderson firmometer against the South African firmometer and iii) relate values obtained using the Anderson firmometer to subjective measures of fruit ripening in 'Hass' avocado such as; skin colour, hand firmness, button and stone removal and taste. Relating subjective measures of fruit ripening to firmometer values will enable both industry and research personnel to have a fixed reference point for discussion of firmness/ripeness.

Materials and methods

During 1996, a new version of the South African firmometer was developed and constructed by Team Horticulture staff and Ross Anderson (Anderson Manufacturing and Toolmaking, P.O. Box 10097, Arataki). A newly manufactured South African firmometer was supplied by Colin Partridge of Team Avocado for comparison. Both firmometers were calibrated against a Staedtler "Rasoplast" eraser.

'Hass' fruit of three different firmness ranges »15, »55 and »70 were measured on both firmometers. Fruit were first tested on the Anderson firmometer, then rotated 90 degrees and measured on the South African firmometer. The firmometer value derived (0-110) is the mm displacement of the button multiplied by 10. A typical value obtained immediately after harvest is approximately 10-15, depending on the time in the season, and as fruit soften the firmometer values increase to a maximum of between 106-109.

'Hass' fruit from the Whangarei area which had been picked, packed, and handled in the standard commercial manner were obtained on four occasions during the season, October 1996 through to January 1997. During October a range of terms and measurements were developed which described the appearance, softness and taste of

the fruit as the firmometer value increased (i.e. fruit ripened). Many of these terms were rated on relative scales of between 0 and 3 or 6 depending on the variable. From November to January the range of variables were described along with firmometer values as fruit ripened.

The following factors are in the chronological order in which they were rated.

Colour: Determined by the extent of skin colour change from green (rating 0), to increasing proportion of purpling of the fruit surface, to black when over-ripe (rating 6).

Skin separation: Determined by cutting a 1.5 cm² square with a scalpel at the fruit equator.

The ease by which the skin square could then be lifted out was determined (0 impossible 3 easy).

Hand firmness: The "give" or deformation of the fruit was rated when squeezed with the fingers when fruit were firm, or with the whole hand when softer (0 very hard 6 deforms with slight pressure).

Button removal: The ease by which the button (peduncle or fruit stem) could be moved laterally, or removed was measured (0 no movement 3 easy to remove).

Stone removal: Where fruit could be cut and separated in half, the knife was lodged into the stone and the ease with which the stone could be twisted out of the fruit half was rated (0 impossible 3 easy to remove).

Taste: Where fruit could be separated, the flesh immediately above the stone (the last flesh to soften in the fruit) was tasted and described (0 inedible, very hard 3 soft smooth texture, full flavour).

Results

Description of the Anderson firmometer

The new Anderson firmometer (Figure 1) uses the same basic principle as the South African firmometer (Figure 2), and its use is similar, but there are two key differences. The zeroing of the displacement meter by the Anderson firmometer (winding the fruit up until it locks into place) is much faster and the use of the timer/arm release mechanism and digital displacement meter makes the 10 second measurement interval accurate and the attention of the operator is not required to make the reading. In addition, the ability to download the data to a computer has advantages where a lot of data is collected.

The South African firmometer was not designed to measure very soft fruit. However, as many consumers eat fruit which are very soft (over a firmometer value of 100), the Anderson firmometer was calibrated on the Staedtler rubber to a value of 15 rather than 20 (as for the South African firmometer) so that fruit in the softer range could be measured. During manufacture of Anderson firmometers, all machines are calibrated to 15 by varying the weight placed on the arm. This means that, unlike the South African firmometers which have weights of exactly 300g and are calibrated by moving the calibration weight along the arm, the weights of different Anderson firmometers are not

necessarily the same.

Calibration of the Anderson firmometer

Comparing the values obtained from the two firmometers using fruit at three nominal firmness values (15, 55 and 70), it can be seen that the two firmometers produced very similar results. The mean firmometer value along with its variability (standard error of the mean; SEM) are presented in Table 1. The major difference noted was the minimal variability of the Anderson firmometer as compared to the South African firmometer. The reduction in variability was as much as 11-fold.

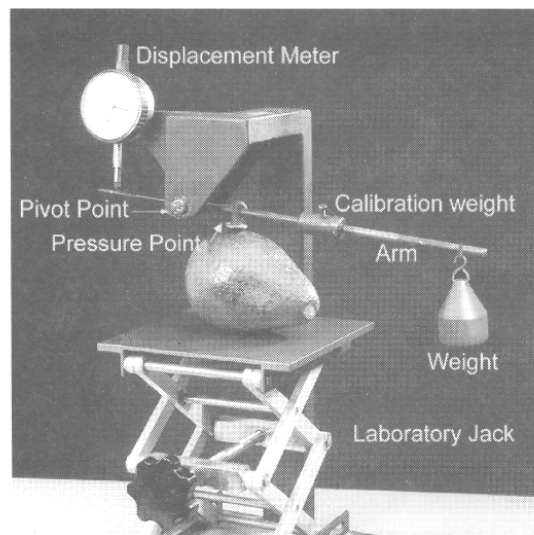


Figure 1 The South African firmometer as described by Swarts (1981)

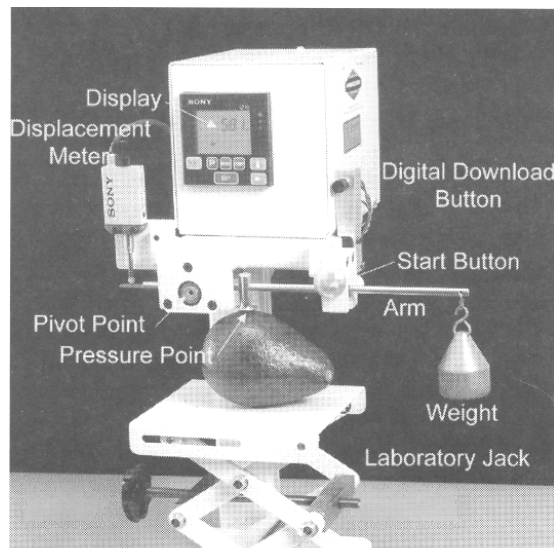


Figure 2 The Anderson digital firmometer

Relating firmometer values to subjective measures of fruit ripening

Changes to subjective measures of fruit ripening and their corresponding Anderson firmometer values are described below. The term "firmometer value" is hereafter abbreviated to f.v.

Colour: At harvest (f.v. between 10 and 15), skin colour was bright emerald green (rating 0), and changed to dull, kahki green at about a f.v. of 20. Purpling of the skin started as early as a f.v. of 20, and full purpling (rating 5) occurred between a f.v. of 50 and 100. Changes in the skin colour from purple to black (indicating over-ripeness) was not observed below a f.v. of 100.

Skin separation: The ease by which skin could be separated from the flesh changed relatively quickly such that the skin of fruit with a f.v. of 30-40 could be separated with moderate difficulty, yet easily separated at a f.v. of 50.

Hand firmness: The first changes which could be detected as fruit softened was the fruit becoming "rubbery" in nature (rating 1) which tended to occur at a f.v. of between 15 and 20.

First detectable softening of the flesh (rating 2) was observed at a f.v. of 30, and with increasing f.v. the flesh could be deformed more easily.

Button removal: As the f.v. increased to 20-30, the button could be moved, or removed with difficulty (rating 1). At a f.v. of >30 the button could be removed, but there was a large variability in the ratings above this point.

Stone removal: It proved difficult to remove the stone from the halved fruit using a knife at a f.v. of <40. Above this value, the stone was easier to remove.

Taste: The taste of flesh in the neck region of the fruit (just above the stone) was rated to be inedible or hard up to a f.v. of 50 (ratings 0-1). Above a f.v. of 50, the flesh was softer, but lacked flavour (rating 2). Generally taste became acceptable (rating 3) above a f.v. of 70.

Key changes to the ripening attributes during softening are summarised in Figure 3. Initial softening of the flesh and button movement were observed at firmometer values of 20-30 at which point the fruit can be described as "sprung". At firmometer values of between 40-50, it became possible to cut the fruit in half, and remove the stone and skin. Taste became acceptable at >70 and fruit generally achieved full colour at about this firmness. Thus fruit were defined as "minimally ripe" at a firmometer value of 70, ripe at 90, and late ripe at >110.

Table 1 Comparison of Anderson and South African firmometers readings for three fruit softness ranges

Fruit firmness	Anderson Firmometer		South African Firmometer	
	Mean	SEM	Mean	SEM
≈15	15.2	0.2	15.0	1.0
≈55	54.6	0.2	56.4	2.3
≈70	69.9	0.4	68.0	3.1

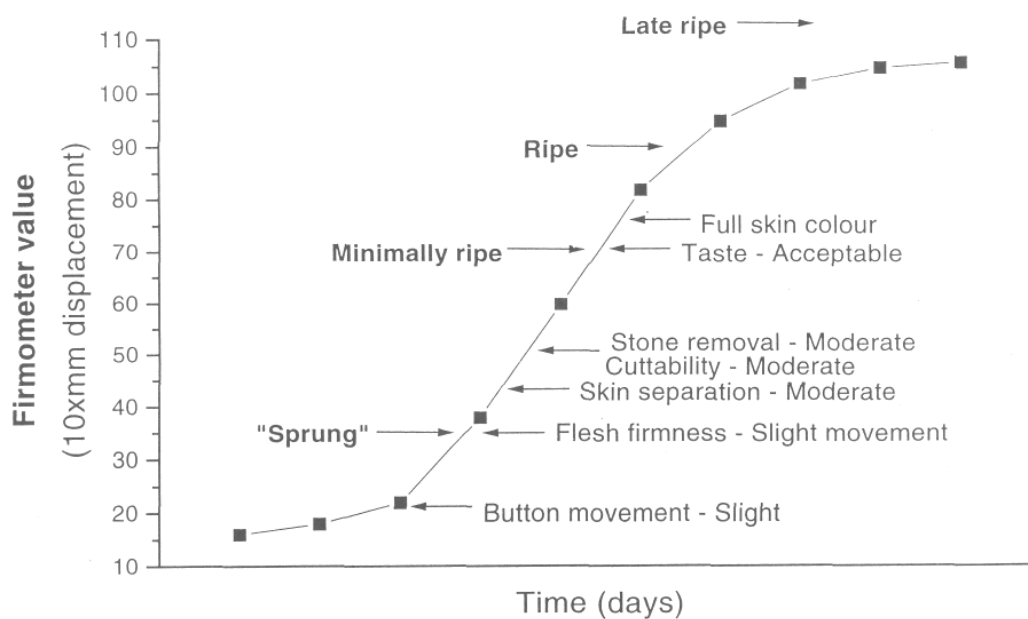


Figure 3 Generalised description of ripening of 'Hass' avocados over time based on softening curve measured by the Anderson firmometer

Discussion

The Anderson firmometer is a significant advancement in the measurement of avocado firmness due to its reduced user variability and increased speed and ease of use. Resulting firmometer values are comparable to those obtained using the South African firmometer.

Although it is difficult to define accurate changes in subjective attributes, the attributes we have endeavoured to describe are commonly used by industry and consumers. Skin colour is the first attribute used by consumers to determine whether Hass avocados are ripe. However, this is one of the more variable attributes and is therefore not a reliable measure of ripening. The ripening parameter "hand firmness" was more consistent and mirrored softening as measured by the firmometer.

As found with most mechanical measures of fruit firmness, the softening curves measured by the firmometer followed a sigmoidal pattern. Thus there is less change at the very firm, and soft end of the spectrum. It is for this reason (and its high speed), that researchers in N.Z. (and in other countries) have historically used hand pressure to determine the final point of "eating ripe". However, mechanical means such as the firmometer are preferable for measuring changes in firmness for fruit in the hard to minimally ripe range (<80 firmometer value) as hand pressure is less accurate at these stages.

The firmometer provides an objective measure of fruit firmness which can be related to subjective descriptions of ripening used by the industry and consumers. The firmometer value can therefore be used for standardisation and unambiguous communication within the avocado industry. The simplicity and reduced variability of the Anderson firmometer has enabled it to be used as a practical method of determining fruit firmness, and it is now being used by a major Australian supermarket to measure firmness for QC procedures.

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