Assessing fruit firmness through supply chains

What is fruit firmness telling us?

Climacteric* fruit such as mangoes, avocados and bananas undergo many changes as they ripen. These include the conversion of starches into sugars, water and carbon dioxide, changes in skin and flesh colour, and softening.

Under good ripening conditions these changes are synchronised so that the fruit have good flavour, colour and texture when ready to eat.

The fruit softens because of softening of the cell walls in the flesh, reduced adhesion between the cells and sometimes softening of the skin. The firmness of the fruit is often the most reliable and easiest measure of the ripeness stage.

Fruit firmness can also indicate when they are mature enough to harvest because some fruit types soften as they mature on the tree.

** Climacteric – the period of maximum respiration in a fruit, during which it becomes fully ripened.*

Who in the supply chain assesses fruit firmness?

- Growers of some fruit (e.g. apples, pears and stone fruit) – to schedule when to harvest.
- Transporters – to assess the effectiveness of their in-transit storage conditions.
- Wholesalers – to assess the suitability of fruit for and during storage.
- Ripeners – to assess whether the fruit have ripened to the correct stage.
- Retailers – to present fruit in store at a ripeness stage to maximise sales.
- Consumers – to understand when the fruit is ready to eat.

Measuring firmness along the chain

The procedures that supply chain members use to measure firmness should be quick, accurate, non-destructive and low cost. Using hand feel, a five-point rating scale such as in Table 1 can be used to describe fruit firmness in avocado and mango.

Table 1: A five-point scale for describing avocado fruit firmness when assessed by hand.

Stage of ripeness	Description
Hard	No give with strong thumb pressure
Rubbery / preconditioned	Slight give with strong thumb pressure
Sprung / softening / breaking	Deforms 2–3 mm with moderate thumb pressure
Firm ripe	Deforms 2–3 mm with slight thumb pressure
Medium to soft ripe	Deforms easily with gentle hand pressure

The hand can be very good at estimating firmness, but it is difficult to ensure consistency between assessors. To help 'calibrate' assessors, silicon fruit models were developed at the Department of Agriculture and Fisheries for each ripeness stage to help make the subjective assessment more consistent.

Figure 1 shows a half yellow (medium to soft ripe) and half green (firm ripe) silicon avocado model with tethering chain.

Figure 1: *Avocado silicon firmness model.*

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Queensland Government

Instruments to estimate firmness

Using an instrument to estimate firmness can reduce the error associated with the operator. Hand-held penetrometers have been in use for some time but only work properly on the flesh once the skin is removed. Several alternative instruments are now available to replace this time-consuming and destructive test.

The most suitable option for a given situation will depend on the following considerations:

- commercial availability,
- acceptance and use by industry,
- purchase cost,
- reliability, accuracy and repeatability,
- whether the process of measurement is simple, quick and neither destructive nor damaging to the fruit,
- suitability of the device firmness scale to the firmness ranges of the fruit as it ripens,
- complexity, cost and frequency of re-calibration,
- known equivalency with other firmness measurement devices, and
- flexibility to measure a range of fruit.

Some supply chain partners still use hand firmness assessment, and retail customers are encouraged to use this simple method. However, objective measurement is becoming the preferred approach because of the increasing availability of firmness units that meet the above requirements. This is facilitating the more effective use of firmness in receival specifications.

Durometers are commonly-used commercial devices in Australia. The plunger size/shape and spring characteristics are chosen to suit the firmness range of the fruit. The readings are given in Shore units, with typical ranges shown in Table 2. The reading reflects the depth a plunger penetrates into the fruit. Examples include the Bareiss analogue HP Fff, the Turoni durometer 53215 and the Bareiss digital HPE II Fff (Figures 2, 3 and 4).

Researchers use more accurate and expensive laboratory units to measure firmness. These are typically bench-mounted units that can accurately measure the force required to push a plunger 1–2 mm into the fruit. Examples include texture analysers (e.g. Shimadzu EZ Tester) that provide readings in Newtons, which is a measure of force.

Comparing readings between devices

The Department of Agriculture and Fisheries have evaluated several hand-held firmness devices for different commodities and cultivars.

The performance of new firmness measuring devices have been compared with a laboratory instrument (an EZ Tester) by measuring firmness on different locations on the same fruits as they ripen, such as shown in Table 2. This way we can compare the data collected from a range of firmness devices. Tables such as this can be developed for any firmness device on any produce where there is an existing firmness scale.

Operating procedure

A strong focus on using the correct operating procedure is required to ensure accurate and consistent results between assessors. The manufacturer's instructions should be followed, including regular calibration. For most instruments, the device should be held vertically and the fruit placed on a hard bench while measuring.

A minimum of two readings should be taken equatorially on each fruit. The number of fruit assessed depends on the number of fruit in the consignment, and is typically about 40 fruit per pallet. An average firmness for the population can then be determined from these readings.

Measurement using EZ / durometer devices will cause a slight indentation and softening of the fruit, particularly in the softer stages. Mark the site of any readings using these devices and avoid re-measuring in the same spots previously tested.

There are five key steps that should be followed when using the Turoni 53215TT Durometer.

1. Hold device vertically away from surfaces and press 'ZERO'.
2. Hold device vertically against glass surface, press 'CAL' until beeps and then it should read 100.
3. Re-zero the device and press 'MAX'.
4. Identify test sites (two per cheek).
5. Press the device vertically against fruit and record values for averaging.

Figure 2: *The Bareiss analogue HP Fff durometer.*

Figure 3: *The Turoni 53215 durometer.*

Figure 4: *The Bareiss digital HPE II Fff durometer.*

Table 2: Comparative readings from two hand-held devices and a laboratory-based EZ Tester for the five ripeness stages of R2E2 and Kensington Pride mango, and Hass and Shepard avocado using the recommended tip size and calibration for these fruit.

	Firmness Rating	Penetrometer[1] (kg Force)	EZ Tester (N)[2] (Neutons)	Durometer[3] (Shore units)
R2E2 mango	Hard	–	>30	>82
	Rubbery	–	22.1 – 30	77 – 82
	Sprung	–	7.1 – 22	51 – 76
	Firm soft	–	5 – 7	43 – 50
	Soft	–	<5	<43
Kensington Pride mango	Hard	–	>30	>83
	Rubbery	–	22.1 – 30	79 – 83
	Sprung	–	7.1 – 22	53 – 78
	Firm soft	–	5 – 7	41 – 52
	Soft	–	2.3 – 4.9	24 – 40
Hass avocado	Hard	>10	>28	>81
	Rubbery	2.2 – 10	15.8 – 28	74 – 81
	Softening	1.1 – 2.1	8.1 – 15.7	59 – 73
	Firm ripe	0.7 – 1.0	4.8 – 8	44 – 58
	Medium-soft ripe	0.4 – 0.6	3.3 – 4.7	33 – 43
Shepard avocado	Hard	>10	>28	>80
	Rubbery	2.2 – 10	15.8 – 28	70 – 80
	Softening	1.1 – 2.1	8.1 – 15.7	54 – 69
	Firm ripe	0.7 – 1.0	4.8 – 8	41 – 53
	Medium-soft ripe	0.4 – 0.6	3.3 – 4.7	32 – 40

[1] *Force required to move 11.1mm tip 8mm into flesh without skin.*

[2] *12 mm diameter spherical probe that travels 2 mm after contact with fruit skin surface at a rate of 10 mm/min.*

[3] *Measure of shore unit firmness through the skin using a 5 mm diameter ball test anvil on either a Bareiss HPE II Fff or Turoni 53215TT durometer.*

Other technologies

Other technologies can measure firmness, but are currently either more expensive, and / or not yet fully adapted for commercial use.

These include acoustic resonance, force sensing resistors (e.g. Readycado), laser doppler vibrometry (e.g. Compact Laser Vibrometer), laser photon counting, low mass impact sensors (e.g. iQ Firmness Tester), micro deformation sensors (e.g. Electronic Firmometer), NIR spectroscopy (e.g. Inspectra), nuclear magnetic resonance, optical-based tactile sensors (e.g. Gelsight), ultrasound and X-ray.

More information

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The Serviced Supply Chains project is funded by the Hort Frontiers Asian Markets Fund (project AM15002), part of the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from the Department of Agriculture and Fisheries (Queensland), Department of Jobs, Precincts and Regions (Victoria), Manbulloo (mangoes), Montague Fresh (summerfruit), Glen Grove (citrus), the Australian Government plus in-kind support from the University of Queensland and the Chinese Academy of Sciences.