Tropical Agricultural Research Vol. 20: 134 - 142 (2008)

Evaluation of Finger-Feel Firmness as a Subjective Measurement of Tomato Quality Degradation in the Retail Market

C.L. Ranatunga, H.H.E. Jayaweera[1] and T.R. Ariyaratne[1]

Department of Physics
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

ABSTRACT. *The versatility of the Finger-Feel-Firmness (FFF) test method has been proved with a series of panel evaluations. Judgment of the panel on the pattern of the variation of FFF, agrees with that of the author. An individual can be trained to monitor the pattern of variation of FFF. Absolute values of FFF however, depend on the personal force-sensitivity of the individual. Degradation of the firmness due to squeezes made in FFF test itself has also been investigated. Retail market tomatoes registered a rate of loss of average FFF from 60 to 65 g/d and the level of ripeness of the sample had no significant effect on this rate. On repeated squeezing in the FFF test itself, the rate of loss of FFF was only about 4 g/squeeze. Development in red colour with shelf-life in less-ripe tomatoes was nearly 3 times faster compared to 0.5 rank/d in red-ripe tomatoes. However, the loss of FFF with the development in red colour in less-ripe tomatoes was 40 g/rank and it was more or less 3 times slower compared to 121 g/rank in red-ripe tomatoes. It was clear that the natural deterioration does about 15 times severe damage to the whole fruit, compared to the induced local damage by squeezing in the FFF test. With knowledge of colour and FFF value, it is possible to estimate the expected shelf life of tomatoes. Tomatoes ripened up to colour rank 10 would spend a shelf-life till they reach a range of FFF as low as 100 to 200 g (subject to personal force-sensitivity, tomato variety and post-harvest management methods.)*

INTRODUCTION

At retail market, the quality of fruit and vegetables (F&V) is mainly sensed by consumer using tactile (touch) methods and kinesthetic (movement) methods. Indirectly, the method sometimes extends to vision and hearing too (Barrett *et al.,* 1998). Kinesthetic methods sometimes extend up to failure mechanism which indicates the breaking point of fruit (*e.g.* Ladies Fingers, Snake Gourd, Luffa). Stiffness is the mechanical property that is measured in such tactile methods. Firmness of F&V refers to almost all the textural properties associated with the commodity (Barret *et al.,* 1998). Texture is not a single, well-defined attribute. It is a collective term that encompasses the structural and mechanical properties of a food and their sensory perception in the hand or mouth (Barrett *et al*., 1998; Abbot, 2004). Texture in food products is generally defined as the overall feeling that a food gives in the mouth and is therefore comprised of properties that can be evaluated by touch (Batu, 1998; Abbot, 2004). Texture is a sensory property and thus only a human being (or an animal in the case of animal food) can perceive and describe it. The so-called texture testing

[1]Centre for Instrument Development, Department of Physics, University of Colombo, Colombo 03.

instruments can detect and quantify only certain physical parameters which then must be interpreted in terms of sensory perception. Texture derives from the structure (molecular, microscopic or macroscopic) of the food. It is detected by several senses, the most important ones being the senses of touch and pressure (Szczesniak, 2002). Firmness of F&V is used as a measure to identify the harvesting maturity at the farm. Loss of fruit firmness can be used as an index to estimate and manage the damages occurred during harvesting, handling and transporting processes. Destructive instrumental test methods are often used for estimation of firmness of tomatoes at harvesting maturity and at less-ripe stages. Instrumental methods are of less use in firmness testing of tomatoes ripened up to retail market level. At this stage, tomatoes have almost reached nearly table-ripe red colour. Colour indices are used worldwide for ranking and monitoring the development of red colour during the shelf-life (Barrett *et al.,*1998; Allende *et al.,* 2004). The Finger-Feel-Firmness (FFF) method can be applied in monitoring the variation of firmness with shelf-life. F&V at the retail market are quickly sorted by consumers mainly with its physical appearance (colour) and with feel at the finger touch which is referred to as Finger-Feel-Firmness (Kader *et al*., 1978; Barrett *et al*., 1998; Batu, 1998). The objectives of this study were establishing the FFF test method and providing a scientific interpretation to the physical appearance (colour) and the pressure exerted on tomato for quality judgment at retail market. The texture of the fruit in terms of sensory perception in the eye and hand is employed in this technique.

MATERIALS AND METHODS

Test sample

Whole fruit tomatoes of similar size and shape with good physical appearance were selected from wooden transport-boxes (48 × 21 × 28 cm) as soon as they were received at retail market. It is assumed that the bulk of the sample had undergone the same management strategies in terms of time and rate of deterioration throughout its journey from farm to retail market (Holt *et al.,* 1983). Equatorial and polar diameters and weights were recorded. Four positions (1, 2, 3, and 4) were marked on the skin of one half of the equatorial circle of each fruit. These positions were nearly equally spaced but strictly avoiding the radial arms of the pericarp. This labelling would facilitate the identification of different positions on a given fruit for testing at different occasions. Ripeness of tomatoes was determined with the colour distribution from green to red. The denser the red colour in the distribution, the higher is the degree of ripeness.

Establishing a colour index

A colour index that can be used to monitor the development of the red colour not only at the harvesting stage but also in close proximity to table-ripe stage was proposed in this study. This is derived from the VBT colour card of Leuven, Belgium (Allende *et al.,* 2004), but different to that of USDA Standards 1975 (Barrett *et al.,*1998). In this colour index, the span of colour from green to red was divided into 10 ranks and it facilitates the discrimination of colour in red-ripe tomatoes as well. Determination of the colour was within the accuracy of ± 1 rank.

The colour index given in Table 1 was used in determination of the development of red colour in retail market tomatoes. G, Y, P, R refers to colours green, yellow, pink and red respectively. Notation for the colour distribution refers to the area of the surface which indicates the particular colour (e.g. G3YP2 means that 3/5 of the area of tomato surface is green whilst the remaining 2/5 is yellow-pink).

Table 1. The Colour Index used for Tomatoes

Colour Rank	Colour Index							
	Colour Combination					Colour Distribution		
	1	2	3	4	5	Green	Y to P	Red
1	G	G	G	G	G	G5		
2	G	G	G	G	YP	G4	YP1	
3	G	G	G	YP	YP	G3	YP2	
4	G	G	YP	YP	YP	G2	YP3	
5	G	YP	YP	YP	YP	G1	YP4	
6	YP	YP	YP	YP	R		YP4	R1
7	YP	YP	YP	R	R		YP3	R2
8	YP	YP	R	R	R		YP2	R3
9	YP	R	R	R	R		YP1	R4
10	R	R	R	R	R			R5

Finger-Feel-Firmness test method; panel judgment and Personality Indices of panellists

As in all other firmness test methods, the FFF test method also suggests a force value as the firmness. In this study, the FFF was considered to be the force exerted with the tip of fore-finger until the panellist just begins to feel that the tomato is being squeezed. Five members were trained for the FFF test method. Taking into consideration the member's perception, decision making and adjustment (Anon. 2003), the sensitivity in loss of FFF per day as sensed by individual member was used as his / her personality index. Attention of panellists was drawn to maintain the consistency of his / her own pattern of loading. Tomato was placed on platform balance (Shimadzu EB 3200H, ± 0.01 g) such that the equatorial circle of the fruit touches the balance pan. Panellists were instructed to squeeze the fruit gently at position 1 on shelf day 1, in vertically downward direction, using the fore-finger until he / she just begins to feel that the fruit is being squeezed. The maximum contact area (mm^2) of the fore-finger of each individual at desired force range exerted on fruit surface was determined. The results of the panel judgment were used to study the average drop in FFF per squeeze as felt by individual panellist.

Use of FFF method to study the quality of tomato

Having established the FFF test method with the panel test, the following tests were undertaken on retail market tomatoes.

i) Loss of FFF and development of red colour with shelf-life,
ii) Loss of FFF due to repeated number of squeezes made in FFF test,
iii) Loss of FFF due to severe drop-damage. The damage taken place on the tomato fruit due to the impulsive impact with the cement floor after having fallen under gravity through a drop-height of 50 cm was considered.

RESULTS AND DISCUSSION

Panel judgment

The loss of FFF with the shelf-life of a particular tomato sample collected from retail market as measured by the panel members and by the author is shown in Figure 1. Force sensitivity of the author which was measured in grammes, was around 37 g/shelf day. The contribution of higher sensitivity of some of the panellists has given rise to a relatively high overall sensitivity (≈ 66 g/shelf day) of the panel (Figure 1).

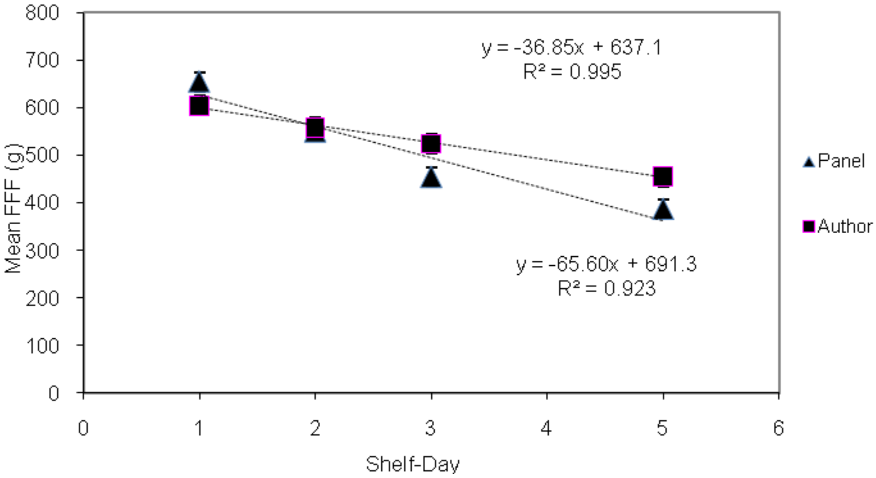

Figure 1. Loss of FFF with shelf-life; panel judgment and author's judgment

Loss of FFF and development of red colour with shelf-life.

Retail market tomatoes, though selected from a single load, were found to have different degrees of ripeness. The sample (n=35) was divided into two categories namely YPR (15 ripe tomatoes; yellow, pink, red in colour) and GYP (20 less-ripe tomatoes; green, yellow, pink in colour) according to the colour distribution observed on day-1. YPR and GYP labelling refers to the colour combination observed on day 1 only. Figure 2 shows the loss of FFF with shelf- life in the two categories. GYP registered a higher FFF than that of YPR. The rate of loss of FFF was slightly faster in less-ripe stages and, with increasing ripeness this rate was found to diminish gradually. With increasing ripeness, the flesh had become feeble and the contribution of the flesh to the resistive force against the FFF squeezes had become weaker. The resistive force might have mainly originated from the peel (Batu, 1998;

Abbot, 2004). The FFF value of GYP tomatoes on day 5 was found to be similar to the corresponding value of YPR tomatoes on day 2, which means that green tomatoes retain their firmness for a longer time on the market shelf.

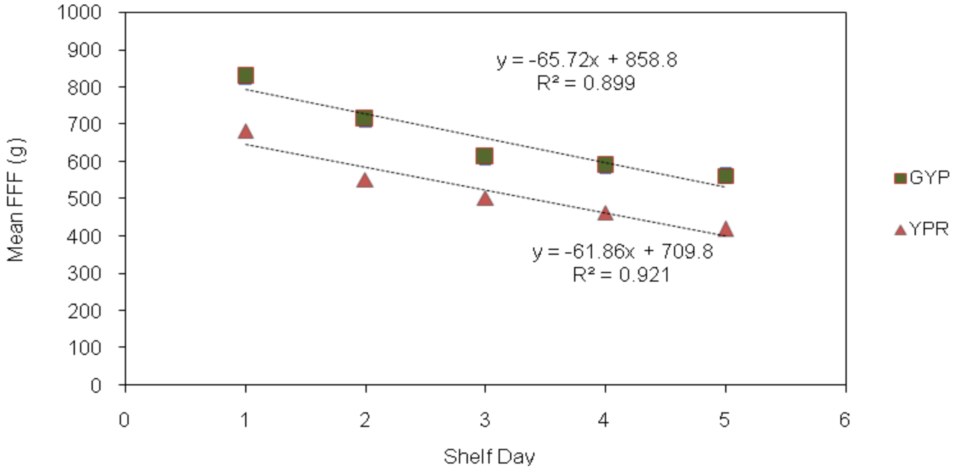

Figure 2. Behaviour of FFF with shelf-life in tomatoes at different ripening stages

In general, the overall rate of loss of FFF, when assumed to be linear, was seen independent of the level of ripeness and was nearly the same in GYP and YPR categories (65 and 62 g/d respectively). Figure 3 shows the development in red colour with shelf-life of GYP and YPR tomatoes. Rate of development of red colour in GYP tomatoes was steeper during the first 3 days. It gradually drops down on days 4 and 5 and this reduced rate approximates to the rate in YPR category during first 3 days. Although the overall behaviour is non-linear, the regression line has been plotted to estimate an average rate for the mean red colour development. Overall development in red colour was nearly 3 times faster (1.7 against 0.5 rank/d) in GYP tomatoes.. Figure 4 illustrates that the loss of FFF with the development in red colour is more or less 3 times slower (40 against 120 g/rank) in GYP category.

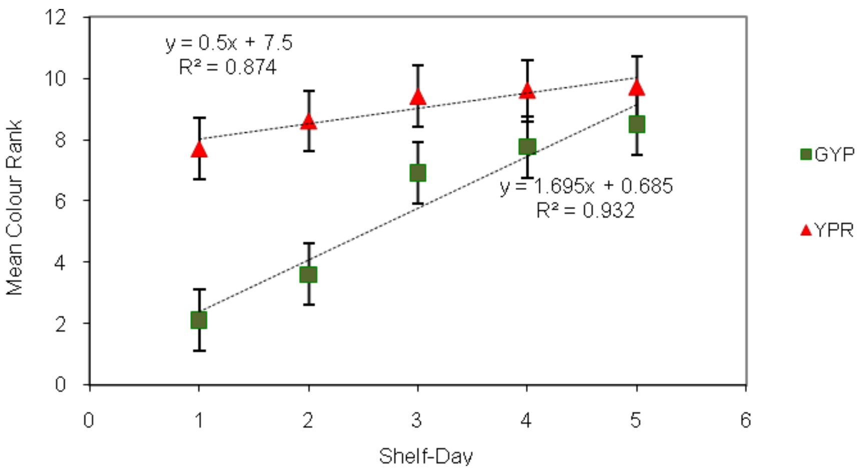

Figure 3. Daily development of red colour in tomatoes at different ripening stages

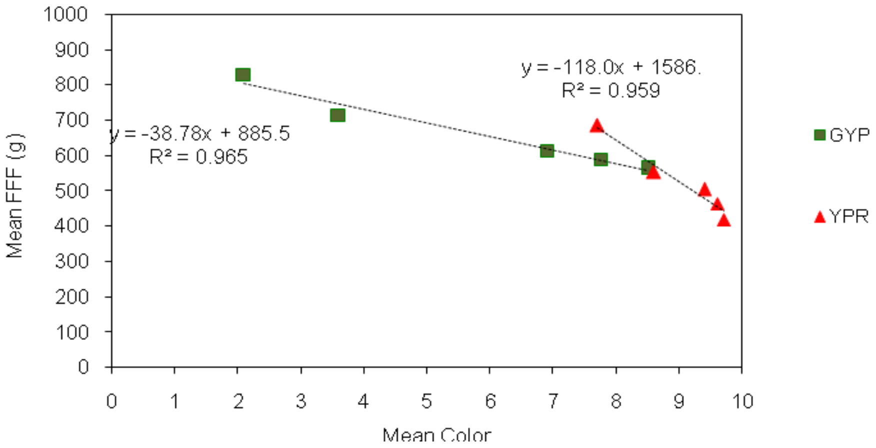

Figure 4. Variation of FFF with red colour development of tomatoes at two different ripening stages

When the firmness and the colour variations of the GYP and YPR tomatoes as depicted in Figures 2, 3, and 4 are considered together, it can be argued that it is an advantage to pluck tomatoes in the GYP stage and introduce to the retail market since those tomatoes gather red colour faster and retain their firmness at a higher level compared to YPR tomatoes. In consumers' point of view, purchasing of less-ripe tomatoes (having green colour still appearing on skin even in traces) at the retail market would provide them fruits with extra shelf-life and a higher firmness.

Loss of FFF with repeated squeezing

The loss of FFF on repeated squeezing in this FFF test was only around 4 g/squeeze and this rate of loss of FFF with squeezing was found to be independent of the level of ripeness (Figure 5). With shelf-life, the FFF drops at a rate of nearly 63 g/d. These results indicate that the daily natural deterioration does much (about 15 times) severe damage to the whole fruit, compared to the highly local damage induced by a single squeeze in this FFF test. Tomatoes ripened up to colour rank 10 would spend a shelf-life till they reach a range of FFF as low as 100 or 200 g (subject to personal force-sensitivity, tomato variety and post-harvest management methods).

The results of the above test provide an estimate of the damage induced by repeated squeezes made by consumers in sorting them at shelves in super markets or retail markets. Provided the consumer stops squeezing as he begins to feel that the tomato is now being squeezed, the resulting damage is negligible. However, many squeezes (about 10 – 15) if made repeatedly on the same location, the resulting damage would definitely shorten the shelf-life of fruit.

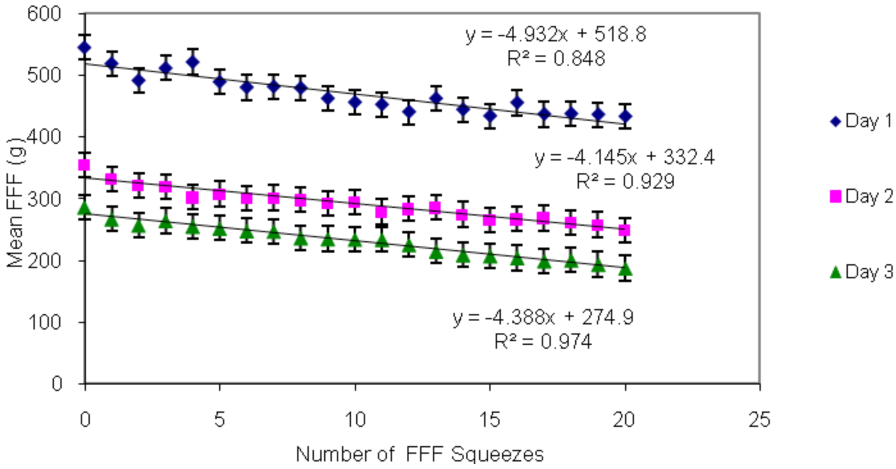

Figure 5. Variation of FFF with repeated number of squeezes

Loss of FFF due to severe drop-damage

A behaviour similar to that observed in repeated squeezing was identified in drop-test (Figure 6). Five numbers of drops (height 50 cm) under gravity brought about a total loss of FFF of 500 g. At the beginning the loss was marked. Between the first and second drop-impacts the loss was about 80%. First drop itself inflicted more than 50% of the total damage (~ 55%) that took place in the series of 5 numbers of drop test.

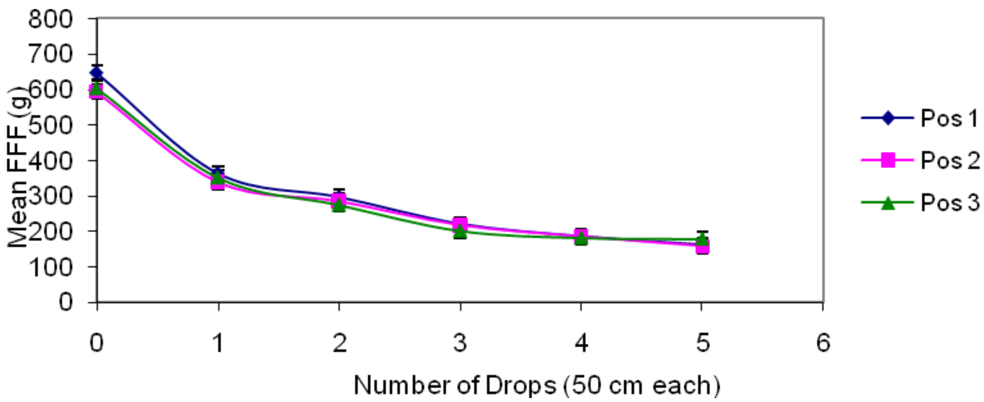

Figure 6. Loss of FFF with Repeated Number of Drop-Damage

With increasing numbers of drop-tests, the rate of loss gradually decreased. The visco-elastic nature that brought about in tomato pulp due to fall might have absorbed greater part of the bruising energy. It confirms the suggestion that the delicate tomato flesh gets damaged easily and the peel is mainly responsible for the resistive force generated from within the fruit against further bruising. Some of the fruits cracked midway during the series of drop tests. It indicates the surpass of the bearable elastic limit of the peel. Soon after reaching the elastic and plastic deformation limits, the peel might have failed. The kinetic energy gained in the course of fall (~ 50 cm) under 1 g acceleration (1 g = 9.84 ms^{-2}) is sufficient to bring about a severe damage when the fruit is brought to an impulsive stop on the cement floor. An acceleration of 1 g is not uncommon in vibration experienced by fruit bins during their vehicular transportation from farm to stores or retail market (Barchi *et al*., 2002). Since fruits are in contact with each other, there is only a very little chance of producing impulsive impacts within fruit bins. However, when effective for a longer period, such vibration induced accelerations can cause damage to fruits (Schoorl and Holt, 1985). The higher the energy transferred to fruits, the greater is the resulting bruise volume (Holt *et al.,* 1983; Schoorl and Holt, 1986).

CONCLUSIONS

The FFF test method is identified to be the most commonly used non-destructive, low-cost, tactile test method used by consumers in sorting out fruit & vegetables at the retail market. Panel judgment discloses that regardless of special skills or training, an individual can be trained to estimate the FFF of tomatoes. Though the FFF test method never provides an absolute value to the firmness, it can be used to estimate the damage inflicted due to natural deterioration, squeezing and impulsive impact. In general, the level of ripeness of tomatoes has very little effect on the overall rate of deterioration with shelf-life. However, rate of loss of FFF was always little faster at less-ripe stages. The rate slightly decreases with increasing ripeness.

The rate of red colour development with shelf-life in less-ripe tomatoes was nearly 3 times faster (1.7 against 0.5 rank/d) compared to pink-ripe tomatoes. With increasing ripeness (redness in colour rank) the rate of red colour development diminishes. Rate of loss of FFF with increasing red colour was 3 times slower (40 against 120 g/rank) in less-ripe tomatoes.

The FFF of tomatoes slowly drops with repeated number of squeezes in the course of FFF test itself. The loss of FFF per shelf day was nearly 15 times higher (65 g/d against 4 g/squeeze) compared to the loss of FFF per squeeze.

Damage due to drop under gravity in tomatoes is serious. The first drop itself is responsible for 80% of the damage occurred in the first two drop tests. The loss of FFF per squeeze gradually drops with increasing number of drop tests. Results obtained both on the repeated squeezing test and the drop-damage test, back the suggestion that the tomato peel provides the protection to the delicate tomato flesh even when the flesh is damaged.

ACKNOWLEDGMENTS

Authors wish to thank the International Science Programme of the Uppsala University, Sweden, the National Science Foundation, Sri Lanka, the Horticultural Crop Research and Development Institute (HORDI), Gannoruwa, Sri Lanka, and the Department of Food

Science and Technology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka. University of Colombo is thanked for providing laboratory facilities.

REFERENCES

Abbott, J. A. (2004). Textural quality assessment for fresh fruits and vegetables. pp. 265-276. In. Shahidi, D.F. (Ed.). Quality of fresh and processed foods. Kluwer, Academic/ Plenum Publishers, Netherlands.

Allande, A., Desmet, M., Vanstreels, E., Verlinden, B.E. and Nicolai, B.M. (2004). Micromechanical and geometrical properties of tomato skin related to differences in puncture injury susceptibility. Postharvest Bio. and Tech. 34: 131-141.

Anon. 2003: Personality Index Extended Report. JohnSample. http://www.testingroom.com /PI/Sample (accessed on 15.07.08)

Barchi, G.L., Berardinelli, A., Guarnieri, A., Ragni, L. and Totaro F.C. (2002). Damage to loquats by vibration simulating intra-state transport. Biosystems Engi. 82(3): 305-312.

Barrett, D.M., Garcia, E. and Wayne, J.E. (1998). Textural modification of processing tomatoes. Critical Reviews in Food Sci. and Nutri. 38(3): 173-258.

Batu, A. (1998). Some factors affecting on determination and measurement of tomato firmness. J of Agri. and Forestry 22: 411-418.

Holt, J.E., Schoorl, D. and Muirhead, I.F. (1983). Postharvest quality control strategies for fruit and vegetables. Agri. Sys. 10: 21-37.

Kader, A.A., Morris, L.L. and Chen, P. (1978). Evaluation of two objective methods and a subjective rating scale for measuring tomato fruit firmness. J. Amer. Soc. Hort. Sci. 103(1): 70-73

Schoorl, D. and Holt, J.E. (1985). Verification and application of a model for predicting damage to horticultural produce during transport. Agri. Sys. 16: 67-83.

Schoorl, D. and Holt, J.E. (1986). Post-harvest energy transformations in horticultural produce. Agri. Sys. 19: 127-140

Szczesniak, A.S. (2002). Texture is a sensory property. Food Quality and Preferences 13: 215-225