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Effect of measurement of non-destructive firmness on Tomato quality and comparison with destructive methods

C.L. Ranatunga[2], H.H.E. Jayaweera[1], S.K.K. Suraweera[1], and T.R. Ariyaratne[1]
[1]*Centre for Instrument Development, Department of Physics, University of Colombo*
[2]*Department of Physics, University of Sri Jayewardenepura, Nugegoda*

ABSTRACT

Almost all instrumental non-destructive (ND) type firmness test methods which involve a physical contact with the tomato when used for testing, deliver at least a minute damage to the fruit. The damage induced on a fruit was estimated when a so-called non-destructive firmness test was performed repeatedly on tomato fruit. The common method of firmness testing uses Magness-Taylor (MT) type firmness tester and in this destructive type test method, after having peeled, the tomato pulp is pierced with a probe. Qualitest (HPE-ll-FFF model) tester and the Bishop (FT 327 model) tester were used as ND and MT type firmness testers, respectively. Tomato variety "Rajitha" grown in Rathkinda area in Matale, during *Maha* season (Sept 2008) was subjected to this investigation. In a series of repeated ND type firmness test , a loss of firmness of 9.5 % was observed between the first and the second measurement, regardless the ripeness level of tomato. At lower ripeness levels, tomato exhibited an exponential decay in percentage loss of firmness when subjected to repeated ND test, while red-ripe tomatoes demonstrated a slightly deviated behaviour. A study on the behaviour of MT vs. ND type firmness suggests a good linear relationship with a non-zero intercept. The relationship proposes a ND type firmness of 0.405 kg for a tomato which registers zero MT type firmness. Hence the contribution of the peel to the ND type firmness would be 0.405 kg.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum*) is considered the main horticultural crop in the world with a production of 60 million tones and three million hectares planted every year [1]. Firmness is a widely used parameter in agricultural and horticultural sector for the estimation of quality of fruit & vegetables (F&V). Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. Management practices can also affect postharvest quality. Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or over-mature produce may not last as long in storage as that picked at proper maturity [2]. Texture is a quality attribute that is critical in determining the acceptability of F&V. It is convenient to define quality as the composite of intrinsic characteristics that differentiate individual units of the commodity. Texture of F&V 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 [3]. In fact, both strength and breakdown characteristics are important components of texture [4]. Texture derives from the structure (molecular, microscopic or macroscopic) of the food [5]. Hence it is understandable that the firmness would describe certain parameters of the texture or the quality of the fruit. Firmness is often used in estimation of the harvesting maturity, and monitoring the maturing process either with shelf-life or under different environmental/experimental conditions. Generally, the firmness refers to the force required for making a pre-determined pierce using a standard probe. The most common technique is the Magness -Taylor (MT) type firmness measurement which is a

destructive type test method. The registered force at the penetration of a standard probe up to a certain depth is read as the firmness in this method. Except for the Finger-Feel Firmness method [3,6,7,8], most of the non-destructive test (NDT) methods (e.g. acoustic firmness, laser air-puff, near IR) require expensive and cumbersome instrumentation. Almost all NDT test methods deliver at least a minute damage to the fruit when sensing its firmness. Depending on the test method, it varies the extent of this damage. Investigation of the effect of repeated NDT firmness measurements on the subsequent NDT firmness measurement is one of the objectives of this study. Further, a comparison between the selected NDT type test and MT type (destructive) type test method will be accomplished with a view of establishing a relationship, if exists, between the NDT firmness and the MT firmness. One of the significant differences between NDT and MT type tests is the contribution of the peel strength to the reading. Term itself describes that the NDT type test method involves no peeling of the tomato in testing. It is of common practice to use peeled fruits for the MT type test, unless the peel is the tissue of interest for the firmness measurement [9]. However, in NDT firmness testing the skin was not removed, as is usually the case when testing tomatoes [10]. Almost all Instrumental methods of firmness measurement which involve a physical contact with the fruit deliver some sort of damage to the fruit, even in trace. The extent of this damage depends on the nature of the test. Measurement of firmness itself was used in this study as a means of monitoring the variation of firmness in repeatedly damaged tomatoes.

2. MATERIALS AND METHODS

Tomato Maturity:
A colour index ranging from mature-green to table-ripe red colour consisting of 10 colour ranks was used for estimation of the maturity / ripeness. Colour estimation was always found to be within the accuracy limit of ± 1 colour rank.

Tomato sample:
Tomato variety “Rajitha” cultivated in the *Maha* season (September 2008) in Rathkinda area in Matale was used as the test sample. Fruits of similar size (equatorial diameter 4 to 5 cm, polar diameter 4 to 4.5 cm) were selected for the test. In both types of test, NDT and MT, care was taken not to select any radial arm of the pericarp. A total number of forty tomatoes (n=40) of two maturity levels, namely colour rank 3 to 4 and 7 to 8, were used for studying the effect of repeated NDT firmness. Fifty number of tomatoes (n=50) of a wider range of maturity level i.e. from harvesting maturity (rank 2) to table-ripe red colour (rank 10), were used for the NDT/MT comparison test.

NDT type firmness tester:
Qualitest (HPE-ll-FFF digital model) firmness tester having a measuring range (corresponding to 0 to 12.5 N force) and an accuracy of ± 0.1 unit was used as the NDT firmness instrument. The cylindrical test probe with a flat end having circular cross sectional area of 0.5 cm^2 was used with it. NDT test was performed on unpeeled tomatoes [10]. In the NDT test, the tomato fruit is not pierced and firmness is attributed mainly to the tomato pulp and partially to the skin or peel. The manufacturer’s force

calibration (12.5 N force indicated by 100 units) for the HPE-ll-FFF model of NDT firmness tester was used in conversion of the reading into firmness (force).

MT type firmness tester:
Bishop fruit pressure tester (model FT 327 , 0 to 13 kg accuracy ± 0.05 kg) was used as the MT type firmness testing instrument. The MT type firmness test was performed with cylindrical test probe of diameter 11.3 mm with a hemispherical end on tomatoes of which about 2 cm^2 area of the peel removed [9]. In the MT test, the tomato fruit is pierced up to a certain depth and therefore as an elastic membrane, the peel would exert a significant resistance which cannot be disregarded.

Repeated NDT Firmness test:
Selected spot on the tomato was subjected to repeated NDT firmness measurement six times. Drop in firmness was monitored at each measurement. The loss of firmness due to first NDT test was determined and the value was used later in the experiment which compares the NDT and MT methods.

Comparison of NDT and MT firmness:
Suitably selected position of tomato was first tested for NDT firmness. Then the peel of the same spot was removed with the peeler which was provided with the MT firmness tester. and the peeled spot was tested for MT firmness. The damage inflicted due to initial NDT test was estimated from the repeated NDT test series and the correction was made to the subsequent MT firmness measurement. The aim of this exercise was only the compensation of the damage due to the NDT test carried out first. Effect of the peel which was present at the NDT test but not at the MT test was ignored since it was the standard common method of analysis. Further, it is emphasized a summary of comparison between the parameters and test criteria between the NDT and MT firmness test methods in the Table 1.

Table 1: Comparison of parameters and test criteria between NDT and MT firmness test methods

	NDT Firmness Test Method	MT Firmness Test Method
Diameter of test probe	7.97 mm	11.3 mm
End of test probe	Flat; 0.5 cm^2 circular cross section	Hemispherical
Tomato peeled / unpeeled	Unpeeled	Peeled
Nature of test	Non-piercing	Piercing

3. RESULTS AND DISCUSSION

3.1 Repeated NDT firmness testing

Table 2 shows the variation of the average firmness when repeated NDT firmness test was performed on the same spot of tomatoes having maturity level at colour rank 3 and 4. Table 3 shows the results obtained with tomatoes having maturity level at colour rank 7 and 8. From the Table 2 and 3 it reveals that the NDT firmness of the less ripe tomatoes (colour rank-3,4), as was expected, is higher than that of the ripe (colour rank-7,8) tomatoes. At each step of the repeated NDT firmness test, the subsequent firmness

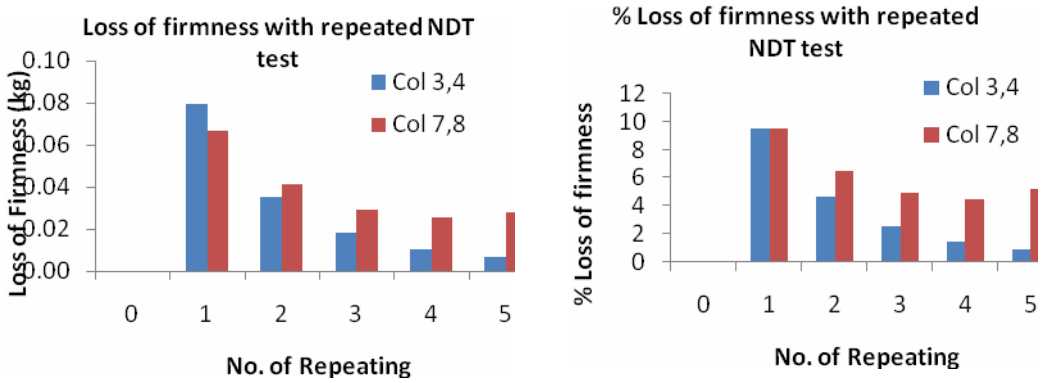
Table 2: Variation of average NDT firmness when repeatedly measured on tomatoes at maturity level colour rank 3 and 4

Number of Repeating	Average Firmness (units)	Average Firmness (kg)	Loss of Firmness (kg)	Loss in Loss-of-Firmness (kg)	% Loss of Firmness	% Loss in Loss-of-Firmness
0	65.4	0.8342				
1	59.2	0.7549	0.0792		9.50	
2	56.4	0.7199	0.0350	0.0442	4.64	55.80
3	55.0	0.7015	0.0184	0.0166	2.55	47.53
4	54.2	0.6913	0.0102	0.0082	1.45	44.48
5	53.7	0.6849	0.0064	0.0038	0.92	37.50

Table 3: Variation of average NDT firmness when repeatedly measured on tomatoes at maturity level colour rank 7 and 8

Number of Repeating	Average firmness (units)	Average firmness (kg)	Loss of Firmness (kg)	Loss in Loss-of-Firmness (kg)	% Loss of Firmness	% Loss in Loss-of-Firmness
0	55.0	0.7015				
1	49.7	0.6346	0.0670		9.55	
2	46.5	0.5931	0.0415	0.0255	6.53	38.10
3	44.2	0.5638	0.0293	0.0121	4.95	29.23
4	42.2	0.5383	0.0255	0.0038	4.52	13.04
5	40.0	0.5102	0.0281	-0.0026	5.21	-10.00

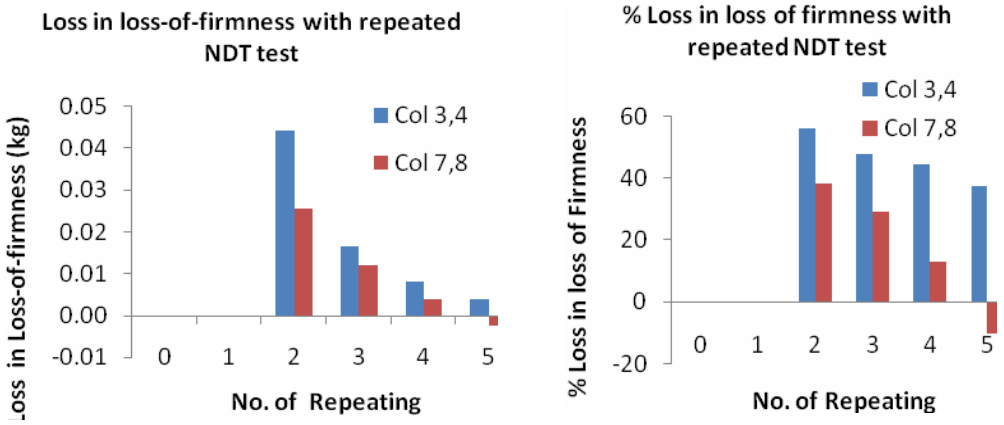
reading of colour-3,4 tomatoes was found to drop down gradually (Figure 1a). Nearly exponential type loss was observed with the less ripe colour-3,4 tomatoes. At the first test, the loss of firmness of ripe tomatoes, i.e. colour-7,8, was smaller than that of less ripe tomatoes, but with increasing number of testing, the loss appeared to be



(a) (b)

Figure 1: Variation of (a) Loss of firmness, (b) % Loss of firmness with repeated NDT firmness testing of tomatoes

pronounced. In the region of 3rd and 4th repetition, the loss remained more or less equal. However, a slight increase in the loss of firmness was observed at the 5th repetition. It is clearly shown in the corresponding curve for the variation of % loss of firmness with repeated NDT firmness testing (Figure 1b). The study was further extended to examine the loss in loss of firmness for the two maturity levels of tomatoes. In this exercise a comparison is made of the amounts of the loss of firmness between a test and the following test. It is commonly observed with tomatoes of both maturity levels, that the loss of loss of firmness between two successive tests drop down with the number of repetition.



(a) (b)

Figure 2: (a) Loss in Loss-of-firmness (b) % Loss in Loss-of-firmness with repeated NDT firmness testing of tomatoes

Figure 2 a shows that the less ripe tomatoes start deterioration rapidly but beyond 3rd repetition, the rate becomes slower. A comparatively higher loss in loss-of-firmness was always observed with less ripe tomatoes. Ripe tomatoes, at times, indicated extra-ordinary losses in loss-of-firmness Despite with a higher loss in loss-of-firmness, less ripe tomatoes still maintain a higher firmness (Table 1 and 2), compared to ripe tomatoes. Again, the result is clearly indicated in the graph of % loss of loss-of-firmness vs. number of repeating test (Figure 2 b).

Loss of firmness: The series of tests reveal that less ripe tomatoes suffer a comparatively higher loss of firmness at the very first squeezing/impact. This loss of firmness follows an exponential type decay with repeated damaging action. At the beginning, ripe tomatoes also behave similarly but with increasing number of repetition, the loss becomes even higher than that observed with less ripe tomatoes. Hence, behavior of the ripe tomatoes deviates from true exponential characteristics.

Loss in loss-of-firmness: Loss in loss-of-firmness between two successive tests is again high in less ripe tomatoes. Also, throughout the series of tests, less ripe tomatoes suffered a higher loss in loss-of-firmness. Unusually higher loss of firmness of ripe tomatoes at the 5th repetition caused negative loss in loss-of-firmness.

3.2 Comparison of NDT and MT firmness testing

The comparison between NDT and MT firmness testing of tomato sample (n=50, maturity level colour rank 2 to 8) is illustrated in Figure 3. NDT firmness vs. MT

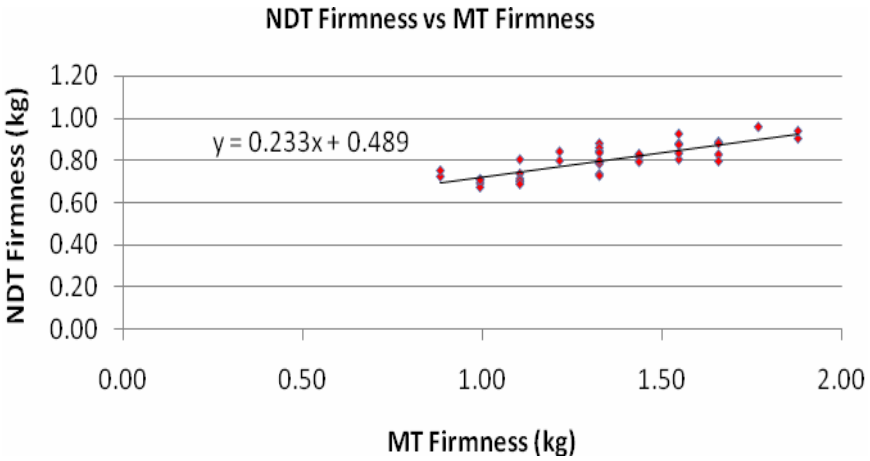


Figure 3: Comparison of NDT and MT firmness tests

firmness fits to a trend line described by equation,

$$Y = 0.233\,X + 0.489 \quad \text{----------} \quad (1)$$

It assigns a NDT firmness (measured with peel) of 0.489 kg for a tomato of which MT firmness (measured without peel) is read to be zero. On the assumption of the linearity of the relationship, it is fair enough to attribute an average NDT firmness of 0.489 kg to the rupture of the peel over the tomato pulp. Hence, the NDT and MT firmness can be related with equation (1) and the method suggests average peel strength of 0.49 kg in terms of NDT firmness.

4. CONCLUSIONS

The following conclusions can be drawn with the study of NDT and MT firmness tests carried out with “Rajitha” variety of tomatoes.

Less ripe tomatoes, though vulnerable to marked losses in firmness they still stand ahead the ripe tomatoes in terms of firmness when faced to identical damage. Non-rupture damages on less ripe tomatoes cause exponential decay of their NDT firmness; however, the loss of firmness of ripe tomatoes never shows such relation. Unexpectedly high losses have been reported specially at excessive (over 5 numbers of) repetitions of the NDT firmness test. % loss of NDT firmness is always higher in ripe tomatoes. It means that higher % loss of firmness take place on ripe tomatoes compared with less ripe tomatoes. A similar behavior can be expected in post-harvest handling of tomatoes from farm to market.

Loss in loss-of-firmness can be related to the extent of damage occurred at a particular event in a series of impact or damage taken place in tomato handling in the field and market. Again the result reveals that extensive damages occur to less ripe tomatoes. The magnitude of the damage taken place on ripe tomatoes was always smaller than that on less ripe tomatoes. The viscoelastic nature of the ripe tomato pulp helps absorb part of impact/damaging energy and reduces the resultant damage to the pulp. However, it is not a reason to use ripe tomatoes in mechanical handling processes because still the less ripe tomatoes possess good higher firmness. Ripe tomatoes exhibit low losses in loss-of-firmness but they only have lower firmness too.

Comparison of the above NDT and MT firmness test methods implies a linear relationship between them. A value of 0.049 kg is suggested for the average NDT firmness of the peel.

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