GOÜ. Ziraat Fakültesi Dergisi, 2003, 20 (2), 25-30

Effects of the Number of Radial Wall and Locular Cavity on the Accuracy of Measurement of Tomato Firmness

Ali Batu
Gaziosmanpasa University, Agricultural Faculty, Food Engineering Department, 60240, Tokat

Abstract: In this paper the effects of the number of radial wall and locular cavity on tomato firmness measurement during ripening period were evaluated. Both the epicarp strength and firmness values of tomatoes decreased from the mature green to pink tomatoes regardless off their radial wall number. Generally, epicarp strength values of tomatoes having two radial walls were slightly lower than those having 3 radial walls. Deformation values of the longer side of tomatoes having 2 radial walls were lower than those having 3 radial walls. Generally, firmness of tomatoes were found to be dependent on the characteristics of deformation values. So deformation values could be called the definitive values of tomato firmness.
Key words: Radial Wall, Locular Cavity, Tomato, Firmness

Domatesin Yarıçap Duvarı ve Hücresel Boşluğunun Meyve Sertliği Ölçüm Doğruluğu Üzerine Etkileri

Özet: Bu araştırmada, domatesin olgunlaşması sırasında sertlik ölçümleri üzerine yarıçap (radyal) duvar sayısı ve hücresel boşluğun etkileri araştırılmıştır. Domatesin yarıçap duvar sayısından bağımsız olarak hem yırtılma kuvveti ve hemde sertlik değeri yeşil olumdan pembe oluma kadar azalmıştır. Genel olarak 2 yarıçap duvarına sahip domateslerin yırtılma kuvvetleri 3 yarıçaplı olanlardan kısmen daha düşük olmuştur. İki yarıçap duvarlı domateslerin uzun kenarlarının deformasyon değerleri ise 3 yarıçap değerli olanlardan daha düşük olmuştur. Genel olarak domatesin sertlik değerlerindeki değişmeler deformasyon değerlerine bağımlı olarak değişmişlerdir. Böylece deformasyon domatesin sertlik değerlerinin tanımlanmasında belirleyici bir değer olarak ortaya çıkmaktadır.
Anahtar kelimeler: Yarıçap duvarı, hücresel boşluk, domates, sertlik

1. Introduction

Firmness is one of the most important factors for the determination of tomato quality, and it is closely assocciated with acceptability levels of the fruits. After harvest, ripening continues and tomatoes can become overripe very rapidly. This can result in loss of quality and restrict shelf life (1). The texture as a quality attribute of tomatoes is influenced by flesh firmness and internal fruit structure such as pericarp/locular material ratio (2). Pericarp wall is divided into two outer and radial walls which separate adjacent locular and the inner wall, and tomato fruits are composed of flesh and pulp (3). Firmness of tomatoes may be the final index for the consumer for deciding to buy the tomatoes (4). Firmness can be determined either in destructive or non-destructive methods (5). Destructive methods measure tissue resistance to force of penetration and the amount of force required to penetrate through to tomato flesh. The non - destructive methods measure the tissue resistance to compression (deformation) force applied at a point on the fruit (6).

Many kinds of machines have been developed which could measure firmness by destructive and non-destructive methods, and they have been used for tomatoes for a long time. Instron Universal Testing machine (IUTM) is the most common fruit firmness tester and it measures firmness or deformation of fruits more accurately for the purposes of destructive or non-destructive firmness assessment (6). Generally, consumers expect tomatoes to be reasonably round and uniform in shape and having an average of three radial walls resulting from crossing a bilocular line as seen in Figure 1. But many of the tomatoes have two radial walls. One side of the radial wall around the tomatoes is slightly shorter than the other side. Therefore inside of the longer side of radial walls have much more locular cavity. Shape of these types of tomatoes are not perfectly round

and they are slightly oval. So shape, locular cavity and radial walls of the tomato fruits are also effective on fruit firmness as well as their maturity stages (9). The main objectives of this study, therefore, were to investigate the real effect of radial wall and locular cavity on firmness characteristics of tomato fruits during ripening.

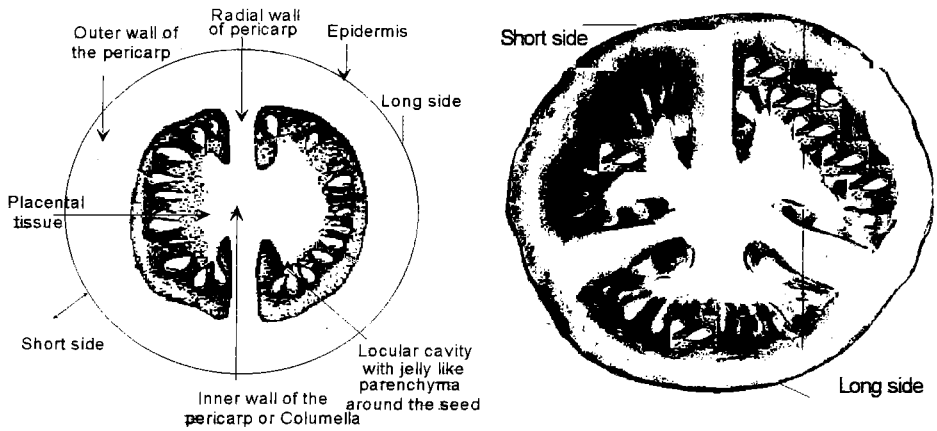


Figure 1. Anatomy of tomato fruits with bilocular structure (7; 8).

2. Material and Methods

Tomatoes were obtained from glasshouse of Silsoe Research Institute. In the experiment, freshly harvested tomatoes (Criterium variety) at mature green, pink and red stages of maturity were used. Then destructive and non-destructive firmness evaluation were done in Silsoe College ,England, in 1995. Fifteen fruits from each having 2 or 3 radial walls were separated from of the the each three ripening stages for destructive or non-destructive firmness evaluation. Therefore 180 tomato fruits (15x2x3x2) were used in this experiment. Maturity was judged for the pink stage as when a pinkish, red or reddish yellow colour was evident on between 30 and 60 % of the external surface of each fruit. Mature green fruits were entirely light to dark green, but mature enough and capable for ripening. Red was suitable for just using in the kitchen (6). For statistical analysis a mean of 15 measurements was taken. These data were subjected to analysis of variance using Genstat statistical package. Treatment effects reported were significant according to as F test at the 5 % level of significance differences between treatments were detected using Least Significant Differences (LSD) (10).

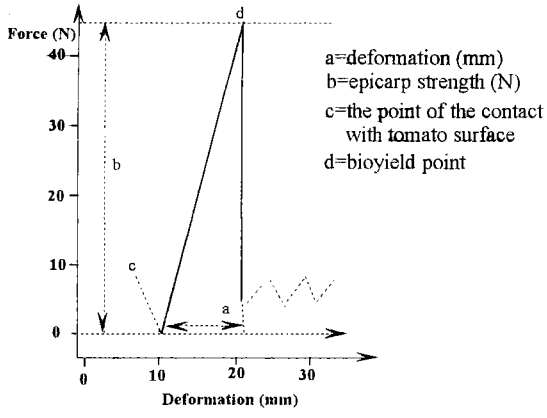


Figure 2. Typical force/deformation curve obtained during penetration or suppression of individual tomato during destructive firmness evaluation.

Destructive and non-destructive firmness assessment were carried out using with an IUTM, model 1122. In the destructive firmness measurements a constant weight of 50 N was applied with a 6 mm diameter flat end round stainless steel probe. Cross-head and chart speed of the machine was 20 mm minute^{-1} (11). The amount of force (N) at the bioyield point, called epicarp strength, which was required to penetrate through the skin to the tomato flesh, and deformation (mm) values during penetration were recorded. Deformation was the distance (mm) travelled by the probe from first contact with the tomato skin to the bioyield point. Force/deformation curve was given in Figure 2. Firmness (N/mm) was defined as the average slope of the force/deformation curve (12).

In the non-destructive deformation evaluation a maximum compression force of 1 N was applied to the fruit surface (13) with the same probe and the same IUTM used for destructive test. An appropriate full scale compression load deflection was chosen. The chart speed was 50 mm minute^{-1} and cross-head speed was 1 mm minute^{-1}. Measurements were made on the long and short sides of each tomatoes. Deformation (mm) due to application of the 1 N compression force was measured (14).

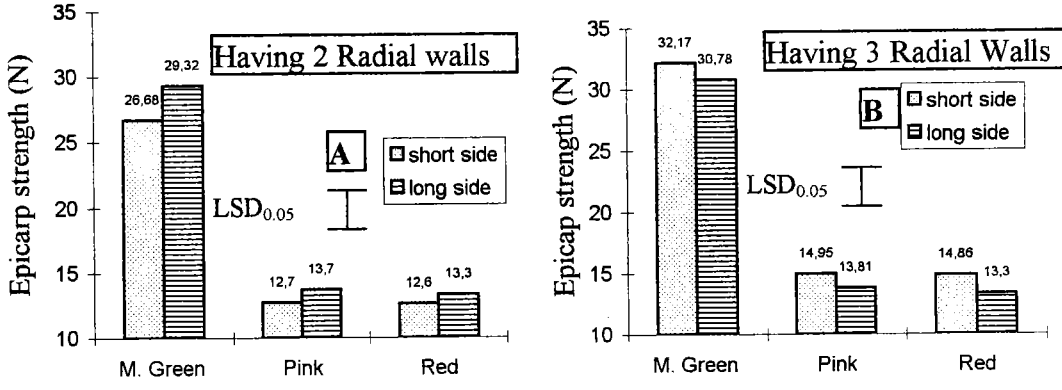
3. Results and Discussion

3.1. Destructive Assessment

Generally, both the epicarp strength and firmness values of tomatoes having 2 or 3 radial walls were significantly (P=0.05) decreased from the mature green to pink tomatoes. The epicarp strength of the tomatoes having both 2 and 3 radial walls remained constant whereas the firmness continued to decrease significantly between pink and red stages. Either short or long sides of radial walls which were determined by the edge of the locular cavity of tomato fruits had no effect on the epicarp strength values of tomatoes harvested at 3 various harvest maturity and having 2 or 3 radial walls, except the tomatoes harvested at mature green stage having 2 radial walls. Epicarp strength values obtained from long side of those tomatoes had significantly (P=0.05) higher than it was obtained from the short sides.

The effect of radial walls on deformation values of tomatoes harvested at three various maturation stages having both 2 and 3 radial walls was also not significantly affected except the only for red tomatoes having 3 radial walls. Deformation values obtained from long side of red tomatoes was significantly (P=0.05) higher than those obtained from the short sides of them.

When the long and short sides were compared to each other generally it was found that the long side of tomatoes having 2 radial walls had slightly higher epicarp strength and lower deformation values. Therefore, because the firmness values was defined as the ratio of the epicarp strength to deformation (13), firmness values of tomatoes obtained from the long side was slightly higher than the short side of tomatoes. In contrast, the long side of the tomatoes having 3 radial walls had lower epicarp strength and lower deformation, therefore it gave higher firmness values than the short side. It could be due to the lower tensile strength of the long side of those tomatoes.



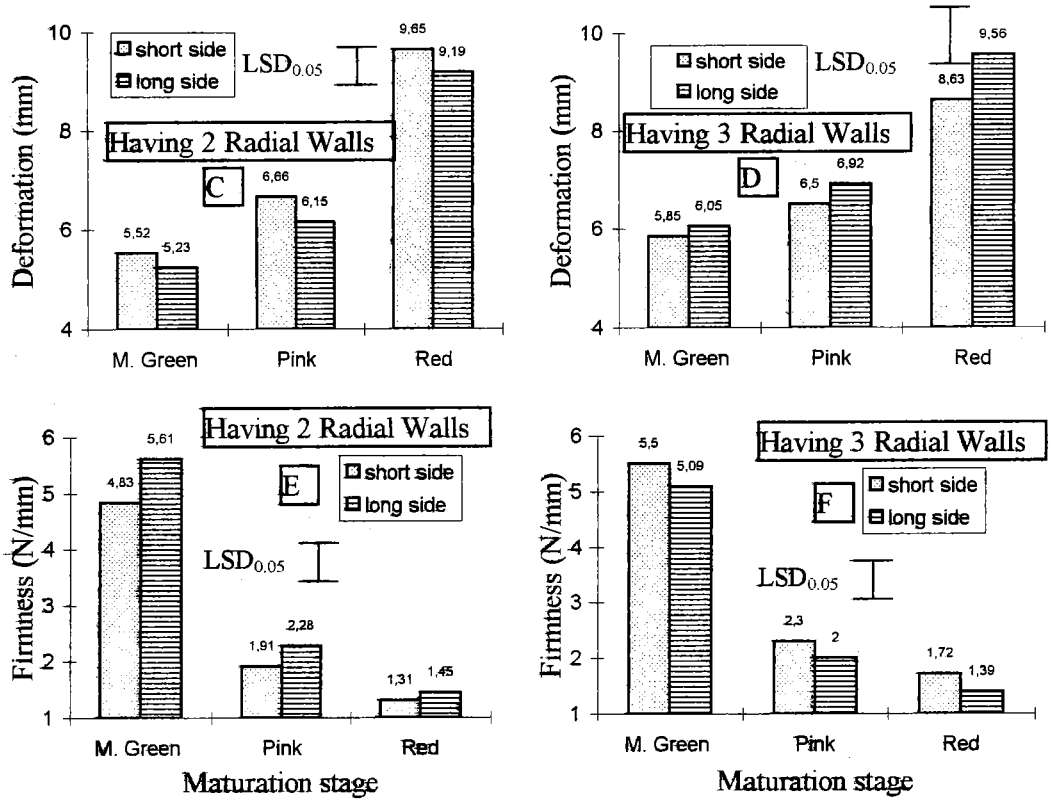


Figure 3. Epicarp strength, deformation and firmness values obtained from destructive firmness measurement of tomatoes having 2 or 3 radial walls.

When the epicarp strength of tomatoes was compared to their radial wall number, the epicarp strength values of tomatoes having 2 radial walls were slightly lower than the tomatoes having 3 radial walls. This could be due to the fact that tomatoes having 3 radial walls had higher tensile strength than the tomatoes having 2 radial walls. Because, those tomatoes had longer locular cavity and it contain more jelly-like parenchymatous tissue in the fruits (7). Therefore, these fruits could have had less tensile strength. However statistically it was not significant. When the deformation values were compared between the tomatoes having 2 or 3 radial walls, a significant difference was not found but the longer side of tomatoes having 2 radial walls gave less deformation than the longest side of the tomatoes having 3 radial walls.

Although epicarp strength was decreased sharply from mature green to pink, it was almost stable from pink to red stages of maturity for both measurements taken from long and short sides of the radial walls. Although epicarp strength of tomatoes were not affected by the radial walls between the pink and red stages of tomatoes (Figure 3/A-B), there were significant increases and decreases on the deformation and firmness values, respectively, between those ripening stages (Figure 3/C-D). Deformation values were increased with the increasing of maturation time. Therefore firmness values of tomatoes were appeared as deformation values(Figure 3/E-F). So deformation values of tomatoes could be called the definitive values of the fruit firmness. It was reported that locular resistancy of tomatoes harvested at mature green and turning stages were significantly higher than the tomatoes harvested at pink and red stage (13). Therefore the locular resistance is the one of the most affective factor on firmness or deformation characteristics of tomatoes. So, tomatoes harvested at mature green stage showed the parallel result with literature above by having less deformation and higher firmness values than both the pink and red tomatoes.

In immature fruits, the placental tissue is firm, but as the fruit mature, the cell walls being to break down, and the locular tissue of mature fruit is more jelly-like, so those could be the

reason for fruits to become softer (3). Because locular cavities occur as gaps in the pericarp and contain the seeds embedded in a jelly-like parenchymatous tissue, and the higher the number of locules in normal fruit, the riper the fruit will be (7).

3.2. Non-Destructive Assessment

Maturation stage did not affect the non-destructive deformation values from mature green to pink stage of maturity. Increasing fruit deformation at a constant compressive force correspond to loss of firmness or softness. Deformation values of the tomatoes either having 2 or 3 radial walls and harvested at red stage of maturity was higher than the deformation values of the tomatoes harvested at mature green and pink stages (Figure 4/A-B). This was because the tomatoes had less tensile strength and the locular tissue of mature fruits is more jelly-like (3). The least deformation values indicates that they are the firmest whereas the higher deformation indicates that they are softer. These changes in the trend could be related to the ripening stages. Fruit deformation, as measured by compression force was increased as the fruits matured on the vine. The effects of radial wall on non-destructive deformation measurement was not significant during the maturation stages except red tomatoes having 3 radial walls. So, side length and number of the radial wall did not effect non-destructive deformation values but red tomatoes having 3 radial walls. Non-destructive deformation values obtained from short side of the red tomatoes having 3 radial walls were significantly (P=0.05) higher than it was taken from long side of them. No literature was found about this issues.

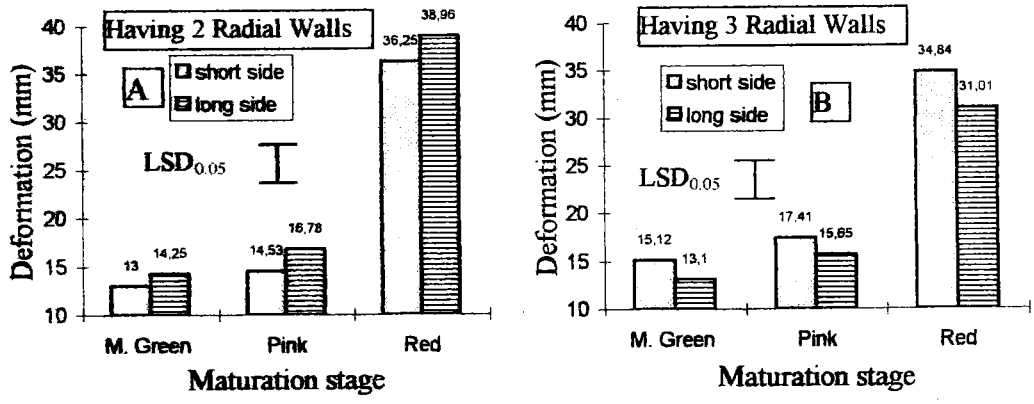


Figure 4. Deformation values obtained from non-destructive firmness measurement of tomatoes having 2 or 3 radial walls.

3.3. Linear Relationship

When individual measurements were plotted against each other many relationships were shown to be significantly linear (Table 1).

Table 1. Linear correlation coefficient (r) of firmness evaluation parameters for tomatoes having two or three radial walls and harvested at different maturation stages.

	2/3	S/L	MS	ES	D1	F	D2
Having 2/3 (2/3)	1	ns	ns	ns	ns	ns	ns
Short/Long (S/L)		1	ns	ns	ns	ns	ns
Maturation stage (MS)			1	-0.85**	0.71**	-0.96**	0.90**
Epicarp strength (ES)				1	ns	0.94**	ns
Deformation 1 (D1)					1	ns	0.94**
Firmness (F)						1	-0.78*
Deformation 2 (D2)							1

ns: Statistically not significant, * Significant at 5 %, ** Significant at 1 %

Maturation stages were positively correlated with the destructive or non-destructive fruit deformation but it was negatively correlated with epicarp strength and firmness. Higher correlation was found between destructive and non-destructive deformation measurement. The measurements of firmness characteristics gave lower correlation with the radial walls of tomatoes.

In conclusion, in destructive measurement, a significant difference was not found on the firmness, deformation and epicarp strength values of tomatoes having either 2 or 3 radial walls. The same results were also obtained between the short or long sides of tomatoes. However, with the non-destructive method which is commonly used for deformation of textural features of tomatoes today, deformation values obtained from especially long side of red tomatoes having 3 radial walls were found to be significently lower than that of red tomatoes having 2 radial walls. Therefore the red tomatoes having 3 radial walls were found to have been firmer than those having 2 radial walls. These results obviously showed that the deformation values of tomatoes should be indicated whether they were obtained from the tomatoes having 2 radial walls or having 3 radial walls. Otherwise correct interpretation will not be possible to determine the correct deformation values of tomatoes.

References

1. Geeson, J.D., Browne, K M., Maddison, M., Shepherd J. and Guarald, F. Modified Atmosphere Packaging to Extend the Shelf Life of Tomatoes. Journal of Food Technology. 20, 339-349. 1985.
2. Kader, A.A. Biochemical and Physiological Basis for Effects of Controlled and Modified Atmospheres on Fruits and Vegetables. Food Technology. 40, 99-100,102-104, 1986.
3. Ho, L.C. and Hewitt, J.D. Fruit Development. In The Tomato Crops (J.G. Atherson J. G. and Ruddic, J. (eds)). London and New York Chapman and Hall. pp:201-239. 1986.
4. Gormley, R.S. and Egan, S. Firmness and Colour of the Fruit of Some Tomato Cultivars From Various Sources During Storage. J. Sci. Food Agric. 29,534-538. 1978.
5. Batu, A. Some Factors Affecting on Determination and Measurement of Tomato Firmness. Journal of Agriculture and Forestry. 22, 411-418. 1998.
6. Grierson, A. and Kader, A.A. Fruit Ripening and Quality. In Tomato Crop. (Atherton, J. G. and Rudich, J. (eds)). Chapman and Hall Ltd. USA. pp,241-280. 1986.
7. Hobson, G.E. and Davies, J. N. The Tomato. In The Biochemistry of Fruits and Their Products. (Hulme, A. C. (ed)). Academic Press London and New York. 2, 437-482, 1971.
8. Batu, A. Controlled and Modified Atmosphere Storage of Tomatoes. PhD Thesis. Cranfield University, Silsoe College, Silsoe, Beds. MK45 4DT. England. 1995.
9. Hobson, G. E. and Grierson, D. Tomato. In Biochemistry of Fruit Ripening. (Seymour, G., Taylor, J. and Tucker, G. (eds)). Chapman and Hall, London. pp:405-442. 1993.
10. Steal, R.G.D. and J.H. Torrie. Principle and procedures of Statistics. A Biometrical Approach. Second Edition. McGraw Hill Book Company. 1987.
11. Batu, A. and Thompson, A.K. Effects of Cross -head Speed and Probe Diameter on Instrumental Measurement of Tomatoes Firmness. Proceedings of the International Conference for Agricultural Machinery and process Engineering October 19-22. Seoul, Korea. pp:1340-1345, 1993.
12. Adegoroye, A.S., Jolliffe, P.A. and Tung, M.A. Texture Characteristics of Tomato Fruits (Lycopersion esculentium) Affected by Sunscald. Journal of Science Food Agriculture. 49, 95-102, 1989.
13. Ghafir, S. and Thompson, A.K. Destructive and non-destructive apple maturity and ripeness assessments. Agricultural Engineer. Summer, 40-43, 1994.
14. Floros, J.D., Chinnan, M.S. and Wetztein, H.Y. Extending The Shelf Life of Tomatoes by Individually Seal Packaging. For Presentation at the International Winter Meeting Of American Society of Agricultural Engineers. Hyatt Regency, Chicago, IL. USA 1987.