Some Factors Affecting on Determination and Measurement of Tomato Firmness

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Abstract: Firmness is one of the most important factor for determination of tomatoes quality. Destructive measurement of tomato firmness is one of the evaluation methods of fruit firmness. The Universal Instron is most common used machine for measurement of most adequate fruit firmness. During destructive measurement of firmness consideredation of force or deformation values as a firmness of fruits could give incorrect result and taking epicarp strength over deformation values is more accurate to concern the firmness of tomato. Two of possible minimum firmness limits were suggested for tomato fruits at the point of retail marketing or using at home. All 100% marketable fruits should have firmness values above 1.45 N mm⁻¹ but the Instron values of the tomato mainly consuming stage at home, should have higher than the 1.28 N mm⁻¹. The firmness of tomatoes is closely associated with acceptability levels of the fruits. Subjective evaluation scores based on finger feel highly and positively correlated 0.96 and 0.98 with epicarp strength and firmness values, respectively. A negative and highly significant correlation (-0.97) exists between deformation values of subjective evaluation scores of Liberto variety, but this correlation slightly lower for Criterium and that was -0.89. Cutting the skin of mature green tomatoes did not affect on firmness but removing the skin highly effect on it. Both cutting and removing of the skin affected measurement of the firmness of tomatoes harvested at pink stage of maturity.

Introduction

There is increasing consumer concern about the eating quality of tomatoes. After harvest, ripening continues and tomatoes can become overripe very rapidly. This can result in loss of quality and restricted shelf life (1). The textural quality of tomatoes is influenced by flesh firmness, the ratio between pericarp and locular tissue, and skin toughness. Changes in firmness were highly correlated with surface appearance characteristics of tomatoes (2) which related to colour, shape and sense of fell to firmness at time purchase or afterwards slicing and eating fruits. The degree of fruit firmness, has been user as an indication of fruit quality (3). However, firmness may be the final index by which the consumer decides to purchase of tomatoes (4) using finger to test tomato firmness at the time of selection (5).

Fruit firmness can be determined in destructive and non-destructive methods. In the destructive method; the amount of force required to penetrate through to tomato flesh (skin and pericarp) and amount of deformation values could be recorded. Onother way is to determine to force required to deform the tissue by a certain distance or by determining the degree of deformation for a certain applied force (6). This was called destructive method.
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. Destructive methods which have been used for tomatoes include pressure tester, Allo-Kramer Shear Press (5) and Instron Universal Testing machine (IUTM (Table 1) most common and more accurate one using for this purposes. Insruments for non-desructive determination of tomato firmness were Cornell Pressure Tester (7) Firme-o-meter (8; 9; 10) and IUTM (11).

A number of works have been involved in tomato fruit firmness measurements, and different insruments for measuring firmness have been illustrated in Table 1. There is a contradictory information about the results of firmness measurements in literature. It is difficult to compare data from one intrument to onother, or to relate these data to sensory wadgments (5). There are no satisfactory information on whether the measured firmness values of tomatoes were within the acceptable levels for consumers concern. Furthermore, the final units of expression of tomato firmness given were too various from one researcher to anotherone. Additionally, the unit of fruit firmness given as a force unit (N or kg) by many researchers for apples (1; 11; 24; 25), for pears (25; 26) and for mango (27).

The main objective of this study, therefore, were; firstly, to investigate the realible determination technique for firmness measurements of tomatoes. Secondly to determine the minimum level of acceptable firmness of tomato fruit cultivars, ‘Liberto’ and ‘Criterium’ at the time of picking and after storage, by evaluating objective tomato firmness and relate these objective measurements to subjective rating scale based on finger feel firmness. Finaly to investigate the skin effect on measurements of tomato firmness.

**Material and Methods**

In the first experiment, tomato fruits from ‘Liberto’ and ‘Criterium’ varieties of tomatoes at pink, ligt red and red stages of maturity were harvested from glasshouse of Silsoe Research Institute and then hold at 20°C. Ten fruits were seperated to the five firmness classes by finger feel firmness (100%, 80%, 60%, 40% and 20%). 100% firmness class was selected on the day of harvest, while those for the other classes were sorted out later on when

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Table 1. Firmness Testers and their applications
tomatoes reached to desirable texture of finger feel firmness. 100 fruits were used for this experiment. The results were expressed as percentages. Separation was tested using a triangular test method. On a subjective basis only 100, 80 and 60% were considered acceptable for marketing. These judgement were based on a ten member of panel.

The five different acceptability (%) levels of tomatoes were:

100 : Just picked up at the pink or light red stage, very fresh and easily marketable

80 : Picked up at pink or light red maturation stage and stored for 2-3 days, but they remained very firm and there was no indication of softness by finger touching test. Easily marketable.

60 : Stored tomatoes, although they were slightly soft but their firmness were good enough for making salads and slicing. Marketable.

40 : Stored tomatoes. They were not good enough for making salads but could be used for cooking or Production of tomato paste. Unmarketable in the supermarket.

20 : Over ripe tomatoes more soft than 50%. They could be used for cooking or production of tomato paste. Unmarketable in the supermarket.

In the second experiment; only Criterium variety was used as in the first experiment. Three treatments (skinless, cut skin and normal) were carried out on the same tomatoes and on the equatorial line of fruits (Plate 1).

Skinless : 1 cm² area of tomatoes skin was cut to 2-3 mm depth then the skin was removed very carefully.

Cut skin : The skin was cut in the same way as the skinless but skin was left in place.

Normal : The skin was not cut and the fruit were left intact.

Desructive deformation tests was used by recorded force and deformation values from force/deformation curve to determine the minimum levels of acceptable firmness of tomatoe. This test was used (21) by applying a constant 50 N weight using with an Instron Universal Testing Machine, model 1122 were carried out. In the firmness measurements 6 mm diameter round stainless steel probe with a flat end was used and cross-head and

![Diagram of firmness measurements on treated tomatoes]

Figure 1. Typical force/deformation curve obtained during penetration of individual tomato

Plate 1. Application of firmness measurements on treated tomatoes
chart speed were 20 mm minute⁻¹. The amount of force (N) which was required to penetrate through the skin to the tomato flesh, and deformation (mm) values during penetration were recorded. Three textural characteristics were determined from the force/deformation curve in Figure 1. Epicarp strength was the (or force required to punch through flesh of tomatoes) force (N) at the bioyield point. Deformation was the distance (mm) travelled by the probe from first contact with the tomato skin to the bioyield point. Firmness (N mm⁻¹) was defined as the average slope of the force/deformation curve (20).

Result and Discussion

Determination of Reliable Measurements of Tomato Firmness

As shown in Figure 2 and 3 the relation between epicarp strength (force) and acceptability levels or deformation and acceptability levels of ‘Liberto’ and ‘Criterium’ varieties were illustrated. The results show that there was significant difference between varieties in terms of epicarp strength and deformation values. Liberto had required higher force to penetrate through fruit skin and flesh, and it gave also higher deformation (figure 3) during this penetration time compared to Criterium ones. In comparison i.e. although both varieties had the approximately the same epicarp strength values with the freshly harvested tomatoes (100% acceptability level) and there was a slight decrease with epicarp strength of Liberto while epicarp strength of Criterium ones were decreasing rapidly with decreasing of acceptability levels of tomatoes. In contrast deformation increases at the marketable stages (100, 80 and 60% levels) of tomatoes. There was a rapid increase in the deformation values of Liberto and Criterium varieties after 60% and 40% acceptability levels respectively. Consequently, Liberto is totally different from Criterium in terms of epicarp strength and deformation values. When they compared i.e. at 80% or 60% acceptability levels Liberto had significantly higher epicarp strength than Criterium one. Although both varieties had, approximately, the same finger feel firmness and they are

LSD 0.01

R²=0.97***

Figure 2. Relationship between epicarp strength values and acceptability levels of tomatoes

LSD 0.01

R²=0.97***

Figure 3. Relationship between deformation values and acceptability levels of tomatoes
supposed to be at the same firmness values if only epicarp strength values were concerned. It seems Liberto is more firmer than Criterium, furthermore when the deformation values were concerned. It seems Liberto is more softer than Criterium. Although there was a significant (p=0.05) difference on epicarp strength and deformation values (Figure 2 and 3) between tomato varieties, significant difference was not observed on firmness (epicarp strength over deformation) values between the same varieties (Figure 6).

More results are available in Figure 4 and 5 on relationship between the force, deformation and firmness values of some tomatoes. Those data were chosen from the field of more than 1000 measurements. First consideration was to keep the force values were approximately the same in order to evaluate the effects of constant values of force or deformation on the variation of firmness values of tomatoes.

As can be from figure 4 there are six different treatments which epicarp strength (force) of the first three treatments (1, 2, 3) had approximately around 15 N and another three (a, b, c) of them had 17 N. But the deformation values of that first group (1, 2, 3) and second group (a, b, c) occurred variable not constant. As can be seen from figure 5 there were some treatments which their epicarp strength (force) values were varied but deformation values approximately the same. So some of the fruits might have the same epicarp strength values and the same time they could have also various deformation values as in Figure 4. In this case their firmness values were occurred to be conversely correlated with their deformation values. In comparison if the same force loaded on different fruits which had lower deformation value that means this fruit is more firmer and if deformation value is higher, this fruit is more softer. If the epicarp strength (force) is various while the deformation values were the same, in this case firmness values were directly correlated with the epicarp strength and the less force requires that those fruits were more softer.

As a consequently, deformation values can be concerned as a firmness for tomatoes when the application force was constant, or epicarp strength (force) also can be concerned as a firmness values of tomato.
fruits when deformation values were kept as constant. This results confirm that during destructive firmness measurements, concerning of only force or deformation values as a firmness of fruits, particularly for tomatoes, generally is not accurate. It is more accurate and important to take epicarp strength over deformation (N mm\(^{-1}\)) values for concerning of firmness asessment of tomatoes.

**Determination of the Minimum acceptable firmness levels**

The relationship between subjective firmness values which is very important for marketing, and objective firmness evaluation (acceptable levels) of tomatoes was investigated. The minimum acceptable firmness values (or marketability levels) of tomatoes were determined by using a force/deformation test.

As expected firmness values of tomatoes decreased with decreasing of acceptability levels over the range of 100% (perfect) to 20% (overripe). There was a significant (p=0.05) decrease firmness values of both varieties of tomatoes (Figure 6). Similar result were seen for epicarp strength values (Figure 2).

There was a consistant decrease in firmness values of ‘Liberto’ between 100% and 40% acceptability levels. This decrease was between 100% and 80% acceptability levels for ‘Criterium’. In both varieties, there was a higher variation between maximum and minimum firmness values at 100% and 80% acceptability levels. Those variation between maximum and minimum firmness values at 100% and 80% acceptability levels. Those variation levels were smaller in the 60%, 40% and 20% acceptability levels. According to the results of this research on the base of objective firmness evaluation (finger feel firmness) it was found that the minimum acceptable levels marketability scores of tomato firmness at which an individual tomato fruit could be acceptable for sale at retail level is about 1.45 N mm\(^{-1}\) and 1.46 N mm\(^{-1}\) for ‘Liberto’ and ‘Criterium’ varieties of tomatoes respectively. However, the firmness values of the tomatoes generally used at home is about 1.28 N mm\(^{-1}\).

![Figures 6 and 7](images)

**Figure 6.** The relationship between measured firmness values and subjective market acceptability levels of tomatoes (cv's 'Liberto' and 'Criterium'). The vertical lines represent maximum and minimum values.

**Figure 7.** Epicarp strength, deformation and firmness values of light red and mature green tomatoes which were tested when either skinless, cut skin or normal (see plate 1).
and 1.22 N mm\(^{-1}\), for tomatoes had 60% acceptability score for the Liberto and Criterium varieties, respectively. Those tomatoes could be also marketable even in supermarkets and they were capable to being sliced those kind of tomatoes in the supermarket and very difficult to slice or to use them for marking salads. If the firmness values of tomatoes above than the 1.28 N mm\(^{-1}\) (slightly soft) they could be used for making salad especially if their firmness is above 1.46 N mm\(^{-1}\) (very firm) those tomatoes easily marketable in the supermarket.

**Skin Effect on Firmness Evaluation**

In this experiment, the effect of the skin on destructive firmness measurement of texture by using force/deformation test was investigated. As would be expected it was found that removing or cutting the skin of tomatoes required a lower penetration force, in another word, epicarp strength values of those teratments were occured lower and resulted in lower deformation values compared with normal (intact) fruits for the both fruits picked at either mature green or at light red stages of maturity (Table 7). Although decreasing the required force for penetration of the probe through tomato flesh was not significant between cut skin and normal, it was significantly less between skinless and the other two treatments of green tomatoes. Difference was found that significant in the amount of force required between those three treatments on light red tomatoes. It was found that there was no significant difference on deformation values of green tomatoes, but it was significant for light red tomatoes.

It was found that there was no difference in measurement of firmness due to cutting the skin of mature green tomatoes (Figure 7). However, these difference were significant when the skin was removed. But this case was the reverse on light red tomatoes.

There was no difference on flesh firmness between cut and removed skin (skinless) treatments. These results are in agreement with the studies of Kader et al (5) who reported that skin removal resulted in lower force values for fruit picked at various ripeness stages and a trend of firmness decreased with increasing ripeness. They had pointed out that although removing the skin is recommended for textural measurements of for fruits such as apples, pears, etc. but it was not essential for tomatoes. This could be due to the thinness of tomato flesh and tomatoes are more juicy than apple, additionaly it is also more difficult to measure the firmness of tomatoes without skin.

**Conclusion**

If the firmness values of tomatoes evaluate by Universal Instron machine using 6 mm round and flat ended probe are above 1.28 N mm\(^{-1}\) they are suitable for making salad and even formarketing. If the firmness value is above 1.46 N mm\(^{-1}\) those tomatoes are definetely very firm and easily marketable in the supermarket. It is very obvious that there are significant differences in the texture measurement techniques between skinless and normal for either mature green or light red tomatoes. It could be interpreted that these differences of firmness could be due to properties of the skin for green tomatoes and could be due to the actual cutting treatment for light red tomatoes. Some publications indicate that skin removal is not suitable treatment for light red tomatoes. Some publications indicate that skin removal is not suitable for texture measurements of firmness in tomatoes which is supported by my work. However, it is important to specify whether the skin was removed or not in reporting firmness measurements.

**References**


