EFFECTS OF MATURITY TIME ON SOME MECHANICAL PROPERTIES OF BEEF TYPE TOMATO FOR TRANSPORTATION

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TAŞIMA İÇİN OLGUNLAŞMA ZAMANIN BEEF TİPİ DOMATESİN BAZI MEKANİK ÖZELLİKLERİ ÜZERİNE ETKİSİ

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ABSTRACT

Effect of maturity time as colour on mechanical properties is important for long way transportation. In this research, some physical and mechanical properties of beef tomato (Tybeef) grown in the Antalya region were determined based on the puncture tests. The tests were carried out at four maturity stages namely green, light pink, pink and red colour. Size and sphericity were measured using the standard methods. Surface colour of tomatoes were determined using a colorimeter and the mechanical properties such as puncture force and stress, puncture energy, deformation, strength and elastic modulus by texture analyser. The puncture force and energy values were found different at 5% probability level for all the maturity stages. Deformation, failure stress and toughness values were found different at 1% probability level for all the maturity stages. Statistically, there is no difference in the modulus of elasticity values for all the maturity stages. In conclusion, it was found that L/a*/b* and C*/h colour parameter can be a good index for evaluating mechanical properties of beef tomato.*

ÖZET

Uzun yol taşımacılığı için renk olarak olgunlaşma zamanının mekanik özellikleri üzerine etkisinin bilinmesi oldukça önemlidir. Bu çalışmada Antalya bölgesinde yetişen beef tipi (Tybeef) domates çeşidinin bazı fiziksel özellikleri ve delinme testi temel alınarak mekanik özellikleri belirlenmiştir. Denemeler 4 farklı olgunlaşma zamanı olan yeşil, açık pembe, pembe ve kırmızı renk domateslerde yürütülmüştür. Boyutlar ve küresellik standart metotlar kullanılarak ölçülmüştür. Domateslerin renkleri kolormetre cihazı ile delinme kuvveti, dayanım, delinme enerjisi, deformasyon ve elastikiyet modülü gibi mekanik özellikler ise tekstür analiz cihazı ile ölçülmüştür. Tün olgunluk düzeyleri için delinme kuvveti ve enerji değerleri istatistiksel olarak %5 önem seviyesinde önemli bulunmuştur. Ayrıca Deformasyon, gerilme ve dayanım değerleri ise istatistiksel olarak %1 önem seviyesinde önemli bulunmuştur. Elastikiyet modülü değerlerinde ise olgunluk düzeyleri için istatistiksel bir fark saptanmamıştır. Sonuç olarak L/a*/b* ve C*/h gibi renk parametrelerinin beef tipi domatesin mekanik özelliklerinin değerlendirilmesinde iyi bir gösterge olabileceği saptanmıştır.*

INTRODUCTION

Tomato *(Lycopercicomesculentum)* is classified under subfamily of the Solanaceae. It (*Lycopersicon esculentum* Mill.) is a self-fertile vegetable and one of the most popular vegetable crops grown all over the world. It has a high amount of vitamin A and C, calcium, potassium and particularly lycopene which prevents people against heart disease and cancer *(Karacali I.,1990; Rao and Agarwal, 2000)*. Additionally, tomato fruit is one of the most consumed vegetables used as fresh, dried or processed for human nutrition and is of secondary importance in its family *(Delina and Mahendran, 2009).*

The quality for agricultural products is generally evaluated under three attributes: texture, colour and taste. Texture and colour are the most important factors that are determining the quality of tomatoes *(Tijkens and Evelo, 1994).* Especially, the colour is an extremely important characteristic for tomato quality. The mechanical properties of agricultural products are most conveniently measured by compression testing. From this curve, a number of mechanical properties can be determined such as maximum force to rupture or puncture, energy, stiffness and deformation *(Fischer et al., 1969).*

Considering that low quality depends on the damages occurred during harvest and postharvest processes, it is quite important to know textural properties of tomato to provide it to the market with minimum damage *(Batu A., 2004).* The distance to the market plays an important role to determine the harvesting time. If the market is close, the tomato can be harvested when their colour is red; on the contrary, if the market is far, they must be harvested at an early maturity stage. From this point of view, the colour is the preferential determining component *(Ince et al., 2016).* However, changes of Tybeef F1 tomato cultivar's textural properties depending on the maturity stage must be known.

Many studies focused on the results of the mechanization of tomato harvest, postharvest and grading with respect to different types of mechanical damage *(Hatton and Reeder, 1963; Sargent et al., 1989).* In a research, the factors that determine the puncture injury during handling were characterized *(Desmet et al., 2003).* Therefore, many researchers' studies on the textural properties of tomato have been published and different methods have been used such as image processing, nuclear magnetic resonance, ultrasonic technique, visible/near infrared and near infrared spectroscopy, which cannot measure the food texture directly *(Sirisomboon et al., 2012; Syahrir et al., 2009).*

For this reason, the aim of this study is to investigate the effects of maturity stages (green, light pink, pink and red) on puncture force, deformation, toughness, failure stress, puncture energy and modulus of elasticity of Tybeef F1 variety.

MATERIALS AND METHODS

The beef tomato variety used for all the experiments in this research was Tybeef F1. This variety of tomato was grown and harvested in the greenhouse of the Batı Akdeniz Agriculture Research Institute at Kocayatak, Antalya, Turkey on the 20th April, 2016.

The 45 samples were randomly selected from the harvested tomatoes of Tybeef F1. All analyses were carried out at a room temperature of 20–21ºC during the laboratory tests. All tests were made at Medicinal and Aromatic Plants Central Laboratory of Batı Akdeniz Agriculture Research Institute in a texture analysis device.

To determine the average size of the tomato fruits, two linear dimensions (length (L) and diameter (D)) were measured by using a digital caliper with accuracy of 0.01 mm, and the samples mass was determined with an electronic balance of 0.1 g accuracy. The geometric diameter was calculated by considering Eq. (1), *(Mohsenin N.N., 1986):*

$$D_g = (LD^2) \tag{1}$$

where: Dg - geometric diameter, L - length, D-diameter (all in mm).

The sphericity, Ø (%) and surface area S (mm^2) were calculated by considering Eqs. (2) and (3), respectively *(Mohsenin N.N., 1986):*

$$\phi = \frac{D_g}{L} x100 \tag{2}$$

$$S = \pi D_g^2 \tag{3}$$

where: Ø - sphericity (%), S – surface area (mm^2), Dg - geometric diameter, L – length

To determine the mechanical properties of the three tomato varieties in the compressive tests, a biologic material test device was used (Fig. 1). A curve-ended cylindrical probe 2 mm in diameter was used to compress the fruit at 10 mm/min loading velocity during all the tests *(Anonymous, 1984)*.

Fig. 1 - Texture analysis device and puncture test

As shown in Figure 2, a typical force-deformation curve was obtained as the result of puncture test. The puncture force, deformation, failure stress were determined by force-deformation curve while puncture energy was obtained by measuring the area under the force-deformation curve.

Hardness (*Q*) was calculated by dividing the puncture force (*F*) by the deformation to the puncture point (*D*), *(Sirisomboon et al., 2007):*

$$Q=\frac{F}{D} \tag{4}$$

The modulus of elasticity *E* in newton per square millimetre of the fruits test was calculated using Boussinesq techniques as follows *(Mohsenin N.N., 1986)*:

$$E = F(1-\lambda^2)/d.\Delta D.r \tag{5}$$

where *E* is the modulus of elasticity in compression, *F* is the compressive force, λ is the Poisson ratio, ΔD is the deformation, *d* is the diameter of the cylindrical probe (2 mm) and *r* is the radius of the fruit curvature.

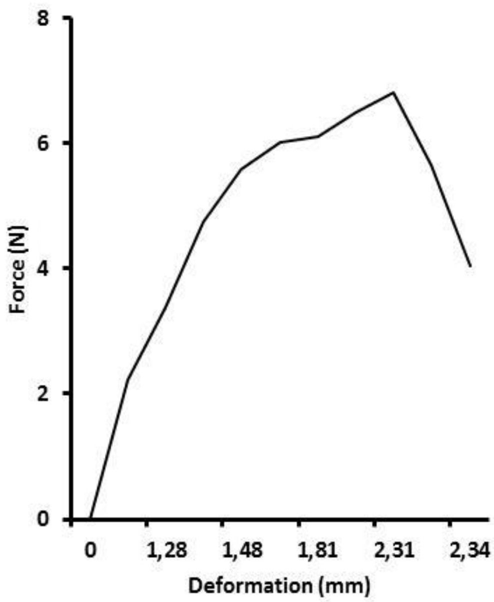

Fig. 2 - Typical force-deformation curve obtained in puncture test for Tybeef (light pink)

The maturities of tomatoes were categorized as green, light pink, pink and red according to their colours. For this purpose, Minolta CR-300 chromometer color measurement device was used (Fig 3). Hue and chroma were also determined *(Sirisomboon et al., 2007).*

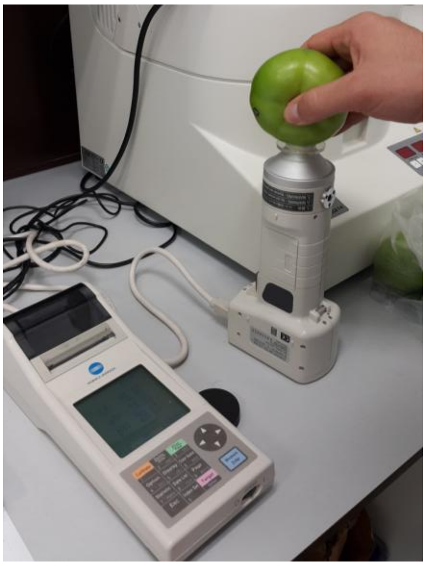

Fig. 3 - Chromometer for color measurement

RESULTS

The data on color and physical properties of Tybeef F1 tomato cultivars are shown in Tables 1 and 2. Also, a summary of the descriptive statistics of the various physical dimensions is shown in Table 1.

Table 1

Measured physical parameters of Tybeef F1

	Min	Max	Average
Mass (g)	289.14	364.11	334.40±8.190
Diameter (mm)	77.34	102.17	88.92±0.651
Length (mm)	60.83	91.08	75.84±0.673
Geometric diameter(mm)	71.67	96.48	80.60±0.420
Sphericity (%)	91.15	121.67	106.58±0.911
Surface area (mm^2)	19435.27	26736.48	20425.61±215.784

Dimensions of Tybeef tomato varied from 77.34 to 102.17 mm in diameter, 60.83 to 91.08 mm in length and 71.67 to 96.48 mm in geometric diameter, with average values of 88.92, 75.84, and 80.60 mm, respectively. The importance of dimensions is in determining the aperture size of machines, particularly in the separation of materials as mentioned by Mohsenin *(Mohsenin N.N., 1986)*. The importance of sphericity is in determining the fruit shape. The average sphericity of tomato was 106.58 %; the sphericity is reported by Mohsenin in the range of 32-1 (%) *(Mohsenin N.N., 1986)*. The surface area of Tybeef F1 varied from 19435.27 to 26736.48 cm^2 with mean values of 20425.61 cm^2.

Table 2

Color properties of Tybeef F1

	L*	a*	b*	C*	h
Green	56.60	-14.18	26.96	30.46	117.75
Light pink	49.51	12.50	28.87	31.87	67.56
Pink	46.44	21.59	31.22	38.18	55.64
Red	42.89	27.99	33.52	41.15	49.01

The skin color (L*, a*, b*, C*,h) mean values of Tybeef F1 tomato variety are presented in Table 2. The average values of L*, a*, b*, C*, h for green maturity stage are 56.60, -14.18, 26.96, 30.46 and 117.75, respectively. The average values of L*, a*, b*, C*, h are 49.51, 12.50, 28.87, 31.87 and 67.56, respectively in light pink tomato. Also, for pink skin colour, they are 46.44, 21.59, 31.22, 38.18 and 55.64 and for red skin, 42.89, 27.99, 33.52, 41.15 and 49.01, respectively.

The mean of puncture force, deformation, failure stress, toughness, puncture energy and modulus of elasticity of Tybeef tomato depending on the maturity stage and the descriptive statistics of the various mechanical properties are presented in (Table 3)

Table 3

Effect of maturity time on Mechanical Properties of Tybeef

	Green	Light Pink	Pink	Red	Sign. level
Puncture Force (N)	10.39^a	6.15^b	4.86^c	4.16^d	**
Deformation (mm)	1.43^c	2.39^b	2.5^b	3.16^a	*
Failure stress (N/mm^2)	4.30^a	3.91^b	2.83^c	2.75^c	*
Toughness (N/mm)	5.87^a	4.27^b	3.74^c	3.53^c	*
Puncture energy (Nmm)	50.66^d	65.485^c	85.94^b	122.62^a	**
Modulus of elasticity (N/mm^2)	0.26	0.31	0.29	0.28	ns

All data represent the mean of three replications with 45 determinations.
ab Letters indicate the statistical difference in rows.
* Significant levels at 1%.
** Significant levels at 5%.
ns, not significant.

As seen in Table 3, the puncture force, failure stress and toughness values decreased as fruit maturity increased and deformation and puncture energy values increased as the maturity decreased.

The average puncture force values were 10.39, 6.15, 4.86 and 4.16 N for green, light pink, pink and red, respectively. The highest value of puncture force was found in the green maturity stage. The mean deformation values for green, light pink, pink and red maturity stages were 1.43, 2.39, 2.50 and 3.16 respectively, so the deformation values were the highest for red colour and the lowest for green colour. Also, the mean failure stress values for maturity stages were 4.30, 3.91, 2.83 and 2.75 from green to red colour so the failure stress values were the highest for green colour and the lowest for red colour. The average for toughness values for green, light pink, pink and red maturity stages were 5.87, 4.27, 3.74 and 3.53 respectively. The highest toughness was obtained in the green maturity stage. The mean modulus of elasticity values for green, light pink, pink and red maturity stages were about 0.26, 0.31, 0.29 and 0.28 respectively, so the modulus of elasticity values were the highest for light pink colour and the lowest for green colour (Fig 4).

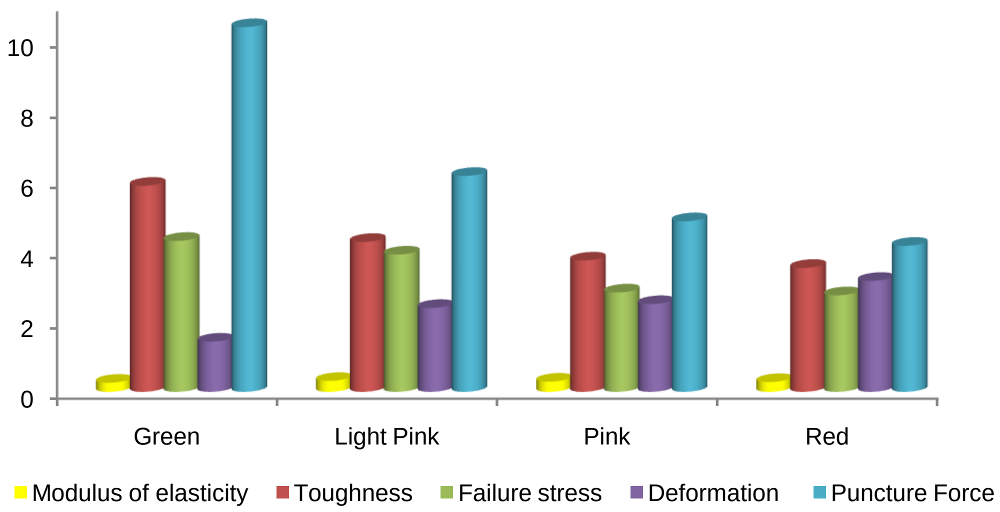

Fig.4. Average values of some mechanical properties for all maturity time

For all maturity stages, the highest puncture energy was obtained for red colour as 122.62 Nmm and the lowest value was found for green colour as 50.66 Nmm (Fig. 5).

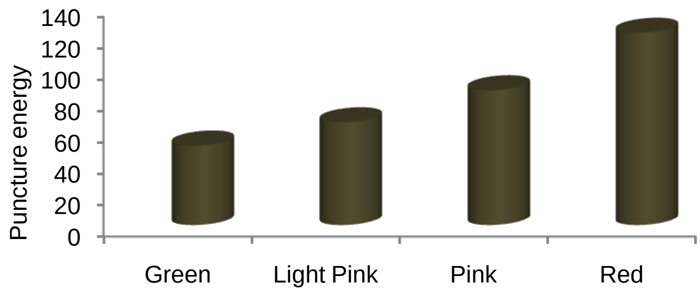

Fig.4. Average values of some mechanical properties for all maturity time

The puncture force values were found different at 5% probability level for all the maturity stages. Also, similarly, the puncture energy values were found different at 5% probability level for all the maturity stages. Similar results have also been reported *(Ince et al., 2016).* Deformation, failure stress and toughness values were found different at 1% probability level for all the maturity stages. Statistically, there is no difference in modulus of elasticity values for all the maturity stages.

Deformation of fruit changes based on the properties of biological materials. It depends on the structure of biological material and cells' pores *(Persson S., 1987)*. Deformation increased as the maturity of fruit increased. This result verified the softening of the tomato fruit. While deformation values for pink and light pink maturity stages were in the same group statically, however, the modulus of elasticity did not show any statically difference for all maturity stages. Similar results have also been reported *(Ince et al., 2016).*

Also, failure stress and toughness decreased as the maturity of fruit increased. We can say that ripe fruit might be damaged more due to its soft texture compared to unripe fruit under the same force. While failure stress and toughness values for pink and red maturity stages were in the same group statistically.

CONCLUSION

In this study, some mechanical properties (puncture force, deformation, modulus of elastic, puncture energy, failure stress and toughness) of Tybeef F1 tomato variety were determined as affected by maturity stage. Puncture force, failure stress and toughness decreased with the increase in maturity stage. On the contrary, deformation and puncture energy increased as the maturity of fruit increased. Also, the modulus of elasticity did not show any statistic difference for all maturity stages. According to the test results, puncture force and energy are more sensitive textural mechanical parameters related to the maturity stage.

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