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Comparison of Some Methods to Determine the Modulus of Elasticity of Some Onion Varieties

S.Sağsöz and F.N.Alayunt
Ege Üniversity, Department of Agricultural Machinery, Faculty of Agriculture,
Ege University, Bornova, Izmir, Turkey

Abstract: Banko and Yalova-12, varieties of onion were studied for some physical parameters such as size, shape, and density. An instron test machine was used to perform a compression test on both varieties. Modulus of elasticity was found from force-deformation curve(experimental method) and Hertz equation. The effects of the loading direction (polar or equatorial), loading speed, onion varieties, and the calculation methods were examined on the modulus of elasticity. The effects of loading speed and varieties on the modulus of elasticity were found to be significant. Modulus of elasticity was decreased with increasing loading speed. No significant differences were found in values of modulus of elasticity for experimental method and Hertz equation and the loading direction (polar or equatorial load).

Key words: Onion, modulus of elasticity, mechanical properties

Introduction

Onion is very useful for human health and includes some natural disease inhibitors and vitamins. Mechanical injury caused quality loss in onion, like other agricultural products. In many cases, physical damage will lead to attack by microorganisms and pyhsiological changes which may increase deterioration of these products.

Maw *et al*. (1996) were determined some physical and mechanical properties of some onion varieties such as diameters, specific gravity, shape factor, volume, surface area and crushing load, ratio of equatorial diameter expansion to polar diameter contraction etc. Some physical parameters such as size, shape and rolling resistance were determined for two different onion varieties by Sağsöz and Alayunt (1999).

Kara and Turgut (1988) studied on some different potatoes varieties to determine their mechanical properties. Six potato varieties were loaded in four different compression tests. Cylindrical plunger with 8 mm diameter was used to compress the intact potatoes and cylindrical potatoes with 32 mm diameter and 12.5 mm height. In addition, cylindrical potatoes with 15 mm diameter and 30 mm height were compressed polar and equatorial between two plates. The modulus of elasticity of different potato varieties were compared in four compression tests. Kara and Turgut (1988) was found that equatorial compression test has appeared to be the most sensitive for monitoring potato firmness.

The difference between the Hertz theory and conventional method for calculating the modulus of elasticity of whole fruit of an apple was so small which were 18.48×10^5 Pa or 268 psi and 17×10^5 Pa or 246.5 psi for Hertz theory and conventional method respectively. Statistical analysis using a t-test showed that the difference between the two methods were not significant at $á_{0,05}$ level (Mohsenin, 1986).

The objective of this experiment was to compare the experimental method(force-deformation curve) with the method of Hertz for determining the modulus of elasticity of some onion varieties and finally, the effects of load direction (polar or equatorial), loading speed and different onion varieties on the modulus of elasticity were examined.

Materials and Methods

This study was carried out on two different onion varieties, Banko and Yalova-12 from Bursa region, Turkey. Onion samples stored for two months, were weighed and dimensions were measured. After storage, onion samples were taken to room temperature (20^{0}C approximately), to study on modulus of elasticity of each variety. Some physical properties of onion varieties were given in Table 1.

Table 1: Physical properties of Banko and Yalova-12 varieties of onion after two months storage period

Varieties	Banko	Yalova-12
Density(g/cm^3)	0.87	0.90
Moisture content (%)	92.00	86.00
Equatorial diameter(mm)	80.50	49.30
Polar diameter (mm)	69.60	45.40
Shape Factor	1.17	1.12

The laboratory tests were carried out by using Instron test machine. The whole onion sample was set on a flat plate (Fig.1). Compression force was applied at a loading speed of 50 mm/min and 100 mm/min .Onions were loaded either equatorial or polar until cracking. On force-deformation graphics, force required to cause permanent deformation was indicated as a peak force. The experimental method were calculated as described by Çakir *et al*. (2000).

The increase in cross-sectional area due to polar expansion under equatorial compression was calculated by using regression equation. This regression was developed by using equatorial and polar diameter and load.

Cross-section area of Banko varieties was determined by using equation 1.

A= -939 + 13.3 x equatorial diameter + 14.4 x Force (load) (mm^2)............................1

Cross-section area of Yalova-12 varieties was determined by using equation 2

A= -905 + 5.78 x polar diameter + 12.8 x equatorial diameter + 11.3 x Force (load) (mm^2)...............2

$\epsilon = \Delta L/L$ 3

ϵ = Strain
L_0 = Original length of onion (mm)
L = Length of onion after deflection (mm)

Table 2: The effect of the loading direction (polar or equatorial), loading speed, different onion varieties and methods on the modulus of elasticity of onion

Replication	Speed	Banko Hertz (Mpa) Equatorial	Banko Hertz (Mpa) Polar	Banko Experimental (Mpa) Equatorial	Banko Experimental (Mpa) Polar	Yalova-12 Hertz (Mpa) Equatorial	Yalova-12 Hertz (Mpa) Polar	Yalova-12 Experimental (Mpa) Equatorial	Yalova-12 Experimental (Mpa) Polar	Average Modules of Elasticity
1	50 mm/min	1.971	2.118	2.275	1.550	1.841	2.432	1.942	1.849	1.947
2		2.473	2.118	2.250	1.552	1.823	2.396	1.886	1.960	
3		1.971	2.118	2.275	1.434	1.392	1.855	1.106	1.622	
4		2.888	1.681	2.454	1.148	2.599	1.155	1.983	1.317	
5		3.188	2.118	2.578	1.166	1.438	2.847	1.134	2.359	
6		2.963	2.125	2.216	1.643	1.786	3.245	1.172	2.840	
7		3.347	2.550	2.391	2.023	1.322	0.783	1.259	1.403	
1	100 mm/min	1.380	1.437	1.607	1.191	0.386	0.553	1.728	0.778	1.058
2		0.745	1.461	1.267	1.538	1.200	0.477	1.494	0.849	
3		0.830	1.607	1.248	1.301	0.561	1.183	0.915	0.608	
4		1.045	1.206	1.399	1.079	0.496	0.649	0.853	0.626	
5		1.170	1.719	1.651	1.528	0.936	0.867	1.176	1.389	
6		1.163	1.549	1.362	0.749	0.641	0.756	1.158	0.475	
7		0.946	0.982	0.952	1.142	0.713	0.587	1.182	0.679	
Average Modulus of Elasticity			1.710				1.335			

Table 3: The effects of loading speed, loading direction, calculation methods and onion varieties on the value of modulus of elasticity

Factor	Degrees of Freedom	Sum of squares	Mean square	F value	Prob
Varieties (A)	1	3.943	3.943	25.2030***	0.0000
Speed (B)	1	24.141	24.141	154.3150***	0.0000
A x B	1	0.019	0.019	0.1223	-
Methods (C)	1	0.210	0.216	1.3782	0.2433
A x C	1	0.408	0.408	2.6081	0.1096
B x C	1	1.870	1.870	11.9534	0.0008
A x B x C	1	0.001	0.001	0.0051	-
Loading direction (D)	1	0.313	0.313	1.9989	0.1607
A x D	1	0.994	0.994	6.3548	0.0134
B x D	1	0.094	0.094	0.5991	-
A x B x D	1	3.617	3.617	23.1180***	0.0000
C x D	1	0.647	0.647	4.1352	0.0448
A x C x D	1	0.058	0.058	0.3688	-
B x C x D	1	0.265	0.265	1.6952	0.1960
A x B x C x D	1	0.034	0.034	0.2157	-
Error	96	15.018	0.156	0.156	
Total	111	51.636			

$\Delta L = (L - L_0)$

Strain-Stress graphics were given(Fig. 2).
Under uniequatorial loading the slope of the stress-strain curve, is representing the elastic modulus E. (Finney, 1963). According to Hertz method, modulus of elasticity was determined by using equation 4(Mohsenin, 1986).

$$E = \frac{(0.531F)(1-\mu^2)}{D^{3/2}} \left[\left(\frac{1}{R_1}+\frac{1}{R'_1}\right)\right]^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ 4$$

E = Modulus of Elasticity(MPa)
F = Normal Load (Force)(N)
D = Combined Deformation at the Point of Contact,mm
μ = Poisson's Ratio
R_1, R'_1 = Radii of Curvature for Sample(mm)

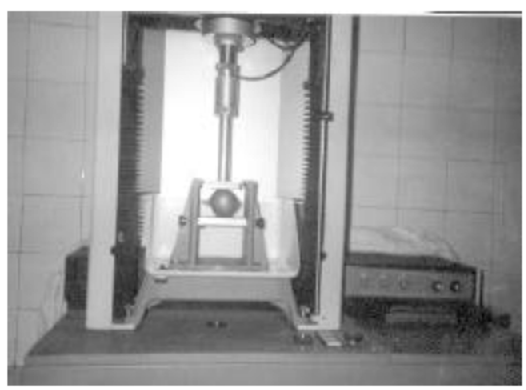

Fig. 1: Compression between parallel plates by using instron test machine

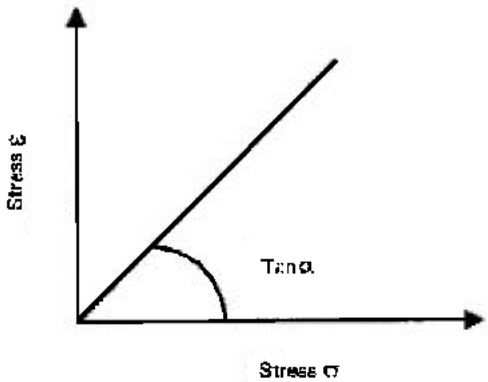

Fig. 2: Stress- Strain curve

Poisson ratio of Yalova-12 and Banko were found as 0.35 and 0.44 (Çakir *et al.*, 2000).

The effects of the load direction (polar or equatorial), loading speed, different onion varieties, and the methods on the modulus of elasticity were compared by using statistical analysis (Table 2)

Results and Discussion

According to results of analysis of variation and F tests, the effects of loading speed and varieties were found to be significant on the modulus of elasticity (Table 3).

Banko has higher modulus of elasticity than Yalova-12. Average modulus of elasticity of Banko and Yalova-12 were determined as 1.710 Mpa and 1.335 Mpa respectively. Banko was found more stiff than Yalova-12.

The loading direction (polar or equatorial load) and methods (Hertz and experimental) were found non significant (Table 3). Modulus of elasticity was decreased by increasing of loading speed. It was found 1.987 Mpa for 50 mm/min loading speed and also 1.058 Mpa for 100 mm/min loading speed (Table 3). Loading direction, calculation methods and their interactions were not significant except for (variation x speed x loading direction) interaction. According to probabilities, there were some little differences between methods and loading directions. But their differences were not found important at $á_{0.05}$ level.

The determination methods of modulus of elasticity may be alternative to each other.

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