Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences
Volume 1 Number 4: 376-378, 2002

A Study on the Determination of Poisson's Ratio and Modulus of Elasticity of Some Onion Varieties

E. Çakir, F. Alayunt and K. Özden
Department of Agricultural Machinery, Faculty of Agriculture, Ege University, Bornova, Izmir, Turkey

Abstract: The objective of this study was to determine the mechanical properties such as poisson's ratio and modulus of elasticity of two onion varieties. The compression test was applied on Banko and Yalova 12 onions by using the load-displacement measurement device at laboratory conditions. From the measured vertical forces and deformation, rupturing force, stress and energy, poisson's ratio and modulus of elasticity of onions were determined. Results showed that the modulus of the elasticity of both onion varieties were the most affected from the storage period. Cracking energy increased with storage time. Due to firmness, onion gets weaker with the storage time, this double increases the cracking energy of the onion. Modulus of elasticity was decreased drastically from 6.54 to 1.35 MPa for Yalova 12 and similar drop was seen for Banko varieties, which was from 8.14 to 1.49 MPa. The poisson ratio was found between 0.15 and 0.44 for both onion varieties.

Key words: Onion, rupturing force, poisson's ratio, modulus of elasticity, stress, energy

Introduction

The onion is the vegetable most widely consumed all year round in Turkey. A large number of commercially grown onions varieties are available in Turkey. Their shape, dimensions, colour and storability are different from each other (Kaynaş *et al*., 1991). The onion production and exports increase gradually in last ten years (Table 1).

Table 1: Cultivated area, production, yield and export status of onion in Turkey (Anonymous, 1997)

Years	Area ('000 ha)	Production ('000 tones)	Yield (t ha^{-1})	Exports ('000 tones)
1985	84.5	1270	15.03	131.3
1987	73.0	1300	17.80	132.7
1988	75.0	1345	17.93	164.0
1997	105.0	2100	20.00	114.54

Since they lack natural disease inhibitors, they have a short shelf life unless extreme care is taken to preserve them at every stage of production. It is suggested that understanding the physical and mechanical properties of onions would contribute handling the onion and increasing the shelf life.

The major problem encountered in onion trade is loss during storage due to rotting, sprouting and weight loss. Mean mass, surface area, volume, density and also crushing load and puncture force of "Grane-Grono" type sweet onions were examined by Maw *et al*. (1996).

There are many studies on fruit and vegetables' poisson's ratio and elasticity modulus (Arnold and Roberts, 1969; Kang *et al*., 1995). Knowledge of elastic modulus allows comparison of relative strengths of various materials to be made.

Timbers *et al*. (1965) has been used to estimate modulus of elasticity for 1-in cylindrical cores of potato tuber, loaded with rigid dies of various diameters. Potato's poisson ratio (υ) was found 0.492 and elasticity modulus (E) was found between 3.31 to 3.75 MPa. Similar results were obtained by Finney (1963). Fridley *et al*. (1968) were obtained force deformation curves for peaches and pears. Modulus of elasticity were calculated as 1.03 and 5.3 MPa for peaches and pears, respectively. The poisson's ratio was between 0.2 and 0.5. Viscoelastic materials' poisson ratio are between 0.35 and 0.5.

Materials and Methods

Two onion varieties were used in this research, Banko and Yalova 12, which produced most for exporting purposes in Bursa region. Before laboratory tests, onions were numbered, weighed and volumes and dimensions were measured for physical properties. Onions were loaded either axially or lateral until cracking (Fig. 1). Loading was made with a circular plate having a diameter of 15 cm with a constant speed of 25 mm min^{-1} driven by a 1.1 kW electric motor connected to a gear drive. Applied load was measured by HBM-Q3 model load cell with 5 kN capacity and at the same time the downwards displacement (axial deflection) was measured with HBM-W100 model LVDT. Both instruments were connected to the computer with an AD card to record each test output.

The applied load and the axial displacement were measured and recorded by the computer. Then the cracking stress, energy and modulus of elasticity were calculated as follows:

$$\sigma = \frac{F}{A} \quad \text{............. 1}$$

σ = Cracking stress (kPa)
F = Cracking force (kN)
A = Cross section area (m^2)

By Trapezoidal rule (Burden and Faires, 1989)

$$U = \sum \left(\frac{x_1 - x_0}{2}\right) [F(x_0) + F(x_1)] \quad \text{.............. 2}$$

U = Cracking energy (Nm)
x_0 = First displacement (m)
x_1 = Second displacement (m)

$$E = \frac{\sigma}{\epsilon} \quad \text{................ 3}$$

E = Modulus of elasticity (kPa)
ϵ = Strain

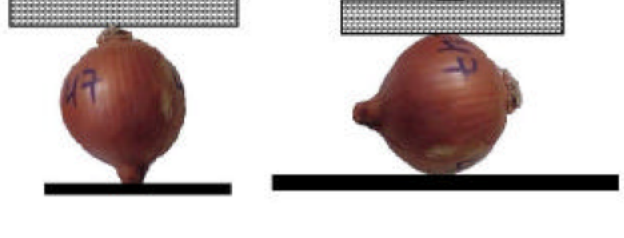


Fig. 1: Onions were loaded axially and lateral.

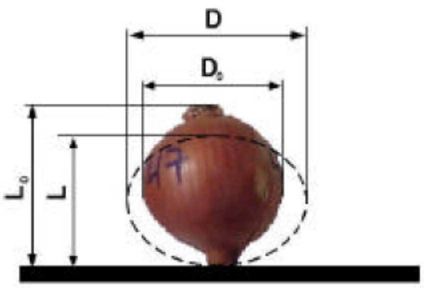


Fig. 2: Measurements taken for poisson's ratio calculation.

Axial and lateral poisson's ratios were calculated by loading the onions axial and lateral. For each step of loading the lateral and axial deflections of the onion were measured (Fig. 2). The experiment was carried out until reaching the cracking limit of axial load. The formulation for calculation of the poisson's ratio is given in equation 4.

$$v = (\delta D/D_o) / (\delta L/L_o) \qquad \text{(Sitkei, 1986).....4.}$$

v = Poisson ratio
D_o = Original diameter of onion (m)
D = Diameter of onion after deflection (m)
$\delta D = (D - D_o)/2$
L_o = Original length of onion (m)
L = Length of onion after deflection (m)
$\delta L = (L_o - L)$
In experiments, results were evaluated using MSTAT Statistical Program.

Results and Discussion

The typical behavior of Yalova 12 and Banko onions during loading was given in Fig. 3. The general behavior of onion against axial loading is linear as the load increases. But rarely the trend was found on both onion varieties was exponential or logarithmic (Fig. 4).

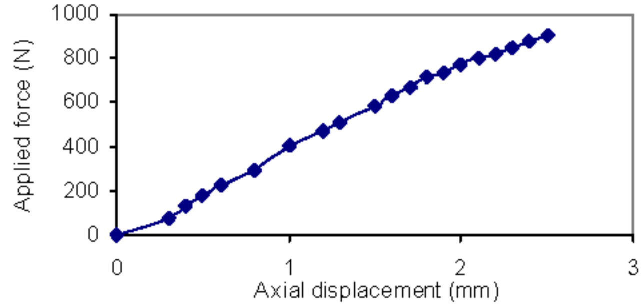


Fig. 3: Typical behavior of both onion varieties during loading until cracking.

The mechanical properties of both onion varieties at different storage periods were given in Table 2. Except cracking stress, the cracking force, energy and the modulus of elasticity were affected from the storage periods. One month of storage time was not found significant for cracking force and modulus of elasticity of both onion.

After two months of storage time, cracking force and the modulus of elasticity of two onion varieties were decreased considerably. Cracking stress was found statistically not significant at $\alpha_{0.05}$ level. Generally small onions required less cracking force and energy.

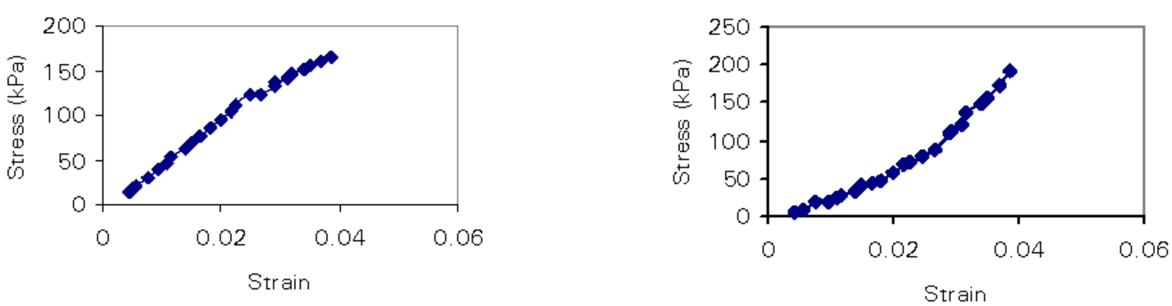
Poisson ratio of both onion was found between 0.15 and 0.44. Since the onion is the viscoelastic material, it is normal that the range of the poisson's ratio differs from 0.15 to 0.44. When look at the poisson ratio trend at the different loading steps it was observe that the poisson ratio varies from 0.14 to 0.45 (Fig. 5). The loading method was not found significant. Axial or lateral load application did not affect the mechanical behavior of the onion varieties (Table 3). This might be due to the onion shape. Onion shape was found most rounded.

The cracking forces increased with the size of the onion. This means that Banko varieties require less cracking force than Yalova 12 onions variety. But the cracking stress did not change the storage period or the size of the onion. The reason for requiring less cracking force of Yalova 12 onion stored for two months

Table 2: Mechanical properties of both onions at different storage periods.

		Cracking force (KN)		Cracking stress (KPa)		Cracking energy (Nm)		Modulus of elasticity (MPa)		Poisson's ratio	
Storage period		Yalova12	Banko	Yalova12	Banko	Yalova12	Banko	Yalova12	Banko	Yalova12	Banko
After Harvest	Min.	0.60	0.17	131.5	85.1	0.68	0.15	3.56	4.75	0.19	0.17
	Max.	1.36	0.74	290.5	336.6	1.80	0.67	9.34	11.73	0.42	0.46
	Avg.	1.03	0.48	213.0	241.5	1.15	0.4	6.54	8.14	0.35	0.44
2 Months	Min.	0.30	0.36	123.2	155.9	0.99	1.00	0.86	0.81	Not measured	
	Max.	0.76	0.79	244.2	316.6	3.24	2.22	1.87	2.82		
	Avg.	0.59	0.52	194.6	232.4	2.22	1.68	1.35	1.49		

Min. Minimum, Max. Maximum, Avg. Average



A: Yalova 12 onion variety

B: Banko onion variety

Fig. 4: Stress versus strain graphics of Valova 12 and Banko onion varieties

Table 3: Results of statistical analysis of cracking force (F), stress (σ) and energy (E) of both onion varieties

Parameters		SS	df	MS	F	P
Method (Lateral, axial)	F	380	1	380	0.6831	0.4126ns
	σ	59201	1	5920	1.208	0.2771ns
	E	32.26	1	32.27	0.0091	0.9243ns
Variety (Banko, Yalova 12)	F	26754	1	26754	48.0985	0.000***
	σ	14353	1	14353	2.9301	0.093ns
	E	98253	1	98253	27.758	0.000***
Time (After harvest, 1 Month, 2 Months storage)	F	8694	2	4347	7.815	0.0012**
	σ	15932	2	7966	1.6263	0.0207ns
	E	161909	2	80954	22.871	0.000***
Method X Variety	F	2.01	1	2.01	0.0036	0.9522ns
	σ	6955	1	6955	1.419	0.2393ns
	E	1092	1	1092	0.3085	0.5811ns
Method X Time	F	469	2	234	0.4221	0.6581ns
	σ	443.73	2	221	0.0452	0.9558ns
	E	3677	2	1838	0.5195	0.5981ns
Variety X Time	F	9095		4547	8.1754	0.009***
	σ	435.75	2	217	0.0444	0.9565ns
	E	8299	2	4149	1.1723	0.3183ns
Method X Variety X Time	F	288		144	0.259	0.7728ns
	σ	16881	2	8440	1.7231	0.1894ns
	E	7516	2	3758	1.0617	0.3538ns

ns, non-significant ** and *** represent significant at 0.01 and 0.001 levels of probability respectively

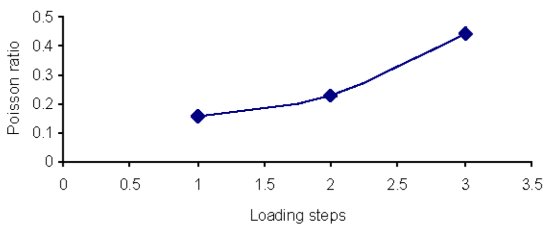


Fig. 5: Variations of poisson's ratio of both onion varieties at different loading steps until cracking.

was the use of small onions. The modulus of the elasticity of both onion varieties was most affected from the storage period. Cracking energy increased with storage time. Due to the firmness, onion gets weaker with the storage time, this double increases the cracking energy of the onion. Modulus of elasticity was decreased drastically from 6.54 to 1.35 MPa for Yalova 12 and similar drop was seen for Banko varieties which was from 8.14 to 1.49 MPa. The poisson's ratio was found between 0.15 and 0.44 for both onion varieties.

Although modulus of elasticity and cracking force of onion varieties were found not significant between right after harvest and one month storage time, onions gets softer day by day. Extending storage period generally creates quality problems. Therefore, if onion bulbs have to stay in store for some period of time, some precautions should be taken for decreasing the quality loss.

The average modulus of elasticities of Yalova-12 and Banko were determined as 6.54 and 8.14 MPa for right after harvest. The poisson's ratio of Yalova-12 and Banko were found 0.35 and 0.44 respectively.

References

Anonymous, 1997. Agricultural Structure, 1997. (Production, Price, Value). 1999. State Institute of Statistics Prime Ministry Republic of Turkey. ISSN 1300-963X.

Arnold, P.C. and A.W. Roberts, 1969. Fundamental Aspects of Load-Deformation Behavior of Wheat Grains. Transactions of the Asae., 12: 104-108.

Burden R.L. and J.D. Faires, 1989. Numerical Analysis. Fourth Edition. PWS-KENT Publishing Company, Boston, MA, USA.

Finney, E.E., 1963. The Viscoelastic Behavior of the Potatoes, Solanum Tuberosum, Under Quasistatic Loading. Unpublished PhD Thesis. Michigan State University, East Lansing.

Fridley, R., R.A. Bradley, J.W. Rumsey and P.A. Adrian, 1968. Some Aspects of Elastic Behavior of Selected Fruits. Transactions of the Asae., 11: 46-49.

Kang, Y.S. and C.K. Spillman, J.L. Steele and D.S. Chung, 1995. Mechanical Properties of Wheat. Transactions of the Asae., 38: 573-578.

Kaynaş, K., S. Özelkök and S. Erkal, 1991. The Onion Situation in Turkey: Problems and Future Prospects. Onion Newsletter for the Tropics. No: 3. Natural Resources Institute, United Kingdom, pp: 10-13.

Maw, B.W., Y.C. Hung, E.W. Tollner, D.A. Smittle and B.G. Mullinix, 1996. Physical and Mechanical Properties of Fresh and Stored Sweet Onions. Technical Notes. Transactions of the Asae., 39: 633-637.

Sitkei, G., 1986. *Mechanics of Agricultural Materials.* Elsevier Science Publishing Co. Hungary.

Timbers, G.E., L.M. Statleyand and E.L. Watson, 1965. Determining Modulus of Elasticity in Agricultural Products by Loaded Plungers. Agricl. Engin., 46: 274-275.