EFFECT OF LOADING POSITION AND STORAGE DURATION ON THE MECHANICAL PROPERTIES OF ABATE FETEL PEAR VARIETY

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Abstract
In the study, the mechanical properties of Abbate Fetel pear have been examined in terms of storage time and loadingposition. The experiments were conducted in two stages; the first experiment was carried out immediately after the harvest and the second experiment was carried out after 30 days in cold storage. The mechanic properties of the pear fruit such as rupture force, deformation, rupture energy and firmness have been examined on the fruit's bloom side, lateral side and stem side. Furthermore, the size, sphericity, mass, amount of soluble solids and volume of the pear fruit have been determined. The relationship between the sides of the fruit and firmness has been found as statistically significant (P<0.001). The maximum firmness value has been found at the stem side, while the lowest firmness value has been found at the bloom side. The lowest rupture energy value of the pear fruit has been determined to be needed at the bloom side.

Key words: pear; mechanical properties; rupture force; rupture energy; firmness.

INTRODUCTION

Biological materials are exposed to mechanic effects in almost all processes from sowing or planting to the time they are offered to the consumer. These effects may be in the form of static or dynamic forces. The sizes, implementation time, structure of the force or type of implementation are mainly effective in the biological material's responses to these forces.

The mechanical deformations occurring in the fruits may be at significant levels during the implementations including cleaning, sorting, grading, packaging, transport and distribution that are harvest and post-harvest operations.

The biological materials that are under static or dynamic loading typically exhibit certain behaviors depending on their structural features. These behaviors emerge as yield or rupture. The implemented pushing force causes biological material to shorten, while the pulling force causes elongation. With the help of force-deformation curve, it is possible to determine modulus of elasticity of the material, biological yield limit, rupture point, and the values related to force-deformation and energy emerging at these points (ALAYUNT, 2000).

There are two important points on the force-deformation curve. These are biological yield point and rupture point. Biological yield point is the point on the curve at which the force decreases or remains constant with increasing deformation. This point indicates the cellular ruptures and it is used in determining the product's sensitivity to damage. The cell is not damaged before this point. The rupture point is the point at which the material ruptures, cracks or deteriorates under loading. After the rupture point, the force decreases rapidly with increasing deformation. The volume of the material/product deteriorates and its resistance to the force decreases; the maximum rupture point is obtained at this point. (MOHSENIN, 1970)

The mechanical properties of biological materials contain the resistance parameters of the product. These properties are determined by analyzing the force-deformation curve related to the product.

The mechanical damages on the fruits cause loss of quality. The pear fruit is among the fruits that are sensitive to different types of mechanical damages that may occur at harvest or post-harvest period. It is necessary to know the mechanical properties of the pear fruit in order to reduce the mechanical damages/losses that occur at harvest and post-harvest period.

When the harvested fruits and vegetables are stored in appropriate conditions, they retaintheir fresh qualifications significantly for a while. The cold storage provides different storage conditions according to the type of product. Depending on the cold storage conditions, certain changes may occur in the properties of the fruits stored at such an environment. For this reason, it is of importance to determine the mechanical properties of the fruites that are stored in cold storage.

In this study, the mechanical properties of the pear fruite, which is among the fresh fruits that is of commercially importance for Turkey, have been examined in terms of static load effect immediately after the harvest at room temperature and after 30 days in cold storage conditions.

The pear is the common name of the edible fruits of several tree and shrub species of genus Pyrus that is classified under the subfamily of Maloideae that belongs to the family of Rosaceae. Following apple and grapefruit, the pear constitutes the third major temperate fruit. The most of the cultivated forms of the genus *Pyruscommunis* L. (Pear) are grown in Anatolia. There are over 5000 varieties of pear in the world. In Turkey, which has so many different ecological conditions, it is reported that 640 varieties of pear are cultivated on a regional and local basis (ÖZAYDIN AND ÖZÇELIK, 2014).

According to the recent data, world pear production is approximately 24 million tons annually. Turkey ranks fifth in terms of production quantity of pear (ANONYMOUS, 2014).

The pear fruit contains K, Ca, Mg, S and Fe elements that have an important role in human nutrition to a large extent.

EMADI ET AL., (2011) examined the physical and mechanical properties of Tabrizi peach variety. The mean of physical properties including mass, volume, dimensions (big, medium and small diameters), arithmetic mean diameter, sphericity and density were respectively found to be 137.37 g, 107.37 cm, 61.1 mm, 60.29 mm, 59.21 mm, 60.14 mm, 96.05% and 1.24 g/cm. The mean of mechanical properties including stiffness of peach, without and with peel, were respectively found as 11.35 and 15.31 N. Linear relationships were respectively found between mass and volume, mass and three orthogonal diameters, volume and three orthogonal diameters, stiffness without peel and geometric mean diameter, also stiffness with peel and geometric mean diameter with correlation coefficients of 0.625, 0.743, 0.63, 0.872 and 0.897.

WASALA ET AL., (2012) examined the physical and mechanical properties of Seeni, Embul and Kolikuttu varieties of banana. The moisture content, linear dimensions of bunches and fruits, sphericity and aspect ratio of fruits, bulk density and true density, coefficient of static friction and the angle of repose on different surfaces such as wood, steel and Styrofoam, and fruit firmness were measured for the abovementioned three cultivars at the harvest maturity. The average bunch length of the banana cultivars Embul and Kolikuttu were higher than those of Seeni. The geometrical mean diameters of Embul and Kolikuttu fruits were also higher than Seeni (p0.05). The bulk density of fruits and hands were higher than those of the whole bunch. The lowest coefficient of static friction was on Styrofoam and the highest was on a wooden surface. There was no significant difference in terms of the firmness of mature green banana fruits between the cultivars ($p>0.05$).

MATERIALS AND METHODS

The Abate Fetel pears used in the research were harvested by hand from the SAMMEY fruit production farm in Samsun Province in October 2015, the commercial harvest period. The harvested pears were stored at 1°C storage temperature and 90% relative humidity for 30 days. Before the measurements, the pear fruits were held in at 21±2°C temperature to reach ambient temperature for 1 h.

The Abate Fetel that originated in France was found in 1866. It can be immediately distinguished with its large and conical fruit with a too long neck. Its rind is thin and partly rusty; its color is dark yellow when the fruit is mature. The fruit is quite juicy and aromatic with its white flesh that has a hard texture and sweet flavor; it is a highly qualified fruit (ANONYMOUS, 2010).

The pear fruits were cleaned from dust, dirt, twigs and impurities before commncing the experiments. The pear size measurements were carried out with a digital calliper having an accuracy of 0.01 mm in term of the major, intermediate and minor diameters.

Using the determined axis measurements, arithmetical mean diameter (D_a), geometric mean diameter (D_g) and sphericity values were calculated by the following equations (where; L major diameter, mm; W intermediate diameter, mm; T minor diameter, mm) (Fig. 1) (MOHSENIN, 1980, 1970; MILANI ET AL., 2007).

$$D_a = (L + W + T)/3 \quad (1)$$

$$D_g = (LWT)^{1/3} \quad (2)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (3)$$

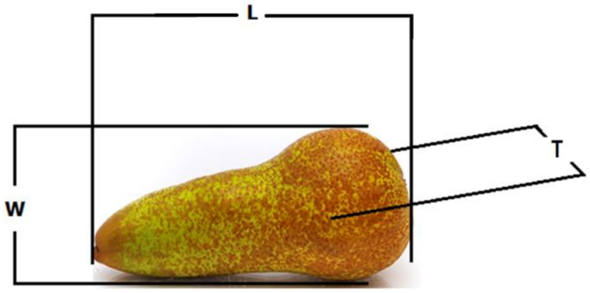

Fig. 1. – Sizes of pear fruit

Geometric mean diameter values and the following equation were utilized in determining the surface area (MOHSENIN, 1980).

$$S = \pi D_g^2 \qquad (4)$$

At this equation;
S: Surface area (mm^2)
Dg: Geometric mean diameter (mm).
The volume of the pear (*V*) was calculated by the following equation (MOHSENIN, 1980):

$$V = \frac{\pi}{6}(LWT) \qquad (5)$$

The content of the total soluble solid (TSS) was determined using Atago Pocket and PAL-1(Japan) digital refractometer.
The mechanical properties of pear fruit were determined using LLoyd (Lloyd Instrument LRX Plus, Lloyd Instruments Ltd, An AMATEK Company) biological material tester. The device is composed of a platform to hold the sample, a movable member, a unit providing movement and a data processing unit (Fig. 2). The data processing unit has a load cell with 100 N capacity and a computer with NEXYGEN Plus software to which the data is transferred. During the experiments, a 8-mm diameter probe was connected to the moving part and load was applied to the blossom side, lateral side and stem side of the pear fruit at the press rate of 20 mm/min (GARCIA ET AL., 1995).

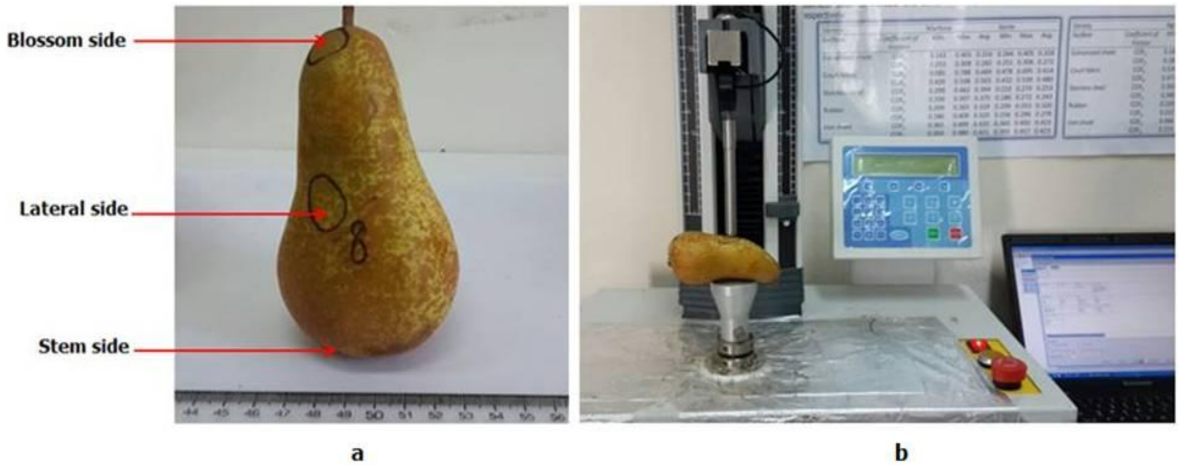

Fig. 2. – a - Representation of the three axes and three perpendicular dimensions of pear, **b -** Lloyd Instrument universal testing machine

The force-deformation curve was plotted based on the values obtained from the load cell by means of the software program. The peak (A) of the force-deformation curve was determined as rupture force (Fig. 3). The rupture energy was determined by calculating the area under the force-deformation curve. The software saves the obtained values into a data file. The experiments were conducted in 10 replicates.

Firmness was calculated by dividing the rupture force by dividing the deformation to the rupture point (YURTLU AND YESILOGLU, 2012).
The value of all the measured properties is summarized in Tab. 1. The length ranged from 113.58 to 130.56 mm; the width ranged from 55.04 to 65.06 mm; and the thickness ranged from 53.69 to 60.50 mm. The geometric mean diameter ranged from 70.08 to 77.54 mm.

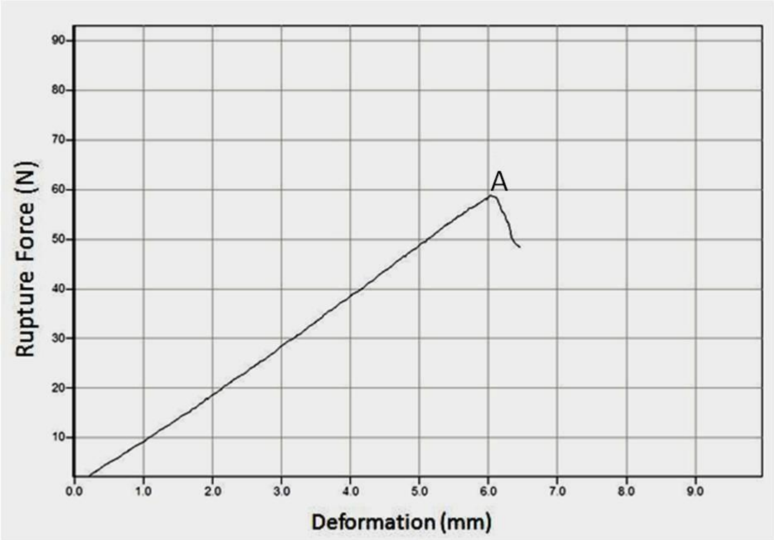

Fig. 3. – Force-deformation curve of pear fruit

RESULTS AND DISCUSSION

Mean, minimum and maximum values together with standard deviations of some physical properties of Abbate Fetel pears are listed in Tab. 1.

Tab. 1. – Physical properties and standard deviation of pear

Pear dimension, mm	*Major diameter (L)*	122.93±5.05
	Intermediate diameter (W)	59.72±3.44
	Minor diameter (T)	57.46±2.01
Average diameter, mm	*Arithmetic mean (L+W+T)/3*	80.03±2.83
	Geometric mean $(LWT)^{1/3}$	74.95±2.61
	Sphericity (%)	0.61±0.02
	Surface area, mm^2	17671.37±1219.82
	Mass (g)	206.99±16.41
	Water soluble dry matter (%)	12.89±1.31
	Volume (mm^3)	229180.6±21671.97

According to research results, the values of the rupture force, deformation and firmness have been observed to increase after the pear fruits were stored for 30 days. The effect of the storage time on the firmness property of the pear fruit has been found statistically significant ($P<0.05$).

Tab. 2 shows the means and statistical values of the mechanical properties resulting from the load applied to the three sides of the pear fruit depending on the storage time.

According to research results, the values related to the rupture force, deformation, rupture energy and firmness respectively ranged between 15.2- 59.26 N; 2.16-6.88 mm; 0.036- 0.26 J; and 4.15- 10.29 N/mm.

The relationship between pear locations and firmness has been found statistically significant ($P<0.001$). The maximum firmness value was found at the stem side, while the lowest firmness value was found at bloom side of the pear fruit.

Tab. 2. – Measurement parameters and some statistical values

Storage Time	Pear locations	Rupture Force (N)	Deformation (mm)	Rupture Energy (J)	Firmness (N/mm)
1 day	B	31.17±11.03	4.59±1.35	0.102±0.04	6.78±0.99
	L	39.51±8.77	4.85±1.06	0.145±0.06	8.12±0.19
	S	42.68±8.98	4.69±0.88	0.152±0.05	9.07±0.33
30 days	B	32.59±7.85	4.86±0.98	0.104±0.05	7.09±0.54
	L	41.18±7.80	4.84±0.94	0.147±0.04	8.52±0.31
	S	48.04±5.49	5.10±0.66	0.157±0.04	9.43±0.44
Means					
1 day		37.79±10.74	4.71±1.11	0.14±0.05	7.99±1.14
30 days		40.59±9.47	4.84±0.86	0.13±0.05	8.34±1.08
	B	31.89^{a}±9.69	4.59^{a}±1.19	0.102^{a}±0.04	6.94^{a}±0.83
	L	40.31^{b}±8.14	4.84^{a}±0.98	0.144^{b}±0.05	8.31^{b}±0.32
	S	45.36^{c}±7.75	4.89^{a}±0.78	0.153^{b}±0.05	9.25^{c}±0.42
P values					
Pear locations		<0.001	0.590	<0.001	<0.001
Storage Time		0.217	0.626	0.742	<0.05

CONCLUSIONS

It has been found that the length (L) of the pear fruit ranged between 113.26 and 130.56; its width (W) ranged between 55.04 and 663.64; and its thickness (T) ranged between 53.69 and 59.81 mm. The fruit's sphericity value ranged between 0.58% and 0.64%; the mass value ranged between 175.66 and 234.94 g; the amount of soluble solids ranged between 10.8% and 15.3%; and its volume value ranged between 180192.1 and 265959 mm^3.

According to the results of the experiments, the stem side of the pear fruit is the area that is mostly ruptured. The lowest rupture energy value of the pear fruit has been determined to be needed at the bloom side.

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