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POST HARVEST CHARACTERISTICS OF POMEGRANATE (*PUNICA GRANATUM* L.) FRUIT

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ABSTRACT - Information and knowledge about the evolution of properties and quality attributes, that are so important for understanding post harvest behavior, is very limited due to the use of completely different frameworks in pre harvest and post harvest quality analyses. This study was conducted to determine firmness of two variety of pomegranate that are cultivated in Iran. The firmness was determined at top, middle and bottom positions of fruit by an Instron Universal Testing Machine with 5 mm, 6 mm and 8 mm diameter probes. The mechanical properties of bottom section were more than top and middle sections. Rupture energy and firmness measured with 8 mm probe was found to decrease during storage time. The mechanical properties of two varieties were found approximately the same. Effect of storage time and variety on mechanical properties was found insignificant ($P < 0.05$).

Key words : Pomegranate fruit; Post harvest; Firmness; Storage time.

INTRODUCTION

Pomegranate is an important fruit crop of many tropical and subtropical regions of the world that is grown such as in the moderate climates of Mediterranean countries. Iran is the native land of pomegranate with an annual production of 700.000 tons (Khoshnam *et al*., 2007).

To separate the arils of pomegranate from its rind it is necessary to find its mechanical properties such as toughness, firmness and shear strength. Also the determination of mechanical properties of pomegranate's peel is important to design machines and processes for harvesting, handling and post-harvesting operations of this fruit.

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For agricultural products, dimensions (length, diameters and Whatnot) are widely used to describe them. Physical dimensions of fruits, such as shape, are very important in sorting and sizing, and determine how many fruits can be placed in shipping containers or plastic bags of a given size (Keramat Jahromi *et al.*, 2008). Fruit volume, shape and density are important to design fluid velocities for transportation (Mohsenin, 1986). Also during harvesting of pomegranate probably some of fruits falls from tree and drops on the ground. This downfall causes splits, bruises or punctures. Compressive, tensile, shear and impact tests are usually applied to study mechanical properties of tissue structure.

Many researches were done by researchers and scientists in this field. Witz (1954) measured resistance to bruising of potatoes to puncture with a plunger. Kaufmann (1970) evaluated the effect of temperature and water potential on the extensibility of citrus rind. Gyasi *et al.* (1981) found Poisson's ratio citrus peel. Fridley and Adrian (1966) assessed the mechanical properties of apple, apricot, peach and pear with compression and impact tests, which involved the effect of impact velocity, multiple impacts, fruit maturity and fruit specimen thickness. Shamsudin *et al.* (2007) surveyed physico-mechanical properties of the josapine pineapple fruit. They reported the firmness of the fruits was decreased with the stage of maturity. Fathollahzadeh and Rajabipour (2008) spanned some mechanical properties of barberry as function of its moisture content. They reported the rupture force and toughness decreased when moisture content was increased. Kiliçkan and Güner (2008) measured physical and mechanical properties of olive fruit. The highest rupture force, rupture energy, and specific deformation of the olive pit and olive fruit among the axes at all deformation rates and sizes were obtained for X-axis except for specific deformation for olive fruit. Celik and Ercisli (2009) investigated some physical properties of pomegranate such as porosity, geometric mean diameter, surface area, fruit mass and dimensions, fruit volume, coefficient of static friction, projected area and skin color. Nazari Galedar *et al.* (2009) studied on mechanical behavior of Pistachio nut and its kernel at various moisture content. They determined rupture force, deformation and rupture energy of specimens. They found that rupture force, deformation and rupture energy values decrease with increasing moisture content. The maximum of these parameters at all moisture levels were obtained for pistachio nut loaded along the X-axis. Hassan-Beygi *et al.* (2009) procured some physico-mechanical properties of Apricot fruit, Pit and Kernel at different moisture content. Emadi *et al.* (2009) investigated mechanical behavior of melon through Compression, Shear, and Cutting Modes. The role of peel (%) on each property was also calculated as the relative contribution of peel to unpeeled produce. They found peeling melons using cutter tools could not be appropriate. As it was mentioned research in this ground is the subject of many scientist, but assessment of physical and mechanical properties of fruits needs more studies.

The objective of this research is to survey variations in some mechanical properties of Hondos-e-Yalabad and Malas-e-Saveh variety of pomegranate that is cultivated in Iran during storage time. Puncture test is applied to extract mechanical properties of pomegranate such as firmness, rupture energy and elastic modulus.

MATERIALS AND METHODS

Samples. The pomegranates used in this study were provided from Yal-abad located at Saveh (Markazi province). The Hondos-e-Yalabad and Malas-e-Saveh were two varieties of pomegranate that selected for this research. 108 fruits of each variety were harvested manually, cautiously and randomly. The specimens were set in boxes to protect from injuries and moisture volatilization. The boxes transported to the material property laboratory, department of agricultural machinery engineering, Faculty of Engineering and technology, University of Tehran and stored in a refrigerator at 5^0C. the experiment carried out three times, at first, fifteenth and thirties days after harvesting. Three cylindrical probes with 5, 6 and 8 mm diameter were selected. The mechanical properties of top (1), middle (2) and bottom of pomegranates were determined as shown in *Fig. 1*.

Puncture test. The mechanical properties of pomegranate under plunger test were measured by an Instron Universal Testing Machine (Instron Universal Testing Machine/SMT-5, SANTAM Company, Tehran, Iran). This device has three main components, which are a moving platform that the probe is attached to it, a driving unit and a data acquisition system (load cell, PC card, software and a monitor). The apparatus was supplied with a load cell of 500 kgf. The system accuracy was ±0.001 N in force and 0.0001 mm in deformation. The penetration speed was set on 25 mm/min. The samples were placed on the fixed plate considering puncture position. The compression test was initiated until rupture occurred as is denoted by a rupture point in the force–deformation curve. The rupture point was detected by a break in the force deformation curve (A point). When the rupture was occurred, the test was flowed to 25 mm of probe length. The mechanical properties of pomegranate were extracted in terms of rupture force and rupture energy required for initial rupture. A typical force–deformation curve for compressed sample is shown in *Fig 2*.

Force corresponding to point ‘A’ in *Fig. 1* was taken as peel firmness whereas the average of forces at ‘B’ and ‘C’ was taken as arils and inside rind firmness, respectively. Firmness of both peel and arils of pomegranate were determined at top (1), middle (2) and bottom (3) positions of the fruit, as shown in *Fig. 1*. Each reported values of firmness represent the mean of three individual measurements taken on pomegranate samples.

Statistical analyze. Statistical analyzeIn this research, four factors were considered as fruit variety in two levels; storage time in three levels, position of puncture test in three levels and diameter of probe in three levels. Experiments were carried out as complete randomized block design with four repetitions. The average and standard deviation of each treatment were reported. Experimental data were analyzed using analysis of variance (ANOVA). These analyses were performed using the Excel Analysis Tool pack option (MS Corporation, Redmond, WA, USA).

Figure 1 - Locations on the fruit where mechanical properties were measured by penetration probe

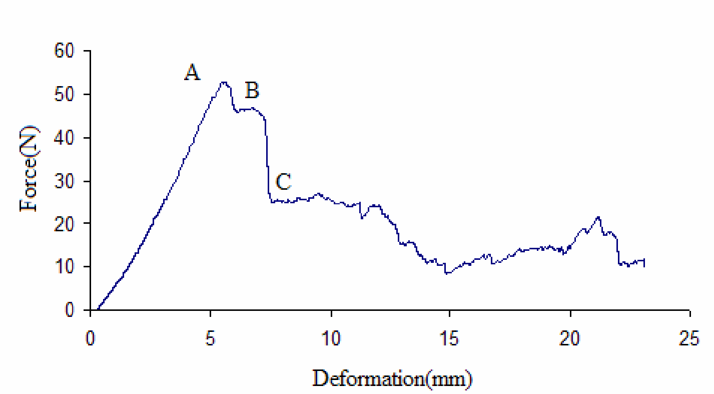

Figure 2 - Force deformation curve obtained from Texture Analyzer

RESULTS AND DISCUSSION

Firmness of fruit. Result of analysis of variance is presented in *Table 1.* Results show that the firmness of two varieties (Hondos and Malas) was different at level of 1% but storage time had insignificant effect on firmness at level of 5%. Also the effect of repetition was non-significant (level of 5%) therefore it is concluded that samples of each variety have same firmness. The firmness of various positions of fruit was severely different (level of 1%). It is because of variation in thickness of peel at various positions. The bottom of pomegranate is thick toward the middle and top of pomegranate. Diameter of cylindrical probe had significant effect on firmness. The firmness that measured by 6 mm diameter probe is presented in *Fig. 3 and Fig. 4.* The firmness of Top and middle of fruits nearly were equal as it is found from *Fig. 3 and Fig. 4.*

Table 1 - ANOVA showing effect of fruit varieties, storage days, position and diameter on firmness of pomegranate and their first order interaction

Source	Sum of squares	DF	Mean square	F-value
Variety (V)	1828.00397	1	1828.00397	8.243**
Storage time (S)	1080.20117	2	540.100587	2.435ns
Position (P)	120079.515	2	60039.7576	270.750**
Probe diameter (D)	69292.8695	3	23097.6232	104.159**
Repetition	809.801379	2	404.90069	1.825ns
VxS	7084.23731	2	3542.11866	15.973**
VxP	3017.00728	2	1508.50364	6.802**
VxD	5401.25861	2	2700.62931	12.178**
SxP	680.354789	4	170.088697	0.767ns
SxD	7844.00316	4	1961.00079	8.843**
PxD	1348.11654	4	337.029136	1.519ns
Error	35258.7717	159	221.753281	
Total	284160.438	215	1321.67646	

** Significant at level of 1%.
* Significant at level of 5% and ns not significant, respectively.

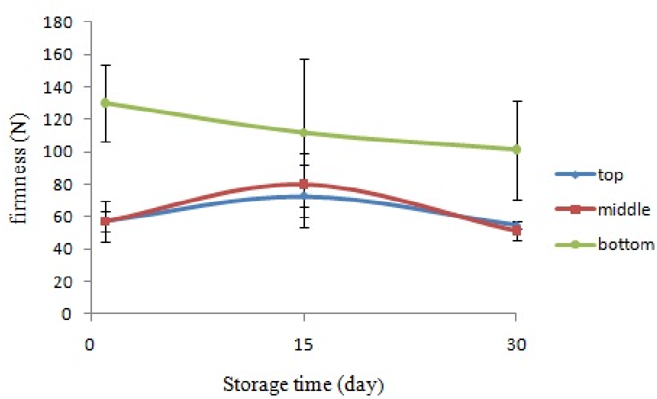

Figure 3 - Change in firmness of Hondos variety during storage at various positions. Vertical lines represent the standard deviations.

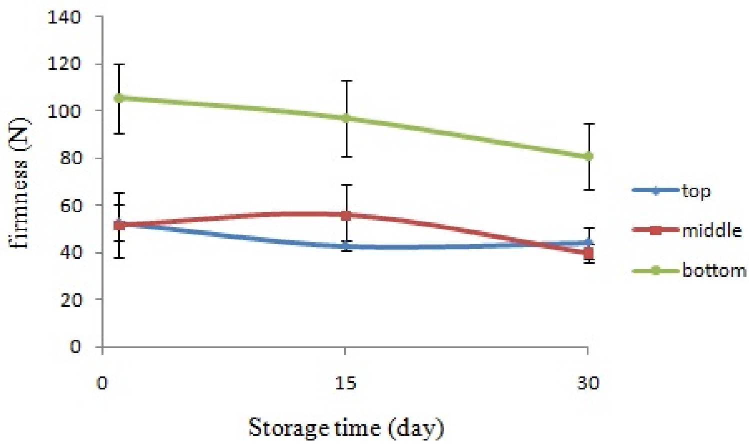

Figure 4 - Change in firmness of Malas variety at different positions of the fruit with storage time. Vertical lines represent the standard deviations.

Fig. 3 shows a decrease in firmness of pomegranate (Hondos) bottom but the middle and top of fruit had stationary firmness. Change in firmness of Malas variety is partly similar to homdos variety (*Fig. 4*). Decrease in firmness of various fruits has also been reported by previous workers. Judith and Tianxia (2002) observed the firmness of tomatoes to be decreasing from 15 to 2 N at different maturity stages. Nnadozie et al. (2007) reported the apple fruit softening during cold air storage. Qin et al. (2006) reported flesh firmness decreasing dramatically at 6 days after harvest. Hosakote et al. (2006) reported ripening of mango being accompanied by a series of biochemical changes resulting in gradual textural softening. Also, Jha et al. (2010) observed at top position whereas minimum at bottom at harvest stage for mango fruit. Peel and pulp firmness decreased about 30% and 5%, respectively, with increase in storage period.

Whereas the effect of storage time was insignificant, this factor is deleted, and then the data was arranged again without storage time factor. Result of this new arrangement is presented in *Fig. 5* for Hondos variety and *Fig. 6* for Malas variety.

Mean values of firmness at different position and with different probe are presented in *Table 3*. The bottom firmness of two varieties are nearly equal that measured with 8 mm diameter probe, but 5 mm and 6 mm diameter probe measured the bottom firmness of Hondos variety higher than Malas variety. At middle position, the firmness of Malas variety was greater than Hondos variety that measured with 8mm diameter probe but this is vice versa at 5 mm and 6 mm diameter probe.

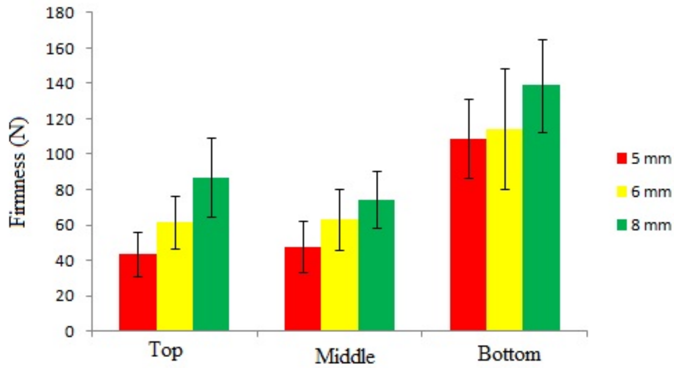

Figure 5 - Change in firmness of Hondos variety at different position. Vertical lines represent the standard deviations.

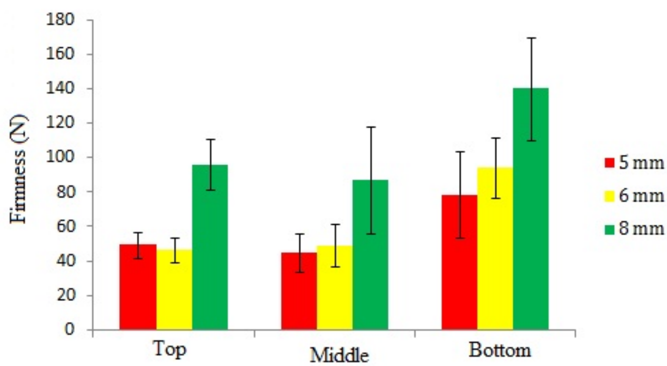

Figure 6 - Variation in firmness at different position of Hondos variety pomegranate. Vertical lines represent the standard deviations.

Rupture energy. The rupture energy of specimens at different position and with different probe was calculated during storage period. *Table 2* shows result of ANOVA of pomegranate rupture energy. It is found from *Table 2* that the rupture energy of two varieties was the same ($P < 0.05$). The effect of treatment repetition was insignificant ($P < 0.05$); this result was attained for firmness too. It means samples of treatment had same mechanical properties. Insignificant effect of Storage time on fruit rupture energy ($P < 0.05$) are given in *Table 2*. Since the structure of pomegranate peel was leathery skin, this result could be attributed to their cellular organization or structure of peel. *Fig. 7* and *Fig. 8* display rupture energy of Hondos and Malas variety respectively that measured at top, middle and bottom of fruit. The top and middle position rupture energy of Hondos variety (*Fig. 7*) measured with 6 mm diameter probe did not vary against storage period, but the top position rupture energy measured with 6 mm diameter probe was decreased when storage time increased. This procedure occurred for Malas variety too. Reason of these results could be change in peel thickness and various structures at various sections of pomegranate varieties.

Table 2 - ANOVA showing effect of fruit variety, storage days, position and diameter on rupture energy of pomegranate and their first order interaction

Source	Sum of squares	DF	Mean square	F-value
Variety (V)	25575.63	1	25575.63	1.825^{ns}
Storage time (S)	43644.51	2	21822.25	1.557^{ns}
Position (P)	7162391	2	3581196	255.644**
Probe diameter (D)	2342143	2	1171072	83.597**
Repetition	33439.16	3	11146.39	0.795^{ns}
VxS	105754.9	2	52877.47	3.774*
VxP	145860.9	2	72930.43	5.206**
VxD	50333.95	2	25166.98	1.796^{ns}
SxP	132960.6	4	33240.15	2.373*
SxD	423522.6	4	105880.7	7.55**
PxD	196866.2	4	49216.55	3.513**
Error	2227352	159	14008.5	
Total	284160.4	215	1321.676	

** Significant at level of 1%;
* Significant at level of 5% and ns, not significant, respectively.

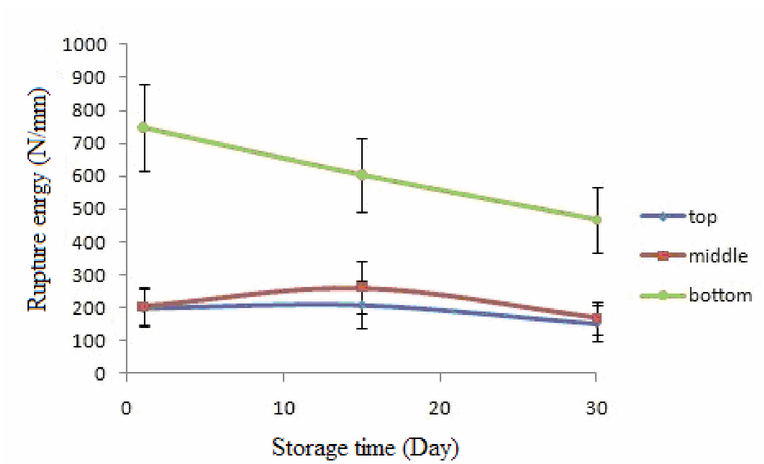

Figure 7 - Variation in rupture energy of Hondos variety at different positions of the fruit with storage time. Vertical lines represent the standard deviations.

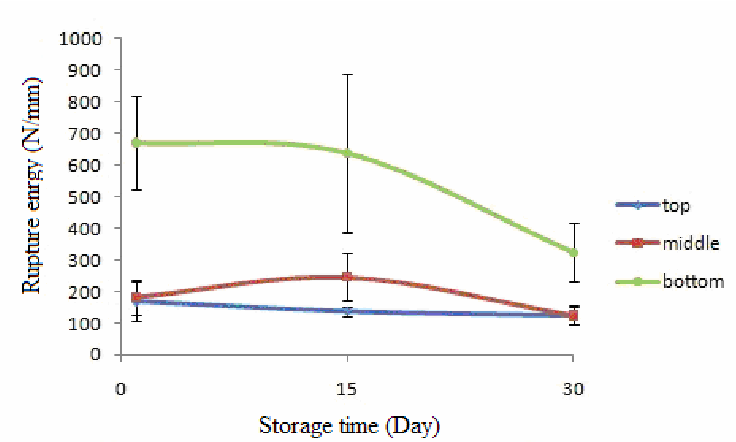

Figure 8 - Change in rupture energy of Malas variety at different positions of the versus storage period. Vertical lines represent the standard deviations.

As it was noted the storage time did not affect the fruit rupture energy. Variation of elastic modulus of Hondos variety and Malas variety are presented in *Fig. 9 and Fig. 10*. It is found from *Fig. 9* the rupture energy of bottom portion was greater than rupture energy of top and middle portion, this true for Malas variety too. Also for two variety difference between rupture energy measured with 5 mm and 6 mm diameter at bottom portion is more vivid than middle and top portion.

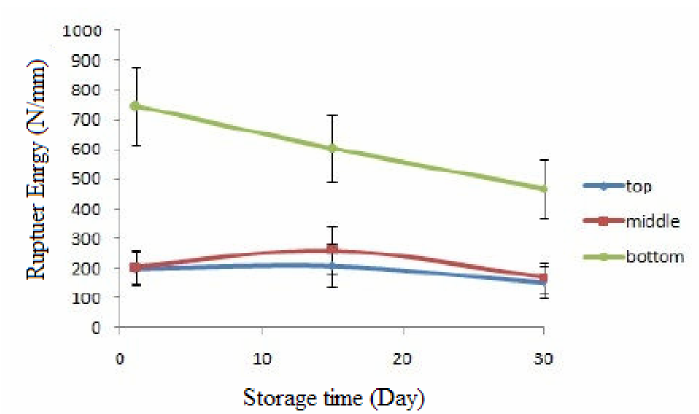

Figure 9 - Rupture energy of different position of Hondos variety. Vertical lines represent the standard deviations.

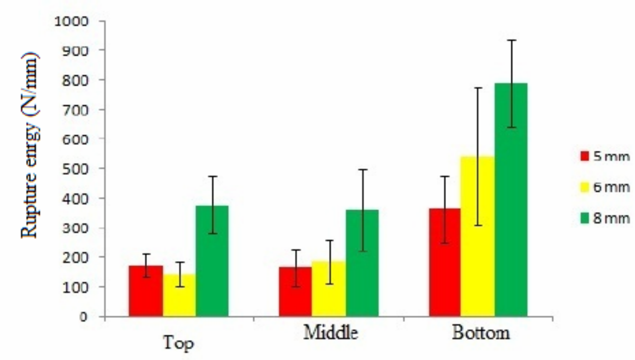

Figure 10 - Rupture energy of Malas variety at different position. Vertical lines represent the standard deviations.

Also, the mean values of rupture energy and firmness for two varieties are reported in *Table 3*. Results showed that in Hondos variety for probe diameters 5, 6 and 8 firmness were 43.50, 61.55 and 86.87 N at top section, respectively. Meanwhile, an overall comparison between top, middle and bottom section of the Hondos variety showed that the mean values of firmness for bottom portion was higher than that for other portions *(Table 3)*. This difference was greater for puncture energy *(Table 3)*. Also, Jha *et al.* (2010) observed in similar research on mango fruit that unlike pomegranate fruit Maximum firmness was observed at top position whereas minimum at bottom at harvest stage.

Table 3 - Mean values of mechanical properties of Hondos variety and Malas variety measured from different positions with different probes.

Variety		Hondos-e-Yalabad		Malase saveh	
Punch location	Probe diameter	Firmness (N)	Rupture energy (J)	Firmness (N)	Rupture energy (J)
Top	5 mm	43.50±12.64*	116.84 ±41.29	49.54±7.55	172.96±40.74
	6 mm	61.55± 14.83	187.08±59.1	46.72±7.24	143.99±42.29
	8 mm	86.87± 22.45	359.32±222.44	96.02±14.7	378.8±99.073
Middle	5 mm	47.64± 14.49	150.52±65.86	44.83±11.18	166.36±62.98
	6 mm	62.81±17.23	211.65±56.06	49.10±12.51	184.41±74.33
	8 mm	74.47± 15.9	293.54±138.64	87.35±31	361.85±134.98
Bottom	5 mm	108.72±22.1	563.39 ±150.06	78.48±25.03	363.74±114.38
	6 mm	114.39±34.0	606.33±255.96	94.46±17.45	544.28 ±230.88
	8 mm	138.88±26.2	813.65 ±255.64	139.97±31.1	790.01±148.37

* Standard deviation

CONCLUSIONS

The mechanical properties of two varieties of pomegranate (Hondos-e-Yalabad and Malas-e-Saveh) were measured in terms of firmness (rupture force) and toughness (rupture energy).

In this study, we found mechanical properties of pomegranate bottom portion were the greatest value. Middle and top portion had equal mechanical properties. The mechanical properties of two varieties were the same approximately.

Storage period did not have a significant effect on mechanical properties ($P > 0.05$). So this fruit can be stored after harvesting without any variation of its mechanical properties. This is profitable for transportation and export.

Also to design post harvesting machines the effect of storage time and can be neglected. Results shown mechanical properties of all samples (repetition) nearly were the same for Hondos and Malas variety ($P > 0.05$).

Also, in this study we found that peel coating of fruit is biggest impediment for detect of maturity.

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