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EFFECT OF SHORT-TERM STORAGE TEMPERATURE ON MECHANICAL PROPERTIES OF 'ISTANBUL' MEDLAR

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Abstract: The study investigated the effect of short-term storage time on the mechanical (rupture force, rupture energy, deformation) properties of the 'Istanbul' medlar cultivar grafted on Quince A (QA) and Quince Province BA29 (BA29) quince clone rootstock. The study gives the average values of the physical properties (weight, size, geometric mean diameter, sphericity, surface area, true density, bulk density, and porosity) of the 'Istanbul' medlar cultivar. The changes in breaking force, breaking energy, and deformation values of 'Istanbul' medlar varieties stored at room temperature (25±1 °C) and cold storage (4±1 °C) for 5 days were investigated. Separate measurements were made for skin and skinless fruits. The average rupture force value of fruits of the 'Istanbul' medlar cultivar stored at 25 °C was determined as 8.82 N, deformation 4.66 mm, and rupture energy 0.035 J. The average rupture force value of the fruits of the 'Istanbul' medlar cultivar stored at 4 °C was determined as 10.06 N, deformation 5.16 mm, and rupture energy 0.043 J. It was found that the storage conditions had a statistically significant effect on the rupture force, rupture energy, and deformation values of the QA and BA29 rootstocks of the 'Istanbul' medlar cultivar (P≤0.001).

Keywords: Medlar, Short-term storage temperature, Mechanical properties, Rupture force, Rupture energy

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1. Introduction

Medlar (*Mespilus germanica* L.) is a perennial plant belonging to the Rosaceae family. Medlar, whose homeland is Europe and West Asia, grows wild in the Marmara and North Anatolian Mountains, Black Sea and Aegean regions in Türkiye (Uzun and Bostan, 2019; Żołnierczyk et al., 2021). It has found a natural habitat with other forest types in the Black Sea region of Türkiye. In the world commonly known as medlar, the names like döngel, töngel and beş bıyık are used in Türkiye (Uzun and Bostan, 2019; Aydın et al., 2020; Diler and Leblebicier, 2020). The cultivars named 'Istanbul' and 'Italian' were registered for the first time in Türkiye. It is rich in nutritional value, highly used for medical purposes, and evaluated as an ornamental plant. All these facts increase the cultivation area of medlar (Gürbüz and Bostan, 2020). The production amount of 5,278 tons was obtained from 259,000 medlar trees in 2022 in Türkiye (TSI, 2023). According to the regions, the highest medlar production in Türkiye is in the provinces of Samsun, Sinop, Trabzon, Düzce, Bartın, Çorum, and Giresun in the Black Sea Region; In the provinces of Afyonkarahisar, Manisa, Aydın, Burdur, Isparta, Kütahya and Uşak in the Aegean Region; It occurs in the provinces of Çanakkale, Bursa and Balıkesir in the Marmara Region (TSI, 2023).

The medlar fruit is very rich in amounts of B2, B1, C, and A vitamins, calcium, potassium, iron, and magnesium minerals. Also, it has phenolic acid, sugar, pectin, and organic acid content (Çakır and Öztürk 2019; Aydın et al., 2020). Medlar fruit is used in making jelly, sauce, and wine; it is consumed in the forms of marmalade, vinegar, pickles, and jelly (Canan et al., 2019; Uzun and Bostan, 2019; Glew et al., 2002). To be eaten as a fresh fruit, it should wait for the fruit flesh to turn brown because the newly harvested medlar fruit is light in color and has a hard texture and a bitter taste. Depending on the ripening period of the fruit, there are changes in its quality content (Ozturk et al., 2019 and Ozturk et al., 2022). The amount of fatty acids in medlar fruit containing twenty different fatty acids can decrease from a maximum of 6,121 ug g^{-1} to 2,583 ug g^{-1} during the ripening process. Unripe (raw) medlar fruit can treat intestinal inflammation, kidney diseases, and constipation (Uzun and Bostan, 2019; Gürbüz and Bostan, 2020; Diler and Leblebicier, 2020). Because of these features, medlar finds its place in markets and markets (Aydın et al., 2020).

The effects of the processes in preserving the post-harvest product quality in fruits are quite high. The use Usingtapplied in post-harvest processes will reduce losses and provide quality products to the consumer (Sessiz and Özdemir, 2007). Experimental data are used to create models that predict agricultural products' quality and product behavior. These data are obtained from the determination of the physical and mechanical properties of the agricultural products. The effects that occur during the harvesting and processing stages of agricultural products can cause a decrease in the quality of horticultural commodities. In this sense, determining the parameters that are caused mechanical damage is important in reducing quality and quantity losses. In addition, in the processing industry, properties such as rupture resistance and hardness are among the parameters that should be known (Gül et al., 2020).

The study aimed to determine the effect of short-term storage time on the mechanical (rupture force, rupture energy, deformation) properties of the 'Istanbul' medlar cultivar, which is grafted on the QA and BA29 quince clonal rootstocks.

2. Materials and Methods

2.1. Plant Materials

In the study, fruits of the 'Istanbul' medlar cultivar, which was grafted on QA and BA29 rootstocks in the year 2018 at the Bafra (Samsun/Türkiye) research station of Ondokuz Mayis University (41° 33' 50'' N; 35° 52' 21'' E; altitude 20 m) were used as plant material. The grafted trees were planted at 3.5 x 3.0 m distances (952 tree ha^{-1}) and were pruned according to the modified leader system. The trees were pruned regularly every year, and irrigation was carried out usually twice a week in June - October, depending on the water requirement of the trees, with pressure compensating drippers at 1.20 m intervals, with two pipes per row on both sides of the trees. Weed control was performed regularly with a rotavator many times each year.

2.2. Climate and Soil Characteristics of the Research Area

The research orchard which fruits were provided from generally has a hot and humid climate in summer and a cool environment in winter. Most of the precipitation occurs in late autumn and early winter. According to the climate data of the Bafra district (Samsun), during the period which was done, the highest temperature was 35.1 °C, the lowest temperature was -4.5 °C, and the average annual temperature was observed at 14.1 °C. The soil of the research area has 2.73 - 10% clay, 13.21 - 20% silt, 6.5 - 20% sand, pH 7.5, 0.2 - 0.3 dS m^{-1} salt, 0.3 - 0.5 organic matter, 3 - 6% lime, 0.03 - 0.06 N, 5 - 10 ppm P level, and soil depth is more than 1 m.

2.3. Methods

Medlar fruits were harvested before they were fully ripe (physiological maturity = ready to harvest but not ready to eat) since they are used in different industrial areas other than fresh consumption. After harvesting, the fruits were immediately placed in the boxes and carried to the laboratory for preservation. The fruits were divided into two parts half was kept at ambient temperature (25±1 °C), and half of the fruits were stored at cold storage (4±1 °C) for 5 days.

2.4. Observations

The dimensions of the medlar fruits were measured with a digital caliper with a precision of 0.01 mm. Geometric mean diameter, sphericity, and surface area were calculated with the given formulas in Equation 1, 2 and 3 (Mohsenin, 1980):

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

D_g : Geometric mean diameter (mm), L: Length (mm), W: Width (mm), and T: Thickness (mm).

$$S = \pi D_g^2 \quad (2)$$

S: Surface area (mm^2)

$$\varphi = \frac{D_g}{L} 100 \quad (3)$$

φ: Sphericity (%).

The fruits' true density values were determined by the liquid displacement method. The measuring cylinder having a volume of 500 ml was used for measurement. Bulk density is the ratio of the medlar mass to its total volume. It was determined by weighing the medlar fruits after filling a cylindrical cardboard box with a height of 150 mm and a volume of 500 ml (Mohsenin, 1980; Mansouri et al., 2017; Lammari et al., 2022).

The given Equation 4 below was used to determine the porosity value of medlar fruits (Mohsenin, 1980):

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (4)$$

P_t: True density (kg m^3), and P_b: Bulk density (kg m^3).

A universal material testing device (Lloyd Instrument LRX Plus, Lloyd Instruments Ltd, An AMATEK Company) was used to determine the rupture force, rupture energy, and deformation, which are the mechanical properties of the medlar. 100N load on the moving part of the device cell installed. The software program (NEXYGEN Plus) processed the obtained data. A force-deformation curve with a sudden decrease in the force value was obtained in the measurements. In the force-deformation curve obtained, the horizontal axis shows the deformation, and the vertical axis shows the force. The penetrating tip used in the trials has a diameter of 8 mm. The measurement values were obtained from the skin and skinless conditions of the medlar fruit. The fruit's skin was gently peeled off with a utility knife (Cevher and Öztekin, 2019).

2.5. Statistical Analysis

(Univariate) ANOVA test was performed to find the effect of short-term storage temperature on the mechanical properties of the 'Istanbul' medlar cultivar.

3. Results and Discussion

After harvesting the QA and BA29 rootstocks of the 'Istanbul' medlar cultivar used in the study, physical properties were determined to provide information about the product. The mean and standard deviation values of the physical characteristics of 'Istanbul' medlar cultivars are given in Table 1. Weight, length, width, thickness, geometric mean diameter, arithmetic values, mean diameter, sphericity, surface area, bulk density, true density, and porosity values are shown in the Table 1.

The largest and smallest values of the 'Istanbul' medlar on the QA rootstock were found to be 46.20 g – 30.23 g for weight, respectively; 49.95 mm – 42.82 mm for length; 44.33 mm – 38.61 mm for width; 45.03 mm - 38.32 for thickness; 45.51 mm-39.87 mm for geometric mean diameter; 45.55 mm – 39.92 mm for arithmetic mean diameter; 99.53% - 88.75% of sphericity; for surface area 6508.15 mm^2 – 4993.43 mm^2 ; bulk for density 390.40 kg m^3 – 380.60 kg m^3 ; true for density 1098.02 kg m^3 – 1046.94 kg m^3 ; It was determined as 64.72% - 63.29% for porosity.

The largest and smallest values of the 'Istanbul' medlar on the BA29 rootstock were acquired 38.41 g – 25.69 g for weight, respectively; 35.97 mm – 34.38 mm for length; 30.87 mm – 29.73 mm for width; for thickness 22.70 mm - 20.04 mm; for geometric mean diameter 28.95 mm - 27.55 mm; 29.41 mm – 28.29 mm for arithmetic mean diameter; for sphericity 83.96% - 78.51%; for surface area 2634.27 mm^2 – 2384.15 mm^2 ; bulk for density 397.20 kg m^3 – 393.6 0 kg m^3 ; true for density 1314.36 kg m^3 – 1101.56 kg m^3 ; 70.03% - 64.12% for porosity.

In addition, the study determined that the average physical properties values of the 'Istanbul' medlar on the QA rootstock were higher than the 'Istanbul' medlar on the BA29 rootstock.

Mechanical properties of medlar fruits of the 'Istanbul' cultivar on the QA and BA29 rootstocks were measured by considering the fruit peel and storage temperature conditions. The average values of the mechanical properties of the medlar fruit are given in Table 2. The statistical significance level of the effect of rootstocks and processes and interactions on the rupture force, rupture energy and deformation is shown in Table 2.

Significant factors and their interactions (for levels ≤0.01 and ≤0.05) are shown in bold in the table. According to the results of the analysis, the effects of rootstock (R), storage condition (S), processing (P), and rootstock x treatment (R x P) interaction on rupture force, rupture energy, and deformation were found to be statistically significant. In addition, the effect of storage condition (S) x process (S x P) interaction on shear force and rootstock x storage condition (R x S) interaction on deformation is statistically significant.

According to the measurement results of 'Istanbul' medlar on the BA29 rootstock stored in a 25°C warehouse environment and made with shell, the largest and smallest values for rupture force were obtained 16.38 N -14.88 N; 6.85 mm – 5.36 mm for deformation; it was observed between 0.062 J – 0.055 J for rupture energy. Under the same conditions, the highest and lowest values of 'Istanbul' medlar on the BA29 rootstock without skin were recorded 3.22 N-2.32 N for rupture force, respectively; 4.02 mm – 3.06 mm for deformation; it was measured as 0.016 J – 0.013 J for rupture energy.

The largest and smallest measurement values of the 'Istanbul' medlar on the QA rootstock, which is stored at 25°C with skin, were obtained 15.01 N - 13.55 N for rupture force, respectively; for 5.66 mm – 4.62 mm deformation; the rupture energy was found to be 0.059 J – 0.033 J. For the same condition, the largest and smallest values of the skinless fruits were recorded at 3.04 N -2.01 N for rupture force; 4.33 mm – 3.46 mm for deformation; it was found in the range of 0.022 J – 0.018 J for rupture energy.

As a result of the experiments, the rupture force value measured with the skin of the medlar fruit was determined as 21.32 N and the smallest 13.55 N. The skinless measurement values were the largest, 4.48 N, and the smallest, 2.02 N.

Table 1. Physical properties of the 'Istanbul' cultivar of medlar on the QA and BA29 rootstocks

Physical Properties	Rootstocks	
	QA	BA29
Weight (g)	38.21 ± 4.72	33.74 ± 4.61
Length (mm)	46.03 ± 2.42	34.96 ± 0.53
Width (mm)	41.56 ± 1.92	30.25 ± 0.16
Thickness (mm)	41.09 ± 2.21	21.51 ± 0.93
Geometric Mean Diameter (mm)	42.82 ± 1.74	28.33 ± 0.48
Arithmetic Mean Diameter (mm)	42.89 ± 1.75	28.91 ± 0.40
Sphericity (%)	93.12 ± 0.04	81.05 ± 0.02
Surface Area (mm^2)	5767.94 ± 466.90	2522.06 ± 84.49
Bulk Density (kg m^3)	383.68 ± 3.85	395.38 ± 1.32
True Density (kg m^3)	1068.88 ± 14.21	1171.26 ± 68.80
Porosity (%)	64.10 ± 0.04	66.14 ± 0.06

Table 2. Mechanical properties of the 'Istanbul' medlar cultivar on the QA and BA29 rootstocks

Rootstocks	Storage Conditions	Processing	Rupture Force (N)	Deformation (mm)	Rupture Energy (J)
BA29	25°C	With Skin	15.67 ±0.53	6.06 ±0.50	0.060 ±0.002
		Without Skin	2.73 ±0.33	3.51 ±0.38	0.014 ±0.001
	4°C	With Skin	17.80 ±2.45	6.37 ±1.85	0.068 ±0.006
		Without Skin	3.53 ±0.84	4.55 ±0.57	0.030 ±0.009
QA	25°C	With Skin	14.42 ±0.56	5.11 ±0.29	0.047 ±0.007
		Without Skin	2.48 ±0.40	3.95 ±0.35	0.020 ±0.001
	4°C	With Skin	15.84 ±0.82	5.48 ±0.45	0.052 ±0.004
		Without Skin	3.07 ±0.60	4.24 ±0.55	0.024 ±0.002
Main Effects					
BA29			9.93 ±7.05^{a}	5.12 ±1.53^{b}	0.047 ±0.007^{b}
QA			8.95 ±6.31^{b}	4.69 ±0.75^{a}	0.036 ±0.15^{a}
	25°C		8.83 ±6.33^{b}	4.66 ±1.08 ^{a}	0.035 ±0.02 ^{a}
	4°C		10.06 ±7.01^{a}	5.16 ±1.30 ^{b}	0.043 ±0.02 ^{b}
		With Skin	15.93 ±1.78^{a}	5.76 ±1.08^{b}	0.053 ±0.01^{b}
		Without Skin	2.95 ±0.69^{b}	4.06 ±0.60 ^{a}	0.021 ±0.01^{a}
P-values					
Rootstock (R)			0.000	0.000	0.016
Storage condition (S)			0.000	0.000	0.040
Processing (P)			0.000	0.000	0.000
R x S			0.327	0.000	0.328
R x P			0.000	0.000	0.005
S x P			0.023	0.410	0.357
R x S x P			0.585	0.150	0.250

* the difference between the averages shown with different letters in the same column is statistically significant..

In the same case, the maximum deformation value was acquired at 9.44 mm, and the smallest was 3.28 mm. Skinless measurement values were the largest at 5.33 mm and the smallest at 3.06 mm.

A similar situation was the largest 0.06 J and the smallest 0.03 J in measurement values for rupture energy as skin. Skinless measurement results were determined as 0.04 J at the largest and 0.01 J at the smallest.

Regarding storage conditions, the rupture force value was measured at 25°C, the largest at 16.38 N and the smallest at 2.02 N. While at cold storage conditions (4°C), the maximum rupture force was recorded at 21.32 N and the minimum at 2.10 N. Rupture energy at 4°C was 0.08 J maximum and 0.02 J minimum. The deformation at 25°C was observed at the largest at 6.85 mm and the smallest at 3.06 mm when the storage condition was 4°C; the maximum deformation was measured as 9.44 mm and the smallest at 3.21 mm.

The study determined the mechanical properties of with and without skin medlar fruit. It was observed that the rupture force, rupture energy, and deformation values of medlar fruits on all the rootstocks stored at 25°C after harvest were lower than those stored at 4°C. This is because the texture of fruits is more softened at 25°C. Singh and Reddy (2006) investigated the physical-mechanical properties of orange fruit in ambient and refrigeration storage conditions. According to the results of the study, it was determined that the puncture force value of orange fruits under ambient conditions was lower than the fruits stored in the refrigerator. Similarly, it has been reported that the cutting energy values of fruits stored in ambient conditions are lower than those held in refrigeration conditions. This situation is compatible with the study.

This study investigated the effect of short-term storage temperature on the mechanical properties of 'Istanbul' medlar fruit grown in Türkiye. The obtained physical and mechanical properties data can contribute to information about the 'Istanbul' medlar fruit. The study determined parameters that can be used in the post-harvest design process of the 'Istanbul' medlar fruit and in the product processing industry. The information obtained may help maintain the product quality of the 'Istanbul' medlar fruit and prevent mechanical losses.

4. Conclusion

The effects of short-term storage temperature on the mechanical properties of the fruits of the 'Istanbul' medlar cultivar were investigated. The results obtained are summarized below.

1. Storage conditions had a statistically significant effect on the rupture force, rupture energy, and deformation values of QA and BA29 rootstocks of the 'Istanbul' medlar cultivar (P≤0.001).
2. The effect of being with or without skin on the mechanical properties of fruits is statistically significant (P≤0.001)
3. The effect of rootstock, storage condition, and processing interaction on mechanical properties is statistically significant (P≤0.001).

4. Average rupture force value of fruits of the 'Istanbul' medlar cultivar stored at 25 °C was determined as 8.82 N, deformation 4.66 mm, and rupture energy 0.035 J.
5. The average rupture force value of the fruits of the 'Istanbul' medlar cultivar stored at 4 °C was determined as 10.06 N, deformation 5.16 mm, and rupture energy 0.043 J

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	E.Y.C.	A.Ö.
C	50	50
D	100	
S		100
DCP	50	50
DAI	50	50
L	30	70
W	80	20
CR	20	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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