The physical, chemical and mechanical properties of medlar (*Mespilus germanica* L.) during physiological maturity and ripening period

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Abstract: In this study, the physical, mechanical and chemical properties of medlar during physiological maturity and ripening period were determined. The physical properties such as geometric mean diameter, sphericity, bulk and true densities, porosity, projected area and colour characteristics were measured during physiological maturity and ripening period of medlar. Mechanical properties such as rupture force, deformation and rupture energy and chemical properties (total soluble solid content, titratable acidity and pH) of medlar fruit were determined. The geometric mean diameter, sphericity, surface area and fruit density of medlar decreased, while, bulk density increased at ripening period. The fruit density of medlars increases of 10.9% occurred while bulk density and surface area decrease of 19.7% and 23.81% observed from physiological maturity to ripening period of medlar fruit, respectively. The static coefficients of friction of medlar fruit during physiological maturity and ripening period were higher for rubber than the other surfaces. The total soluble solid content and total acidity of medlar fruit decreased at ripening period.

Keywords: Medlar (Mespilus germanica), physiological maturity and ripening period, physical, mechanical and chemical properties

Muşmula (*Mespilus germanica* L.) meyvesinin hasat ve yeme olumu dönemlerindeki fiziksel, mekanik ve kimyasal özellikleri

Özet: Bu çalışmada, muşmula meyvesinin hasat ve yeme olumu dönemindeki fiziksel, mekanik ve kimyasal özellikleri belirlenmiştir. Fiziksel özellikler olarak geometrik ortalama çap, küresellik, yığın ve gerçek hacim ağırlığı, porozite, projeksiyon alanı ve renk özellikleri hasat ve yeme olumu döneminde ölçülmüştür. Mekanik özellikler olarak kopma kuvveti, deformasyon ve kopma enerjisi belirlenmiştir. Muşmula meyvesinin kimyasal özellikleri olarak toplam suda çözünebilir kuru madde, titre edilebilir asitlik ve pH değerleri belirlenmiştir. Geometrik ortalama çap, küresellik ve meyve hacim ağırlığı yeme olumunda azalırken, yığın hacim ağırlığı ise artış göstermiştir. Muşmulanın meyve hacim ağırlığı hasat olumundan yeme olumuna kadar %10,9 oranında azalırken, yığın hacim ağırlığı ve yüzey alanı ise sırasıyla %19,7 ile % 23,81 oranında azalmıştır. Muşmula meyvesinin hasat ve yeme olumunda statik sürtünme katsayısı değerleri lastik yüzeyde diğer yüzeylere göre daha yüksek bulunmuştur. Muşmula meyvesinin toplam suda çözünebilir kuru madde ve toplam asitlik değeri yeme olumunda ise azalma göstermiştir.

Anahtar kelimeler: Muşmula (*Mespilus germanica* L.), hasat ve yeme olumu, fiziksel, mekanik ve kimyasal özellikleri

1. Introduction

Medlar is the fruit of Mespilus germanica L. in the family of Rosaceae (Milovan et al. 2013). Medlar is a large shrub or small tree and it grows in poor soils. It has been cultivated for 3000 years and it is indigenous to southwest Asia and South-eastern Europe, mostly the Black Sea coasts of Turkey. (Baird and Thieret, 1989; Glew et al., 2003a).

Medlar fruit contains sugar, organic acid, amino acids and tannins. As the principal sugars, fructose, glucose and sucrose were identified and their levels varied remarkably during development of medlar fruits. The medlar fruits are firmness at harvest. Later, they become soft and edible and for several months, they can be kept in a cold storage. The flavour of medlar fruit resembles that of dried apples or quinces (Dirr, 1990; Glew et al., 2003a, 2003b).

The collection of medlar fruits at the physiological and ripening stage and their storage in straw until over-ripening is known traditions (Glew et al., 2003a, 2003b). In general, ripening occurs late in medlars. The fruit of medlars are used as nutrition material and marmalade by the local customer people. The medlar fruit has been of recent interest for its edible fruits and also used as treatment of constipation, to rid the kidney and bladder of stones (Baird and Thieret, 1989; Glew et al., 2003a).

To design of equipment used in plantation, harvesting, transportation, processing and storing of biological materials, there is need to know the physical, mechanical and chemical properties of them. The physical, mechanical and chemical properties of medlar fruits are to be known for design and improve of relevant machines and facilities for harvesting, handling, processing and also storing. To designing of harvesting, separating, sizing, storage and packaged machines, the size and shape and mechanical behaviours of medlar fruits are important. It is also necessary, the coefficient of friction of the medlar fruits against the various surfaces for the designing of conveying, transporting and storing structures. Bulk density and porosity of medlar fruits has an important effect to the designing of storage and transporting structures. The maturity level, sugar, colours, size, soluble solid content, mechanical defect and firmness are considered in medlar marketing.

Several researchers have investigated the physical and chemical properties of medlar fruits (Dincer et al. 2002; Haciseferogulları et al. 2005; Ayaz et al. 2008; Rop et al. 2011; Gulcin et al. 2011; Gruz et al. 2011). No detailed study concerning physical, a mechanical and chemical property during physiological maturity and ripening period of medlar was studied comparatively. Therefore, in this study, beside the determination of physical properties, mechanical properties and chemical properties during physiological maturity and ripening period of medlar fruit have been investigated.

2. Materials and Methods

This research was carried out during physiological maturity and ripening period of medlar fruits. The medlars were harvested manually from Tokat-Niksar city in Mid-Black Sea Transition Climate Belt region during the harvest season on 15 November 2012. Fruits were randomly collected from 9 trees and they were cultivated at 650 m above sea level. Medlar were grafted to the quince trees and harvested medlar fruits were transferred to the laboratory in polyethylene bags to reduce water loss during transport. To determine the medlar size, one hundred medlar fruits were randomly selected and the fruits were cleaned to remove all foreign matters and immature and damaged fruits. To ripening period, the medlar fruits were packed in a hermetic glass vessel and kept in cold storage (-18°C) until use (Haciseferogulları et al. 2005). Then, they were transported to the laboratory.

The length and diameter of medlar fruits were measured using a digital-micrometer (0.01 mm accuracy), and the medlar fruit masses were measured using a digital electronic balance (0.01 g resolution). The geometric mean diameter (D_g), sphericity (Φ), volume, fruit and bulk densities of a fruit of medlar were determined methods presented by Mohsenin (1970); Altuntas et al. (2008). The initial moisture content of medlar fruits was determined by using a standard method (Brusewitz, 1975). The projected area was measured by a digital planimeter (Placom Roller-Type, KP90N). The projected area measurements, along X-, and Y- axes, were determined according to the method of Razavi and Parvar (2007).

The colour of medlar fruits in terms of *L**, *a**, *b** values was determined using a Minolta colorimeter (CR-3000 Model). *L** denotes the lightness or darkness of fruit; *a** is green or red colour of fruit; and *b** is blue or yellow colour of the medlar fruit samples. The colours were measured at three points of each medlar fruit sample and measurements were computed as the means of three replication values. Colour measurements were conducted on skin and flesh surface along longitudinal axis (Jha et al., 2005).

The coefficient of friction of medlar fruit is defined as tangent value of the angle of slope between sliding surface and vertical and horizontal planes (Celik et al., 2007). The experiment was conducted using laminate, rubber, chipboard and galvanized steel friction surfaces.

To rupture force and deformation measurements, a biological material test device, Universal Material Testing Machines (Zwick/Roell, BDO-FB 0.5 TS; Ulm, Germany), was used. Universal Material Testing Machine has three main component, which are moving platform, a driving unit and a data acquisition, load cell, PC card and software, system (Altuntas and Yildiz, 2007). The medlar fruit was placed on the moving platform considering along longitudinal axis (X-axis) at the 1.06 mm/s puncture speed and punctured with a needle and cylindrical probes fixed on the load cell until the medlar fruit ruptured (Figure 1). These speed is relevant to study by Haciseferogulları et al.

(2005). The puncture mechanical measurements of skin and flesh medlar fruits was measured using by a 7.9 mm and 1.2 mm diameters stainless steel probes, respectively. Force–deformation curves of medlar fruit were recorded. The mechanical behaviour of medlar fruit were expressed in terms of rupture force, deformation, and rupture energy required for initial rupture. Three replications were made each test and 15 samples in each test were used. Rupture energy of medlar fruits at the moment of rupture was determined directly from the chart by measuring the area under the force–deformation curve using a digital planimeter (Braga et al. 1999; Güner et al. 2003).

The chemical properties such as pH of medlar fruit was determined according to the methods presented by the Association of Official Analytical Chemists (1984). The total soluble solid content of medlar fruit samples was determined by a digital refractometer (Kyoto Company, Kyoto, Japan). Titratable acidity of medlar fruits was measured by titration with 0.1 N NaOH.

3. Results and Discussion

The physical properties of medlar fruits during physiological maturity and ripening period are given in Table 1. Moisture content of medlar fruits for physiological maturity and ripening period were found to be 71.80%±4.16 and 66.32%±1.93 (dry basis), respectively. The geometric mean diameter and unit mass of medlars ranged between 27.4 to 32.2 mm and 18.6 to 21.7 g during physiological maturity, respectively, while, the geometric mean diameter and unit mass changed between 24.4 to 27.8 mm and 14.2 to 17.4 g for ripening period, respectively.

The geometric mean diameter and fruit mass of medlar fruits decreases of 12.8% and 23.4% occurred at ripening period, respectively. The sphericity, surface area and volume ranged between 0.97 to 0.95; 29.69 to 22.62 mm^2 and 15.3 to 10.3 cm^3 from physiological maturity to ripening period of medlar fruits, respectively (Table 1). The geometric mean diameter, fruit mass, volume and sphericity of medlar was reported as 28.9 mm, 12.0 g, 13.7 cm^3 and 0.90 at 72.2% (d.b) by Haciseferogullari et al (2005) for ripening period. The geometric mean diameter and sphericity values of medlar fruits were found low and in accord with literature values. The fruit mass and volume values were found higher than that of Haciseferogullari et al (2005). Owolarafe et al. (2007) reported that, the size of fresh palm (cv. Dura) such as fruit length and width were found to be 30.25 mm and 19.94 mm and 15.66 mm, respectively.

The fruit density of medlars increases of 10.9% occurred while bulk density decreases of 19.7% observed from physiological maturity to ripening period of medlar fruit, respectively (Table 1). The projected area of medlar fruits decreases of 1.8% occurred at ripening period, respectively. The porosity and volume values of medlar fruits ranged from 75.4 to 67.0% (11.1% decrease) and 15.3 to 10.3 cm^3 (32.7% decrease) from physiological maturity to ripening period, respectively. The measured values of projected area along X- and Y-axes for medlar fruits ranged from 7.2 to 7.02 cm^2 (1.8% decrease) and 6.87 to 6.14 cm^2 (32.1% decrease) from physiological maturity to ripening period, respectively. Haciseferogullari et al (2005) reported as the fruit density of 1031.1 kg m^{-3}, bulk density of 379.9 kg m^{-3}, porosity of 63.1% and projected area of 9.3 cm^2 for at ripening period medlar fruits. The fruit density, porosity and bulk density values of medlar fruits were found lower than that of Haciseferogulları et al (2005).

Razavi and Parvar (2007) reported that the average the geometric mean diameter, sphericity, the surface area, bulk and fruit densities and porosity of 54.1 mm, 79.8%, 91.97 cm^2, 563.2 kg m^{-3}, 996 kg m^{-3} and 43.4%, respectively. The projected area along X- and Y- axes of the kiwifruit has been reported as 4.11 and 3.24 mm^2, respectively (Celik et al., 2007).

The $L*$, $a*$ and $b*$ values of skin medlar fruits were between 37.3 to 47.6; 5.0 to 11.7 and 19.5 to 26.0 at physiological maturity, while, $L*$, $a*$ and $b*$ values of flesh medlar fruits were between 66.3 to 75.2; 2.5 to 4.2 and 20.5 to 24.2 at ripening period, respectively (Table 1,2). The $L*$ and $b*$ values of skin colour of medlar fruit decrease of 25.7% and 53.7% and flesh colour of medlar fruit decrease of 65.7% and 50.6% observed from physiological maturity to ripening period, respectively (Table 1).

The skin colour of kiwifruit was found as $L*$, $a*$ and $b*$ values of 43.94, 5.51 and 24.04 by Celik et al. (2007), while the flesh colour for kiwifruits as $L*$ of 56.41, $a*$ of -17.47 and $b*$ of 32.35 reported by Costa et al. (2006).

The mechanical characteristics of medlar fruits during physiological maturity and ripening period are presented in Table 2. Rupture force and rupture energy of medlar fruits punctured using with cylindrical probe along X- axis ranged from 82.3 to 8.1 N (90.2% decrease) and 593.6 to 74.0 N mm (87.5% decrease) from physiological maturity to ripening period, respectively. Rupture force and rupture energy of medlar fruits punctured using with needle probe ranged from 17.4 to 1.20 N (93.1% decrease) and 127.9 to 12.6 N mm (90.1% decrease) from physiological maturity to ripening period, respectively. Deformation values of medlar fruits increased from 14.4 to 18.3 mm (with cylindrical probe) and from 15.6 to 20.1 mm (with needle probe), from physiological maturity to ripening period respectively. This was a result of the higher rate of fruit maturity and decrease firmness of medlar fruits.

Celik et al., (2007) reported that the skin and flesh firmness of kiwifruit were 95.05 and 78.28 N at physiological maturity of fruit, respectively. Kabas and Ozmerzi (2008) reported that the rupture energy were 74.32, 85.28 and 71.67 N mm for 'Zucchero F1', 'Mosaica F1' and '1018 F1' for cherry tomatoes, respectively. Kilickan and Guner (2008) reported that the rupture energy were 0.32 N m and 0.26 N m for the olive fruit along X- and Y-axes, respectively.

The static coefficients of friction of medlar fruits during physiological maturity and ripening period were higher for rubber than the other friction surfaces. The static coefficients of friction linearly increased at ripening period of medlar fruits for all (laminate, galvanized steel, chipboard and rubber) surfaces (Table 2). This is a result of the increasing adhesion between the product and the friction surface of softened fruit at higher maturity according to physiological maturity of medlar fruits (Razavi and Parvar, 2007). Demir and Kalyoncu (2003) reported that the static coefficient of friction were ranged from 0.79 to 0.85 (steel), 0.89 to 0.91 (plywood), 0.93 to 0.96 (rubber), respectively. Owolarafe et al (2007) reported that the coefficient of static friction were as 0.58, 0.53, 0.56 and 0.56, for plywood, aluminium, mild steel sheet and galvanized steel sheet respectively variety of fresh palm fruit (cv. Dura).

The chemical characteristics of medlar fruits fruit during physiological maturity and ripening period are presented in Table 3. The total soluble solid content, titratable acidity and pH of persimmon fruit ranged from 11.5 to 11.6%; 0.12 to 0.12 g 100 g^{-1} and 5.52 to 5.58, respectively. Celik and Ercisli (2008) reported that the average total soluble solids, pH, titratable acidity of persimmon cv. Hachiya fruits were 17.1, 5.40, and 2.06%, respectively. The pH obtained was similar to pH reported in the literature.

The total soluble solid, sugar and titratable acidity contents were similar to the findings of previous reports (Candir *et al.,* 2009; Celik and Ercisli, 2008).

The total soluble solid content and pH of medlar fruit ranged from 17.8 to 15.5%; and 4.01 to 4.70 during physiological maturity and ripening period, respectively. While, pH of medlar fruit increase of 13.1%, the total soluble solid content decrease of 17.2% observed from physiological maturity to ripening period, respectively (Table 3). The titratable acidity of medlar fruit ranged from 0.68 to 0.39 g/100 g during physiological maturity and ripening period, respectively. Haciseferogullari et al (2005) reported that, pH and titratable acidity of medlar fruits were 4.3% and 0.3%, respectively at ripening period. These results are essentially consistent with results of previous studies (Haciseferogullari et al (2005).

4. Conclusion

In this study, the geometric mean diameter, sphericity, surface area, projected area, fruit density and porosity, except for bulk density increased from physiological maturity to ripening period of medlar fruits. L^*, a^* and b^* values of skin colour of medlar decreased whereas a^* value of flesh medlar fruit increased from physiological maturity to ripening period.

Rupture force and rupture energy of medlar fruits punctured using with cylindrical and needle probes along X- axis at physiological maturity are higher than the ripening period. The rubber surface offered the maximum static coefficient of friction followed by chipboard, galvanized steel and laminate.

Medlar fruits collect at the physiological stage and storage in straw until over-ripening. The medlar fruit has been used for edible and marmalade. For medlar marketing, the physiological and ripening maturity level, size, colours, mechanical defect and firmness, soluble solid content and sugar have been considered.

To physical, mechanical and chemical properties of medlar fruits are necessary considerations in the design and effective utilization of the equipment used in the harvesting, separating, sizing, transporting, processing, storing, and packaging treatments. The measured physical, mechanical and chemical properties will serve to design the equipment used in harvest and postharvest treatment and processing of medlar fruit.

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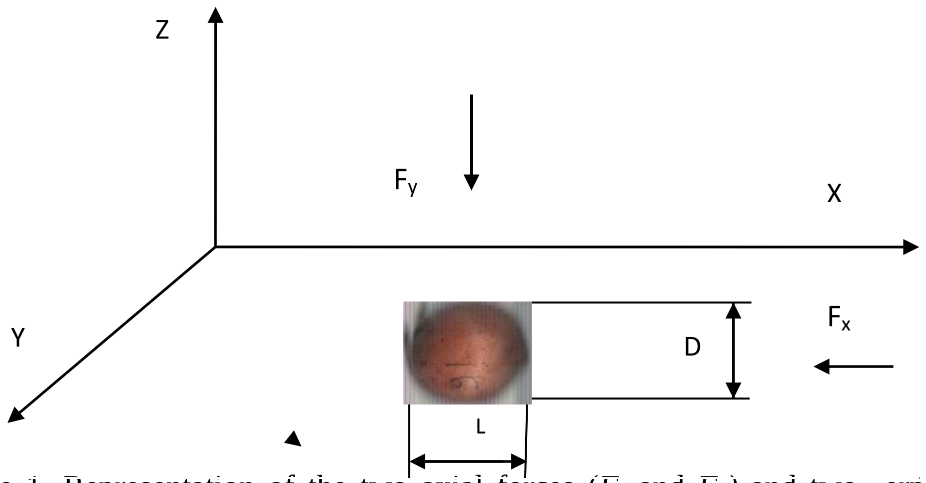

Figure 1. Representation of the two axial forces ($\bar{F}_x$ and $\bar{F}_y$) and two erpendicular dimensions of medlar fruit.

Table 1. Some physical properties of medlar fruits at physiological maturity and ripening period.

	Physiological maturity	Ripening period
Physical properties	Mean±SEM*	Mean±SEM
Length, L (mm)	31.76±0.22	28.30±0.18
Diameter, D (mm)	30.37±0.26	26.34±0.31
Geometric mean diameter, D_g (mm)	30.74±0.10	26.82±0.17
Sphericity, Φ (%)	0.97±0.01	0.95±0.01
Fruit mass, M (g)	20.21±0.13	15.48±0.14
Bulk density, ρ_b (kg m^{-3})	256.89±1.95	307.56±3.93
Fruit density, ρ_f (kg m^{-3})	1048.46±16.44	933.80±8.67
Porosity, ε (%)	75.41±0.46	67.00±0.64
Surface area, S (cm^2)	29.69±0.19	22.62±0.28
Volume (cm^3)	15.32±0.16	10.28±0.18
Projected area		
X (length) (cm^2)	7.15±0.23	7.02±0.28
Y (diameter) (cm^2)	6.87±0.24	6.14±0.16
Colour properties		
Skin		
*L**	44.10±0.94	32.76±0.55
*a**	7.94±0.78	3.26±0.19
*b**	23.33±0.67	10.81±0.52
Flesh		
*L**	71.48±0.97	24.50±1.10
*a**	-8.92±0.39	3.14±0.45
*b**	22.47±0.31	11.10±0.58

SEM*: Standard error of the mean

Table 2. Some mechanical characteristics of medlar fruits at physiological maturity and ripening period.

	Physiological maturity	Ripening period
Mechanical properties Cylinder probe	Mean±SEM*	Mean±SEM
Rupture force (N)	82.3±0.88	8.1±0.48
Deformation (mm)	14.4±0.85	18.3±1.53
Rupture energy (N mm)	593.6±45.6	74.0±6.86
Mechanical properties Puncture needle		
Rupture force (N)	17.38±4.36	1.20±0.23
Deformation (mm)	15.6±1.65	20.1±2.07
Rupture energy (N mm)	127.9±21.3	12.6±3.29
Coefficient of friction		
Laminate	0.357±0.007	0.397±0.007
Galvanized steel	0.452±0.007	0.460±0.031
Chipboard	0.404±0.012	0.547±0.020
Rubber	0.518±0.032	0.692±0.023

SEM*: Standard error of the mean

Table 3. Some chemical properties during physiological maturity and ripening period of medlar fruit.

Chemical properties	Physiological maturity	Ripening period
	Mean±SEM*	Mean±SEM*
pH	4.01±0.035	4.70±0.037
TTSC (%)	17.83±0.754	15.50±0.265
TA (g/100 g)	0.681±0.063	0.385±0.022

SEM*: Standard error of the mean