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Full Length Research Paper

Some chemical and physico-mechanical properties of pear cultivars

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Two pear (*Pyrus communis* L.) cultivars namely Deveci and Santa Maria, which dominate pear production in Turkey, were analyzed for several physico-mechanical (moisture, fruit dimensions, aspect ratio, geometric mean diameter, sphericity, surface area, projected area, fruit mass, fruit volume, fruit density, bulk density, density ratio, porosity, coefficient of static friction, rupture force, deformation, absorbed energy, fruit firmness, toughness, hardness and skin color values) and chemical (protein, fatty acids, ash, pH, acidity, vitamin C, total soluble solids, antioxidant activity, total phenolic content and mineral elements) properties. There is a statistical difference between cultivars in terms of most of the physico-mechanical and chemical properties. The average fruit mass ranged from 190.36 (cv. Santa Maria) to 289.85 g (cv. Deveci). The bulk density, porosity, rupture force and fruit hardness determined as 365.84 - 543.12 kgm^{-3}; 45.67 - 66.57%; 23.04 - 39.59 N and 9.87 - 13.74 N/mm between cultivars.

Key words: Fatty acids, mechanical properties, mineral elements, pear (*Pyrus communis* L.).

INTRODUCTION

The Caucasus Mountains and Asia Minor (Trans-Caucasia, Iran, and Turkmenistan) were reported to be the centers of diversity for cultivated pears. This area is of special importance because it is thought to be the origin of domesticated forms of the European pear, *Pyrus communis* L., which is the main commercial species in Europe, North America, South America, Africa, and Australia. *P. communis* L. is mainly distributed west to southeastern Europe, Turkey and Eurasia (Bell et al., 1996).

In Turkish, the general term for cultivated pear is 'Armut'. The word 'Ahlat' is also used for smaller-size fruited wild grown pears. In Turkey, pears are the second important pome fruit after apple and they are grown in almost all parts of the country. The major edible pear species in Turkey is *P. communis* as well (Ercisli, 2004).

World pear production reached 19.5 million metric tonnes in 2006 (Anon., 2006) ranking second, after apples, among global production of deciduous fruit tree species. China, USA, Argentina, Italy, France, South Africa, Japan, South Korea and Turkey were main pear producer countries in the world and Turkey ranks 7th place in pear production in the world with 318,000 tonnes annual production (Anon, 2006).

The interest to pear in Turkey has been increasing year by year. The main problem is the crop losing during transportation after harvest because of vulnerable nature of pear fruits. Thus, information with regard to some physical, chemical and nutritional properties of pear are to be more important in both machinery and equipment design for harvesting and post-harvest technology such as transporting, sorting, cleaning, sizing, packaging etc. and also in processing it into different food. For example, fruit firmness and skin color is one of the important indicators for both quality and maturity of pears (Kawamura, 2000). Fruit weight and soluble solids can be

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Nomenclature: L- fruit length, mm; **R_d**- density ratio, %; **W**- fruit width, mm; ε- porosity, %; **R_a**-aspect ratio, % μ_s- static coefficient of friction ; D_g-geometric mean diameter, mm; **F_r** rupture force, N; ϕ- sphericity; **D_r**- deformation at rupture, mm; **S**- surface area, cm^2; **E_a**- energy absorbed by fruit until rupture, Nmm; **V**- fruit volume, cm^3; **Q**- hardness, Nmm^{-1}; ρ_f- fruit density, kgm^{-3}; **P**- toughness, mJcm^{-3}; ρ_b- bulk density, kgm^{-3}; α- angle of tilt, deg.

used in order to determine the best time of harvest of pears (Karacali, 1990). The volume and density of pear fruits can also play an important role in numerous technological processes and in the evaluation of product quality. Fruit firmness is also often used for fruit quality assessment; for example selective/multiple picking and post-harvest sorting at the packing house.

Many studies have been reported on the physico-mechanical and chemical properties of different fruit species, such as kiwifruit (Celik et al., 2007) orange (Topuz et al., 2004), sweet cherry (Vursavus et al., 2006) etc. However, to our knowledge, no study concerning physico-mechanic properties of fresh fruits of pears has been performed in the literature. Therefore, the present research aimed to investigate the chemical and physico-mechanical properties of pear fruits and then establishing convenient reference tables by using chemical and physico-mechanical data for pear mechanization and processing.

MATERIALS AND METHODS

Material

Two pear cultivars (Deveci and Santa Maria), which grown in private orchard in Bursa city of Turkey was used for this study. In 2007 harvest season, the fruits were harvested carefully by hand at their commercial maturity stage and transferred to the laboratory in cooled polythene bags to reduce water loss during transport. The fruits were cleaned to remove all foreign matters such as dust, dirt and chaff as well as immature and damaged fruits. The analyses were carried out at a room temperature of 23°C. All tests were carried out at the Biological Material Laboratory in Agricultural Machinery Department and Fruit Science Laboratory in Horticulture Department of Ataturk University, Erzurum, Turkey.

Chemical analysis

All chemical properties of the pear cultivars were investigated on randomly selected fifty fruit samples. The chemical composition of the pears was studied as explained below: ash, protein and pH of the samples were determined according to the methods of AOAC (1984). Ascorbic acid was quantified with the reflectometer set of Merck Company (Merck RQflex). The acidity was measured by titration with 0.1 N NaOH (AOAC, 1984). Total soluble solid contents (TSS) were determined by extracting and mixing two drops of juice from the two cut ends of each fruit into a digital refractometer (Kyoto Company, Japan) at 23°C and the result expressed as Brix. Fatty acids in fruits were determined with a gas chromatography.

In β-carotene-linoleic acid assay, antioxidant capacity of pear fruits is determined by measuring the inhibition of the volatile organic compounds and the conjugated diene hydro peroxides arising from linoleic acid oxidation (Barriere et al., 2001). Total phenolic constituents of pear cultivars were performed employing the literature methods involving Folin- Ciocalteu reagent and gallic acid as standard (Slinkard and Singleton, 1977).

The mineral composition were determined by using Atomic Absorbance Spectrophotometer, except phosphorus which determined by spectrophotometer (AOAC, 1984).

Physico-mechanical properties

The physico-mechanical properties of pears cv. Deveci and Santa Maria were determined by the following methods:

Moisture content (%) of the samples was determined according to the methods of AOAC (1984). Linear dimensions of fruits as length (L) and width (W) were measured by using a digital calliper gauge with a sensitivity of 0.01 mm.

The aspect ratio (R_a) of fruit was calculated by using the following equation (Omobuwajo et al., 1999):

$$R_a = \frac{W}{L} 100 \quad (1)$$

Geometric mean diameter (D_g) and sphericity (ϕ) were calculated by using the following equations (Mohsenin, 1986):

$$D_g = \left(L W^2\right)^{1/3} \quad (2)$$

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

The surface area (S) of the fruit was calculated from the relationship given by Baryeh (2001):

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

Projected area of the pears was determined from pictures taken by a digital camera (Casio Exilim EX-Z60, 6.0 Mpixels), and then comparing the reference area to a sample area, by using the Image Tool for Windows (version 3.00) program.

Fruit mass was measured by using a digital balance with a sensitivity of 0.001 g. Fruit volume and fruit density were determined using the liquid displacement method. Toluene (C_7H_8) was used, rather than water, because water is absorbed by the fruits. A weighed quantity of fruits was immersed into the toluene; the volume of toluene displaced was read from the graduated scale of the cylinder (Mohsenin, 1986).

Bulk density (ρ_b) was determined with a weight per hectoliter tester, which was calibrated in kgcm^{-3} (Deshpande et al., 1993).

Density ratio was ratio of bulk density to fruit density expressed as percentage (Omobuwajo et al., 2000):

$$R_d = \frac{\rho_b}{\rho_f} 100 \quad (5)$$

The porosity (ε) was calculated by the equation given below (Mohsenin, 1986):

$$\varepsilon = \left[1 - \left(\rho_b / \rho_f\right)\right] 10C \quad (6)$$

The coefficients of static friction on three different frictional surfaces, namely steel, plywood, and fibreglass were measured for pear fruits using the inclined plate method. A topless and bottomless cartoon box was filled with a sample of about 7 kg an d was placed on an adjustable inclined plate in contact with the frictional surface. The frictional surface with the sample on its top was raised gradually until the sample just started to slide down and the tilt angle was read from a graduated scale (Dutta et al., 1988).

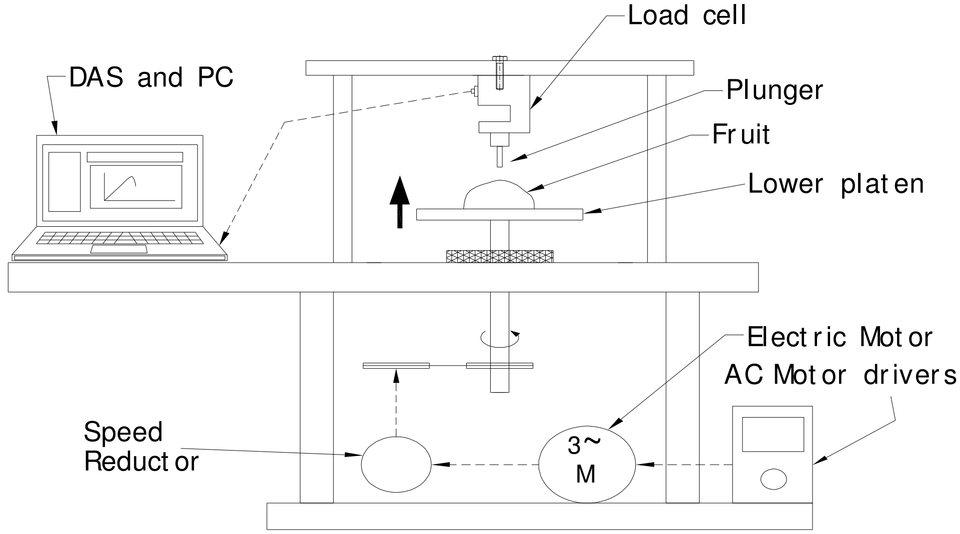

Fıgure 1. Measurement setup for ruptures properties.

The friction tests were replicated five times. The coefficient of static friction was calculated from the following equation:

$$\mu_s = \tan\alpha \tag{7}$$

The rupture properties of the pear fruits were determined by a quasi-static loading device (Turgut et al., 1998). The device consists of three main units (Figure 1). A load cell connected to a stationary cylindrical plunger with 8 mm diameter (Anon, 2005), a platen mounted to a driving unit and a PC equipped with a DAS. A half-one fruit was placed on the platen and the platen moved up with a fixed speed of 27 μms^{-1} compressing the sample until it ruptured. The load cell sensed the force applied to the sample which increased with time and transmitted the data to the DAS. The test was repeated twenty times.

From the fixed loading speed and time the deformation occurred during the loading was determined (Altuntas and Yildiz, 2007). The energy absorbed during the loading up to rupture was calculated from the area under the load-deformation curve using the following equation (Mohsenin, 1986):

$$E_a = 1/2(F_r\, D_r) \tag{8}$$

Toughness (P), the ratio of energy absorbed by the fruit up to the rupture point to the volume of the fruit, was calculated from the following formula (Gupta and Das, 2000):

$$P = E_a/V \tag{9}$$

Hardness (Q) was calculated by dividing the rupture force by the deformation at rupture (Sirisomboon et al., 2007):

$$Q = F_r/D_r \tag{10}$$

Fruit firmness was measured at 23°C using a non-destructive firmness device (Acoustic Firmness Sensor) (Aweta Company, The Netherlands).

Skin color of fruits was measured on the cheek area of 50 fruit with a Minolta Chroma Meter CR-400 having a measuring area of 8 mm in diameter for readings of small samples without cut-off (Minolta-Konica, Japan). Chromameter was calibrated to a standard white reflective plate and used Commission Internationale de l'Eclairage (CIE) illuminant C. *L** (lightness), *a** (green to red) and *b** (blue to yellow) values were measured. Minolta *a** and *b** values were used to compute values for hue angle $H = \left[\tan^{-1}\frac{b}{a}\right]$ chroma $\left(a^2 + b^2\right)^{1/2}$, two parameters that are effective for describing visual color appearance (Bernalte et al., 2003).

Descriptive statistics was carried out on the two pear cultivars, and the difference between the mean values was investigated by using the T tests. Mean values were reported with the standard deviation.

RESULTS AND DISCUSSION

Chemical properties

Total soluble solids, pH, protein, ash, titrable acidity, fatty acids, vitamin C, skin colors and mineral element content of two pear cultivars are shown in Table 1. There was no statistical differences between pear cultivars in terms of all chemical properties except titrable acidity, ascorbic acid, C16:1 palmitoleic acid, C18:3 Linolenic acid, *L*, Hue angle, Ca and Fe values (Table 1). Between cultivars, cv. Deveci had the higher total soluble solids (14.00%), pH (4.28), titrable acidity (0.60%), ash (4.00 g/l) and protein (3.80 g/l), whereas cv. Santa Maria had the higher vitamin C (4.70 mg/100 ml) content (Table 1).

It was previously showed that total soluble solids, titrable acidity, pH, protein, ascorbic acid and ash values of pear fruits which grown in different agro climatic region of Turkey are between 6 - 18%; 0.21 - 0.56%; 3.84 - 4.52;

Table 1. Some chemical and colour properties of pear cultivars.

Chemical properties	Deveci (mean±SD)	Santa Maria (mean±SD)	Significant level
pH	4.28±0.71^a	3.94±0.55^b	*
Titrable acidity (%)	0.60±0.03	0.48±0.04	NS
Total Soluble Solids (%)	14.00±1.72^a	12.50±1.46^b	**
Ascorbic acid (mg/100 ml)	3.30±0.98	4.70±0.86	NS
Ash (g/l)	4.00±0.57^a	2.02±0.23^b	*
Protein (g/l)	3.80±0.19^a	1.20±0.08^b	**
Antioxidant activity, %	14.07±1.9^a	9.97±1.7^b	**
Total phenolic content, mgGAE/kg fresh mass)	393±13.7^b	438±25.3^a	**
Fatty acids (Relative percent)			
Palmitic acid (C16:0)	13.80±2.13^b	19.70±3.94^a	**
Stearic acid (C18:0)	2.24±0.13^b	4.25±0.33^a	*
Palmitoleic acid (C16:1)	0.80±0.06	1.16±0.11	NS
Oleic acid (C18:1)	14.05±2.33^a	9.90±1.59^b	*
Linoleic acid (C18:2)	51.65±7.74^a	42.32±6.98^b	**
Linolenic acid (C18:3)	16.30±2.11	19.40±2.44	NS
Colour properties			
L	74.46±2.47	75.68±2.28	NS
a	-3.40±1.72^a	-7.61±1.95^b	**
b	37.28±3.28^b	44.06±1.92^a	**
Hue (deg)	95.22±2.57^b	99.74±2.30^a	**
Chroma (color intensity)	37.47±3.30^b	44.75±2.09^a	**
Mineral elements (mg/kg)			
P	350±17^b	370±19^a	**
K	1800±133^a	1600±127^b	**
Ca	35±7	28±6	NS
Mg	110±11^a	65±9^b	**
Na	20±2^a	4±1^b	**
Fe	4±1	5±1	NS

*, ** Significant levels at 5 and 1%. NS: Not significants.
a-b Letters indicate the statistical difference within same rows.

0.96 - 4.90 g/l; 3 - 12 mg/100 ml and 1.94 - 4.81 g/l, respectively (Karadeniz and Sen, 1990; Edizer and Gunes, 1997; Guleryuz and Ercisli, 1997). Our findings such as TSS, acidity, pH, protein, ascorbic acid and ash results were close to these studies. The variation of TSS, acidity, pH, protein, ascorbic acid and ash in pear fruits could be result of cultivars and the effect of different environmental conditions where the cultivars grown. Wide variations in physico-chemical properties have been reported among cultivars of different fruit species, such as peach (Moriguchi et al., 1990), apricot (Gurrieri et al., 2001) and strawberry (Ngo et al., 2007).

As shown in Table 1, the apparent color (a, b) and color intensity (chroma) of the pear cultivars was found to be statistically significant at 1% statistical level. The cultivar Santa Maria had the higher *L* (75.68%), *b* (44.06), hue (99.74%) and chroma 215 (44.75%) values than cv. Deveci (Table 1). Fruit skin color is considered to be the most important index of pear quality and maturity. Previously reported that there were strong relationships between maturity and *L*, *a* and *b* values of pear cultivars and *L, a* and *b* values increased with maturation. The *b* values of skin color was also found the most important color parameter to correlate sugar increase in pear fruits (Kawamura, 2000).

Fatty acid analysis has shown that pear cultivars studied contained six fatty acids (palmitic, palmitoleic, stearic, oleic, and linolenic acid) (Table 1). Linoleic acid 18:2 was the dominant fatty acid (42.32 - 51.65%) in both pear cultivars, and followed by linolenic acid 18:3 (16.30 – 19.40%) (Table 1). Chen et al. (2007) previously reported that the C16:0, C18:0, C18:1, C18:2 and C18:3 fatty acids were clearly the most abundant fatty acids in pear fruits and the highest fatty acids found in fruits of

Table 2. Some physico-mechanical properties of pear cultivars.

Properties	Deveci (mean±SD)	Santa Maria (mean±SD)	Significant level
Moisture , %w.b	84.04±1.11[b]	88.56±0.84[a]	**
Fruit length, mm	87.55±4.65[b]	107.27±4.46[a]	**
Fruit width, mm	83.98±3.07[a]	64.25±2.88[b]	**
Aspect ratio (%)	96.25±7.14[a]	60.04±4.37[b]	**
Geometric mean diameter, mm	85.11±2.25[a]	76.18±2.07[b]	**
Sphericity	0.98±0.05[a]	0.71±0.03[b]	**
Surface area, cm^2	227.71±12.09[a]	182.42±9.96[b]	**
Projected area, cm^2	57.13±4.47[a]	50.86±2.69[b]	**
Fruit mass, g	289.85±19.11[a]	190.36±15.49[b]	**
Fruit volume, cm^3	256.00±18.91[a]	189.60±20.55[b]	**
Fruit density, kg/m^3	1094.65±20.61[a]	999.83±11.15[b]	**
Bulk density, kg/cm^3	365.84±27.41[b]	543.12±15.61[a]	**
Density ratio, %	33.43±2.48[b]	54.33±1.78[a]	**
Porosity, %	66.57±2.48[a]	45.67±1.78[b]	**
Coefficient of static friction			
Plywood	0.448±0.03[a]	0.360±0.01[b]	**
Steel	0.484±0.03[a]	0.418±0.02[b]	**
Fibreglass	0.648±0.05	0.621±0.04	NS
Rupture force, N	39.59±9.06[a]	23.04±6.36[b]	**
Deformation, mm	2.96±0.51[a]	2.38±0.59[b]	**
Energy absorbed, Nmm	58.64±17.00[a]	28.65±14.32[b]	**
Fruit hardness, N/mm	13.74±3.65[a]	9.87±2.48[b]	**
Fruit toughness, mJ/cm^3	0.46±0.13[a]	0.30±0.15[b]	**
Fruit firmness, MPa	2.75±1.02[a]	1.70±0.22[b]	**

** Significant levels at 1%. NS: Not significants.
[a-b]Letters indicate the statistical difference within same rows.

eight pear cultivars were linoleic acid (54.10 – 69.00%), palmitic acid (20.00 - 25.00%) and linolenic acid (1.13 - 6.86%), which are in accordance with our results. Linoleic acid is one of the two essential fatty acids that humans require. It is called ‘‘essential’’ because they cannot be produced by the human body.

The antioxidant activity in pear cultivars is shown in Table 1. A statistical significant difference ($p < 0.01$) was found among the samples. All two pear cultivars showed lower antioxidant activity. The antioxidant activity of cv. Deveci (14.07%) was higher than cv. Santa Maria (9.97%). It was previously reported that pear cultivars had low antioxidant activity compared to the other fruits (Karadeniz et al., 2005).

The results for total phenolics clearly showed that fruits of cv. Santa Maria had higher total phenolic content (438 mgGAE/kg fresh mass) than cv. Deveci (393 mgGAE/kg fresh mass) and their wide differences among cultivars (Table 1). Earlier, total phenolic content in pear cultivars was reported which ranged from 326 to 473 mg/kg of fresh mass (Karadeniz et al., 2005). The difference of the pear cultivars in terms of total phenolics is supposed to its genetic derivation because all plants found same age and ecological conditions. It is previously reported that plant genotype (Scalzo et al., 2005) affects total phenolic content in fruits.

The mineral contents of pear cultivars are shown in Table 1. Statistical important differences among the pear cultivars on P, K, Mg and Na content were observed. The P, K, Ca, Mg and Na content of pear cultivars varied from 350 mg/kg (cv. Deveci) to 370 mg/kg (cv. Santa Maria); 1600 mg/kg (cv. Santa Maria) to 1800 mg/g (cv. Deveci); 28 mg/kg (cv. Santa Maria) to 35 mg/kg (cv. Deveci); 65 mg/kg (cv. Santa Maria) to 110 mg/kg (cv. Deveci) and 4 mg/kg (cv. Santa Maria) to 20 mg/kg (cv. Deveci), respectively (Table 1).

It is well known that cultivar, soil characteristics, climate and sample preparation method affects fruit nutrient concentrations in fruit species (Salunkhe and Kadam, 1995).

Physico-mechanical properties

A summary of the result of some determined physico-mechanical parameters of pear cvs. Deveci and Santa Maria are shown in Table 2. There were statistical differences ($p < 0.01$) between pear cultivars in terms of all physico-mechanical properties except for coefficient of static friction (fiberglass) (Table 2). According to the results, moisture content of pear cultivars cvs. Deveci and Santa Maria were 84.04 and 88.56%, while fruit dimensions (length and width) were 87.55 -107.27 mm and 64.25 - 83.98 mm, respectively. On the other hand, average fruit mass and fruit volume determined as 190.36 g (Santa Maria)- 289.85 g (Deveci) and 189.60 (Santa Maria) and 256.00 cm^3 (Deveci) (Table 2).

Some studies previously conducted on pear cultivars revealed that fruit mass, fruit length and fruit width ranged from 50 to 368 g; 61 to 91 mm and 59 to 78 mm, respectively (Karadeniz and Sen, 1990; Guleryuz and Ercisli, 1997; Edizer and Gunes, 1997). Our fruit mass, fruit length and fruit width results were within limits of those studies. The variation of fruit mass, fruit length and fruit width of pear could be due to different cultivars, rootstocks used, environmental conditions and nutritional status of orchards as well.

The average values of the geometric mean diameter was calculated as 85.11 mm for cv. Deveci and 76.18 mm for cv. Santa Maria (Table 2).

Sphericity and aspect ratio of pear cultivar were 0.98 and 96.25% for cv. Deveci and 0.71 and 60.04% for cv. Santa Maria. Sphericity is an expression of a shape of a solid relative to that of a sphere of the same volume while the aspect ratio relates the width to the length of the fruit which is an indicative of its tendency toward being oblong in shape (Omobuwajo et al., 2000).

Fruit and bulk density of pear cv. Deveci and Santa Maria were between 999.83 - 1094.65 kg/m^3 and 365.84 - 543.12 kg/m^3, respectively. The porosity ranged between 45.67 and 66.57% for cv. Santa Maria and Deveci (Table 2).

The highest coefficient of static friction was obtained on fiberglass as 0.621 for cv. Santa Maria and 0.648 for cv. Deveci and followed by steel (0.418 - 0.484) and plywood surface as 0.360 and 0.448, respectively. In comparison with the other fruit specie, the static friction of pears was higher than those kiwifruit (Celik et al., 2007), medlar (Haciseferoglu et al., 2005) and sweet cherry fruits (Vursavus et al., 2006). These physico-mechnical results should be considered in the harvesting, handling and processing of pear.

As a conclusion, besides chemical properties, the physico-mechanical properties of the pear cultivars were described in order to better design a specific machine for harvesting and post harvesting operation. Therefore, the differences between the physical properties of pear cultivars should be considered in optimizing pear mechanization and processing.

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