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SOME COLOR AND PHYSICAL PROPERTIES OF PEPINO (*SOLANUM MURICATUM* AITON) FRUIT

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Abstract

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The aim of this study is to determine some color and physical properties of pepino fruit (*Solanum muricatum* Aiton) which is one of the latest introduced vegetables to Turkey. The demand for pepino is increasing in the country due to its nutritional value, flavor and attractive appearance and medicinal uses. For this purpose, some color and physical properties of pepino fruits grown in Samsun province in Turkey were examined. The average fruit mass and shape factor were 285.74 g and 0.90, respectively. The minimum and maximum fruit length and width ranged between 83.64-120.75 mm and 53.33-89.19 mm. The average aspect ratio was determined as 76.94%. Fruit firmness varied from 14.60 to 26.40 kg cm^{-2} as an average of 17.53 kg cm^{-2}. The mean color intensity (chroma) was 15.79 while hue angle was found to be 76.93. The minimum and maximum values of bulk density, porosity and sphericity were determined as between 374.44-501.09 kg m^{-3}; 48.93-61.90% and 67.82-97.76%, respectively. The results of this study can be used for pepino mechanization and processing.

Key words: Pepino (*Solanum muricatum* Aiton), color, physical properties

Nomenclature: L- fruit length, mm; W- fruit width, mm; %; ε- porosity, %; R_a- aspect ratio, %; μ_s- static coefficient of friction; D_g- geometric mean diameter, mm; Φ- sphericity; S- surface area, cm^2; V- fruit volume, cm^3; ρ_f- fruit density, kgm^{-3}; ρ_b- bulk density, kg m^{-3}; α- angle of tilt, deg.; SF- shape factor; c- chroma; h- Hue angle, deg

Introduction

Pepino, (*Solanum muricatum* Aiton), originated in Andean region and was domesticated in pre-Hispanic times. The cultivation of *Solanum muricatum* originated along the Andes, from Southern Colombia to Bolivia and the Peruvian coast in South America. Later it was introduced to Mexico and Central America (Anderson et al., 1996; Prohens et al., 1999; Ruiz-Bevia et al., 2002).

Commercial crops produced with advanced technology are known in the countries of Chile, New Zealand and the United States (California) because of this fruit's acceptance on North American, European and Japanese markets (Gonzalez et al., 2000). During the 1990s and first years of 2000s, Spain has been a reference of breeding and marketing of pepinos (Rodriguez-Burruezo et al., 2011).

The fruit is eaten raw or cooked. In all cases, the skin is removed as it has a bitter flavour. When ripe, the fruit is eaten raw as a fresh fruit with a melon taste. More frequently, it is eaten as a dessert of fruit in syrup. The completely pedunculated fruit is cooked for a short time in water so that the skin can easily be removed (Huyskens-Keil et al., 2006).

Pepino (*Solanum muricatum* Aiton) is one of the latest introduced vegetables to Turkey. The demand for the solanaceous and Andean pepino, also called pepino dulce or melon pear, is increasing in Turkey due to its nutritional value, flavor and attractive appearance. It is accepted as a medicinal plant in the country as well. The acreage and production of pepino have been increasing in the last years in Turkey (Cavusoglu et al., 2009; Yalcin, 2010). However, there are important crop losses of pepino after harvest in Turkey. Although the postharvest losses in pepino fruits at different rates depending on technical and physiological characteristics of the product, the major part of these losses occur during sorting, packaging, shipping and transportation due to delicate nature and high water content of pepino fruits (Huyskens-Keil et

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al., 2006). This situation adversely affects the growers and consumers, as well as the national economy within the period from the harvest to the marketing of product. This also reveals the need for conducting the studies to develop relevant equipments and machinery taking into account color and physical properties of pepino fruits to overcome these problems. In addition, about preserving and processing fresh pepino, the knowledge on color and physical properties of pepino is needed.

Previously, a number of studies have been carried out on the physical and chemical properties of pepino fruits throughout world (El-Zeftawi et al., 1988; Prohens et al., 1999; Gonzalez et al., 2000; Rodriguez et al., 2004; Yalcin, 2010). However, to our knowledge, no detailed study concerning color and physical properties of pepino fruits has been performed in Turkey in the literature.

Therefore, the present research aimed to investigate the color and physical properties of pepino fruits and then to establish convenient reference tables by using color and physical data for pepino mechanization and processing.

Materials and Methods

Pepino fruits (cv. Miski), grown in a farm located in Samsun province in the Black Sea Region in Turkey, were used as fruit material. Fruits were hand harvested at commercial ripening stages in 2009. Then fruits were also selected according to uniformity in colour, shape and size as well as for lack of injuries and irrelevant odour. Harvested fruits were immediately transferred to the laboratory and placed into cooled polythene bags to reduce water loss during transport. The analyses were carried out at a room temperature of 22°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.

Linear dimensions of fruits as length (L) and width (W) were measured by using a digital caliper gauge with a sensitivity of 0.01 mm. To determine the length and width, a sample of 50 fruits was used.

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

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

Sphericity (Φ) was determined by the following equation (Mohsenin, 1986; Ozturk et al., 2009).

$$\Phi = \frac{D_g}{L} 100 \quad (2)$$

Geometric mean diameter (D_g) was calculated by using the following equations (Mohsenin, 1986):

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

A sample of 20 fruits was used to determine the surface area. 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 pepinos was determined from pictures taken by a digital camera (Casio Exilim EX-Z60, 6.0 Mpixels), and then compared the reference area to a sample area, by using the Image Tool for Windows (version 3.00) program.

A sample of 20 fruits mass was measured by using a digital balance with a sensitivity of 0.001 g. Fruit density and Mohsenin (1986) determined compactness.

Shape factor (SF) was calculated using the values of projected area (PA) and perimeter (P) (SigmaScan®Pro, 2004). SF was automatically calculated by SigmaScan software using the following equation of (5):

$$SF = 4\pi \left(\frac{PA}{P^2}\right) \quad (5)$$

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

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

$$\varepsilon = \left[1 - \left(\frac{\rho_b}{\rho_f}\right)\right] 100 \quad (6)$$

The coefficients of static friction on three different frictional surfaces, namely aluminum, steel and plywood were measured for pepino fruits using the inclined plate method. A bottomless cartoon box was filled with a sample of about 7 kg and 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). The friction tests were replicated five times. The coefficient of static friction was calculated from the following equation (Ozturk et al., 2009):

$$\mu_s = \tan\alpha \quad (7)$$

Fruit firmness was measured at 23°C using a non-destructive firmness device (Acoustic Firmness Sensor) (Aweta Company, The Netherlands). A sample of 50 fruits was used to determine the firmness.

The skin color of fruits was measured on the cheek areas with a Minolta Chroma Meter CR-400 (Minolta-Konica, Japan) based on CIE L*a* b* color space (Celik and Ercisli, 2009). L* represents lightness (100: white, 0: black), a* indicates the difference between red (+a*) and green (-a*), and b* resembles the difference between yellow (+b*) and blue (-b*). Minolta a* and b* values were used to calculate values for hue angle:

$$h^* = \left[\tan^{-1} \frac{b^*}{a^*} \right] \quad (8)$$

and chroma:

$$c^* = \sqrt{(a^*)^2 \quad (b^*)^2} \quad (9)$$

Color tests were repeated thirty times.

The maximum and minimum values of the pepino fruits were determined and the mean values were reported with the standard deviation.

Statistical analysis

Firstly, descriptive statistics for some color and physical properties were determined by using least squares methods. Secondly, Shapiro-Wilk test was used for evaluating the normal distribution of the static coefficient of friction values. Then, One-way ANOVA was performed in a completely randomized design: $\hat{Y}_{ij} = \mu + \alpha_i + e_{ij}$ where $\hat{Y}_{ij}$ is observation value for static coefficient of friction, μ is the overall mean, α_i is the effect of the ith surface (aluminum, plywood, steel) and e_{ij} = residual error. Finally, Tukey multiple range test was utilized to separate these differences. All the computational work was performed by means of MINITAB (Minitab V. 13.20, 2000).

Results and Discussion

Descriptive statistics (mean, STD deviation, min. and max. values) for color and physical properties of pepino fruits are shown in Tables 1 and 2, respectively. Minimum

Table 1
Some color properties of pepino fruits (cv. Miski)

Color properties	Mean	Std. Dev.	Minimum	Maximum
Lightness, L	74.19	4.352	63.43	89.09
Green to red, a	3.50	1.097	1.14	5.79
Blue to yellows, b	15.36	2.745	11.29	23.50
Hue angle, α (deg)	76.93	3.770	71.38	87.22
Chroma (color intensity), c	15.79	2.740	11.52	23.53

Table 2
Some physical properties of pepino fruits (cv. Miski)

Physical properties		Mean	Std. Dev.	Minimum	Maximum
Fruit length, mm		99.04	8.443	83.64	120.75
Fruit width or thickness, mm		75.63	7.028	53.33	89.19
Aspect ratio, %		76.94	9.975	55.85	96.66
Geometric mean diameter, mm		82.59	5.483	64.76	93.75
Sphericity, %		83.81	7.291	67.82	97.76
Surface area, cm^2		215.21	27.955	131.74	276.09
Projected area, cm^2		61.81	10.631	44.50	77.89
Shape factor		0.90	0.077	0.62	0.99
Compactness		14.11	1.557	12.70	20.17
Fruit mass, g		285.74	60.619	177.77	404.45
Fruit density, kg m^{-3}		984.64	4.637	981.23	989.92
Bulk density, kg m^{-3}		452.95	68.576	374.44	501.09
Porosity, %		54.00	6.933	48.93	61.90
Fruit firmness, kg cm^{-2}		17.53	2.181	14.60	26.40
Static coefficient of friction*	Aluminum	0.38 a	0.043	0.35	0.45
	Plywood	0.31 b	0.013	0.29	0.32
	Steel	0.23 c	0.013	0.22	0.25

*: Different lower case letters in the same column indicate a significant difference between between contact surfaces ($P < 0.01$)

and maximum values of external fruit colours determined as lightness (*L*), apparent color (*a, b*), color intensity (chroma) and hue of the pepino fruits were found to be between 63.43 and 89.09; 1.14 and 5.79; 11.29 and 23.50; 11.52 and 23.53; and 71.38 and 87.22, respectively. The average values of these characters were 74.19, 3.50, 15.36, 15.79 and 76.93, respectively (Table 1). The skin color of pepino is accepted good indicator for determining maturity of fruits (Gonzalez et al., 2000). Previously *L, a, b*, hue angle and chroma values of pepino cultivars were determined as 57.91-64.36; -7.84-(-11.82), 18.65-23.56, 20.56-24.84 and 108.48-120.58 (Gonzalez et al., 2000), respectively. Lizana and Levano (1977) reported that colour changes in pepino vary with the stage of maturity. Although firmness, soluble solids and taste are important maturity characteristics, colour is the most important index of maturity in pepino. Colour changes from green to yellow or orange colour, with purple stripes. Completely yellow or orange-yellow colour is demanded for market, although fruits have to be harvested earlier for handling purposes (Arenas, 1992). Gonzalez et al. (2000) also revealed that the best parameters for distinguishing between different stages of pepino fruits are α and hue angle.

The average fruit mass, width and length of pepino fruits were 285.74 g, 75.63 mm and 99.04 mm (Table 2). When the fruit mass in this study was compared with previous study, the mean fruit mass was within normal limits, which determined between 65-372 g (Prohens et al., 1999; Prohens et al., 2005; Tomaszewska and Mazur, 2007; Cavusoglu et al., 2009). Cavusoglu et al. (2009) determined fruit length and width between 76.7-82.8 mm and 62.3-66.8 mm.

The minimum and maximum geometric mean diameter, sphericity, surface area, projected area, shape factor and compactness were found to be between 64.76 and 93.75 mm; 67.82 and 97.76%; 131.74 276.09 cm^2; 44.50 and 77.89 cm^2; 0.62 and 0.99 and 12.70 and 20.17, respectively (Table 2). 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., 1999).

The average fruit and bulk density of pepino fruits were 984.64 kg m^{-3}, and 452.95 kg m^{-3}. Shapiro-Wilk test showed normal distribution of the static coefficient of friction values (P=0.814). The results showed that the highest static coefficient of friction was obtained from aluminum surface as 0.38 and followed by plywood (0.31) and steel (0.23) surface, respectively. The average fruit firmness of pepino fruits was recorded as 17.53 kg cm^{-2} (Table 2).

Conclusion

As a conclusion, some color and physical properties of pepino fruits grown in Turkey were described in order to manufacture better design a specific machine for harvesting and post harvesting operations. Therefore, the color and physical properties of pepino fruits should be considered in optimizing pepino mechanization and processing.

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