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ORIGINAL ARTICLE

Physical and chemical characteristics of goldenberry fruit (*Physalis peruviana* L.)

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Abstract Some physical and chemical characteristics of goldenberry fruit (*Physalis peruviana* L.) were investigated. These characteristics are necessary for the design of equipments for harvesting, processing, transportation, sorting, separating and packing. The fruit length, diameter, geometric and arithmetic mean diameters, sphericity, surface area, projected areas (vertical-horizontal) and aspect ratio of goldenberries were determined as 17.52 mm, 17.31 mm, 17.33 mm, 17.38 mm, 98.9 %, 0.949 cm^2, 388.67–387.85 mm^2 and 0.988, respectively. The mass of fruit, bulk density, fruit density, porosity and fruit hardness were 3.091 g, 997.3 kg/m^3, 462.3 kg/m^3, 53.61 % and 8.01 N, respectively. The highest static coefficient of friction was observed on rubber surface, followed by stainless steel sheet, aluminum sheet, and plywood materials. The dry matter, water soluble dry matter, ash, protein, oil, carbohydrate, titratable acidity, pH, total sugar, reducing sugar, antioxidant capacity were 18.67 %, 14.17 %, 2.98 %, 1.66 %, 0.18 %, 13.86 %, 1.26 %, 6.07, 63.90 g/kg, 31.99 g/kg and 57.67 %, respectively. The fresh fruits have 145.22 mg gallic acid equivalent (GAE)/100 g total phenol content and skin colour data represented as L^*, a^*, b^*, Chroma (C) and Hue angle (α) were 49.92, 25.11, 50.23, 56.12 and 63.48, respectively.

Keywords Goldenberry · Physical and chemical characteristics · Fruit hardness · Colour · Total phenol content

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Introduction

The goldenberry (*Physalis peruviana* L.) is an exotic fruit that belongs to the *Solanaceae* family. The fruit is orginated in South America and today it is grown commercially in several tropical and subtropical countries (Novoa et al. 2006). A goldenberry is an annual plant that grows all over the world. *Physalis peruviana* L. known as goldenberry in English speaking countries, uchuva in Colombia, cape gooseberry in South Africa, uvilla in Ecuador, ras bhari in India, aguaymanto in Peru, topotopo in Venezuela are some of the multiple names for this fruit around the world (Erkaya et al. 2012). World's goldenberry fruit cultivation area is nearly 30,622 ha and 162,386 tonnes of yield is obtained from this area (FAOSTAT 2013).

A single plant has a potential to yield 300 fruits, and carefully tended plants can provide 20 to 33 t per hectare. The fruit of goldenberry is yellow to orange in skin colour, ovoid in shape and ranges from between 1.25 and 2.50 cm in diameter, 4 to 10 g in weight. The fruit is containing inside around 100 to 200 small yellowish seeds and protected by the calyx (Tapia and Fries 2007).

The goldenberries are popular fruits known for their organoleptic properties (flavor, odor and colour), nutritional value (vitamins A and C, potassium, phosphorous and calcium), and health benefits (Puente et al. 2011). Although goldenberries are generally commercialized as fresh products, the fruits are also used in sauces, syrups, and marmalades (Puente et al. 2011), or dehydrated (similarly to grape raisins) for use in bakeries, cocktails, snacks, and cereal breakfast. The physical characteristics of any product are valuable for design of equipments for handling, transportation, sorting, separating, packing and also processing into different foods. Any system designed without taking these criteria into consideration results in inadequate applications decreasing work efficiency and increasing product loss. Therefore, for the proper mechanization of goldenberry, its physical characteristics are a pre-requisite for the design and development of any equipment. In recent years, physical, chemical and nutritional characteristics have been studied for various fruits such as hackberry (Demir et al. 2002), cornelian cherry (Demir and Kalyoncu 2003), wild plum (Calisir et al. 2005), wild medlar (Haciseferogullari et al. 2005), sweet cherry (Vursavus et al. 2006), kiwifruit (Celik et al. 2007), jujube fruit (Akbolat et al. 2008), simarouba fruit and kernel (Dash et al. 2008), date fruit (Keramat et al. 2008), jatropha fruit (Pradhan et al. 2009), persimmon (Altuntas et al. 2011), goldenberry (Ersoy and Bagci 2011) and kumquat (Jaliliantabar et al. 2013). However, no detailed studies have been published on physical and chemical characteristics of goldenberry.

The aim of this study was conducted to investigate the physical characteristics (axial dimensions, sphericity, surface and projected areas, aspect ratio, fruit mass, fruit and bulk densities, porosity, skin hardness, coefficients of static friction, colour (L^*, a^*, b^*, C and α) and the chemical characteristics (dry matter, water soluble dry matter, ash, protein, oil, carbohydrate, titratable acidity, pH, total sugar, reducing sugar, antioxidant capacity and total phenol content) of goldenberry fruits grown in Turkey.

Material and methods

Mature goldenberry fruits were used for all the experiments in this study. The fruit was harvested at Bursa (İnegöl) during the summer season of 2012. After harvest, the fruit was immediately placed in cardboard boxes and transported to the postharvest physiology laboratory. The cardboard boxes are 5 kg capacity and 40×60×13 cm dimensions. It is divided into three cases for the analysis of goldenberries. The fruits were cleaned to remove all foreign matter such as dust and dirt as well as immature and damaged fruits. The initial moisture content of fruit was determined using an oven (ED115 Binder, Tuttlingen, Germany) set at 105±5 °C until they reached constant weight. The remaining material was packed in a 2,000 ml hermetic glass vessel and kept in cold storage at 4 °C until use. All of the analyses were carried out at room temperature in the Dept. of Biosystems and Food Engineering laboratories of the University of Uludag, Bursa, Turkey.

Determination of physical characteristics

One hundred fruits were randomly selected from the remainder of the 15 kg sample. To determine the average size of the fruits, two linear dimensions, namely length (L) and diameter (D), were measured by using a digital caliper with accuracy of 0.01 mm. The geometric mean diameter D_g (mm) was calculated by considering Eq. 1 (Mohsenin 1986):

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

The sphericity, S_p (%), defined as the ratio of surface area of a sphere having the same volume as that of fruit to the surface area of the fruit, was determined using the following formula (Mohsenin 1986):

$$S_p = 100\left(D_g/L\right) \quad (2)$$

The surface area and aspect ratio of the fruit were calculated by using the following formula (Mohsenin 1986):

$$S = \pi D_g^2 \quad (3)$$

$$R_a = D/L \quad (4)$$

where:

S surface area (mm^2)
R_a aspect ratio.

Projected area with two major axes (X and Y-Axis) of the goldenberry fruit was determined from pictures of the goldenberries taken by a digital camera (Sony DSC-W730, Sony Corp. Chine), and then comparing the reference area to a sample area, by using the Sigma Scan Pro 5 program (SPSS Science, Chicago IL, USA).

Sample mass was measured by using a digital balance with a sensitivity of 0.01 g.

The volume of fruit (V) and fruit density defined as the ratio of the mass of a sample to the solid volume accordingly occupied was determined by the liquid displacement method. The amount of displaced toluene (C_7H_8) was recorded from the graduated scale of the measuring cylinder (Akbolat et al. 2008). The bulk density is the ratio of the mass of a sample of a fruit to its total volume and was determined with a weight per hectoliter tester, which was calibrated in kg m^{-3}. The hectoliter tester filled with fruits from a height of about 15 cm, striking the top level and then weighing the contents (Altuntas et al. 2011).

Porosity of bulk fruit (ε) is defined as the ratio of the intergranular space to the total space occupied by the fruit and can be calculated from fruit and bulk densities. Porosity (ε) was calculated by the following equation (Mohsenin 1986):

$$\varepsilon = 100\left[1-\left(\rho_b/\rho_f\right)\right] \quad (5)$$

where:

ρ_b bulk density (kg m^{-3})
ρ_f fruit density (kg m^{-3}).

Coefficient of static friction was measured by a friction device having aluminum, rubber, plywood and stainless steel surfaces. For this measurement, the material was placed on the surface, and then gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the material started rolling over the surface, and the nursing the tangent value of the angle so that the coefficient of friction was found (Calisir et al. 2005; Akbolat et al. 2008).

For the fruit hardness measurement, a biological material test device (Sundoo, 50 SH, accuracy 0.1 N, China) was used. For measurement, the apparatus was directly inserted into the external surface. The hardness of goldenberry fruits was measured using by a 8 mm diameter conical stainless steel probe. The apex angle of the conical probe was 55° (Unal and Akbudak 2008). The values were measured at 35 mm/min test speed. Goldenberry fruit samples were penetrated along an axial dimension (diameter) to determine the hardness. The process was replicated 20 times and the average of the 20 readings was taken as the representative value.

Skin colour measurements of goldenberries were done by using Hunterlab Colour Analyzer (HunterLab MSEZ-4500L, Virginia, USA) in L^* (lightness: 100, white; 0, black), a^* (+, red; −, green) and b^* (+, yellow; −, blue) colour scale. After initial calibration against standard white and black surface plates, ten measurements were taken (Reddy 2006). A glass cell with a diameter just close to the nose cone of colourimeter, containing samples without cut-off, was placed above the light source and L^*, a^* and b^* colour values were recorded (Odjo et al. 2012). According to following equations (Rattanathanalerk et al. 2005), a^* and b^* values were used to calculate Chroma (C) (Eq. 6) and Hue angle (α) (Eq. 7) values. These parameters are effective for describing visual colour appearance (Bernalte et al. 2003).

$$C = \sqrt{(a^*)^2 + (b^*)^2)} \tag{6}$$

$$\alpha = \tan^{-1}(b^*/a^*) \tag{7}$$

Determination of chemical characteristics

The chemical characteristics (dry matter, water soluble dry matter, ash, protein, oil, titratable acidity, pH, total sugar and reducing sugar) of the goldenberry fruits were analyzed according to Cemeroglu (2010). The dry matter of samples was determined by drying (ED115 Binder, Tuttlingen, Germany) at 105±5 °C until they reached constant weight. Water soluble dry matter (°Brix) of fruits was determined by an Abbe refractometer (2WAJ, SIONTECH, Germany) at 20 °C. Ash was determined in a muffle furnace (MF100 Nüve, Ankara, Turkey) at 550 °C to a white colour. Protein was determined by the Kjeldahl method and calculated by using the conversion factor 6.25. Total oil was extracted with n-hexane (60 °C) for 8 h using a Soxhlet extractor. Titratable acidity was determined by titration with NaOH 0.1 N solution, using phenolphthalein as indicator, until obtaining pink colour and the results were calculated in terms of citric acid. pH of the fruits was determined by pH meter (Hanna pH 211 Microprocessor, Portugal) at 20 °C. Total sugar and reducing sugar content of goldenberries was determined by the Luff-Schoorl method. The samples were analyzed in three replications.

The carbohydrate content of the fruits was calculated by the difference between 100 and the sum of moisture, ash, proteins, and oil percentages (Rodrigues et al. 2009).

The goldenberry extracts were prepared based on the method described by Turkmen et al. (2005). By this method, 1 g of homogenized goldenberry samples were extracted with 4.5 mL methanol (80 %) on a mechanical shaker (Biosan OS-20, Latvia) at 140 rpm for 2 h at room temperature, then centrifuged at 10.000 rpm 15 min (Sigma 3 K30, Osterode am Harz, Germany). Clear supernatant was taken out and the residue was reextracted under identical conditions. Supernatants of the two extracts were combined and filtered through Whatman No.1 filter paper (Whatman International Ltd., Maidstone, England). All obtained clear extracts were used for determination of antioxidant capacity and total phenolic content. DPPH (2,2-Diphenyl-1-picrylhydrazyl) free radical scavenging activity of the fruit extracts was determined spectrophotometrically (Shimatzu UV/VIS 1800, Kyoto, Japan) according to the method of Zhang and Hamauzu (2004) with a minor modification. 0.5 mL of each sample extracts was added to 0.1 mM methanolic solution of DPPH radical and vortexed (WiseMix VM-10, Daihan, Korea) for 15 to 30 s. Instead of methanolic extract of goldenberry samples, pure methanol was used as control. After the reaction took place in the dark at room temperature for 60 min, the absorbance (A) was measured at 517 nm. The samples were analyzed in three replications. Antioxidant capacity was expressed as percent inhibition of DPPH radical and was calculated from the following equation:

$$Antioxidant\,capacity(\%) = [(A\,blank - A\,sample)/A\,blank] \times 100 \tag{8}$$

The total phenolic content of the extracts was determined according to the method of Turkmen et al. (2005) with a minor modification. 0.25 mL of goldenberry extract was first diluted with 2.3 mL H_2O, then 0.15 mL 1/5 diluted Folin-Ciocalteu solution was added, and vortexed (WiseMix VM-10, Daihan, Korea) for 15 s. After the 5 min incubation, 0.3 mL of 35 % Na_2CO_3 was added to mixture and the absorbance of the sample was determined by a spectrophotometer (Shimatzu UV/VIS 1800, Kyoto, Japan) at 725 nm after it was incubated in the dark for 2 h at room temperature. Distilled water was used as control. The results were expressed as mg gallic acid equivalent (GAE) per 100 g fresh weight of sample.

Results and discussion

Physical characteristics

The length, diameter, geometric mean diameter and fruit mass of goldenberry ranged from 13.92 to 19.87, 13.58 to 20.75, 13.66 to 20.14 mm and 2.734 to 3.091 g, respectively (Table 1). About 79 % of the goldenberry fruits have a length ranging from 15.11 to 18.68 mm, about 85 % diameter ranging from 15.01 to 19.30 mm, about 80 % fruit mass ranging from 2.93 to 3.51 g, respectively (Fig. 1). The correlation coefficients between D/L, D/D_g, D/S_p, D/M, D/S and D/V were statistically significant (Table 2).

The following general expression can be used to describe the relationship among the average dimensions of the fruit:

$$D = 0.988L = 0.999D_g = 17.497S_p = 5.644M = 18.447S = 6.360V \quad (9)$$

The coefficients of correlation show that the D/L, D/D_g, D/S_p, D/M, D/S and D/V ratios were found to be highly significant. Similar results were found by Haciseferogullari et al. (2005) for wild medlar fruit and by Altuntas et al. (2011) for persimmon fruit. This indicates that the length, the geometric mean diameter, sphericity, mass, surface area and volume are closely related to the diameter of the fruit.

A summary of the results of determined physical parameters of goldenberry fruit is shown in Table 1. Dimensions varied from 13.92 to 19.87 mm in length and 13.58 to 20.75 mm in diameter with average values of 17.52 and 17.31 mm, respectively. The importance of dimensions is in determining the aperture size of machines, particularly in separation of materials as discussed by Mohsenin (1986). These dimensions can be used in designing machine components and parameters. For example, they may be useful in estimating the number of fruits to be engaged at a time. The major axis has been found to be useful by indicating the natural rest position of the fruit.

The geometric mean diameter, sphericity and surface area varied from 13.66 to 20.14 mm, 91.5 to 107.6 % and 0.586 to 1.274 cm^2, while mean values were 17.33 mm, 98.9 % and 0.949 cm^2, respectively. These values of goldenberry were lower than that of sweet cherry fruit (Vursavus et al. 2006) and higher than that of cornelian cherry fruit samples (Demir and Kalyoncu 2003).

The aspect ratio of fruit is 0.988. Taken along with the high aspect ratio (which relates the ratio of seed diameter to length), it may be deduced that the fresh goldenberry fruit will rather roll, like kiwifruit (cv. Hayward) (Celik et al. 2007), than slide on their flat surfaces like jujube fruit (Akbolat et al. 2008).

Table 1 Some physical characteristics of the goldenberry fruit

Parameters	Number of replications	Min	Max	Mean	Standard deviation
Length (mm)	100	13.92	19.87	17.52	1.23
Diameter (mm)	100	13.58	20.75	17.31	1.46
Geometric mean diameter (mm)	100	13.66	20.14	17.33	1.32
Sphericity (%)	100	91.5	107.6	98.9	3.2
Surface area (cm^2)	100	0.586	1.274	0.949	0.141
Projected area (mm^2)					
X-axes	10	364.71	398.37	387.8	13.3
Y-axes	10	378.19	398.55	388.7	8.0
Aspect ratio	100	0.879	1.120	0.988	0.049
Mass of fruit (g)	20	2.734	3.707	3.091	0.270
Fruit volume (cm^3)	20	2.2	3.2	2.72	0.28
Fruit density (kg m^{-3})	20	952.2	1032.2	997.3	26.7
Bulk density (kg m^{-3})	20	439.4	498.3	462.3	15.8
Porosity (%)	20	48.96	56.29	53.61	2.00
Fruit hardness (N)	20	5.3	10.7	8.01	1.56
Coef. of static friction					
Rubber	20	0.123	0.194	0.157	0.019
Stainless-steel	20	0.123	0.213	0.151	0.027
Aluminum	20	0.123	0.231	0.150	0.027
Plywood	20	0.123	0194	0.149	0.021

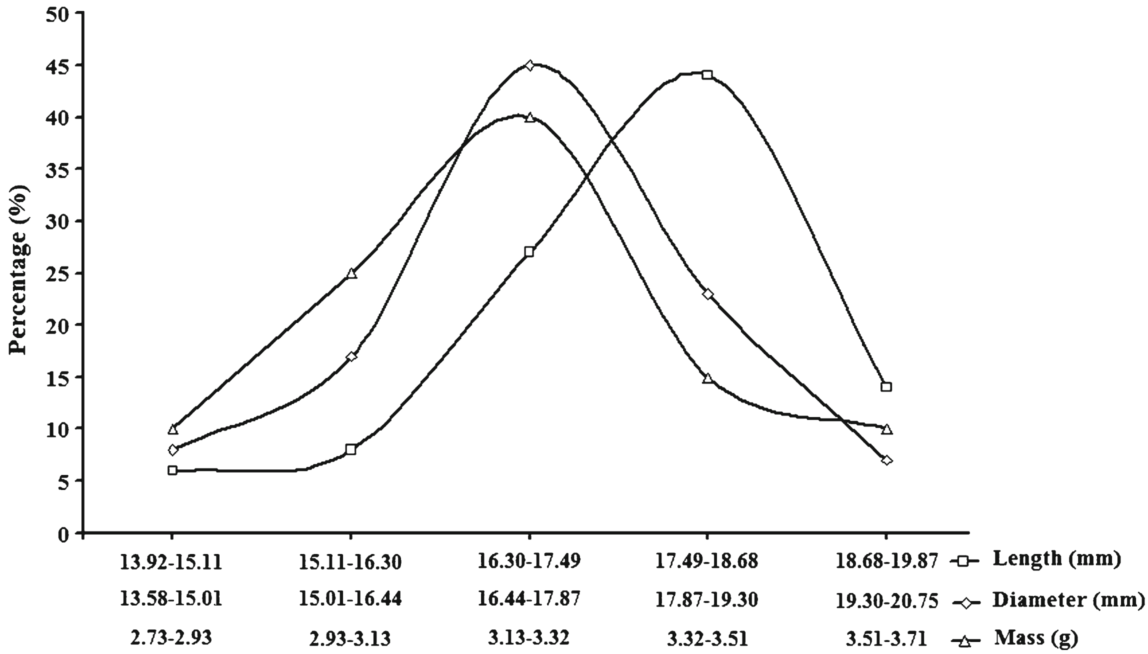

Fig. 1 Diameter, length, and mass frequency distribution

This tendency to either roll or slide is very important in the design of hoppers. Furthermore, the shape indices indicate that the goldenberry fruit may be treated as an equivalent sphere, like kiwifruit, for analytical prediction of its drying behaviour.

The mean projected areas along X-Axes and Y-Axes were obtained as 387.8 and 388.7 mm^2, with variation of 364.7 to 398.4 mm^2 and 378.2 to 398.6 mm^2, respectively. The experimental projected areas of goldenberry resulted to be lower than that of Juniperus drupacea fruits (Akinci et al. 2004) and myrtle fruit (Aydin and Ozcan 2007), and higher than that of hackberry (Demir et al. 2002) and cornelian cherry (Demir and Kalyoncu 2003).

The average fruit mass and fruit volume were determined as 3.09 g and 2.72 cm^3. Average mass and volume values of golden berry fruit were found to be greater than cornelian cherry fruit (Demir and Kalyoncu 2003), myrtle fruit (Aydin and Ozcan 2007) and simarouba fruit (Dash et al. 2008) whereas there were smaller than wild plum (Calisir et al. 2005), sweet cherry fruit (Vursavus et al. 2006) and kumquat fruit (Jaliliantabar et al. 2013).

Table 2 The correlation coefficient of goldenberry (98° of freedom)

Particulars	Ratio	Correlation coefficient (R^2)**
D/L	0.988	0.648
D/D_g	0.999	0.967
D/S_p	17.497	0.310
D/S	18.447	0.971
D/V	6.630	0.924

** Significant at 1 % level

Whole fruit density was measured and found to be between 952.2 and 1032.2 kg/m^3 and with average value of 997.3 kg/m^3. Thus the value is within the same range as 979 kg/m^3 reported for African bread fruit (Omobuwajo et al. 1999), 932.7 kg/m^3 for persimmon fruit (Altuntas et al. 2011), 970 kg/m^3 for date fruit (cv. Dairi) (Keramat et al. 2008) and 950.9 kg/m^3 for apple (cv. Starking Delicious) (Ozturk et al. 2010), but lower than 1,400 kg/m^3 for aonla fruit (cv. Krishna) (Goyal et al. 2007), 1069.7 kg/m^3 for tomato (cv. AlidaF1) (Kaymak et al. 2010) and 1,200 kg/m^3 for kumquat fruit (Jaliliantabar et al. 2013).

The results are similar to those reported by Ozturk et al. (2010) for apple cultivars (cv. Golden delicious), but the values were higher than those for Jujube fruit (Akbolat et al. 2008) and sweet cherry fruit (cv. Noir de guben) (Vursavus et al. 2006).

The average skin hardness of the goldenberry fruit was 8.01 N, while the skin hardness for sweet cherry (for varieties Van, Bing and 0900 Ziraat) 7.78, 7.68 and 7.42 N, respectively (Unal and Akbudak 2008).

The highest coefficient of static friction was obtained on rubber as 0.157, followed by stainless steel sheet, aluminum sheet and plywood as 0.151, 0.150 and 0.149, respectively. These physical results should be considered in the harvesting, handling and processing of goldenberry fruits. In comparison with the other fruit species, the static fraction of goldenberry was lower than those of wild plum fruits (Calisir et al. 2005), medlar (Haciseferogullari et al. 2005) and persimmon (Altuntas et al. 2011). Static friction coefficient reached their maximum values on rubber surface in different studies (Demir and Kalyoncu 2003; Calisir et al. 2005; Akbolat et al. 2008).

Table 3 Colour characteristics of goldenberry fruit

Parameter	Min	Max	Mean	Standard deviation
L^*	49.25	50.28	49.92	0.32
a^*	24.75	27.79	25.11	0.94
b^*	49.94	50.44	50.23	0.19
C	55.76	57.54	56.12	0.51
α	61.15	63.86	63.48	0.82

The colour parameters L^*, a^*, b^*, C and α of goldenberry fruit are presented in Table 3. Colour measurement results for the fruit samples were: L^* value in the range of 49.25 to 50.28, a^* value in the range of 24.75 to 27.79, b^* value in the range of 49.94 to 50.44. In addition, mean values of the C and α for goldenberry were found to be 56.12 and 63.48, respectively. Valdenegro et al. (2013) reported L^*, a^*, b^*, C and α values for goldenberry fruit were 69.56, 17.12, 60.78, 63.15 and 74.26, respectively. Colour values of studied fruit samples are higher than the corresponding values of 36.81 (L^*), 16.71 (a^*) and 37.47 (b^*) reported for cape gooseberrry fruit (Vasquez-Parra et al. 2013).

Chemical characteristics

The chemical characteristics of the goldenberry fruit are given in Table 4. The dry matter, water soluble dry matter, ash, protein, oil and carbonhydrate were found to be 18.67 %, 14.17 %, 2.98 %, 1.66 %, 0.18 % and 13.86 %, respectively. Sharoba and Ramadan (2011) reported that goldenberry fruit contain 21.00 % dry matter, 16.40 % water soluble dry matter, 1.08 % ash, 0.84 % protein and 0.32 % oil. Different researchers found carbonhydrate values as 11.00 % and 17.30 % (Osorio and Roldan 2003; Carrasco and Zelada 2008). The oil content of many fruits are usually lower than 2 %. The mean titrateble acidity and pH values of goldenberry were found to be 1.26 % citric acid and 6.07, respectively. This titratable acidity was similar to the range of 0.78 to 1.83 % reported for goldenberry by different researchers (Ersoy and Bagci 2011; Sharoba and Ramadan 2011). Ersoy and Bagci (2011) reported that ripe fruits of goldenberry contain 4.47 pH. The total sugar content was found to be for goldenberry 63.90 g/kg which was composed to of 31.99 g/kg reducing sugar. This total sugar and reducing sugar contents were lower than the values reported in goldenberry fruit by Sharoba and Ramadan (2011). The antioxidant capacity and total phenolic content in fruit analyzed in the study were 57.67 % and 145.22 mg GAE/100 g, respectively. The goldenberry is called as a functional food due to bioactive compounds in it. There are various bioactive compounds (withanolides and phenolics) for the goldenberry (Dinan et al. 1997) and some of them has a strong antioxidant property (Chang et al. 2008). Goldenberry is rich in phenolic compounds and the main phenolic compound of the fruit is quercetin, subsequently by myricetin and kaempferol (Hakkinen et al. 1999). Valdenegro et al. (2013) reported the following antioxidant capacity and total phenolic content data for goldenberry as 5.84 mmols DPPH/100 g and 2.46 g GAE/100 g on dry weight basis. It is thought to be helping the fruit processing technology to be known the chemical composition of goldenberry fruit.

Conclusions

The following conclusions were drawn from this investigation about the physical and chemical characteristics of goldenberry fruit at an average dry matter content of 18.67 % (d.b.). The

Table 4 Some chemical characteristics of goldenberry fruit

Parameter	Min	Max	Mean	Standard deviation
Dry matter (%)	17.74	20.46	18.67	1.55
Water soluble dry matter (%)	14.00	14.50	14.17	0.29
Ash (%)	2.95	3.00	2.98	0.03
Protein (%)	1.58	1.80	1.66	0.12
Oil (%)	0.15	0.20	0.18	0.03
Carbohydrate* (%)	12.91	15.72	13.86	1.62
Titratable acidity (%) (as citric acid)	1.21	1.28	1.26	0.04
pH	6.05	6.08	6.07	0.02
Total sugar (g/kg)	63.39	64.31	63.90	0.47
Reducing sugar (g/kg)	31.55	32.35	31.99	0.41
Antioxidant capacity (%)	57.00	59.00	57.67	1.15
Total phenol content (mg GAE/100 g)	136.64	154.55	145.22	8.98

* % Carbohydrate = 100 − (%moisture + %ash + %protein + %oil)

dimensions varied from 13.92 to 17.52 mm in length and 13.58 to 17.31 mm in diameter. Geometric mean diameter, sphericity and surface area varied from 13.66 to 17.33 mm, 91.5 to 98.9 % and 0.586 to 0.949 mm^2, respectively. The correlation coefficients between physical parameters of goldenberry fruits (*D/L*, D/D_g, D/S_p, *D/M*, *D/S* and *D/V*) were significant. The average mass and volume varied from 2.734 to 3.091 g and from 2.20 to 2.72 cm^3. The projected areas along X-axis were lower than along Y-axis. Fruit density, found to be between 952.2 and 997.3 kg/m^3. Bulk density and porosity obtained were found to be 462.3 kg/m^3 and 53.61 %. Skin hardness is an important criterion to maintain quality during the postharvest period. Skin hardness of fruit is found 8.01 N. The coefficient of static friction on rubber surface was higher than that on stainless steel and aluminum and lower than that of plywood surface.

The chemical characteristics in the research were found to be different from to some goldenberry studies in the world. This could be explained by the fact that ecological factors affect the composition of goldenberry. The antioxidant capacity and total phenolic content of fruit were found to be 57.67 % and 145.22 mg GAE/100 g, respectively. In addition to fruit general nutritional properties, goldenberry is attracting interest for potential health benefits due to its biologically active compounds.

As a conclusion, besides chemical characteristics, the physical characteristics of goldenberry fruit were described in order to better design a specific machine for harvesting and post-harvesting operation. In this study, many properties were determined to be significant. Therefore, the differences between the physical characteristics of goldenberry should be considered in optimizing persimmon mechanization and processing.

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