Int. Agrophys., 2010, 24, 357-361

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Physical and chemical properties of three late ripening apple cultivars

I. Ozturk[1]*, *S. Bastaban*[1], *S. Ercisli*[2], *and F. Kalkan*[1]

[1]Department of Agricultural Machinery, Faculty of Agriculture Ataturk University 25240 Erzurum, Turkey
[2]Department of Horticulture, Faculty of Agriculture, Ataturk University, 25240 Erzurum, Turkey

Received July 27, 2009; accepted December 29, 2009

A b s t r a c t. Physical, mechanical and chemical properties of three autumn apple cultivars, namely Golden Delicious, Granny Smith and Starking Delicious, are presented. Most of them were strongly affected statistically by cultivars. The differences could be individual characteristics of these varieties because all the cultivars originated from the same ecological conditions.

K e y w o r d s: apples, physical properties, mechanical properties, chemical properties

INTRODUCTION

The losses in apples occur 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 the delicate nature and high water content of apple fruits (Karacali, 1990; Kaynas, 1987). This reveals the need for conducting studies to develop relevant equipments and machineries taking in account physical properties of apple fruits to overcome these problems. There were several studies conducted on Starking Delicious, Golden Delicious and Granny Smith apple cultivars in different parts of Turkey and other countries, related to chemical contents of the fruits (Kardeniz *et al*., 2005; Liu *et al*., 2001; Markowski *et al*., 2007; Ozyigit, 1991). However, to our knowledge, no comparative study concerning the physical, mechanical and chemical properties of those cultivars has been performed.

The aim of this paper was to show the physical, mechanical and chemical properties of late ripening apple cultivars (Golden Delicious, Granny Smith and Starking Delicious).

MATERIALS AND METHODS

The apple cultivars used were Granny Smith (GS), Golden Delicious (GD) and Starking Delicious (SD). The cultivars were grafted on MM106 rootstocks grown in the same private orchards in Tokat city. The fruits were hand harvested in October at commercial maturity stage by using 1-10 starch scores (5 for GD and SD and 7 for GS) and were immediately transferred to the laboratory in cooled polythene bags to reduce water loss. The healthy fruits were chosen and stored at 0-1°C, 90-95% humidity. The analyses were carried out at room temperature of 22°C at the Biological Material Laboratory of the Agricultural Machinery Department and the Fruit Science Laboratory of the Horticulture Department of Ataturk University, Erzurum, Turkey. Moisture content (%) of the samples was determined according to AOAC (1984).

The fruit linear dimensions were measured using a digital calliper gauge with sensitivity of 0.01 mm. Fruit mass was measured by using a digital balance with a sensitivity of 0.001 g. The aspect ratio, geometric mean diameter, sphericity surface area, fruit volume, fruit and bulk density, density ratio and porosity were determined according to Desphande *et al*. (1993), McCabe *et al*. (1986), Mohsenin (1986) and Omobuwajo *et al*. (2000). Projected area of the apples was determined from pictures taken by a digital camera (Casio Exilim EX-Z60, 6.0 Mpixels), and then the reference area was compared to a sample area using the Image Tool for Windows (version 3.00) program. The friction force and rupture properties were determined using a method described by Kara *et al*. (1999). The energy absorbed during the

*Corresponding author's e-mail: iozturk@atauni.edu.tr

loading up to rupture point was calculated from the area under the load-deformation curve (Altuntas and Yildiz, 2007). Toughness, the ratio of energy absorbed by the fruit up to the rupture point to the volume of the fruit, was calculated according to Gupta and Das (2000). Fruit firmness was measured at 23°C using a non-destructive firmness device (Acoustic Firmness Sensor) (Aweta Company, The Netherlands). Skin colour of fruits was measured on the cheek area of 50 fruits with a Minolta Chroma Meter CR-400 (Minolta-Konica, Japan).

The pH, acidity, total soluble solids (TSS) and vitamin C were determined in fruit juice; however, the antioxidant activity and total phenolic content were determined in dried peel+flesh. The pH, acidity and ascorbic acid were quantified with the reflectometer set of Merck Company (Merck RQflex). 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 22°C and the result was expressed as Brix. In β-carotene-linoleic acid assay, antioxidant activity of apple fruits is determined by measuring the inhibition of the volatile organic compounds and the conjugated diene hydroperoxides arising from linoleic acid oxidation (Barriere *et al*., 2001). Total phenolic constituents (TPC) of apples were determined by standard method (Slinkard and Singleton, 1997).

Descriptive statistics was carried out on the three apple cultivars and differences between the mean values were investigated using the Duncan tests. Mean values were reported with the standard deviation.

RESULTS AND DISCUSSION

The physical properties of apples are shown in Table 1. When the fruit mass in this study was compared with previous studies, the mean fruit mass was within normal limits, determined as 155.00-257.00 g for SD, 140-207 g for GD and 136-223 g for GS (Guleryuz *et al*., 2001; Eren *et al*., 2002; Ozyigit, 1991). Also, our fruit dimension results (width and length) were found to be within the limits of previous studies (Gunel and Karacali, 1988; Liu *et al*., 2001; Ozdemir *et al*., 1994). Sphericity and aspect ratio of apple cultivars were 96.47 and 94.77% for SD and 93.93 and 91.06% for GD and 93.80 and 90.87% for GS. Sphericity is an expression of the shape of a solid relative to that of a sphere of the

T a b l e 1. Physical properties of apple cultivars

Physical properties		Golden Delicious	Starking Delicious	Granny Smith	Significant level
Moisture (% w.b.)		86.68±0.13a[a]	85.13±0.19b	85.14±0.21b	**
Fruit length (mm)		70.89±1.45c	74.88±2.82b	80.02±1.79a	**
Fruit width (mm)		64.53±2.35c	70.94±3.35b	72.68±2.85a	*
Aspect ratio (%)		91.06±3.78b	94.77±3.54a	90.87±3.96b	**
Geometric mean diameter (mm)		66.57±1.70c	72.22±2.93b	75.03±2.08a	**
Sphericity (%)		93.93±2.59b	96.47±2.41a	93.80±2.72b	**
Surface area (cm^2)		139.30±7.09c	164.10±13.43b	177.00±9.82a	**
Projected area (cm^2)		40.65±1.66c	45.85±2.31b	49.60±2.57a	**
Fruit mass (g)		145.96±7.22c	172.44±17.36b	201.75±11.82a	**
Fruit volume (cm^3)		148.80±8.97c	181.10±26.51b	233.40±8.07a	**
Fruit density (kg m^{-3})		948.56±28.72a	950.87±11.37a	887.82±12.74b	**
Bulk density (kg m^{-3})		465.47±7.52a	469.53±20.79a	440.47±17.31b	**
Density ratio (%)		49.10±1.44	49.40±2.54	49.62±1.89	NS
Porosity (%)		50.90±1.44	50.60±2.54	50.39±1.89	NS
Shell thickness (mm)		0.18±0.02c	0.30±0.02b	0.35±0.04a	**
Fruit firmness (MPa)		1.39±0.17c	2.49±0.35b	2.92±0.13a	**
Dynamic coefficient of friction	Steel	0.344±0.017	0.331±0.021	0.300±0.027	NS
	Galvanized steel	0.295±0.012	0.305±0.006	0.288±0.017	NS
	Plywood	0.282±0.016	0.286±0.002	0.267±0.017	NS
	Fiberglass	0.459±0.048b	0.663±0.047a	0.600±0.125ab	*

*, **Significant levels at 5 and 1%, NS – non-significant, [a]letters indicate statistical difference within same rows.

same volume, while the aspect ratio relates the width to the length of the fruit which is indicative of its tendency toward being oblong in shape (Omobuwajo *et al*., 1999). Fruit and bulk density of apples were in the ranges of 950.87-469.53 kg m^{-3}(SD), 948.56-465.47 kg m^{-3} (GD)and 887.82-440.47 kg m^{-3}(GS). The density ratio ranged at 49.40, 49.10, and 49.62% for SD, GD and GS. The surface and projected area were 139.30 and 40.65 cm^2 (GD), 164.10 and 45.85 cm^2 (SD), 177.00 and 49.60 cm^2 (GS). Fruit firmness and skin thickness of apple cultivars were recorded as 1.39 MPa and 0.18 mm(GD), 2.49 MPa and 0.30 mm (SD), 2.92 MPa and 0.35 mm (GS), indicating that GS fruits were stronger than the other cultivars. Fruit firmness and skin thickness of apple cultivars showed a linear relationship with a positive correlation coefficient of R^2=0.886 (Karacali, 1990). The highest coefficient of dynamic friction was obtained on fibreglass – 0.663 (SD), 0.600 (GS) and 0.459 (GD), followed by steel (0.331-0,300-0,344), galvanized steel (0.305-0.288-0.295) and plywood surface, at 0.286, 0.267 and 0.282, respectively.

The values of rupture force, deformation at rupture, energy absorbed by the fruit up to rupture, and toughness of apple cultivars are given in Table 2. The values of rupture force and deformation at rupture were found to be about 26.75, 37.36, 63,26 N; and 2.90, 3.03, and 3.14 mm for GD, GS and SD, respectively. Energy absorbed and toughness of apple cultivars were recorded as 39.14 Nmm and 0.53 mJ cm^{-3} (GD), 56.97 Nmm and 0.64 mJ cm^{-3} (SD), 100.02 Nmm and 0.86 mJ cm^{-3} (GS).

Tables 1 and 2 indicate that cultivars affected significantly all the measurements except for density ratio, porosity, deformation energy, and coefficient of dynamic friction on steel, galvanized steel and plywood surfaces.

The apparent colour (a, b) and colour intensity (chroma) of the apple cultivars were found to be statistically significant at the 1% statistical level (Table 3). The cultivar Golden Delicious had the highest *L* (72.98%), *b* (51.18) and chroma (53.32%) values among the three cultivars analysed. However, the SD cultivar with its red skin colour, not surprisingly had a higher *a* value (30.22). The skin colour of apple is accepted as a good indicator for determining maturity in apple cultivars (Reid., 1992). Previously, *L, a* and *b* values of Golden Delicious, Starking Delicious and Granny Smith apple cultivars grown in the lake regions close to the Mediterranean area in Turkey were 73.27, -13.07, 41.15; 46.60, 23.06, 17.45 and 64.70, -16.90, 38.36 (Eren *et al*., 2002), respectively.

There were wide differences among the apple cultivars in terms of both total phenolic content and antioxidant activity ($p<0.05$) (Table 4). The total phenolic content of the apple cultivars per 100 g fresh w. b. ranged from 25.69 mg GAE to 40.96 mg, following the order SD> GD> GS. Earlier, it was reported that there was a wide variation in total phenolic contents among apple cultivars, ranging from 54 to 357 mg/100 g fresh w.b. (Karadeniz *et al*., 2005 Liu *et al*., 2001; Podsedek *et al*., 2000; Wolfe *et al*., 2003;). Our results indicated lower values than the literature data, but they can be comparable to the above results. The phenolic

T a b l e 2. Mechanical properties of apple cultivars

Cultivars	Rupture force (N)	Deformation at rupture (mm)	Energy absorbed (Nmm)	Toughness (mJ cm^{-3})
GD	26.75±2.68c[a]	2.90±0.60a	39.14±10.53c	0.53±0.15c
SD	37.36±5.54b	3.03±0.40a	56.97±13.54b	0.64±0.15b
GS	63.26±7.13a	3.14±0.41a	100.02±21.63a	0.86±0.19a

GD – Golden Delicious, SD – Starking Delicious, GS – Granny Smith. [a]There is no significant difference (P<0.05) between cultivars with the same lowercase letter in the same column.

T a b l e 3. Colour properties of apple cultivars

Colour properties	Golden Delicious	Starking Delicious	Granny Smith
L	72.98 1.70a[a]	40.57 4.14c	64.61 2.04b
a	-14.91 1.29b	30.22 3.62a	-19.30 1.13c
b	51.18 1.70a	19.84 3.58c	39.75 2.16b
Hue (deg.)	106.25 1.54b	33.30 7.00c	115.90 0.68a
Chroma	53.32 1.58a	36.39 2.69c	44.19 2.38b

[a]There is no significant difference (P<0.01) between cultivars with the same lowercase letter in the same row.

T a b l e 4. Chemical properties of apple cultivars

Chemical properties	Golden Delicious	Starking Delicious	Granny Smith	Significant level
Total phenolic content (mg GAE/g d.b.)	31.46±3.31b[a]	40.96±4.46a	25.69±1.48c	*
Antioxidant capacity (%)	63.03±2.02c	74.39±2.91b	79.26±2.36a	*
Total soluble solids (%)	12.50±1.35	14.32±1.18	13.09±1.46	NS
Acidity (%)	0.573±0.024b	0.409±0.018c	0.780±0.044a	**
pH	3.83±0.05b	4.11±0.05a	3.38±0.02c	**
Vitamin C (mg/100 ml)	11.34±0.95b	15.30±0.38a	11.30±0.16b	**

Explanations as in Table 1.

content of apple fruits depends on several factors such as cultivar, climate, degree of ripeness of the fruit and growing area (Karacali, 1990; Karadeniz *et al*., 2005; Wolfe *et al*., 2003). A statistically significant difference ($p<0.05$) in antioxidant activity was found among the samples and β-hydroxyle acids (BHA). The protection of β-carotene bleaching by the samples is lower than that of BHA standard (82.33%). These results agree with those previously reported for apple fruits that had relatively high antioxidant activity and where the antioxidant activity of apple fruits was strongly affected by cultivars (Karadeniz *et al*., 2005; Markowski *et al*., 2007). Antioxidants retard or inhibit the oxidation, possibly by reactive radicals including reactive oxygen species in a biological system. Among the cultivars, cv. Starking Delicious had the highest TSS content (14.32%), followed by cv. Granny Smith (13.09%) and cv. Golden Delicious (12.50%). The SD had also the highest pH (4.11) value, followed by GD (3.83) and GS (3.38). Earlier, it was reported that genetic background of apple cultivars, ecology, soil type and cultural practices applied strongly affect the total soluble solid (TSS) and pH content of apples (Guleryuz *et al*., 2001), and a wide variation in total soluble solids and pH of apple fruits grown in different agroclimatic regions of Turkey are recorded. For example, previously TSS was reported between 11.50-15.86% (SD), 11.50-15.64% (GD) and 12.84-13.47% GS grown in different agroclimatic regions in Turkey (Acican et al., 2007; Eren *et al*., 2002; Gunel and Karacali., 1988; Ozdemir *et al*., 1994). On the other hand, the pH values of apple cultivars grown in the western part of Turkey were recorded as 3.17, 3.28 and 4.04 for GS, GD and SD, respectively (Ozdemir *et al*., 1994). Our TSS and pH results were in accordance of these results. The vitamin C and acidity were 11.30-15.30 mg/100 ml and 0.409-0.780%, respectively. The variation of a vitamin C and acidity in SD,GD and GS apple fruits in Turkey were found between 5-15 mg/100 ml and 0.21-1.13% by Eren *et al*. (2002); Hicyakmazer *et al*. (1994) and Ozyigit (1991). The differences on all four parameters, except vitamin C, were found to be statistically significant at the $p<0.01$ level.

CONCLUSIONS

1. The cultivars of apples affected significantly the physical properties, except density ratio, porosity, deformation energy and coefficient of dynamic friction on steel, galvanized steel and plywood surfaces.

2. The apparent colour (a, b) and colour intensity (chroma) of the apple cultivars were found to be statistically significant ($p<0.01$).

3. The differences in total phenolic content, antioxidant activity, acidity, pH and vitamin C of apple cultivars were found to be statisticaly significant.

REFERENCES

Acican T., Alibas K., and Ozelkok I.S., 2007. Mechanical damage to apples during transport in wooden crates. Biosys. Eng., 96(2), 239-248.

Altuntas E. and Yildiz M., 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. J. Food Eng., 78(1), 174-183.

AOAC, **1984**. Official Methods of Analysis. AOAC Press, Arlington, VA, USA.

Barriere C., Centeno D., Labert A., Leroy-Setrin S., Berdague J.L., and Talon R., 2001. Roles of superoxide dismutase and catalase of *Staphylococcus xylosus* in the inhibition of linoleic acid oxidation. FEMS Microbiology Letters, 201(2), 181-185.

Desphande S.D., Bal S., and Ojha T.P., 1993. Physical properties of soybean. J. Agric. Eng. Res., 56, 89-98.

Ercisli S., 2004.A short review of the fruit germplasm resources of Turkey. Gen. Res. Crop Evol., 51, 419-435.

Eren I., Koyuncu M.A., and Akgul H., 2002. Determination of optimum harvest time for some apple cultivars. Proc. 2nd Symp. Handling and Storage of Horticultural Crops. September 24-27, Isparta, Turkey.

Guleryuz M., Ercisli S., and Erkan E., 2001. Physical and chemical changes during fruit development in apple cultivars in Erzincan plains and their interrelationships. J. Agric. Faculty Ataturk Univ., 32(1), 51-59.

Gunel T. and Karacali I., 1988. Determination the best harvest time for Starking and Golden Delicious grown in Inner Aegean Region in Turkey. J. Agric. Faculty Ege Univ., 22(3), 1-19.

Gupta R.K. and Das S.K., 2000. Fracture resistance of sunflower seed and kernel to compressive loading. J. Food Eng., 46(1), 1-8.

Hicyakmazer T., Agar T., and Kaska N., 1994. Determination of optimum harvest time and storage capability of important apply cultivars grown Pozanti-Kamisli valley. Proc. 3rd Cong. National Climate and Cooling, May 4-6, Adana, Turkey.

Kara M., Guler I.E., and Erkmen Y., 1999. Effect of moisture content on the static particle strength of granular fertilizers. Proc. 7th Int. Cong. Agricultural Mechanisation and Energy in Agriculture, May 26-27, Adana, Turkey.

Karacali I., 1990. Storage and Handling of Horticultural Crops (in Turkish). Ege Univ., Agric. Fac. Press, Ege, Turkey.

Karadeniz F., Burdurlu H.S., Koca N., and Soyer Y., 2005. Antioxidant activity of selected fruits and vegetables grown in Turkey. Turkish J. Agric. Forestry, 29(3), 297-303.

Kaynas K., 1987. Storage capability of important apple cultivars grown in East Marmara Region in Turkey. Ph.D. Thesis, Graduate School of Natural and Applied Sciences, Ege University, Izmir, Turkey.

Liu R.H., Eberhardt M.V., and Lee C.Y., 2001. Antioxidant and antiproliferative activities of selected New York apple cultivars. New York Fruit Quarterly, 9, 15-17.

Markowski J., Płocharski W., and Mieszczakowska M., 2007. Effect of cultivar and processing on phenolics and antioxidant activity of apple products. Acta Hort., 744, 363-368.

McCabe W., Smith J., and Harriot P., 1986. Unit Operations of Chemical Engineering. McGraw-Hill Press, New York, USA.

Mohsenin N.N., 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Press, New York, USA.

Omobuwajo T.O., Akande A.E., and Sanni L.A., 1999. Selected physical, mechanical and aerodynamic properties African breadfruit (*Treculia africana*) seeds. J. Food Eng., 40(4), 241-244.

Omobuwajo T.O., Sanni L.A., and Olajide J.O., 2000. Physical properties of ackee apple (*Blighia sapida*) seeds. J. Food Eng., 45(1), 43-48.

Ozdemir A.E., Agar T., and Kaska N., 1994. Determination of optimum harvest time of some apple cultivars grown in different part in Turkey. Proc. 3rd Nat. Cong. Climate and Cooling, May 4-6, Adana, Turkey.

Ozyigit S., 1991. Determination of pomological properties of important apple and pear cultivars grown in Egirdir. M.Sc. Thesis, Graduate School of Natural and Applied Sciences, Trakya University, Tekirdag, Turkey.

Podsedek A., Wilska-Jeska J., Anders B., and Markowski J., 2000. Compositional characterization of some apple varieties. Eur. Food Res. Technol., 210(4), 268-272.

Reid M.S., 1992. Maturity and maturity indices. In: Postharvest Technology of Horticultural Crops (Ed. A.A. Kader). Division Agriculture and Natural Resources, Publ., 3311, Univ. California Press, Oakland, CA, USA.

Slinkard K. and Singleton V.L., 1997. Total phenol analyses: automation and comparison with manual methods. Am. J. Enology Viticulture, 28(1), 49-55.

Wolfe K., Wu X., and Liu R.H., 2003. Antioxidant activity of apple peels. J. Agric. Food Chem., 51(3), 609-614.