Alinteri J. of Agr. Sci. (2021) 36(1): 21-26
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V36I1/AJAS21004

RESEARCH ARTICLE

Assessment of Some Biotechnical Characteristics of Japanese Crabapple Depending on Fruit Size and Maturity Stage

Onur Saracoglu[1*] • Ebubekir Altuntas[2]

[1*]*Department of Horticulture, Faculty of Agriculture, University of Gaziosmanpasa Tokat, Tasliciftlik, Tokat - Turkey.*

E-mail: onur.saracoglu@gop.edu.tr

[2]*Department of Biosystem Engineering, Faculty of Agriculture, University of Gaziosmanpasa Tokat, Tasliciftlik, Tokat - Turkey.*

E-mail: ebubekir.altuntas@gop.edu.tr

ARTICLE INFO

Article History:
Received: 18.06.2020
Accepted: 09.10.2020
Available Online: 02.02.2021

Keywords:
Japanese crabapple
Maturity
Size
Porosity
Hue Angle
pH

ABSTRACT

In this study, some biotechnical characteristics as affected by the fruit size categories and maturity stage of Japan apple fruits were investigated. Japan apple fruits were graded into three size categories ($20 \le S_1 < 25$ mm,Small; $26 \le S_2 < 31$ mm, Medium, and $32 \le S_3 < 36$ mm, Big) and two maturity stages as Semi Maturity and Full Maturity). The fruit mass and geometric mean diameter varied between 6.46 to 16.69 g, between 22.89 to 31.69 mm according to size categories, while, varied between 10.86 to 11.67 g, between 27.01 to 27.44 mm according to the maturity stage of japan apple fruits, respectively.Generally, as the fruit size increased from S1 to S3, the bulk density decreased, while the fruit size increased from S1 to S3, the porosity increased. The titratable acidity and soluble solid content varied between 1.00 to 3.20%,between 12.89 to 14.06%according to the maturity stageof Japan apple, respectively.

Please cite this paper as follows:

Saracoglu, O. and Altuntas, E. (2021). Assessment of Some Biotechnical Characteristics of Japanese Crabapple Depending on Fruit Size and Maturity Stage. *Alinteri Journal of Agriculture Sciences, 36*(1): 21-26. doi: 10.47059/alinteri/V36I1/AJAS21004

Introduction

Japanese crabapple (Malus floribunda L.) is a small crabapple. The diameter of the Japanese crabapple is 3-5 cm, it has firm skin, and also the taste is acid. The fruit size of the Japanese crabapple is one of the smallest among Malus species. The trees of Japanese crabapple are used for pollination and decoration in common large apple plantations(Cepeda & Villaran, 1999). Japanese crabapple fruit is mainly used for juice production, rarely used in jelly making.Due to their nutritional qualities and superior sensory, cloudy juices production has increased the market potential. The juices of Japanese crabapple are juices are treated with sugary solutions. Concentrated juices of Japanese crabapple concentrated fruit juices show similar density with other comman apple juices.

* Corresponding author: onur.saracoglu@gop.edu.tr
ORCID: 0000-0001-8434-1782

Fruit quality factors of Japanese crabapple fruit are an economically important feature of marketing. These factors are color, firmness, and flavor, and size. Stanley et al. (2001); Atkinson et al. (2001) reported that the environmental factors have affected the size of the Japanese crabapple. Rarefaction of fruits in the early period provides an increase in the fruit sizes in the harvest period: fruit ratio, due to an increase in the leaf of the plant (Forshey & Elfving, 1977; Cepeda & Villaran, 1999).

There are large differences between Malus species in terms of fruit size. For example, some grown apples are usually larger than 10 cm, while Japanese crabapple apples are rarely larger than 5 cm. While the fruits of Malus sieversii (wild apple of Central Asia) are only about 4 cm in diameter, in some trees the size of the fruits exceeds 6 cm, hence approaches many commercial varieties (Luby et al., 2001; Harris et al., 2002).

However, some crabapple varieties have larger fruits, while others have smaller fruits. At this point, noticeable differences in fruit sizes between varieties are of genetic origin even when grown under the same conditions (Harada et al., 2005). The fruit size difference between species in apple fruits is the cell number and / or cell size. Many studies show a very close relationship between the last fruit size and the number of cells.(Bain & Robertson, 1951).

In the design and development of machinery and equipment used in the harvest and post-harvest processing (transportation, processing, storage, and packaging) of Japanese crabapple fruits, the biotechnical properties of the fruits should be determined to take into account the fruit size and maturity level. The size and shape of Japanese crabapple fruits are influenced by varieties and environmental factors. In this sense, these fruit properties are important for the design of harvesting, sorting and sizing systems. Fruit density and viscosity are fruit quality indicators. However, data on fruit density and viscosity are required to design many devices for use in the food processing stage. (Alvarado & Romero, 1989). The chemical and colorproperties of Japanese crabapple fruits should be considered for plant growers, engineers, food scientists, processors and consumers. For post-harvest technologies of Japanese crabapple fruits, the level of maturity, sugar, color, size, soluble solids must be taken into account during processing.

In the scientific literature, there is a lack of technical information and data regarding the evaluation of the biotechnical properties of Japanese crabapple depending on the fruit size and level of maturity. Therefore, in this experiment, it was tried to determine fruit size effecting and ripening stage in evaluating some biotechnical properties of Japanese crabapple fruits.

Material and Methods

Japanese crabapple fruit trees are located in the plantation landscape area of Tokat Gaziosmanpaşa University, Faculty of Agriculture.In this study, fruits were harvested manually from 9 trees during the harvest season in August and September 2015. Tokat is located in the Mid-Black Sea region. Fruits were immediately transferred to the laboratory in plastic packs. Foreign materials, immature and damaged fruits were removed from the sample and cleaned.

To determine the Japanese crabapple fruits, the size categories and maturity stages; the fruits were graded into three fruit size ($20 \leq S_1 < 25$ mm as Small, $26 \leq S_2 < 31$ mm as Medium, and 32 $\leq S_3 <$ 36 mm as Big) and two maturity stages as Semi Maturity and Full Maturity stages (Figure 1). For each category, One hundred Japanese crabapple fruits were randomly selected for size dimension at three fruit size categories and maturity stages with three replicates. The dimensions (length, width and thickness) of and the skin thickness (T_s) were measured with a digital caliper of Japanese crabapple fruitswas measured by a dial-micrometer (Model No; CD-6CSX, Mitutoyo, Japan) to an accuracy of 0.01mm. The fruit masses of Japanese crabappleswere measured with an electronic scale (Kern EW 620- 3 NM, Germany) a0.001 g. accuracy resolution.

a)

b)

Figure 1. The *samples of* Japanese crabapple fruits according to three size categories (S_1, $S_2$and S_3 and maturity stages (Semi maturity (a), and Full maturity (b).

The geometric mean diameter (D_g), sphericity (Φ), volume (V), surface area (S) of Japanese crabapple fruit samples were determined using the following equations:

$$D_g = (abc)^{1/3} \quad (1)$$

$$\boldsymbol{\Phi} = \left[\frac{(\boldsymbol{abc})^{1/3}}{\boldsymbol{a}}\right] \mathbf{100} \quad (2)$$

$$V = \left(\frac{\pi}{6}\right) abc \quad (3)$$

$$S_a = \pi D_g^{\ 2} \quad (4)$$

Where *a*= length (mm), *b* = width (mm),c: thickness (mm), *V* = volume (mm^3), S_a = surface area (mm^2) (Mohsenin, 1986).

Liquid displacement technique was used to measure the density of Japanese crabapple fruits, in this process toluene (C_7H_8) was used as liquid.The standard hectolitre method was used to determine the bulk density of the fruits (Altuntas et al., 2013). Porosity (ε) is determined by the following equation:

$$\varepsilon = \left[1 - \frac{\rho_b}{\rho_f}\right] \times 100 \quad (5)$$

Where ρ_b and ρ_f are the bulk and fruit densities, respectively (Mohsenin, 1980).

*L**, *a**, *b** measurements as color properties for Japanese crabapple fruits were determined using a Minolta colorimeter (Minolta Corp., Model CR-300, Japan). As the colour of the fruits; *L** identifies dark or light; *a**identifies red or green; and *b** identifies the yellow or blue. The color properties of Japanese crabapple fruits were measured at three points for each fruit according to fruit size categories and maturity levels. All the colour measurements of Japanese crabapple fruitswere conducted on the skin surface of fruits (Jha et al., 2005). The other color parameters (Hue angle and chroma) of the fruits are effective parameters for describing the visual colour appearance. Following equation was used for calculating these parameters. (Bernalte et al., 2003):

$$h^{\circ} = \left[\tan^{-1}\frac{b*}{a*}\right] \quad (6)$$

$$C = \left(a*^2 + b*^2\right)^{\frac{1}{2}} \quad (7)$$

The chemical properties, such as the pH of Japanese crabapple fruits, have been determined according to the methods offered by the Official Analytical Chemists Association (1984). The total soluble solids content (TSSC) and titration acidity (TA) of Japanese crabapple fruits were determined with a digital refractometer (McCormick Fruit Tech., PAL-1, Yakima, Wash.), and by titration with 0.1 N NaOH, respectively.The effects of fruit sizes and maturity stages on the some biotechnical (physical, colour, and chemical) characteristics of Japanese crabapple fruits were determined using ANOVA (Analysis of Variance) method. Duncan's least significant difference test was used with SAS software for means compared.

Results and Discussion

Physical Properties

The physical properties of Japanese crabapple fruits as depending on changes by fruit size categories (Small, Medium, and Big), and maturity stage (Semi and Full)are presented in Table 1. The geometric mean diameter and surface area of Japanese crabapple fruits varied between 22.9 to 31.7 mm, 16.6 to 31.6 mm with increasing fruit sizes from S_1 to S_3 fruit size, respectively. The geometric mean diameter, sphericity, surface area, and skin thickness of Japanese crabapple fruits varied between 27.4 to 27.0 mm, 0.94 to 0.97, 24.2 to 23.5 mm, 0.37 to 0.42 mm for semi and full maturity stages, respectively (Table 1). The size dimension (*a*, *b*, *c*), geometric mean diameter, skin thickness, surface area, and sphericity of Japanese crabapple fruits were affected significantly by fruit size categories and maturity stages. All mentioned these properties values were found to be higher in big fruit size than the other fruit size categories.The size dimension (*a, b, c*), geometric mean diameter were as 74.8, 83.8, 80.4, and 79.5 mm for Redspar apple samples, while same geometrical parameters were as 58.3, 67.0, 65.0, and 63.4 mm for Delbarstival apple samples, respectively reported by Tabatabaeefar and Rajabipour (2005). The length and width were found to be 30.3 mm and 19.9 mm for Dura palm cultivar, respectively reported by Owolarafe et al. (2007). The surface area, geometric mean diameter, and sphericity were found as 91.97 cm^2, 79.8%, and 54.1 mm, for kiwifruits respectively reported that by Razavi and Parvar (2007). The geometric mean diameter, length, width, thickness size dimension length, width, and thickness were obtained as 69.0, 63.6, 73.6, 71.2 mm for Braeburn apple, respectively reported by Ozkan et al (2012). The surface area and sphericity of medlar fruits ranged between 29.7 to 22.6 mm^2, 0.97 to 0.95 with the maturity stage from physiological maturity to ripening period, respectively reported by Altuntas et al. (2013).

Table 1. The effects of fruit sizes and maturity stages on the physical properties of Japanese crabapple fruits

	Physical properties (*)											
Categories	***a (mm)***	***b (mm)***	***c (mm)***	***D_g (mm)***	***ϕ***	***S (mm^2)***	***T_s (mm)***	***M (g)***	***V (mm^3)***	***ρ_b (kg/m^3)***	***ρ_f (kg/m^3)***	***P (%)***
Fruit size												
S_1 (Small)	21.00 c*	23.95 c	24.53 c	22.89 c	0.96 a	16.61 c	0.40 a	6.46 c	6.51 c	448.32 a	931.29 a	51.57 a
S_2 (Medium)	24.89 b	28.31 b	28.64 b	27.10 b	0.96 a	23.14 b	0.40 a	10.64 b	10.62 b	439.14 b	952.65 a	53.20 a
S_3 (Big)	29.52 a	33.41 a	32.71 a	31.69 a	0.95 a	31.64 a	0.38 a	16.69 a	16.98 a	432.62 c	938.03 a	53.50 a
Maturity stage												
Semi	24.79 a	29.11 a	29.28 a	27.44 a	0.94 a	24.15 a	0.37 b	11.67 a	11.60 a	439.67 a	954.96 a	53.24 a
Full	25.48 a	28.00 b	27.98 b	27.01 a	0.97 b	23.45 a	0.42 a	10.86 b	11.14 a	438.58 a	929.38 a	52.56 a
Significance	0.0795	0.1887	0.4241	0.1187	0.9905	0.1448	0.9868	0.4751	0.2433	0.0454	0.249	0.0956

(*): L: Length, W: Width, T: Thickness, Dg: Geometric mean diameter, ϕ: Sphericity, S: Surface area, T_s:Skin thickness, M: Fruit mass, V: Fruit volume, ρ_b: Bulk density,
ρ_f Fruit density, P: Porosity,
*: The means in the same group not followed by the same letter (within the same line) are not significantly different (P =0.05)

The bulk density of Japanese crabapple fruits varied between 448.4 to 432.6 kg m^{-3}, while fruit density varied between 931.3 to 952.7 kg m^{-3} for fruit size categories, respectively (Table 1). The bulk density of Japanese crabapple fruits commonly decreased as fruit size increased from S_1 to S_3, the porosity of Japanese crabapple fruits commonly increased as fruit size increased from S_1 to S_3. The porosity, fruit, and bulk densities decreased from semi maturity to full maturity stage of Japanese crabapple fruits. The effects of fruit size categories and maturity stages on volumetric properties (bulk and fruit densities, porosity, fruit mass and volume) of Japanese crabapple fruits were statistically significant. The fruit volume and fruit mass increased with increasing fruit size categories from S_1 to S_3, whereas, the fruit mass and fruit volume decreased with increasing maturity stage from semi-maturity to full maturity stage for Japanese crabapple fruits.

The bulk density, porosity, and fruit density for wild medlar fruits were found as 380 kg m^{-3}, 63%, and 1031 kg m^{-3} for the ripening period reported by Haciseferogullari et al (2005). The sphericity, geometric mean diameter, the porosity and fruit density were found as 80%, 54 mm, 43%, and 996 kg m^{-3}, respectively reported by Razavi and Parvar (2007). The bulk density, porosity, and fruit density for medlar fruits varied for the physiological maturity to ripening period from 257 to 308 kg m^{-3}, from 75 to 67%, and from 1049 to 934 kg m^{-3} by the maturity stages, respectively reported by Altuntas et al (2013). The fruit density of Japanese crabapple fruits was similar to the experimental data were reported by Haciseferogulları et al. (2005) reports, whereas, the bulk density was found higher than that of Altuntas et al. (2013) and Haciseferogulları et al. (2005).

Colour Characteristics

Colour characteristics of Japanese crabapple for skin and flesh fruits were presented in Table 2. For the skin fruits of Japanese crabapple fruits, *L***, *a***, and *b*** characteristics were found between 37.02 to 38.26; 17.26 to 19.70; 41.71 to 43.60, respectively, whereas, for flesh, fruits were found between 59.60 to 62.28; 5.24 to 7.45; 29.08 to 31.49 for S_1 to S_3 fruit size categories, respectively. Hue angle and chroma for Japanese crabapple skin fruits ranged from and 65.04 to 68.30 and 46.26 to 48.12; whereas, for the flesh, fruits ranged from 16.95 to 35.65 and 30.82 to 33.33 for S_1 to S_3 fruit size categories, respectively (Table 2). Among the skin color variables, *L*** exhibited *a*** decrease as the fruits mature. *b*** and hue angle demonstrated similar patterns, while the *a** and chroma variables displayed increase pattern. For maturity stages of Japanese crabapple flesh colour parameters, *a** and *b**, *C** and h° increased from semi-maturity to full maturity stage, while *L** decreased.

Table 2. The effects of fruit sizes and maturity stage on the colour characteristics (L*, a*, b*, Chroma, hue angle) of Japanese crabapple fruits.

Categories	Colourcharacteristics									
	Skin					Flesh				
Fruit sizes	*L**	*a**	*b**	*C*	*h°*	*L**	*a**	*b**	C	H
S1 (Small)	37.02 b	19.70 a	43.60 a	48.12 a	65.90 a	59.60 b	5.24 a	30.43 a	31.67 a	35.65 a
S2 (Medium)	37.83 a	17.26 a	42.76 a	46.46 a	68.30 a	62.28 a	6.58 a	31.49 a	33.33 a	16.95 a
S3 (Big)	38.26 a	19.63 a	41.71 a	46.26 a	65.04 a	60.73 ab	7.45 a	29.08 a	30.82 a	23.19 a
Maturity stages										
Semi	42.11 a	17.09 b	42.75 a	46.40 a	68.58 a	64.33 a	-0.23 b	28.25 b	28.49 b	-11.64 b
Full	33.30 b	20.64 a	42.64 a	47.49 a	64.25 b	57.41 b	13.08 a	32.42 a	35.39 a	62.16 a
Significance	0.0826	0.1729	0.2158	0.1113	0.2492	0.2744	0.307	0.4945	0.2913	0.3627

Celik et al. (2008) reported that *L**, *a**, and *b** for the kiwifruit skin colours (cv. Hayward) were found as 44.9, 5.5 and 24.0; whereas, Costa et al. (2006) reported that for kiwifruit flesh colours were found as 56.4, -17.5, 32.4, respectively. Reported that the skin colour characteristics of Braeburn apple such as *h*° and *C** and were as 39.6 and 40.1, respectively reported by Ozturk et al. (2012a). Braeburn apple skin colour for *h*° and *C** were found as 40.7 and 40.1, whereas, for flesh were as 95.3 and 37.6, respectively reported by Ozkan et al. (2012). For Fuji apple skin colour *L**, *a**, *b** were as 53.5, 24.6 and 26.1, respectively by reported by Altuntas et al. (2012). In this study, *h*° value was found to be similar to the results given by Ozturk et al. (2012a) for Braeburn apple, whereas, *a** and *b** were similar to the findings reported by Celik et al. (2008); Altuntas et al. (2012) for kiwifruit and Fuji apple.

Chemical Properties

The chemical properties such as total soluble solids content, titration acidity, pH of Japanese crabapple fruits were given in Table 3. The total soluble solids content, titratable acidity, pH of Japanese crabapple fruits varied between 5.73 to 6.13%; 0.132 to 0.179 %; 6.08 to 6.19 for fruit size, whereas, 12.89 to 14.06%; 1.00 to 3.20 %; 3.20 to 3.28 for maturity stages, respectively. There was an overall increase in TSSC and TA, while pH averages decreased as the fruits matured. In general, TSSC and pH content of Japanese crabapple fruits decreased as fruit size increased. TA, pH, and TSSC for Red Chief apple changed from 0.18 to 0.24 %, 3.3 to 3.9, and 10.4 to 11.4% respectively reported by Ozturk et al (2012b). TA and pH for wild medlar fruits at the ripening period were found as and 0.3 %, and 4.3 reported by Haciseferogullari et al. (2005). pH, TA, and TSSC for Fuji apple were 3.1, 0.4 %, 14.0% respectively by reported by Ozturk et al. (2013a). Ozturk et al. (2013b) reported that TA, pH, and TSSC for Braeburn apple were 0.86 %, 2.87, and 15.44%, respectively. In this study, for Japanese crabapple fruits, pH is similar to the results reported by Ozturk et al. (2012b); Ozturk et al. (2013b).

Table 3. The effects of fruit sizes and maturity stages on the chemical properties of Japanese crabapple fruits.

		Chemical properties		
Categories		pH	TA(%)	TSSC (%)
Fruit sizes	S_1 (Small)	3.28 a	1.22 a	13.68 a
	S_2 (Medium)	3.23 b	3.75 a	13.45 ab
	S_3 (Big)	3.21 b	1.33 a	13.28 b
Maturity stages	Semi	3.28 a	1.00 a	12.89 b
	Full	3.20 b	3.20 a	14.06 a
	Significance	0.4813	0.4069	0.0001

Conclusions

In this study, the effects of maturity stage and fruit size categories on fruit mass, fruit volume, bulk density, fruit porosity, and fruit density for Japanese crabapple fruits were statistically significant. The size dimensions, sphericity, geometric mean diameter, surface area, and skin thickness of Japanese crabapple fruits were affected significantly by fruit size categories and maturity stages. The fruit volume and mass for Japanese crabapple fruits increased with increasing fruit size S_1 to S_3 size categories, whereas, the fruit mass and fruit volume decreased with increasing maturity stage from semi-maturity to full maturity stage. The sphericity, surface area, size dimensions, skin thickness, and geometric mean diameter were measured higher in big size than medium and small size categories. In general, the chemical properties of Japanese crabapple were affected by fruit size categories and maturation stages. There was an overall increase in TSSC and TA, while pH values decreased as the fruits matured. TSSC and pH content of Japanese crabapple fruits generally decreased as fruit size increased.

More detailed studies about the physical, colour characteristics and chemical characteristics of Japanese crabapple fruits for different size categories and maturity stages need to be pursued and their relation to phytochemical content, flavour and other attributes should be carried out. Moreover, for Japanese crabapple fruits, biotechnical characteristics require the design of processes, structures, and machines at post-harvest applications. To a new product development, evaluate and maintain the final product the quality for the consumer, the biotechnical characteristics must be considered. Further research could elucidate the main sources of quality of different size categories and maturity stages of Japanese crabapple fruits, which could help in genetic improvement programs.

References

Altuntas, E., Ozturk, B., Ozkan, Y., and Yildiz, K., 2012. physico-mechanical properties and colour characteristics of apple as affected by methyl jasmonate treatments. *International Journal of Food Engineering,* 8(1): 1-16.

Altuntas, E., Yilmaz, G., Karan, Y.B., and Dulger, E., 2013. Assessment the physicomechanical, chemical and colour characteristics of potatoes depending on tuber size and cultivar. *International Journal of Food Engineering,* 9(4): 487-498.

Alvarado, J.D., and Romero, C.H., 1989. Physical properties of fruits I. density and viscosity of juices as functions of soluble solids content and temperature. *Latin American Applied Research,* 19(15): 15–21.

Anonymous, 2016. Marvelous Malus. http://www.bbg.org/gardening/article/marvelous_malus.

Atkinson, C.J., Taylor, L., and Kingswell, G., 2001. The importance of temperature differences, directly after anthesis, in determining growth and cellular development of Malus fruits. *The Journal of Horticultural Science and Biotechnology,* 76(6): 721–731.

Bain, J.M., and Robertson, R.N., 1951. The physiology of growth in apple fruits I. Cell size, cell number, and fruit development. *Australian Journal of Biological Sciences,* 4(2): 75-91.

Bernalte, M.J., Sabio, E., Hernandez, M.T., and Gervasini, C., 2003. Influence of storage delay on quality of 'Van' sweet cherry. *Postharvest Biology and Technology*, 28(2): 303-312.

Celik, A., and Ercisli, S., 2008. Persimmon cv. Hachiya (Diospyros kaki Thunb.) fruit: some physical, chemical and nutritional properties. *International Journal of Food Sciences and Nutrition*, 59(7-8): 599-606.

Cepeda, E., and Villaran, M.C., 1999. Density and viscosity of Malus floribunda juice as a function of concentration and temperature. *Journal of Food Engineering*, 41(2): 103-107.

Forshey, C.G., 1977. Fruit numbers, fruit saize, and yield relationships in 'McIntosh' apples. *Journal of the American Society for Horticultural Science*, 102: 399-402.

Hacıseferogˇulları, H., Özcan, M., Sonmete, M.H., and Özbek, O., 2005. Some physical and chemical parameters of wild medlar (Mespilus germanica L.) fruit grown in Turkey. *Journal of Food Engineering*, 69(1): 1-7.

Harada, T., Kurahashi, W., Yanai, M., Wakasa, Y., and Satoh, T., 2005. Involvement of cell proliferation and cell enlargement in increasing the fruit size of Malus species. *Scientia horticulturae*, 105(4): 447-456.

Harris, S.A., Robinson, J.P., and Juniper, B.E., 2002. Genetic clues to the origin of the apple. *TRENDS in Genetics*, 18(8): 426-430.

Jha, S.N., Kingsly, A.R.P., and Sangeeta, C., 2005. Physical and mechanical properties of mango during growth and storage for determination of maturity. *Journal of Food Engineering,* 72(1): 73-76.

Luby, J., Forline, P., Aldwinckle, H., Bus, V., and Geibel, M., 2001. Silk road apples, collection, evaluation and utilization of Malus sieversii from Central Asia. *Hort Science,* 36(2): 225–231.

Mohsenin, N.N., 1980. *Physical properties of plant and animal materials.* Gordon and Breach Science Publishers, New York.

Owolarafe, O.K., Olabige, M.T., and Faborode, M.O., 2007. Physical and mechanical properties of two varieties of the fresh oil palm fruit. *Journal of Food Engineering,* 78(4): 1228–1232.

Ozkan, Y., Altuntas, E., Ozturk, B., Yildiz, K., and Saracoglu, O., 2012. The effect of NAA (1-naphthalene acetic acid) and AVG (aminoethoxyvinylglycine) on physical, chemical, colour and mechanical properties of Braeburn apple. *International Journal of Food Engineering,* 8(3): 1-18.

Ozturk, B., Altuntas, E., Yildiz, K., Ozkan, Y., and Saracoglu, O., 2013a. Effect of methyl jasmonate treatments on the bioactive compounds and physicochemical quality of 'Fuji' apples. *Ciencia e Investigación Agraria (Cien. Inv. Agr.),* 40(1): 201-211.

Ozturk, B., Altuntas, E., Ozkan, Y., and Yıldız, K., 2012a. Effect of AVG treatments on some physico-mechanical properties and colour characteristics of apple (*Malus domestica* Borkh.). *Bulgarian Journal of Agricultural Science,* 18(6): 871-879.

Ozturk, B., Yıldız, K., Ozkan, Y., Cekic, C., and Kılıc, K., 2012b. The effect of Aminoethoxyvinylglycine (AVG) and Naphthalene Acetic Acid on the preharvest drop and fruit quality in Red Chief apple variety. *Anadolu Journal of Agricultural Sciences,* 27(3):120-126.

Ozturk, B., Ozkan, Y., Altuntas, E., Yıldız, K., and Saracoglu, O., 2013b. Effect of aminoethoxyvinylglycine on biochemical, physico-mechanical and color properties of cv. 'Braeburn' apple (*Malus domestica* Borkh). *Semina: Ciencias Agrarias,* 34(3): 1111-1120.

Razavi, S.M., and Parvar, M.B., 2007. Some physical and mechanical properties of kiwifruit. *International Journal of Food Engineering,* 3(6): 1-14.

Stanley, C.J., Stokes, J.R., and Tustin, D.S., 2001. Early precision of apple fruit size using environmental indicators. *Acta Horticulturae (ISHS),* 557: 441–446.

Tabatabaeefar, A., and Rajabipour, A., 2005. Modeling the mass of apples by geometrical attributes. *Scientia Horticulturae,* 105(3): 373–382.