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ORIGINAL PAPER

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DETERMINATION OF PHYSICO-MECHANICAL PROPERTIES OF SOME DOMESTIC AND FOREIGN WALNUT (*Juglans regia* L.) VARIETIES

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ABSTRACT

In this research, we examined some of the physical (fruit dimensions, geometric mean diameter sphericity and surface area) and mechanical (puncture force, deformation, energy absorption and hardness) properties on the four different domestic (Şebin, Kaman, Bilecik and Yalova-3) and two different foreign (Chandler and Fernor) walnut (*Juglans regia*) varieties. For this purpose, we applied puncture force on the walnuts at the direction of width orientation (x–x), length orientation (y–y) and suture orientation (z-z). According to obtained results, there are significant differences among the walnut varieties for crustacean walnut weight and walnut weight. The maximum and minimum values of crustacean walnut weight were observed as 18.27 g and 10.98 g for Kaman and Chandler, respectively. In addition to these results, Bilecik has a maximum walnut weight – 8.71 g, while the minimum walnut weight was observed for Yalova-3 – 4.57 g. Furthermore, geometric mean diameter and sphericity values ranged to 31.93–38.57 mm and 82.78–92.54%, respectively. There are statistically significant differences on the puncture force, deformation, energy absorption and hardness according to the load axes. The maximum and minimum puncture force values were determined at the Fernor (572 N) with y–y axes and Chandler (211.9 N) with z–z axes, respectively. Also, the highest hardness and the lowest deformation values were obtained for Kaman (y–y axes) and the highest deformation and the lowest hardness were determined at Bilecik (x–x axes). The energy absorption values changed as follows: 0.455–1.086 J, 0.404–0.985 J and 0.426–1.051 J for x–x, y–y and z–z axes, respectively.

Key words: physical properties, mechanical properties, walnut

INTRODUCTION

Turkey is located on one of the genetic diversity centers of walnut with about 195 000 tons walnut production [Sen 1986, Akca 2009, FAO 2016] and ranks fourth in annual walnut production after China (1 785 879 tons), US (607 814 tons), and Iran (405 281 tons). A large part of walnut production in Turkey is from the seed grown trees. Nevertheless, in recent years there has been an increase in the number of walnut orchards planted with standard varieties [Çiftçi 2004]. Varieties such as Şebin, Bilecik, Kaman, and Yalova-3 are widely grown in the walnut orchards [Şen 2011]. In addition to the number of orchards established with the imported (Non-Turkish) varieties such as Chandler and Fernor is also increasing [http://ogm.gov.tr/kutuphane/Yayinlar/Ceviz%20Eylem%20Plan%C4%B1.pdf].

Various important studies have been carried out concerning the physical and mechanical properties

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of nuts such as raw cashew [Balasubramanian 2001], walnut [Çağlarırmak 2003, Koyuncu et al. 2004, Koçtürk and Gürhan 2007, Altuntas and Özkan 2008, Ercisli et al. 2011], almond [Ledbetter et al. 2006, Arslan and Vursavus 2008, Rasouli et al. 2010, Mirzabe et al. 2013, Sunmonu et al. 2015], hazelnut [Valentini et al. 2006, Kibar and Öztürk 2009, Delprete and Sesana 2014, Giacosa et al. 2016], pistachio [Kashaninejad et al. 2006, Altuntas and Mutlu 2007, Galedaret al. 2009], chestnut [Yurtlu and Yeşiloğlu 2011].

In extent. Postharvest separation of the kernels from the shell is conducted manually with hammers [Şen 2011]. In the production process, crushing is one of the most important steps in extracting the high quality walnut kernels. The successful removal of the whole walnut kernel from the shell is a direct attribute to the total retail price and thus an important economic goal. Therefore, easy breakage of the walnut shell and removal of the walnut kernels as a whole from the shell will reduce both labor and cost and increase the market value of the walnut [Akça 2009]. In this regard, the physical and mechanical properties of walnut varieties should be considered while developing new product processing machines [Güzelet al. 1999].

In this study, we aimed to determine the physical and mechanical properties of four Turkey origin walnuts varieties (Şebin, Bilecik, Kaman and Yalova-3) and 2 foreign origin walnut varieties (Chandler, Fernor).

MATERIALS AND METHODS

In this study utilized 6 different types of walnuts. All the varieties were obtained from local producers in Diyarbakır (Şebin, Bilecik, Kaman, Yalova-3) and Kocaeli (Chandler and Fernor) provinces.

In this research, Şebin, Bilecik, Kaman and Yalova-3 walnut varieties are Turkey's special walnut varieties. In addition, Chandler and Fernor walnut varieties are ABD and France's special walnut varieties, respectively [Şen 2011]. All of the varieties which used in this research has commercial importance.

The measurements regarding the physical and mechanical aspects of the walnut specimens were carried out in the biological material laboratory at the Iğdır University Agricultural Faculty Department of Biosystems Engineering. Prior to the experiments, all samples were exposed to 105°C for 24 h for moisture content determination and uniformity. The moisture contents of the shell and the kernel were found to be 3.87% and 2.14% for Şebin, 6.01% and 2.76% for Bilecik, 6.35% and 2.90% for Kaman, 12.56 and 4.78% for Yalova-3, 5.19 and 2.82% for Chandler and 10.52% and 3.13% for Fernor respectively.

The length, thickness, and width of the walnut specimens were determined using a digital caliper with a sensitivity of 0.001 mm. In addition, the weight of each sample was recorded with a 0.01 g precision scale. The geometric mean diameter and sphericity values of the walnut specimens were calculated using Equation 1 and Equation 2 [Olajide and Ade-Omowaye 1999, Aydin 2003].

$$D_g = (L \cdot W \cdot T)^{1/3} \tag{1}$$

$$ø = (D_g/L) \cdot 100 \tag{2}$$

In these equations, Dg represents the geometric mean diameter (mm), $Ø$ is roundness (%), L corresponds to the length (mm), W is the width (mm), and T is the thickness (mm).

The surface areas of walnut samples were calculated using the following equation. In this equation S is surface area (mm^2):

$$S = \pi \cdot (D_g)^2 \tag{3}$$

In order to determine the mechanical properties of walnuts, MITECH brand dynamometer and dynamometer stand were used. Loading directions were set in the top surface (x–x), the vertical surface (y–y) and the side surface (z–z) directions of the walnuts and the force values at the cracking moment were determined from the dynamometer as N value (Fig. 1). The dynamometer stand was set for the loading speed of 1 mms^{-1}.

Energy absorption during fracture of samples [Altuntas and Yildiz 2007] and hardness values [Sirisomboonet al. 2007] were calculated using Equations 4 and 5.

$$E_a = 0{,}5 \cdot (Fr \cdot Dr)/1000 \tag{4}$$

$$Q = \frac{Fr}{Dr} \tag{5}$$

In these equations, E_a represents the absorbed energy (mJ), Fr is the breaking force (N), Dr is the deforma-

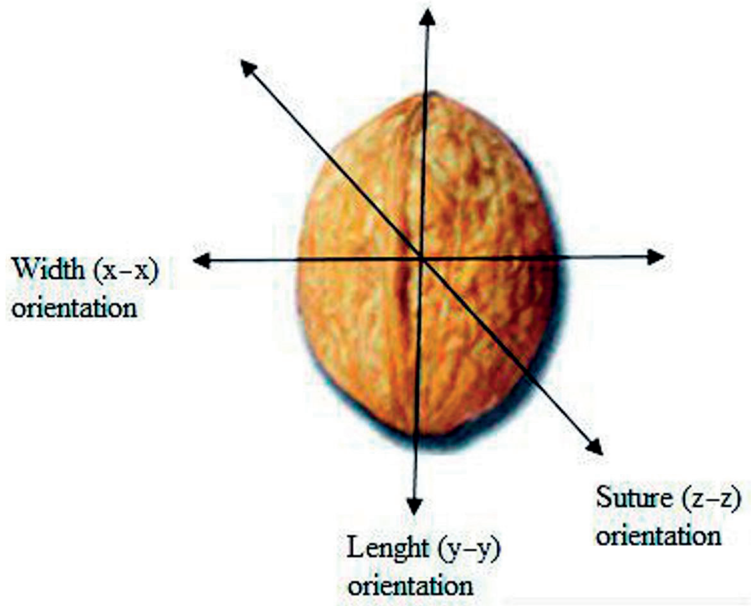

Fig. 1. Representation of the three axes for the walnut (*Juglans regia*) compression test

tion in fracture (mm), and Q is the hardness (Nmm^{-1}).

Statistical evaluations. Analysis of the variance (ANOVA) was conducted on the mean values to assess different properties of walnuts. Significant differences among the means were determined using the protected least significant difference (LSD) tests at probability level of 0.05.

RESULTS AND DISCUSSION

Physical properties. The analysis of variance for the physical characteristics investigated in the present study and the multiple comparison test results are given in Table 1.

The results indicated that the physical properties of the nuts vary significantly among the varieties tested here ($P < 0.01$). The overall length, width, and thickness values of walnut varieties revealed that Bilecikhas the biggest nut size where as Fernorhas the smallest among all the variety evaluated here. The average weight of an unshelled nut for each variety ranged from 11.6 g to 18.27 g. The highest unshelled nut weight was found in Kaman and the lowest was in Chandler. Among the walnut varieties analyzed here, the highest kernel weight was measured in Bilecik with a mean value of 8.71 g for each nut and the lowest value was recorded in the Yalova-3 with a mean of 4.57 g. In an earlier study, nut weight of Maraş-18 variety reported to be in the range between 12.44 g and 12.70 g and that of Yalova-1 varieties were ranged from 7.38 g to 7.40 g [Ercisli et al. 2011]. As expected, the geometric mean diameters of walnuts were ranged according to the length, width and thickness measurements. The Bilecik variety had a geometric mean diameter of 38.57 mm, where as in Yalova-3 the value recorded as 31.93 mm. In addition, the highest sphericity value was found in Yalova-3 (92.54%). Among the varieties of walnut, Kaman was found to have the thinnest shell with an average thickness of 1,198 mm, followed by Fernor with 1.394 mm and Bilecik with 1.657 mm. Chandler was found to have the thickest shell with 2.168 mm. In an earlier study, Ercisli et al. [2011] reported the geometric diameters of 36.33 mm and 36.83 mm in the Maras-18 and Yalova-1 varieties, respectively. The sphericity values of the both varieties were determined as 87.41% and 81.08%, respectively. The results obtained in this study were similar to those reported previously. When the surface

Table 1. Variance analysis and multiple comparison test results of physical properties of walnut varieties

Physical properties	Bilecik	Kaman	Şebin	Yalova-3	Chandler	Fernor
Lenght (mm)	43.86 a*	44.22 a	42.94 a	34.54 d	40.88 b	39.05 d
Width (mm)	35.50 a	34.95 a	31.17 b	30.00 c	30.86 c	31.51 b
Thickness (mm)	36.91 a	36.70 a	33.53 b	31.46 c	32.37 c	31.90 c
Nut weight (g)	16.21 a	18.27 a	12.83 b	11.60 bc	10.98 c	11.70 bc
Shell thickness (mm)	1.394 c	1.198 c	1.965 a	2.093 a	2.168 a	1.657 b
Kernel weight (g)	8.71 a	7.83 a	5.62 b	4.57 c	5.26 bc	6.04 b
Geo. mean diameter (mm)	38.57 a	38.42 a	35.53 b	31.93 d	34.43 c	33.98 c
Sphericity (%)	88.30 b	86.90 b	82.78 c	92.54 a	84.28 c	87.01 b
Surface area (mm^2)	4679.9 a	4640.5 a	3966.6 b	3203.3 d	3723.5 c	3628.8 c
P	0.001	0.001	0.001	0.001	0.001	0.001

*The differences between the averages with the same letter on each line are statistically insignificant at the level of $P < 0.05$ probability

Table 2. The behaviors under force of walnut varieties

	Cracking force (N)	Deformation (mm)	Energy absorbed (J)	Hardness (Nmm^{-1})
Bilecik	276.69 cd*	4.18 a	0.579 cd	480.90 b
Kaman	338.10 bc	4.03 ab	0.687 bc	500.57 ab
Şebin	371.70 b	4.00 ab	0.751 bc	503.60 ab
Yalova-3	390.70 b	4.09 ab	0.796 b	490.92 ab
Chandler	210.10 d	4.03 ab	0.428 d	499.51 ab
Fernor	539.40 a	3.85 b	1.041 a	519.77 a
Loading orientation	Cracking force (N)	Deformation (mm)	Energy absorbed (J)	Hardness (Nmm^{-1})
Width	423.2 a	4.09 a	0.863 a	491.77 a
Suture	324.6 b	4.01 a	0.656 b	500.65 a
Lenght	315.5 b	3.99 a	0.627 b	505.25 a

* The differences between the averages with the same letter on each line are statistically insignificant at the level of $P < 0.05$ probability

areas of the nuts were examined, the Bilecik variety had a surface area of 4679.9 mm^2 and had the largest nut surface area.

The magnitude of the force required to crack the walnuts ranged from 539.40 N to 276.69 N, resulting deformations after applying the force ranged from 3.85 mm to 4.18 mm, and hardness values ranged from 519.70 Nmm^{-1} to 480.90 Nmm^{-1}. Among the walnuts examined in the study, Fernor had the highest cracking force, energy absorption, and hardness values. In an analogous manner, the highest cracking force was reported for Yalova-3 with a 383.9 N [Koyuncuet al. 2004] and for Maras-18 with a 227.6 N [Ercisliet al. 2011] when the force applied from a latitudinal direction.

When the deformation values were examined, the Bilecik variety nuts were observed to be the most affected from the force applied (Tab. 2). During force application from the above, the maximum values were obtained in terms of the cracking force, the deforma-

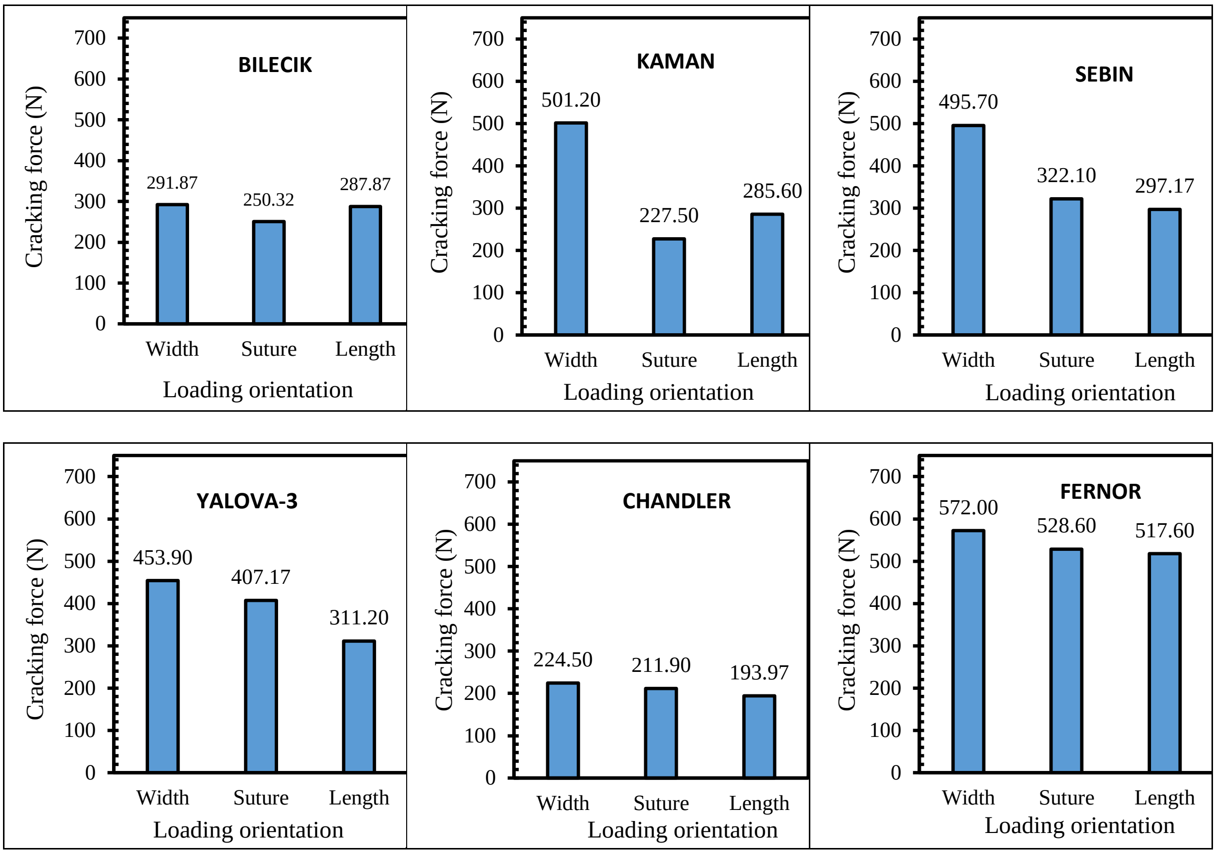

Fig. 2. The change of cracking force

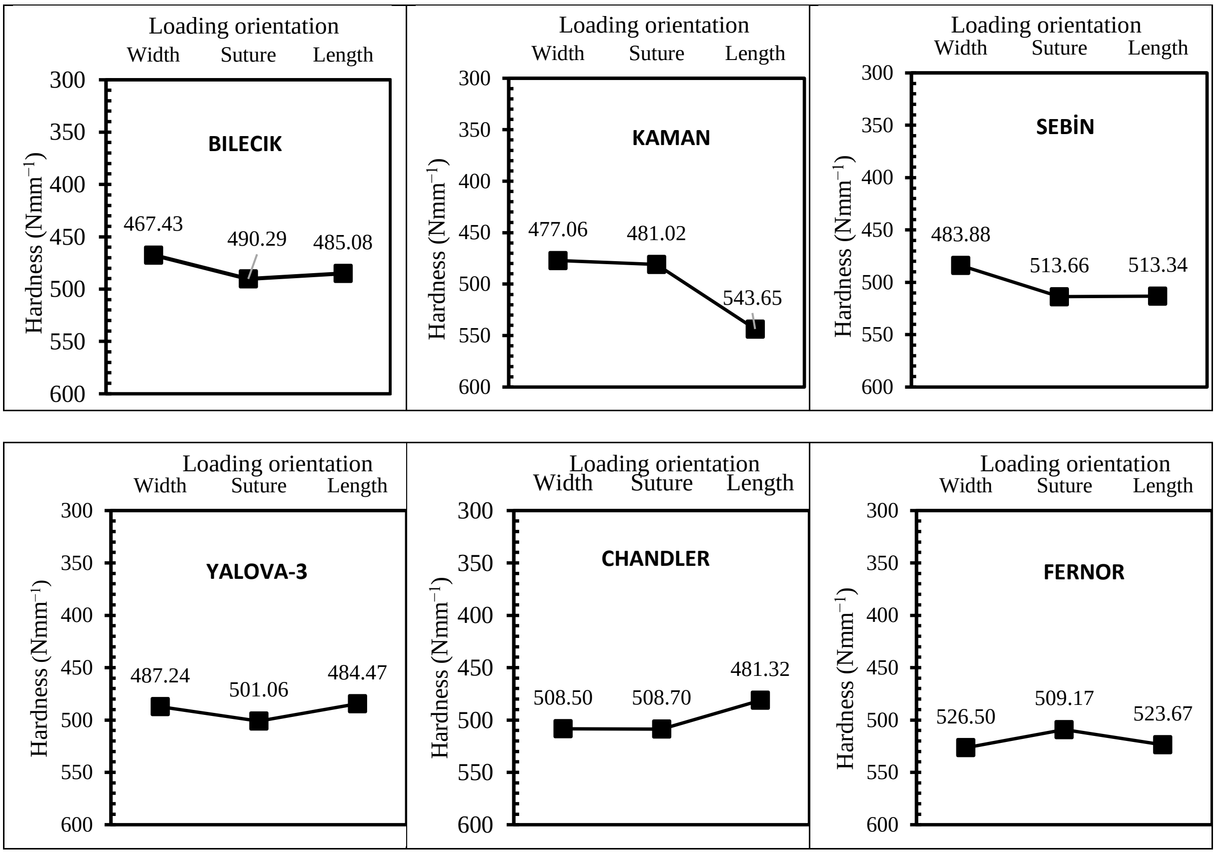

Fig. 3. The change of hardness values

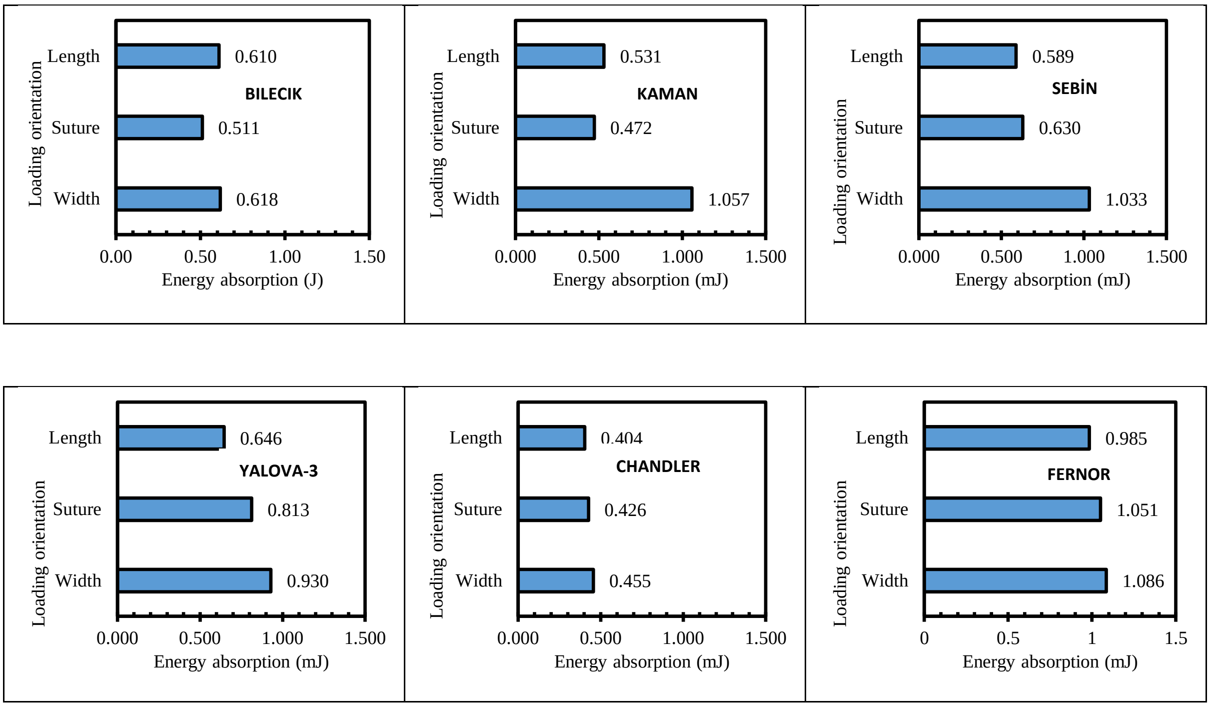

Fig. 4. The change of energy absorption

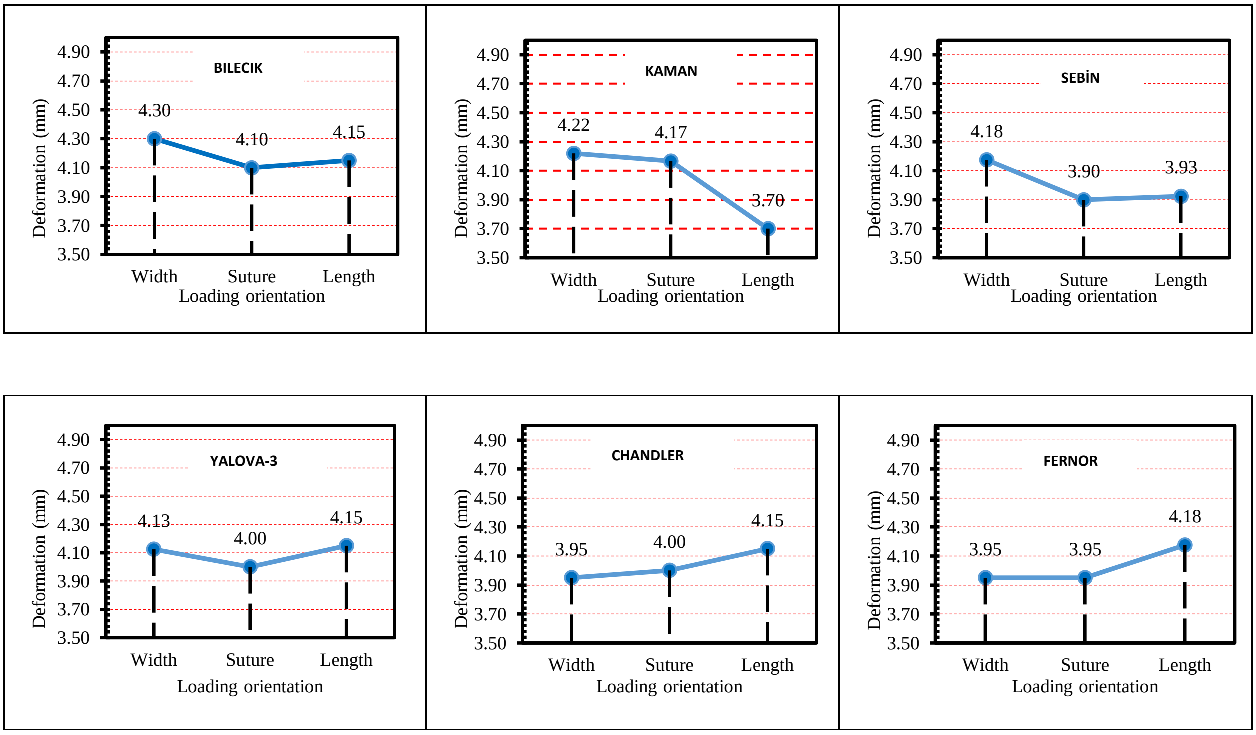

Fig. 5. The change of deformation

tion, the energy absorption, and the hardness; while the lowest value was observed when the force was applied in the perpendicular direction (Tab. 2). The results show that the change in deformation with the application of the force from the top surface, the vertical surface, and the side surface largely depends on the walnut varieties.

Depending on the direction of application, statistically significant interactions were detected among cracking strength, deformation, energy absorption, and hardness properties of walnut varieties (Figs 2–5). The highest cracking force of 572 N resulted in the application of force from above to the Fernor. The lowest value (211.9 N) was obtained as a result of application from the side surface (cheek) to the Chandler walnut (Figs 2).

The highest hardness value was obtained in the Kaman variety during application of force from the vertical direction (543 Nmm^{-1}). The hardness values obtained in the study were higher than those reported by Ercisli et al. [2011]. This may be due to the different shell thicknesses of the varieties utilized. Koyuncu et al. [2004] reported that the increase in crustal thickness of walnuts elevated the cracking strength. The highest deformation value was obtained with 4.3 Nmm^{-1} in the Bilecik variety when the force applied from the above and the lowest value was observed with 3.7 Nmm^{-1} during the vertical application to the Kaman (Fig. 3).

Energy absorption values of the varieties depending on the direction of force are given in Figure 4. When the results are examined, the force applied from the above was found to cause a greater energy absorption in all varieties. Fernor had the maximum energy absorption of 1.086 J. The lowest energy absorbance value was obtained from the Chandler when the force was applied from perpendicular angle with a value of 0.404 J. Koçtürk and Gürhan [2007] determined that the Yalova-3 variety had the highest cracking forcewhen they compared Yalova-3, Kaman, and Şebin varieties. However, the results reported in their study on the rank of deformation of the varieties are in contradiction with this study. This could be attributed to the fact that the force has been applied at different moisture levels in both studies.

Deformation values of nut shells of different walnut varieties at fracture time ranged from 3.95 mm to 4.30 mm. The maximum deformation values were observed in Bilecik, Kaman and Şebin varieties when the force applied from the above whereas the maximum deformation from the Chandler, Fernor and Yalova-3 was observed when the force was applied in the vertical direction (Fig. 5).

CONCLUSIONS

There are considerable differences of profitability in all the crops with the different postharvest procedures along with the use of various product processing techniques, packaging, and the transfer to the market. Products that are harvested, processed, and packaged by appropriate methods that are maximizing the income are therefore highly demanded in the market. With the knowledge of the physical and mechanical properties of nuts, a high quality and more profitable product could be delivered to the market. In this research, important measurements and analyzes for posthar vestnut processing were carried out to determine the physical and mechanical properties of 6 different Turkish and imported walnut varieties. The results revealed that the highest shell thickness, internal weight, geometric mean diameter and surface area values of the nut were obtained in the Bilecik variety. The two imported walnut varieties, Fernor and Chandler, generally had the lowest surface area, geometric mean diameter and sphericity values. The highest values of cracking force and energy absorption were obtained in Chandler and the lowest values were observed in the Fernor. Furthermore, high cracking force, deformation, energy absorption, and hardness values were obtained in all varieties when the force applied from the above direction.

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