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Some Physical, Mechanical and Ripening Properties of the Boğazkere Grape (*Vitis vinifera* L.) and Theirs Relationships

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Abstract: In this study, some physical, mechanical and ripening properties of local variety Boğazkere grape and their relationships were determined depend on three different phenological stages and five cane internode (IN) diameters. This research was performed at commercial vineyard in Diyarbakır province, which is located in the southeastern part of Turkey. Cutting properties and energy values were measured by The Lloyd LRX plus materials testing machine. In addition to cutting properties of cane, grape berries' include length, with, thickness, geometric mean diameter, sphericity, surface area, berry detachment force (BDF), berry weight (W), berry detachment force/weight (BDF/W) were determined.
The mean length, width and thickness values of berries were found as 16.64 mm, 15.49 mm, and 15.42 mm, respectively. The arithmetic mean diameter, geometric mean diameter, surface area values were not changed statistically with phenological stages.
There were found closely relationships between ripening and mechanical properties at different phenological stages for grape berries. The ratio of BDF/W decreased with phenological stages. The BDF was decreased from 2.60 N to 2.13 N, the grape berries skin firmness decreased from 1.60 N to 0.93 N, while berries weight increased from 2.48 g to 2.76 g with harvesting stages. Total soluble solids content and pH values increased with phenological stages. Whereas the total acids were slight changed and reduced from 0.413 to 0.323 % with ripening stages.
The phenological stages has not significant effect on the cutting properties of cane (P >0.05). However, cutting force were found highly correlated with the cane diameter, the significant differences were found among internodes diameter of grape canes at a 5 % probability level. While the maximum cutting force and energy were obtained at IN5 diameter as 600.92 N and 5.05 J, the minimum cutting force and energy were obtained at IN1 diameter as 289 N N and 1.52 J, respectively.
Key words: Grape, grape cane, cutting properties, cutting energy, engineering properties

INTRODUCTION

Grape is an important product for the economy of Turkey. Turkey is sixth largest producer of worldwide with an estimated production of 4 million tons in 550.000 ha production area in 2016. It is the biggest exporter of raisin grapes. Each year over 200.000 tons golden coloured raisins is exported all over the world. The grape export is 170.000 ton valued at 133 million $ (Anonymous, 2016). Turkey will continue to acting an important role in grape production and raisin exportation in the world because of its large number of grape varieties, favorable ecological conditions and large amount of production areas. However, pruning and harvesting of grape berries are mainly performed by manually and labor intensive. So, production cost is very high and labor efficiency is low in vineyard. Whereas, pruning and harvesting are the most critical operations in the management of the vineyard. To increase production, total costs and labor requirement must be reduced to reasonable level. The reduces of labor and production cost can be accomplished by utilizing a mechanical pruner and grape harvester (Morris,2000; Sessiz et al.2015). So, use of mechanization application should be increased in vineyard.

Also, use of mechanization can help improve grape yield and quality in vineyard. Percentage presence of undamaged grapes and dimensions are an important quality criteria both table grape and juice industry. Therefore, the economic value of grape mostly depends on the presence of undamaged grape fruits. To reduced harvest and postharvest losses, we need to know some physical, mechanical and ripening properties of each grape cultivar separately. Because, these properties are important parameters for design of a pruner, harvester, sorting and grading machines. Some of these properties include the dimensional size, shape, sphericity, geometric mean diameter, surface area, mass, volume, etc. The knowledge related to shape and physical dimensions are useful in sorting and sizing of fruits and determining how many fruits can place in box or shipping containers. These properties depend on the species, variety, diameter, maturity, moisture content and cellular structure (Persson, 1987; Kabas et al., 2005; Morris, 2000; Sessiz et al., 2013). In addition to physical properties, we have to know some cutting properties of grapes canes for pruning, and we need information related to grape berries detachment force from cluster and some quality criteria such as ripening, skin firmness, soluble solids content, pH, total acidity and maturity index for suitable design of grape harvesters and grape industry. Knowing those properties will be useful industry, academia, research Institutes, consumers, manufacturer of machines and producers of food processing equipment (Nesvadba et al., 2004). Until now, many studies have been conducted related to mechanical and physical properties of agricultural products and biological materials such as fruits, grains and seeds. But, published researches were not found directly cutting properties of grape internodes of canes, and physical, mechanical and ripening properties of grape berry and theirs relations. Romano et al. (2010), determined cutting force for certain vine branches such as Cabernet, Sauvignon and Chardonnay in different regions in Italy, Sessiz et al. (2015) determined cutting properties of some grape varieties in Turkey. Some physical properties of Rasa grape were determined by Khodaei and Akhijahani (2012). Cutting properties of some wine grapes cultivars were determined by Özdemir at el (2015).

The objective of this study was to determine mechanical properties of grape cane and physical and ripening properties of grape berry and their relationships. The specific objectives were to:(1) evaluate cutting forces and energy along canes internodes of Boğazkere variety at different phenological stages, (2) development empirical model between berry axial dimensional and other physical properties, (3) to determine the relationship between phenological stages and berry ripening properties.

MATERIAL and METHOD

Vineyard and Samples

This study was performed with Boğazkere (Vitis vinifera L) local grape variety (Figure 1). The tests samples were obtained from an organic commercial vineyard in Diyarbakır province, which is located in the southeastern part of Turkey.

Figure 1. View of vineyard area and Boğazkere grape variety

The grape berry and cane cutting tests were carried out during the different phenological stages of the veraison (30 August), 15 days after veraison (15 September) and harvesting time (30 September) in 2016. Grape canes (Figure 2), which have between five internode, has different diameters. The test samples were randomly harvested by hand from vineyard. Harvested and collected canes which have different internode and grape clusters (Figure 3) were transported to laboratory of Department of Agricultural Machinery and Technologies Engineering, University of Dicle. All samples were preserved at room temperature until the time of the cutting tests.

Figure 2. Grape canes

This study was conducted in two phases. In the first phase, grape berries length, width, thickness, arithmetic and geometric mean diameter, sphericity, roundness, force detachment (FDF), weight (W), ratio of FDF/W, skin firmness, total soluble solids content, pH, total acidity and maturity index were measured. In the second phase, grapevine cane cutting force, cutting strength, upper yield and cutting energy were determined under compression load.Yabancı ot mücadelesinde, kültürel önlemlerden en önemli yeri tohum temizliği almaktadır. Bunun yanında ekim nöbetini ihmal etmemek gerekir. Ayrıca tarla temizliğine uyulmalı, tarım alet ve makinalarıyla yabancı otların yayılmalarına engel olunmalıdır (Güncan, 2010).

Measurement of Grape Berry Physical and Pomological Properties

To determine the dimensional sizes and physical properties of grape, 25 berries randomly taken from five grape clusters at each phenological stages during the harvest season. The three linear dimensions namely, length, width and thickness were measured by using an electronic micrometer with a reading accuracy within 0.01 mm. The geometric mean diameter, sphericity, roundness, and surface area of individual fruits were calculated using the following equations (Mohsenin 1986; Zare et al., 2012; Sessiz et al., 2013).

$$Da = \frac{(\mathrm{L} + \mathrm{W} + \mathrm{T})}{3}$$

$$\mathrm{Dg} = (\mathrm{LWT})^{1/3}$$

$$Ø = \frac{(\mathrm{LWT})^{1/3}}{L} = \frac{Dg}{L}$$

$$\mathrm{Ro} = \frac{\mathrm{W}}{\mathrm{L}} \mathrm{x}100$$

$$\mathrm{S} = \pi \mathrm{D_g}^2$$

Where L is the length (mm), W is the width (mm), T is the thickness (mm), Da is arithmetic mean diameter (mm), Dg is geometric mean diameter (mm), Ø is sphericity (%), Ro is roundness.(%)

Measurement of Mechanical and Phomological Properties of Grape Berries

Berry fruit detachment force (BDF), berry weight (W), and the FDF/W ratio are important mechanical and ripening properties for fruit harvesting (Sessiz and Özcan, 2006;Morris 2007; Putri et al., 2015), and firmness is the resistance of the individual fruit to deformation under applied forces (Renny et al., 2015). Therefore, to determine of these parameters of grape berries were measured at three different phenological stages during the harvest period. Length, width and thickness of grape berries were measured with a micrometer to within 0.01 mm. Grape berries were weighed by means of a digital balance with 0.01g (Figure 3). The maximum berry detachment force from cluster and berry skin firmness were measured in Newton (N) by using a pull digital force gauge (Model FG-20, Lutron Instrument) with stainless steel cone head (Figure 3). The digital force gauge is shown in Figure 3. Some basic important fruit ripening parameters, like Total soluble solids content (TSSC) (by refractometer), pH (by pH meter) and total acidity (by Digital Burette) values were measured (Jha et al., 2006; Morris, 2007; Özdemir et al., 2016).

Figure 3. View of grape cluster, force gauge, micrometer and balance

Measurement of Cane Cutting Properties

Prior to the tests, the grapevine canes were cutted into five different groups (Figure 2). Five internodes of grape canes were named first to fifth from the top toward the bottom. The mechanical properties include the cutting force, cutting strength, upper yield and cutting energy were determined along the canes from first internode to fifth internode in three phenological stages. Five internodes of grape cane, namely, IN1, IN2, IN3, IN4 and IN5, were studied in this study. The average diameter of cane internodes (between two nodes were considered a internode) were changed from 6.00 mm to 11.00 mm. Each group was determined separately. The average internode diameters were considered as 6.5, 7.5, 8.5, 9.5, 10.5 mm. The ranges of internode diameter of cane (mm) values were converted to cross-section area in mm2 (33.16, 44.15, 56.71, 70.84, 86.54 mm^2) The cane diameters were measured before the test using a caliper. Testing was completed as rapidly as possible in order to reduce the effects of drying. The initial moisture content of canes were determined according to ASABE standard (ASABE, 2006, Sessiz at al., 2007) by oven-drying 50 g of each sample at 105 °C for 24 h. The average moisture content levels of internode of cane were determined in three phenlogical stages at 44.48%, 53.04 % and, 55.58% w.b., respectively.

Lloyd LRX Plus Materials Testing Machine were used for cutting tests(Figure 4). During the tests, the cane samples were placed on the machine loading table in its flat position. Loading was applied vertical direction. The cutting knife was steel, 50 mm width, 6 mm thickness and the blade angle of 17◦. Cutting measurements were performed at 100 mm/min fixed loading speed for all tests.

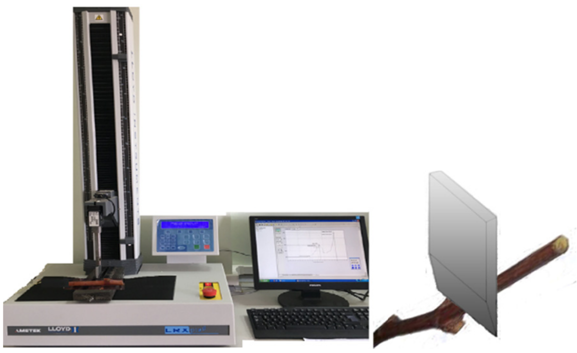

Figure 4. The Lloyd LRX Plus Materials Testing Machine and cutting blade

The peak cutting strength, obtained from the cutting force findings, was determined by the following equation (Mohsenin, 1986; Beyhan, 1996; İnce at al., 2005; Taghijarah et., 2011; Sessiz et al., 2013):

$$\sigma s = \frac{F}{A}$$

Where: σs is the maximum shearing strength in (MPa), Fmax is the maximum shearing force in (N) and A is the cross-sectional area in (mm2).

The cutting energy was calculated by measuring the surface area under the force-deformation curve (Georget et al.,2001;Yore et al., 2002; Chen, et al., 2004; İnce at al., 2005; Ekinci et al., 2010; Zareiforoush, et al., 2010; Heidar and Chegini, 2011; Alizadeh at al., 2011; Sessiz at al., 2015; Nowakowski, 2016A computer data acquisition system recorded all the force-displacement curves during the cutting process. A typical force- deformation curve for grapevine cane under compression is shown in Figure 5. The first peak corresponds to the yield point at which cane damage was initiated. The second peak corresponds to maximum compressive force. This bioyield point is characterized by the fact that any further compression yields no increase in applied load (Mohsenin, 1986; Lu and Siebenmorgen, 1995; Emadi et ., 2004).

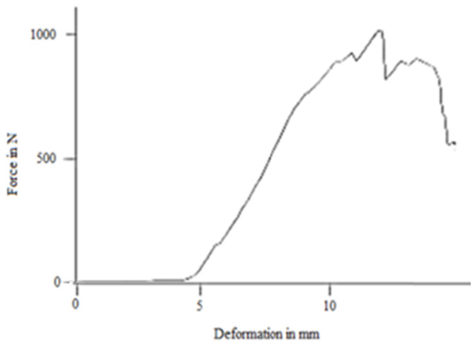

Figure 5. Typical force-deformation curve

Data Analysis

All data were determined using the analysis of variance (ANOVA) method and significant differences of means were compared using the least significant difference test (LSD) at 5% significance levels using the Tukey multiple range tests in JMP software, version 11.All these tests were replicated 15 times and the average values were reported. The relationship between physical properties of grape berries and phenological stages were determined using regression analysis of Microsoft Excel (2010) program.

RESULTS and DISCUSSION

Linear Dimensions and Physical Properties

Average berry dimensions and other physical sizes at three phenological stages are presented in Table 1. The variance analysis of the data indicated that the effect of phenological stages on physical dimensions, namely, length, volume, sphericity and roundness were found significant at 5 % probably, while there were not found significant differences ($p>0.05$) between the phenological stages and other physical properties. In addition, the values of three axial dimensions of grape berries were observed very close to each other. The mean length, width and thickness values were found obtained as 16.64 mm, 15.49 mm, and 15.42 mm, respectively. Although statistical differences were not found between phenological stages and physical properties, except volume, sphericity and roundness, the rest all of other physical properties of berry slightly decreased with the period of maturity time. Also, the arithmetic mean diameter, geometric mean diameter, surface area values were not changed statistically dependent on phenological stages. Nearly, arithmetic and values geometric mean diameters were founded the same. But, it was observed negative relationship between physical properties and phenological stages.

In order to determine relationships between the berries axial dimensional and the other physical properties, namely, arithmetic mean diameter, geometric mean diameter, surface area, sphericity and roundness, multiple regression equations were derived from the values of three axial dimensions at different phenological stages. Their relationships are given in Table 2. According to the regression equations, A significant and high correlation were found between investigated axial dimensions and the other physical properties values (Table 2). As can be seen from the Table 1 and Table 2, especially, average sphericity and roundness and values for R2 were found very high for three phenological stages. It means that the three axial dimensions are more related to the other physical properties. Because, these parameters were directly derived from the axial dimensions. Due to higher correlation coefficients, this equations can be used for predict the arithmetic mean diameter, geometric mean diameter, surface area, sphericity and roundness of Boğazkere grape variety as a function of axial dimensions and maturity time. These dimensions values and equations can be considered in design of sorting and separating machine and food industry for grape (Sessiz et al., 2015). Similar results were found by Khodaei ve Akhijahani (2012) for Rasa grape variety. Nowakowski (2016) for cutting giant miscanthus stalks depending on grinding process parameters.

Table 1. Axial dimensions and physical properties of Boğazkere grape berries at different phenological stages.

	Phenological Stages				
Properties*	Veraison	15 days after Veraison	Harvest	Mean	LSD
Length(mm)	16.97a**	16.63ab	16.30b	16.64	0.506
Width(mm)	15.63	15.37	15.48	15.49	ns
Thickness(mm	15.47	15.39	15.38	15.42	ns
Volume (cm^3)	2.41b	2.51b	2.94a	3.69	0.453
Arithmetic Mean dia (mm)	16.03	15.79	15.72	15.85	ns
Geometric mean dia(mm)	16.00	15.78	15,71	15.83	ns
Surface Area(mm^2)	809.23	784.63	778.39	790.75	ns
Sphericity (%)	0. 943b	0.949b	0.965a	0.952	0.015
Roundness (%)	0.921b	0.925b	0.970a	0.938	0.015

* All data represent the average of three replications with 15 values.
**means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level, ns: not significant

Table 2. Regression equations of cutting properties as a function of three axial dimensions

Parameters*	Regression equation	R2
Arithmetic mean diameter (mm)	Y= 1.78x 10-15 +0.333L+0.333 W+0.333T	1.00
Geometric mean diameter (mm)	Y= -0.00717+0.3174L+0.340W+0.343T	0.999
Surface area (mm2)	Y= -797.86+31.46 L+33.77W+35.14T	0.999
Sphericity (%)	Y= 0.9557-0.0382L+0.02057W+0.0204T	0.994
Roundness (%)	Y=0.936-0.0562 L+0.0606W+0.00054T	0.997

*L: Length (mm), W: Width (mm), T: Thickness

Grape Berries Mechanical and Ripening Properties

Some mechanical and ripening properties, namely, berries detachment force (BDF) from grape cluster, fruit weights (W), BDF/W ratio and, berries skin firmness and their relationships are shown in Table 3. Negative relationship was observed between detachment force and berries weight. The maximum berries detachment force from grape cluster decrease, while fruit weights increase with phenological stages, and high correlation was observed between the ratio of FDF/W and phenological stages. The ratio of BDF/W decreased with phenological stages and maturity time. The berries detachment force from the grape cluster stalk was decreased from 2.60 N to 2.13 N, while berries weight increased from 2.48 g to 2.76 g depend on phenological stages. As the water content of grape berries increased with maturity, the weight of grape has increased with phenological stages. These values are valuables data for maturity criteria of Boğazkere grape berries. Because, BDF/W ratio is an important parameter of fruits mechanical harvesting. Similar results were observed between skin firmness and phenological stages. The maximum firmness was observed as 1.6 N when the TSS content was 17.27 %. Then the grape skin firmness decreased from 1.60 N to 0.93 N with phenological stages. The situation can be explain that the water content of fruit increased with maturity (Jha et al., 2006). According to these results we can express that there is a high correlation between BDF/W ratio and fruit skin firmness. There were found closely relationships between ripening and mechanical properties depend on phenological stages for grape berries of Boğazkere variety. Total soluble solids content (17.27-21.93 %) and pH (3.45-3.70) values increased with phenological stages, whereas the total acids were slight changed and reduced from 0.413 to 0.323 % with phenological stages. While the lowest values of TSSC and pH were observed at verasion stage as 17.27 % and 3.45, respectively, the maximum detachment force and grape shell firmness were observed at verasion stage as 2.60 N and 1.60 N, respectively (Table 3 and Table 4). Also, while berries weight increased, TSSC and pH increased, acidity decreased with phenological stages. Similar results were reported by Morris (2007), he found that the mean pH was in range 3.35 to 3.77 and titratable acidity was in the range of 6.44 to 7.31 g·L−1 for veraison stage.

Cutting Properties

The mean tests results of the grape cane cutting properties at different phenological stages and their relationships are given in Table 5. As shown in the Table 5 the phenological stages has not significant effect on the cutting properties of grape canes (P >0.05). However, cutting force and energy slightly increased with phenological stages. The average mean cutting force, cutting strength and cutting energy values were obtained at verasion stage as 419.16 N, 7.40 MPa, 369.89 N and 2.89 J, respectively. The main maximum force was obtained at 15 days after veraison, maximum cutting strength and cutting energy were obtained at harvest season.

Table 3. Main some mechanic properties of Boğazkere berries at different phenological stages

Phenological Stages	Properties			
	Force detachment (FDF) (N)	Weight (W) g	(FDF/W) N/g	Shell firmness (N)
Veraison	2.60a	2.48b	1.048a	1.60a
15 days after Veraison	2.44ab	2.71ab	0.900a	1.16b
Harvest	2.13b	2.76a	0.771b	0.93b
Mean	2.39	2.65	0.906	1.23
LSD	0.362	0.230	0.138	0.21

Table 4. Some ripening properties of Boğazkere grape berries (average value) at three phenological stages

Phenological Stages	Properties		
	TSSC, %	pH	Acidity, %
Veraison	17.27	3.45	0.413
15 days after veraison	19.23	3.54	0.368
Harvest	21.93	3.70	0.323

Table 5. The mean cutting properties at three phenological stages

Phenological Stages	Cutting Force (N)	Cutting strength (Nmm^{-2})	Cutting energy (Joule)
Veraison	419.16	7.40	2.89
15 days after Veraison	441.92	8.17	3.05
Harvest	428.69	7.42	3.20
Mean	429.63	7.66	3.05
LSD	ns	ns	ns

*means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level.

Table 6. The relationship between average cutting properties and internode diameter

Internode and diameter	Cutting force (N)	Cutting strength (Nmm^{-2})	Energy (Joule)
IN1 (6,5)**	289.29c	8.72a	1.52a
IN2 (7,5)	398.29b	8.86a	2.43b
IN3 (8,5)	423.81b	7.47ab	3.10b
IN4 (9,5)	447.43b	6.31b	3.27c
IN5 (10,5)	600.92a	6.94b	5.05d
Mean	429.63	7.66	3.05
LSD	74.97	1.34	0.67

*means followed by the same letter in each column are not significantly different by Tukey's multiple range test at the 5 % level.

The mean cutting properties dependent on diameter of internodes of grape cane are shown in Table 6. The results shown in Table 6 indicate that the cutting force, cutting strength, upper yield and cutting energy increased with increase internode diameter of Boğazkere grape canes. The significant differences were found between all of internodes' diameter of canes at a 5 % probability level. Especially, the canes diameter has a significant influence on cutting force and energy (Ghahraei et al 2011). The shearing energy was obtained closely related to cane diameter. As the diameter increased, energy linearly increased. While the maximum cutting force and energy were obtained at IN5 diameter as 600.92 N and 5.05 J, respectively.

Maximum cutting strength was obtained at IN2 diameter as 8.86 MPa. The minimum cutting force, upper bio-yield and cutting energy were obtained at IN1 diameter as 289 N, 271 N and 1.52 J, respectively. Energy values has varied from 1.52 J to 5.05 J depend on cane diameter. Energy was found higher in the higher internode (IN5). Also, cutting force was found highly correlated with the cane diameter, cutting force linearly increased with increased diameter of cane. The effect of stem diameter on the maximum cutting force and cutting energy is consistent with Chen et al. (2004), who reported that both the cutting energy and maximum cutting force are directly proportional to the cross-sectional area of hemp stalk. Similar results were found by Sessiz at al., (2013) for the olive sucker and Sessiz et al,(2015) for grape sucker. Esgici et al. (2017) for Şire grape cane. Acording to Ghahraei et al(2011) cutting energy increase with cross-sectional area of kenaf stems. Heidari and Chegini (2011) studied on shear strength and energy for rose flower.

CONCLUSION

Some physical, mechanical and ripening properties of Boğazkere grape variety and their relationship were determined in order to design of pruning, harvesting, transporting and processing machines. The tests results indicated that the data obtained from the measured values gave the significant correlations between axial dimensions and other physical properties include arithmetic mean diameter, geometric mean diameter, surface area, sphericity and roundness. The mean length, width and thickness values were found as 16.64 mm, 15.49 mm, and 15.42 mm, respectively. Also, the arithmetic mean diameter, geometric mean diameter, surface area values were not changed statistically dependent on phenological stages. Nearly, arithmetic and values geometric mean diameters were founded the same. But, it was observed negative relationship between physical properties and phenological stages.

Negative relationship was observed between the ratio of BDF/W and phenological stages. While berries weights increase with phenological stages, the ratio of BDF/W decreased depending on phenological stages and maturity time. The berries detachment force from the grape cluster was decreased from 2.60 N to 2.13 N, while berries weight increased from 2.48 g to 2.76 depend on phenological stages. The grape berry skin firmness decreased from 1.60 N to 0.93 N with phenological stages. However, there were found closely relationships between ripening and mechanical properties depend on phenological stages for grape berries of Boğazkere variety. Total soluble solids content and pH values increased with phenological stages, whereas the total acids were slight changed and reduced from 0.413 to 0.323 % with phenological stages.

The phenological stages has not significant effect on the cutting properties end energy of grape canes ($P > 0.05$). However, cutting force and energy were found highly correlated with the diameter. While the maximum cutting force and energy were obtained at IN5 diameter as 600.92 N and 5.05 J, respectively, maximum cutting strength was obtained at IN2 diameter as 8.86 MPa. The minimum cutting force and energy were obtained at IN1 diameter as 289 N and 1.52 J, respectively.

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