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# A STUDY ON THE DETERMINATION OF MECHANIC HARVEST PROPERTIES OF SOME SWEET CHERRY VARIETIES

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**Abstract:** Cherry is a hand-harvested fruit due to various difficulties and constraints. This condition results in the use of labor at a high rate. Turkey's annual cherry production is at the level of 724 thousand tons. Various tools or machines that have been developed for cherry harvest have the potential to contribute greatly to the production in this area. The share of the labor required for harvesting in cherry production in the total labor requirement is around 70%. In this research, it was aimed to collect the necessary data to mechanize the cherry harvest by determining the physico-mechanical properties of cherry fruit. As a result of the present study, several physical, biological, and mechanical properties of four sweet cherry variety (0900 Ziraat, Starks Gold, Merton Late, Lambert) were determined and compared in terms of fruit mass, net fruit weight, tensile force, weight, thickness, length, width, sphericity, surface area, volume of fruit, and also weight, width, length, sphericity of seed, tensile force of stalk, stalk length, and weight. Tensile force of fruit, tensile force of stalk and weight of the fruit of 0900 Ziraat variety were found 2.579 N, 7.041 N, 9.592 g, respectively. After the evaluation of the obtained data, it was determined that all four cherry varieties examined were suitable for mechanical harvesting. However, the most suitable variety for mechanical harvesting was found as '0900 Ziraat'.

**Keywords:** Sweet cherry, Fruit harvesting, Mechanization, Tensile force

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## 1. Introduction

Cherry (*Purunus avium* L.) belongs to Rosaceae family, Prunoideae subfamily, Prunus genus in botany. The origin of the cherry is known as the region between the Southern Caucasus, the Caspian Sea, and Northeast Anatolia. It spread east and west from these gene centers and covered a large area on Earth. Accordingly, our country is one of the origin centers of cherries (Başkaya, 2011). There are around 1500 cherry variety in the world, and this number is increasing day by day with ongoing breeding studies. Besides, the same varieties were named with different names, and different varieties were named with the same names in terms of regions (Çakaryıldırım, 2003).

Cherry cultivated areas and the amount of cherry produced accordingly increase every year in Turkey. Our production, which was 230000 tons from 29000 ha in 2000, increased from 67046 ha to 417905 tonnes in 2010 and from 82729 ha to 724944 tonnes in 2020 (Anonymous, 2022).

According to 2020 World cherry production data, Turkey ranks first in terms of cherry production and cultivated area (Table 1; Anonymous, 2022). Of the 664224 tons of cherries produced in Turkey in 2019, 80508 tons were exported. This amount constitutes 12.1% of the total production. 69% of the exported cherries were sold to EU member countries (Anonymous, 2020; Anonymous, 2021). '0900 Ziraat' variety is the cherry variety with the highest production volume in Turkey and is an important export product (Erogul, 2018).

**Table 1.** The highest cherry produced countries in the world (Anonymous, 2022)

| Rankings | Country | Production (metric ton) | Cultivated Area (ha) |
|---|---|---|---|
| 1 | Turkey | 724944 | 82729 |
| 2 | USA | 294900 | 34400 |
| 3 | Chile | 255471 | 39645 |
| 4 | Uzbekistan | 185068 | 12718 |
| 5 | Iran | 164080 | 24033 |

Harvesting of cherry fruit is still mostly done by hand both in the world and in Turkey. Therefore, harvesting is one of the areas where the labor requirement per unit area is high in fruit growing and hand-harvesting constitutes 30-60% of the total production cost (Moser, 1989; Gezer, 2001). When the situation of mechanical fruit harvesting in Turkey is examined, it is seen that the process with the highest labor requirement per unit area is harvesting. When we look at the share of the labor required for harvest in the total labor requirement, sour cherry, and cherry production ranks first with 70% (Gezer, 2001). Like cherries, sour cherry harvest costs account for 30-60% of the total production cost (Yılmaz and Gökduman, 2020). Kocabiyik et al. (2009) determined the human energy cost, work success, and some physico-mechanical properties of fruits in apple, peach, apricot, cherry, and plum harvest. As a result, they determined the highest human energy input for cherry harvest. Pırlak and Güleryüz (2000) reported that the fruit harvest is 100-250 times higher than the grain harvest in terms of labor and approximately 40 times higher in terms of production costs.

Erdoğan (1988) evaluated the human labor needs in horticultural agriculture in terms of harvest mechanization. According to the results of the study, human labor needs in strawberry and cherry harvesting were found to be higher than other fruits. Pırlak and Güleryüz (2000) examined the mechanical harvesting of fruit species and concluded that the human labor required for manual cherry harvesting is high. This process constitutes 40-80% of the working time in production.

Knowing the biological properties of agricultural products are necessary and important in the design, construction, operation, control, determination of yields, analysis and evaluation of the quality of the products. Knowing these properties is beneficial not only for engineers but also for food scientists, processors, plant-breeding designers and specialists (Mohsenin, 1986). For these reasons, studies have been carried out by many researchers to determine the physico-mechanical and biological properties of different fruits. Research has been carried out for many fruits such as apricot (Altıkat and Temiz, 2019), apple (Polat et al., 2020), plum (Alnıak Sezer and Çetin, 2021), black berry (Çalışır and Aydın, 2004), sour cherry and cherry (Özgüven et al., 2001; Vursavuş et al., 2006; Kocabıyık et al., 2009; Pérez-Sánchez et al., 2010; Göksel and Aksoy, 2014; İkinci and Bolat, 2015; Taşova and Güzel, 2017; Krumov and Christov, 2018; Sarısu et al., 2019). However, it should not be forgotten that there are many variety of each fruit and that even the same variety vary according to the climate, soil, and cultivation method of the region in which they are grown (Altikat and Temiz, 2019). Due to that, it is important to conduct studies on the samples of fruit variety in different regions, to have a large amount of data on the characteristics of that fruit variety, and to create a more reliable infrastructure for studies on mechanical harvesting. In this study, it was aimed to determine the physico-mechanical properties of four cherry variety grown in Tekirdağ, to collect the data necessary for the mechanization of cherry harvest and to determine the suitability of these variety for mechanical harvesting.

## 2. Material and Methods

### 2.1. Cherry Varieties

The cherry fruits used for the research were obtained from the trees in the orchard of Tekirdağ Viticulture Research Institute (40.970860 N, 27.472279 E). Four different cherry varieties (0900 Ziraat, Starks Gold, Merton Late, and Lambert) were used in the study (Figure 1).

**Figure 1.** Photos of garden and cherry varieties used in the experiments.

For each cherry variety, measurements and calculations were made on a total of 103 samples from randomly selected trees, in order to determine the properties of cherries for mechanical harvesting and to determine their suitability for mechanical harvesting. These are weight, thickness, width, height, sphericity, surface area, volume, density, net fruit weight, tensile force of the fruit from the stalk, seed weight, width, thickness, height, sphericity, surface area, and tensile force of the fruit stalks from the branch, weight, length, thickness, and number of the stalks. In addition, pH measurements and color analyzes were performed for the examined varieties (Vursavuş et al., 2006; Kocabıyık et al., 2009; Pérez-Sánchez et al., 2010; İkinci and Bolat, 2015; Sarısu et al., 2019).

The thickness, width, height of the fruits, and the length and thickness of the fruit stalks were measured with a digital caliper (Mitutoyo) with an accuracy of 0.01 mm, and the weights of the fruits and stalks were measured with a precision balance (AND - GF 600) with an accuracy of 0.001 g. The tensile force of the fruit (from the stalk) and the tensile force of the fruit stalk (from the branch) were made with a 1 gr precision hand dynamometer (Lutron FG 5020), pH measurements were analyzed by pH meters (Hanna Instruments pH 211), and color measurements were obtained from a colorimeter (HunterLab D25LT - Reston, VA). Sphericity, net fruit weight, surface area, and density values were calculated from the obtained measurement results. Additionally, net fruit weight was calculated by subtracting the weight of the fruit stalk and seed from the total fruit weight.

### 2.2. Statistical Analysis

Analysis of variance (ANOVA) was applied to the data obtained from the study by using the statistical package program (Statistica, 1999), and the differences between the group means were determined with the Duncan Multiple Comparison Test (Genç and Soysal, 2018).

### 2.3. The Tensile Force of the Fruit from the Stalk ($F_{T-f}$) and the Stalk from the Branch ($F_{T-s}$)

To determine the tensile force of the fruit (from the stalk), an equipment was made on the tip of the hand dynamometer to pull the fruit from the stalk. With the help of this equipment, the samples were pulled in the direction of the fruit stalk axis and the tensile forces ($F_{T-f}$)

were determined as N (Newton). After the fruits were plucked from their stalks, the remaining stalks were pulled from the branch with the help of an equipment and the tensile force ($F_{T-s}$) was measured. Fruits and stalks which tensile forces were measured were numbered for further measurements.

2.4. Fruit Sizes and Sphericity

The size measurements of the fruits were made with a digital caliper and the sphericity values were calculated by placing the values in Equation 1 given below (Moser, 1989; Vursavuş et al., 2006; Yılmaz and Gökduman, 2020):

$$\phi = (xyz)^{1/3}/z \quad (1)$$

where;

$\phi$ = Sphericity (%)

$x$: Height of fruit (mm)

$y$: Thickness of the fruit (mm)

$z$: Width of the fruit (mm)

## 3. Results and Discussion

### 3.1. pH Values

The juices of the fruits were squeezed, and pH measurements were made in three replications for each cherry variety, and the averages are given in Table 2. Numerically the highest pH was measured in Lambert, and the lowest pH was measured in 0900 Ziraat variety. The results are in line with the work done by Vursavuş et al. (2006), Göksel and Aksoy (2014), Sarısu et al. (2019), Eroğul and Özmen (2020).

### 3.2. Color Measurements

L* (lightness), a* (redness), b* (yellowness) values were measured with HunterLab colorimeter. The measurements were made from randomly selected 3 samples for each variety and their mean values are summarized in Table 3.

According to the results of the study, the variety with the highest brightness (L*) and yellowness (b*) values was 'Starks Gold', and the variety with the highest redness (a*) value was '0900 Ziraat'.

**Table 2.** pH analysis results of cherry varieties

| Varieties | pH |
|---|---|
| 0900 Ziraat | 3.86 |
| Starks Gold | 3.95 |
| Merton Late | 3.97 |
| Lambert | 4.24 |

**Table 3.** Color analysis results of cherry varieties

| Varieties | L* | a* | b* |
|---|---|---|---|
| 0900 Ziraat | 18.25 | 9.25 | 2.66 |
| Starks Gold | 60.32 | 0.55 | 28.19 |
| Merton Late | 15.86 | 6.93 | 1.28 |
| Lambert | 13.83 | 1.56 | 0.23 |

Findings for the variety 'Ziraat 0900' are in agreement with Vursavuş et al. (2006). There are differences between the values measured in the study and the values obtained by Göksel and Aksoy (2014), Sarısu et al. (2019), Eroğul and Özmen (2020). It is thought that these differences may be caused by cultivation and environmental conditions.

The data obtained by measuring the parameters of fruit, seeds, and stalks of four different cherry varieties were statistically analyzed and the results were summarized in Table 4, 5, and 6.

### 3.3. Fruit Parameters Measurements

Measured and calculated fruit parameters of investigated cherry variety are shown in Table 4.

When the tensile forces of the fruits pulling from the stalk were examined, the highest value (2.579 N) was measured in 0900 Ziraat variety, the lowest value (1.530 N) was measured in Lambert variety and the difference was statistically significant (P < 0.05). When the weights of the fruits were examined, all variety were found to be statistically different from each other, the highest value was found in 0900 Ziraat with 9.592 g, and the lowest value was determined in Lambert variety with 3.684 g.

**Table 4.** Results of investigated fruit parameters

| Fruit parameters | Cherry varieties | | | |
|---|---|---|---|---|
| | 0900 Ziraat | Starks Gold | Merton Late | Lambert |
| Tensile force of fruit (from stalk) (N) | 2.579±0.117$^a$ | 2.187±0.872$^b$ | 2.246±0.664$^b$ | 1.530±0.803$^c$ |
| Weight (g) | 9.592±1.095$^a$ | 6.000±0.948$^c$ | 7.130±1.592$^b$ | 3.684±0.732$^d$ |
| Width (mm) | 26.351±1.384$^a$ | 22.526±1.474$^c$ | 23.424±1.885$^b$ | 15.917±1.133$^d$ |
| Thickness (mm) | 23.213±1.201$^a$ | 19.858±1.236$^b$ | 20.143±1.719$^b$ | 17.557±1.496$^c$ |
| Length (mm) | 24.957±1.121$^a$ | 21.267±1.096$^b$ | 20.850±1.550$^c$ | 16.467±1.208$^d$ |
| Sphericity (%) | 0.939±0.022$^b$ | 0.939±0.022$^b$ | 0.912±0.025$^c$ | 1.042±0.032$^a$ |
| Surface area (cm$^2$) | 19.228±1.712$^a$ | 14.049±1.514$^b$ | 14.402±2.188$^b$ | 8.672±1.260$^c$ |
| Volume (cm$^3$) | 9.850±1.544$^a$ | 5.728±1.066$^c$ | 6.966±1.621$^b$ | 3.528±0.760$^d$ |
| Density (g/cm$^3$) | 0.984±0.097$^c$ | 1.061±0.122$^a$ | 1.027±0.059$^b$ | 1.063±0.181$^a$ |
| Net fruit weight (without seed) (g) | 9.223±1.090$^a$ | 5.623±0.927$^c$ | 6.794±1.567$^b$ | 3.403±0.717$^d$ |

$^{a-d}$Mean values with different superscripts in the same row indicate a significant difference (P<0.05), n=103.

**Table 5.** Results of investigated seed parameters

| Seed parameters | Cherry varieties | | | |
|---|---|---|---|---|
| | Ziraat 0900 | Starks Gold | Merton Late | Lambert |
| Weight (g) | 0.369±0.041[a] | 0.377±0.042[a] | 0.336±0.046[b] | 0.284±0.044[c] |
| Width (mm) | 11.126±0.421[a] | 10.332±0.440[c] | 10.581±0.429[b] | 9.473±0.506[d] |
| Thickness (mm) | 7.153±0.323[b] | 6.988±0.291[c] | 7.360±0.373[a] | 6.823±0.390[d] |
| Length (mm) | 9.240±0.342[a] | 8.901±0.385[b] | 8.976±0.372[b] | 8.300±0.353[c] |
| Sphericity (%) | 0.810±0.023[c] | 0.834±0.022[b] | 0.837±0.029[b] | 0.856±0.024[a] |
| Surface area (cm$^2$) | 2.547±0.155[a] | 2.330±0.159[c] | 2.462±0.147[b] | 2.067±0.188[d] |

[a-d]Mean values with different superscripts in the same row indicate a significant difference (P<0.05), n= 103.

**Table 6.** Results of investigated stalk parameters

| Stalk parameters | Cherry varieties | | | |
|---|---|---|---|---|
| | Ziraat 0900 | Starks Gold | Merton Late | Lambert |
| Tensile force of stalk (from branch) (N) | 7.041±2.793[ab] | 6.355±2.391[b] | 7.669±2.577[a] | 7.522±2.567[a] |
| Number of stalks in cluster (unit) | 1.320±0.546[c] | 2.350±0.667[a] | 1.728±0.795[b] | 1.728±0.795[b] |
| Weight (g) | 0.317±0.024[b] | 0.106±0.016[c] | 0.176±0.060[a] | 0.176±0.063[a] |
| Length (mm) | 55.680±5.549[a] | 41.630±4.381[b] | 54.534±5.917[a] | 54.534±6.105[a] |
| Thickness (mm) | 1.113±0.143[b] | 1.196±0.086[c] | 1.156±0.163[a] | 1.164±0.157[a] |

[a-d]Mean values with different superscripts in the same row indicate a significant difference (P<0.05), n= 103.

The sphericity values of the fruits were calculated, the highest value (104%) was calculated for Lambert variety, the lowest value (91%) was calculated for Merton Late variety and the difference was statistically significant (P<0.05). The surface area values of the fruits were calculated, the highest value (19.228 cm$^2$) was found for 0900 Ziraat variety, the lowest value (8.672 cm$^2$) was found for Lambert variety and the difference was statistically significant (P<0.05). When the net fruit weights were examined, all variety were found to be statistically different from each other, the highest value was found in 0900 Ziraat with 9.223 g, and the lowest value was determined in Lambert variety with 3.403 g. The results regarding fruit sizes are consistent with the findings obtained in previous studies (Vursavuş et al., 2006; Delice et al., 2012; Sarısu et al., 2019; Eroğul and Özmen, 2020).

### 3.4. Fruit Seed Parameters Measurements

When fruit seed weights were examined, the highest values were measured in 0900 Ziraat and Starks Gold, the lowest value was obtained from in Lambert variety and the differences were found to be statistically significant. The measurement results were given in Table 5. In addition, the sphericity values of the fruit seeds were calculated, the highest value (85%) was in Lambert variety, the lowest value (81%) was in 0900 Ziraat variety and the differences compared to other variety was found to be statistically significant (P<0.05). The results are in line with the values measured by İkinci and Bolat (2015).

### 3.5. Fruit Stalk Parameters

The tensile force of the cherry stalks from the branch was measured, and there was no statistical difference between the 0900 Ziraat variety and the other examined varieties. However, the highest values were found in Merton Late and Lambert varieties, and the lowest values were found in Starks Gold varieties. Measured and calculated values are summarized in Table 6.

The number of cherry stalks in cluster was evaluated, and there was no statistical difference between Merton Late and Lambert variety (P>0.05). The highest value was measured in Starks Gold with 2.350 units, and the lowest value was measured in 0900 Ziraat variety with 1.320 units (P<0.05). The lengths of the cherry stalks were determined, and there was no statistical difference between Merton Late, 0900 Ziraat, and Lambert varieties. Starks Gold variety was found to have the shortest stalk length statistically. Similarly, as a result of stalk thickness measurements, the lowest value was found in Starks Gold variety. Merton Late and Lambert were measured as the varieties with the highest stalk thicknesses. The obtained results are similar to other studies on the subject (İkinci and Bolat, 2015; Sarısu et al., 2019).

For 0900 Ziraat variety, the tensile force of the fruit while pulling from the branch was found to be 2.579 N, and the tensile force of the fruit stalk from the branch was found to be 7.041 N. Therefore, if the cherry is picked by pulling from the fruit, the fruit will be separated from the stalk first, and the stalk will remain on the branch. When it is desired to collect the cherries without a stalk, they can be picked by applying a lower force, but since the upper part of the fruit whose stalk is broken off will be opened, the endurance time will be reduced. In addition, when stalkless picking is preferred, pulling down from the top of the fruit rather than squeezing from the sides will cause less damage.

If cherries are to be picked with a stalk, they should be picked by pulling from the stalk, not from the fruit. Since the thickness of the stalks is an average of 1.157 mm, a design should be made to hold the fruit tightly so that the stalk does not slip while pulling. In addition, the stalk length, which was found to be 51.59 mm on average, is sufficient for the handle to be held by an apparatus.

Since the difference between the tensile force values of the fruits from the stalks is statistically significant, it will be beneficial for the tensile force to be adjustable rather than fixed in the designs to be made. The difference between the weight, width, thickness, height, and volume values of the cherries was also found to be statistically significant. For this reason, the system should be designed to be able to change and adjust according to different properties of fruit varieties when necessary. According to the results of the research conducted by Krumov and Christov (2018), cherry fruits should be transported with appropriate methods and the variety are suitable for mechanized harvesting. In the study conducted by Peterson and Wolford (2001) on mechanization, they stated that the cherries harvested by the machine they developed were damaged only 2-6% more than the traditionally harvested cherries, and the ratio of marketable cherries were found as 85-92%. Eroğul and Özmen (2020) reported that 0900 Ziraat variety is the most suitable variety after storage, shelf-life properties and stands out in terms of some quality characteristics.

### 3.6. Ratio of Fruit Mass to Tensile Force ($M/F_T$)

Moser (1989) stated that if the ratio of fruit mass to tensile force ($M/F_T$) is equal or greater than 1, the fruit is machine harvestable. The relationship between the tensile force of the product and the mass of the product is very important in the design of the harvesting units of the harvesters, especially in terms of the selection of the harvesting method. Table 7 summarizes the fruit mass to tensile force ratio results of the research.

The results indicates that all variety were suitable for machine harvesting ($M/F_T>1$) in the case of harvesting the fruit without a stalk, and 0900 Ziraat variety was suitable for harvesting with a stalk. When the results were examined, it was determined that 0900 Ziraat was the most suitable variety for machine harvesting in the case of picking cherries with or without stalks. The results found are in agreement with similar studies (Kocabıyık et al., 2009). Between the examined varieties, least suitable variety for machine harvesting is Lambert variety (Figure 2).

**Table 7.** Ratio of fruit mass to tensile force ($M/F_T$) results

| | Symbol | Unit | Cherry varieties | | | |
|---|---|---|---|---|---|---|
| | | | 0900 Ziraat | Starks Gold | Merton Late | Lambert |
| Tensile force of fruit (from stalk) | $F_{T-f}$ | N | 2.579 | 2.187 | 2.246 | 1.530 |
| Tensile force of stalk (from branch) | $F_{T-s}$ | N | 7.041 | 6.355 | 7.669 | 7.522 |
| Weight | M | g | 9.592 | 6.000 | 7.13 | 3.684 |
| According to tensile force of fruit (from stalk) | $M / F_{T-f}$ | | 3.719 | 2.744 | 3.175 | 2.408 |
| According to tensile force of stalk (from branch) | $M / F_{T-s}$ | | 1.362 | 0.944 | 0.930 | 0.490 |

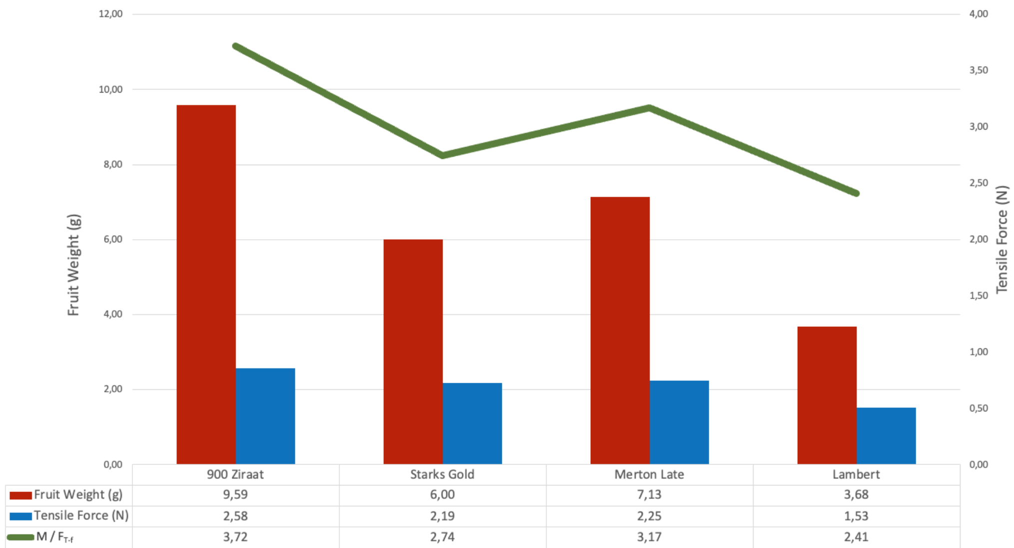


**Figure 2.** $M/F_{T-f}$ values for the cherry varieties.

## 4. Conclusion

In the research, the physico-mechanical properties of four cherry varieties grown in Tekirdag were determined and the data were measured to mechanize the cherry harvest. As a result of the evaluation and analysis of the obtained data, it was determined that all four cherry varieties were suitable for mechanical harvesting. However, it was determined that the most suitable variety for mechanical harvesting was '0900 Ziraat'. However, it would be beneficial to conduct similar studies in different regions for different cherry varieties, and thus to collect more results and high diversity of data on mechanization.

**Author Contributions**

E.O.: initiated the research idea, developed, organized, analyzed and interpreted the data and wrote the manuscript. S.A.: supervised the research, suggested the research methods, structured the paper and edited the manuscript.

**Conflict of Interest**

The author declared that there is no conflict of interest.

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