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Determination of the Effects of Rotational Velocity on Energy Consumption, Cracking Efficiency and Kernel Hazelnut Quality in Centrifugal Hazelnut Cracker

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Abstract

In this study, the effects of different hazelnut varieties and impeller velocities on energy consumption, hazelnut cracking efficiency and kernel quality in the centrifugal hazelnut cracking method were examined. Giresun Quality Tombul, Levant Quality Çakıldak and Kara hazelnuts, which are important Turkish hazelnut varieties, were selected as the study material. A centrifugal type machine, which does not require grading, crackes with the help of a rotating impeller, and has a crushing capacity of 100 kg per hour, was used as the experimental device. The study was carried out at 4 different fan rotation speeds: 350, 750, 1100 and 1450 rpm. According to the study results, although it is resulted that each hazelnut varieties different behaviors at different impeller velocities, it can be said that the optimum benefit is achieved at 1100 rpm. The results of the article emphasize that equipment adjustments and the development of hazelnut variety-specific processing strategies are important in optimizing cracking and parted rates in the hazelnut processing process. This study can serve as a basis for studies aimed at contributing to efficiency and quality improvements in the hazelnut processing industry.

Keywords: hazelnut cracking, energy efficiency, process efficiency, kernel quality

Savurmalı Fındık Kırma Makinesinde Dönme Hızının Enerji Tüketimi, Kırma Verimi ve İç Fındık Kalitesi Üzerine Etkilerinin Belirlenmesi

Öz

Bu çalışmada, savurmalı fındık kırma yönteminde farklı fındık çeşitlerinin ve işleme hızlarının enerji tüketimi, fındık kırma verimi ve iç kalite üzerindeki etkileri incelenmiştir. Çalışma materyali olarak önemli Türk fındık çeşitleri olan Giresun Kalite Tombul, Levant Kalite Çakıldak ve Kara fındık seçilmiştir. Deney düzeneği olarak boylama gerektirmeyen, dönen fan yardımıyla kırma yapan, saatlik 100 kg kırma kapasitesine sahip savurmalı tip makine kullanılmıştır. Çalışma 350, 750, 1100 ve 1450 rpm olamk üzere 4 farklı fan dönüş hızında yürütülmüştür. Çalışma sonuçlarına göre farklı fan dönüş hızlarında her fındık çeşidinin farklı davranışlar sergilediği görülse de optimum faydanın 1100 rpm'de sağlandığı söylenebilir. Makalenin sonuçları, ekipman ayarlamalarının ve fındık çeşitlerine özgü işleme stratejilerinin geliştirilmesinin, fındık işleme sürecinde çatlama ve parçalanma oranlarının optimize edilmesinde önemli olduğunu vurgulamaktadır. Bu çalışma, fındık işleme sanayinde verimlilik ve kalite iyileştirmelerine katkı sağlamak amacıyla yapılan çalışmalara temel teşkil edebilecek özelliktedir.

Anahtar Kelimeler: fındık kırma, enerji verimliliği, proses verimliliği, iç fındık kalitesi

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Introduction

Hazelnut (*Corylus avellana* L.) is one of the most popular nuts that can be consumed both natural and roasted, with an annual production of approximately 1.150.000 tons. Turkey, which produces 62% of global hazelnut product, is the most important producer, followed by Italy (13%), USA (6%), Azerbaijan (5%), Chile and Georgia (3%). Hazelnuts are also grown in countries such as Spain, Iran, Poland and France (FAO, 2020). The 18 types of hazelnuts grown in Turkey are divided into two according to their quality: Giresun Quality (prime quality) and Levant Quality (second quality). Prime quality consists of Tombul hazelnuts grown in the Giresun region, while other hazelnuts are classified as Levant Quality (Alasalvar et al., 2009).

Hazelnut, with its unique taste and crisp texture, is one of the most important nuts, which is used extensively in the confectionery and bakery industries, especially in chocolate, and can also be consumed as natural and roasted. In addition to its organoleptic properties, it is also important that hazelnut has a beneficial nutritional composition for human health (Ghirardello et al., 2016; Moscetti et al., 2012). It has been reported in many studies that regular hazelnut consumption reduces the risk of cardiovascular, diabetes, obesity, some cancer types and inflammatory diseases (Amaral et al. 2006; Pelvan et al. 2018; Pycia et al. 2019). In order to reduce the risk of coronary heart disease, the European Food Safety Authority recommends consuming 32.5 g of nuts containing hazelnuts daily (European Food Safety Authority, 2011).

The beneficial effects of hazelnut on human health are closely related to its special fatty acid profile, high content of tocopherol and phytosterol, and being rich in biologically active phytochemicals (Pelvan et al., 2018). Nutrient composition of hazelnut is also highly sensitive to hydrolytic or oxidative enzymes and degradation of oil by oxidation (Wang et al., 2018). It is very critical to crack the hazelnuts without damaging the inside of the fruit in order to preserve the nutritional components of the hazelnut during its shelf life and to reduce the development of undesirable flavors by fat oxidation.

In order for hazelnuts, which are a hard-shelled fruit, to be consumed as human food, the outer brown hard shell must be broken and separated from the fruit. Therefore, the hazelnut cracking process is a vital step in the hazelnut industry, which is the first and must-be implemented process and directly affects the quality of the hazelnut kernels (Delprete & Sesana, 2014). Hazelnut is a fruit that is rich in unsaturated fatty acids, especially oleic and linoleic acids. Although this makes hazelnuts beneficial for health, it also makes them very sensitive to hydrolytic or oxidative enzymes and oxidative oil degradation (Sun et al., 2022). Due to the special fatty acid composition of hazelnuts, it is of great importance to minimize the defect called bruising by damaging the fruit tissue during the cracking process (Akar, 2016). As a result of damage to the fruit tissue as a consequence of damage, the oil comes out of the tissue and enters into an intense reaction with air oxygen. Because of the rapid oxidation of unsaturated fatty acids, an increase in the amount of free fatty acids occurs and then a rancid taste called rancidity occurs. On the other hand, enzymatic discoloration occurs with the activation of polyphenol oxidase enzymes, especially as a result of physical damage to the brown membrane surrounding the fruit (Karaosmanoğlu, 2023). Therefore, in order to preserve the sensory quality during the shelf life, it is essential to develop cracking units that will not damage the fruit during the hazelnut cracking process.

Of course, there is a close relationship between hazelnut cracking and energy consumption. Hazelnut cracking is generally done by using electrical energy. Therefore, energy is needed to operate the machines used for the process. Electric motors are used to ensure the operation of hazelnut crackers. In addition, the energy consumption during the hazelnut cracking process may vary depending on the capacity of the machines used, the processing volume and the hardness of the shells outside the hazelnuts. Cracking hazelnuts with thicker shells may require more energy. According to Dursun (2023), there is a linear relationship between hazelnut shell thickness and cracking force. Cracking force varies depending on the shell thickness and can reach up to 200 N. The energy consumption of the machines used for the hazelnut cracking process depends also on factors such as the processing efficiency, the level of technology and the characteristics of the hazelnuts. More efficient machines and energy saving methods can both reduce energy costs and reduce environmental impact (Dursun, 2023).

In Turkey, which is the most important producer country, hazelnut cracking is traditionally carried out in cracking facilities with stone mills. In this system, hazelnuts are first calibrated according to their dimensions, and then the distance between the crackers in the stone mill is adjusted and the cracking process takes place. However, in this system, high and wide structures are needed especially for classification, which results in very high installation costs. Cracking systems, which have been developed on a smaller scale in recent years, still need calibration, although they take up less space. This situation both reduces the cracking capacity and increases the amount of energy consumed. Due to all these negativities, the development of hazelnut cracking machines that do not need fruit calibration, have high cracking efficiency and low energy consumption, and do not damage the inside of the fruit during cracking is of great importance, especially for the expansion of small-scale processing facilities. In this study, the effects of the cracking process on the energy, cracking efficiency and hazelnut kernel quality of Giresun Quality Tombul, Levant Quality Çakıldak and Kara varieties using a rorational system hazelnut cracking machine were investigated.

Materials and Methods

Materials

In the study, Tombul (Giresun Quality), Çakıldak and Kara (Levant Quality) hazelnut varieties, which are commercially important Turkish hazelnut varieties, were used. Tombul, Kara and Çakıldak hazelnut samples are respectively Akköy (Giresun- 40°51'37.73" N, 38°18'59.61" E), Çaldağ (Giresun- 41°06'02.25" N, 39°15'01.00" E) and from the orchards produced by conventional farming methods in Yeşiltepe (Giresun-40°75'69.53" N, 38°53'16.74" E) regions. The harvested hazelnuts were separated from their green husks with a thresher and then left to dry in a concrete blend on a jute awning (5x5 m) under the sun for 4 days (36 hours) between 09:00 in the morning and 18:00 in the evening (average temperature 23.6 °C). It was also mixed 5 times every day during the drying period. After 18:00 in the evening, each awning was gathered in the middle and covered with a nylon cover to prevent moisture transfer. At the end of the 4th day, the drying process was terminated when the moisture content of the hazelnuts dropped below 6%. Dried hazelnuts were kept in jute sacks under ambient conditions until the day of analysis.Before the analysis, nut sizes, weights and shell thicknesses of the samples were measured according to the methods mentioned in Karaosmanoğlu (2022) (Table 1).

Each experiment was conducted with 100 hazelnuts in 3 repetitions. For every 100 hazelnuts, whole hazelnut, uncracked, damaged, parted and partially cracked were separated and reported as a percentage. When determining the amount of damaged hazelnuts, visible damage was taken into account.

Table 1. Nut and Kernel Dimensions, Weights and Shell Thicknesses of Hazelnut Samples

Cultivar	Nut length (mm)	Nut width (mm)	Nut depth (mm)	Kernel length(mm)	Kernel width (mm)	Kernel depth (mm)	Nut weight (g)	Kernel weight (g)	Shell thickness (mm)
Tombul	18.56±1.22	15.02±1.24	16.58±0.99	14.32±1.09	11.79±1.11	12.73±1.50	1.70±0.23	1.03±0.09	0.95±0.10
Çakıldak	19.06±1.02	15.36±1.11	16.46±1.19	14.01±1.01	11.12±1.01	12.37±1.25	1.57±0.22	0.87±0.10	0.91±0.09
Kara	18.88±0.89	14.38±0.76	16.04±0.52	14.77±0.77	9.81±0.21	10.62±0.71	1.50±0.12	0.77±0.08	0.99±0.08

All values are presented as mean ± standard deviation (n= 3).

Cracking Setup

In the study, a whirlwind type hazelnut cracking machine was used. The hazelnuts are poured from the upper chamber and broken by hitting the blades of the impeller connected to the end of the engine. The schematic picture of the machine is shown in Figure 1 below. There is a shaft coupled to the electric motor and a impeller at the end of the machine. Nuts poured from the feeding chamber get broken by hitting the rotating impeller blades without undergoing any sorting process. There is a 120 Watt motor on the machine. In order to find the amperage drawn by the machine during cracking, an ampere meter is connected in series on the power cable of the machine.

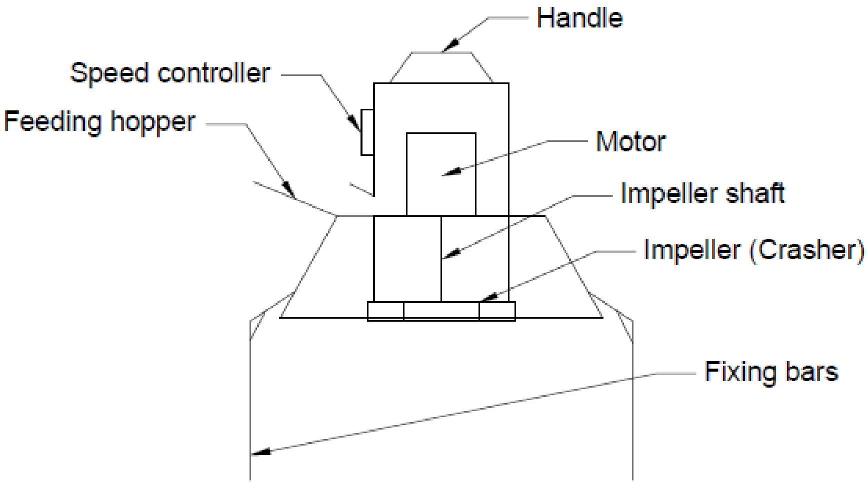

Figure 1. Representation of Hazelnut Cracking Machine

The velocity drive and the cracking impeller in the hazelnut cracking machine were operated at 4 different velocities (350, 750, 110,1450 rpm). Nuts were poured from the feeding chamber on the side of the machine in each revolution and taken into a box. In the box, the hazelnuts were handled one by one and they were categorized under 5 different groups as whole hazelnut, uncracked, damaged, parted, partially cracked.

The amount of current drawn at each of four different velocities was measured with an ampere meter connected in series on the line and the current value was read directly from the ampere meter. The amount of electrical energy consumed was calculated from the Equation 1.

$$P=V.I \quad (1)$$

Where P (Watt) is the power, V (Volt) is the voltage, and I (Ampere) is the current

While normally the current drawn by the motor is expected to increase with increasing velocity, the opposite happened in this study. There is theory between RPM and armature current explained by the principle of electromagnetic induction. Accordingly, as the machine velocity increases, the magnetic field change rate also increases. This leads to a decrease in armature current. A model can be created by considering the forces acting on the hazelnut and the laws of motion.

There are three basic forces acting on the nuts in the rotating impeller. These forces are (1) weight force (mg), (2) centrifugal force ($mr\omega^2$) and (3) friction force ($\mu mr\omega^2$).

where m is the mass, g is the gravitational acceleration, r is the radius of rotation of the impeller, and ω is the angular velocity.

If the impact velocity of the nut is greater than the linear velocity of the wheel V, it will accelerate towards the falling direction of the nut and suffer more damage. This is because the centrifugal force acting on the nut increases its effect in the direction of falling.

If the falling velocity of the nut is less than the linear velocity of the wheel V, the centrifugal force will still be effective, but less in the falling direction. In this case, it is expected that the nut will gain less velocity and suffer less damage while falling. Net force acting on the hazelnut can be defined as:

Total force = Centrifugal force - Weight force

$$F_{net} = mr\omega^2 - mg \quad (2)$$

Impact force: $F_{net} = mV'$ where V' is the impact velocity of the nut. If V' is drawn from here;

$$V' = (mr\omega^2 - mg) / m \quad (3)$$

V' : (impact velocity, m/s), m: mass (kg), r: diameter (m), ω: angular velocity (rad/s)

Statistical Analysis

Analyses were conducted using JMP (pro-16) statistical software. One-way ANOVA followed by Tukey's post-hoc test was used to compare the means of the study sets. A p-value less than 0.05 was considered to be statistically significant. Results were expressed as means ± and standart deviation (n=3) for each determination.

Results and Discussions

As a result of the experiments, it is seen that the nut cracking rate increases up to a certain velocity of the impeller and then the crack rate does not increase. This situation can be explained by the effects of the rotating impeller and the behavior of the hazelnut. In the rotating impeller, the forces acting on the hazelnut include weight force (mg) and centrifugal force ($mr\omega^2$). The spilled hazelnut accelerates as it is subjected to these forces, and a friction force also interacts. Up to a certain velocity value, as the velocity of the hazelnut increases, the centrifugal force also increases and the effect of the hazelnut in the direction of impact becomes stronger. In this case, the nut crashes faster and is damaged more. Frictional force can also increase with increasing velocity, but generally has a smaller effect than centrifugal force. However, even if the velocity of the hazelnut increases after a certain point, the increase in centrifugal force is limited. At this point, the centrifugal force remains constant or increases very little. Friction force continues to increase rapidly. At this point, the friction force dominates the centrifugal force and limits the impact velocity of the hazelnut. Thus, the hazelnut is less damaged after a certain velocity because the increase in impact velocity slows down.

Energy Consumption

In the study, the data was obtained by operating the machine at 4 different velocities (350, 750, 1100, and 1450 rpm). The average amperage values drawn at no load and at load in each revolution were read. During both idle and load operation, the amount of amperage drawn by the machine increased with the increasing revolution velocity, and the increase in the current value decreased after a certain velocity value. In the idle state, 112, 104, 89 and 88 W energy consumption was achieved for 350, 750, 110 and 1400 rpm, respectively, while this value varied between 135 and 120 W during hazelnut cracking. Since the working principle of the machine is based on the principle that the nuts hit the impeller blades, the current drawn by the machine at load was higher than the current drawn at no load. Figure 2 shows the idle and load power consumptions.

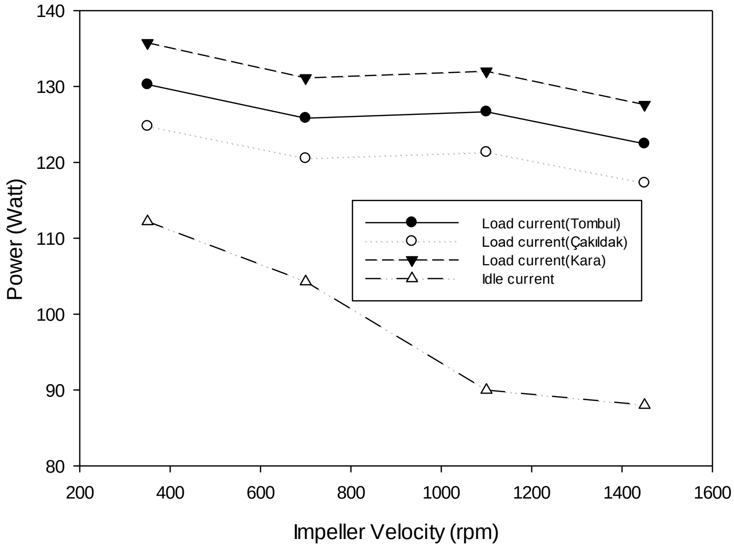

Figure 2. Power Consumption of the Machine

The relationship between impeller velocity and armature current can be explained by the principle of electromagnetic induction. Basically, as the number of revolutions of the machine (especially the rotor) increases, the rate of change of the magnetic field within the armature also increases. This means that the induced electromotive force (EMF) in the armature also increases, leading to a decrease in the armature current. Conversely, as the RPM decreases, the induced EMF decreases, resulting in an increase in armature current. This is known as the "EMF equation" in electrical machines.

Variation of the Number of Whole Hazelnuts with Rotational Velocity

Figure 3, given below, shows the number of whole hazelnut kernels formed in hazelnut cultivars in the cracking process at different velocities. Based on these data, we can observe that each hazelnut cultivar has different nut yields at different times. According to the results, the highest efficiency in Tombul was detected at 350 rpm, while the efficiency increased at a statistically significant level at 750 rpm ($P<0.001$). There was no significant difference between 1100 and 1450 rpm ($P>0.05$). While the highest efficiency in Çakıldak was observed at 750 rpm, the lowest efficiency was detected at 350 rpm. The difference between 1100 and 1450 rpm was not found to be statistically significant. As expected, the highest yield in the Kara was detected at 1450 rpm. However, interestingly, while there was no difference between 350 and 750 rpm, the efficiency decreased at 1100 rpm. It is well known that the chemical and physical properties of hazelnuts vary significantly depending on the variety (Amaral et al. 2006). These differences may be due to differences in physical properties such as hazelnut shell thickness and flexibility. Based on these data, we can observe the differences in the nut yield of different hazelnut cultivars.

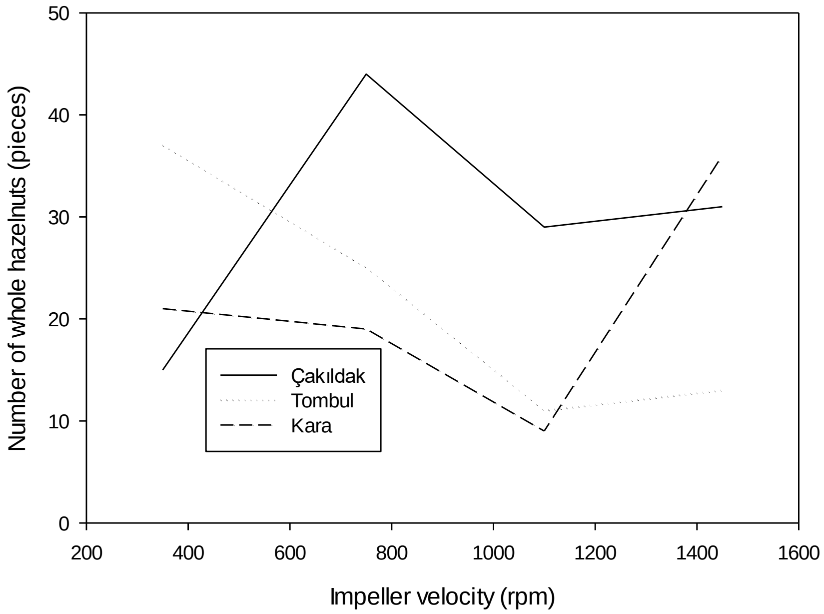

Figure 3. Variation of the Number of Whole Nuts with Impeller Velocity

Variation of the Number of Uncracked with Impeller Velocity

Figure 4 shows the variation of the number of uncracked hazelnuts with the change of impeller velocity. According to these data, we can observe that each hazelnut cultivar has the number of uncracked hazelnuts at different impeller velocities. According to the statistical analysis results, as the rotationalvelocity increased in Tombul, the proportion of uncracked hazelnuts decreased (P<0.001) and all samples cracked at 1450 revolutions. In addition, the uncracked rate in Tombul, which was 13% at 350 rpm, dropped dramatically to 4% at 750 rpm. There is only a 2% difference between 750 and 1100 rpm. While the highest rate of uncracked hazelnuts in the Çakıldak variety was detected at 350 rpm, it was observed that the other velocities were statistically in the same group (P<0.001). In addition, the rate of 35% in Çakıldak 350 rpm dropped below 2% in other velocities. In Kara, the highest unbroken rate was found at 350 cycles (P<0.001), while no difference was observed between 1100 and 1450 rpm. However, in Kara, the dramatic decrease was recorded at 1100 rpm, probably due to the high crustal thickness. The ratio, which was 46% at 350 rpm, decreased to 27% at 750 rpm and 3.67% at 1100 rpm and remained unchanged thereafter.

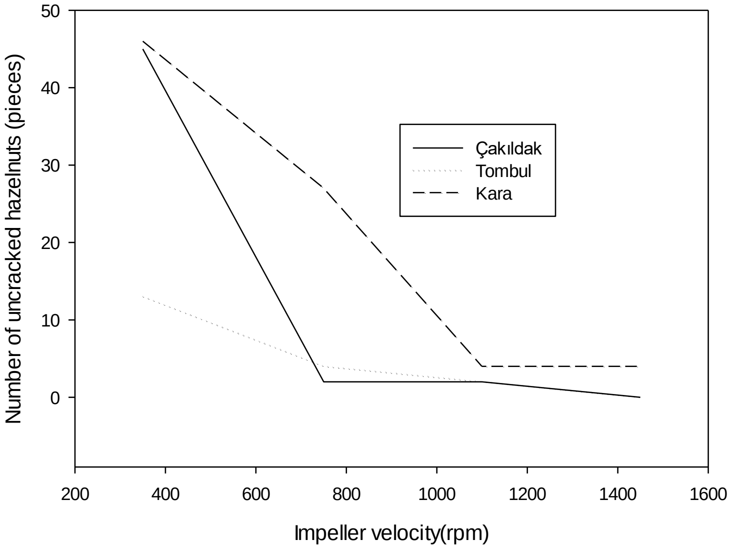

Figure 4. Variation of the Number of Uncracked Hazelnuts with The Rotation Velocity

Variation of the Damaged Nut Number with the Impeller Rotation Velocity

During the cracking process, some nut kernels may be damaged by the effect of rapid impact. As a result of this problem, the oil goes out of the tissue and the oxidation rate increases. Depending on the oxidation, in addition to the rancid taste formation, discoloration may also occur (Akar, 2016). For this reason, it is desired that the damaged nut ratio is low in the cracking process. Figure 5 shows the data on the number of damaged nuts. According to these data, we can observe that each hazelnut cultivar results in varying number of damaged nuts at different impeller velocities. For example, while the highest damaged rate in Tombul and Kara was reached at 1450 rpm, it was at 1100 rpm in Çakıldak. In addition, it is noticed that the number of hazelnuts that are damaged generally increases with the increase in the impeller velocity. According to the results of the statistical analysis, it was observed that as the rpm increased in the Tombul variety, the rate of damaged also increased ($P<0.001$). The lowest number of damaged was detected at 350 cycles (12%) and the highest at 1450 cycles (25%). While similar behavior was observed for Kara, at 350 and 750 rpm were statistically in the same group. Similarly, in Çakıldak, the lowest damaged was resulted at 350 rpm, while interestingly, a higher damaged rate was determined at 1100 rpm compared to 1450. This may be due to the flexibility in the skin of the Çakıldak variety. Based on these data, it was observed that the rate of damaged generally increased as the rpm increased ($p<0.001$).

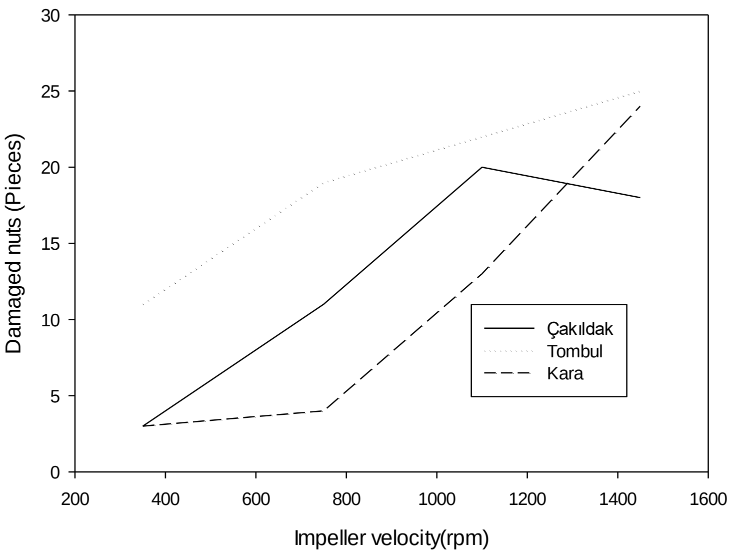

Figure 5. Variation of the Number of Damaged Nut With the Impellerrotation Velocity

Variation of the Number of Parted Hazelnuts with Impeller Rotation Velocity

Figure 6 gives the variation of the number of parted hazelnuts. We can observe that each hazelnut cultivar has the number of hazelnut kernels that are parted at different impeller velocities. For example, in the Tombul variety, the highest parted rate was seen at 1100 rpm, while the parted rate at 1450 rpm was significantly less ($P<0.001$). The lowest parted rate was observed at 350 rpm, as expected. While there was no statistical difference between 1450 and 1100 rpm for Çakıldak, the lowest parted rate was observed at 350 rpm due to the decrease in revolution. Kara hazelnuts showed a very variable effect. While there was a significant difference between all rpm ($P<0.001$), the lowest parted rate was resulted at 350 rpm and the highest rate was resulted at 1100 rpm. In addition, it is observed that the number of parted hazelnut kernels increases with the increase in the impeller velocity in general. Based on these data, it is seen that there are differences in the number of cracked hazelnut kernels and the impeller velocity is effective on the number of cracked hazelnut kernels.

It is remarkable that the number of parted hazelnuts does not increase or even decreases although the velocity increases between the 3rd and 4th impellers for different hazelnut cultivars. This indicates that different hazelnut cultivars respond differently to mechanical effects and that the cracking resistance is not directly related to the increase in velocity. Such a situation indicates that the internal structure of hazelnut cultivars may be different and other factors besides impellervelocity may affect the cracking rate. The reasons for the differences between hazelnut cultivars may be factors such as genetic characteristics, shell thickness, compactness or elasticity in the internal structure. This observation indicates that there are factors that need to be optimized in the hazelnut processing and cracking process. Perhaps the adjustment of the equipment used in the cracking process or the development of special processing methods for hazelnut cultivars may affect the increase or decrease in the cracking rate (Delprete & Sesana, 2014; Güner et al., 2003).

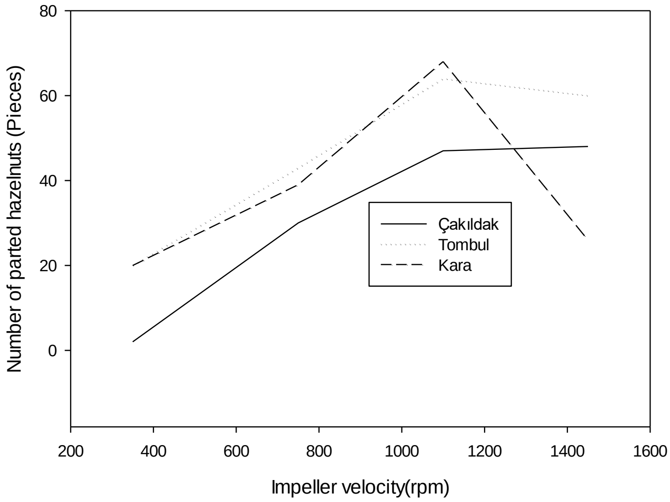

Figure 6. Variation of the Number of Parted Hazelnuts with Impeller Velocity

Variation of the Number of Partially Cracked Hazelnuts with Impeller Velocity

Figure 7 shows the change in the number of partially cracked hazelnuts. According to these data, we can observe that each hazelnut cultivars has the number of partially cracked hazelnuts at different impellervelocities. According to the statistical analysis results, the highest partial cracked rate in Tombul resulted in the lowest rpm, while as the rpm increased, the amount of partial cracked decreased, as expected. However, there was no significant difference between 1100 and 1450 rpm. While the Çakıldak exhibited a similar behavior to Tombul, it showed higher partial crack at low speeds. Interestingly, in Kara hazelnuts, the lowest partial crack rates were resulted at the lowest and highest rpm ($P<0.001$). While the highest partial crack was detected at 750 rpm, a decrease in partial crack was observed at 1100 rpm ($P<0.001$). Based on these data, it is seen that there are differences in the number of partially cracked hazelnuts the impeller velocity is effective on the number of partially cracked hazelnuts ($P<0.001$). Especially in the hazelnut processing process, taking these differences into account, making appropriate adjustments may be important to minimize the number of partially cracked hazelnuts.

According to these data, we can observe that the number of partially cracked hazelnuts in Kara hazelnuts at the 4th impellervelocity increased compared to the 3rd impellervelocity. A similar trend is observed in Çakıldak and Tombul hazelnuts, which are other hazelnut cultivars. This may suggest that the 4th impellervelocity increases the cracking resistance of hazelnut cultivars or that there are less cracked hazelnuts at the 3rd impellervelocity. In conclusion, in the light of these data, we can draw attention to the increase in the number of partially cracked hazelnuts at the 4th impellervelocity compared to the 3rd impellervelocity.

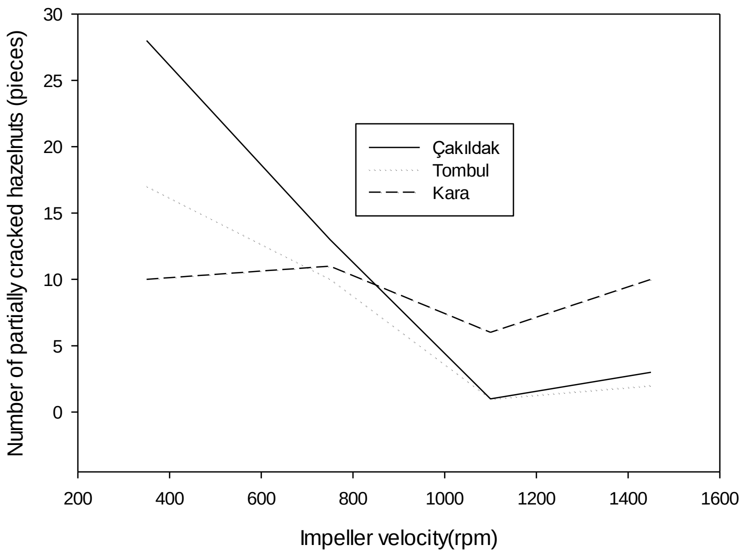

Figure 7. Variation of the Number of Partially Cracked Hazelnuts with Impeller Velocity

Conclusion

Depending on the different hazelnut cultivars (Tombul, Çakıldak, Kara) and their impeller velocity, the cracking and splitting conditions of hazelnuts differ. Differences are observed in the number of cracked hazelnuts and the number of cracked hazelnut kernels among hazelnut cultivars. Each hazelnut cultivar exhibits different cracking and splitting tendencies depending on the impeller velocity. According to the results of the study, it was resulted that impeller velocity affected the energy consumption, whole hazelnuts, uncracked, damaged nuts, parted hazelnuts, partially cracked hazelnuts levels of hazelnut varieties. Energy consumption decreases with increasing impeller velocity. However, no significant difference was observed between 1100 and 1450 rpm. While the amount of whole hazelnut kernels increased up to 750 rpm for Çakıldak, it decreased thereafter. In Tombul and Kara, it decreased up to 1100 rpm and increased at 1450 rpm. The number of uncracked hazelnuts decreased with increasing impeller velocity in all varieties. However, the change after 1100 rpm was not significant. The number of hazelnuts tended to increase with increasing impeller velocity in all three hazelnut varieties. In Çakıldak, it fell after 1100 rpm. While the number of cracked hazelnuts increased up to 1100 rpm for all varieties, it generally decreased thereafter. The number of partially cracked hazelnuts decreased with increasing impeller velocity, but generally increased after 1100 rpm. As a result, when hazelnut kernel quality and other parameters are considered together, it has been seen that the cracking process at 1100 rpm has optimum efficiency.

Author Contribution

Birkut Güler, prepared the experimental environment and followed the experimental process. Performed data collection and statistical analysis. *Hasan Karaosmanoğlu*, performed the data collection and statistical analysis. The authors co-wrote, read, and approved the manuscript.

Ethic

There are no ethical issues regarding the publication of this article.

Conflict of Interest

The authors state that they have no conflict of interest.

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References

Akar, A. (2016). Tombul, *Palaz ve Kalınkara fındık çeşitlerinde elle ve patozla ayıklanmış örneklerde depolama süresince meydana gelen kalite değişimleri* [Master's thesis]. Ordu University.

Alasalvar, C., Amaral, J. S., Satır, G., & Shahidi, F. (2009). Lipid characteristics and essential minerals of native Turkish hazelnut varieties (Corylus avellana L.). *Food Chemistry, 113*, 919–925. https://doi.org/10.1016/j.foodchem.2008.08.019

Amaral, J. S., Casal, S., Citova, I., Santos, A., Seabra, R. M., & Oliviera, B. P. P. (2006). Characterization of several hazelnut (Corylus avellana L.) cultivars based in chemical, fatty acid and sterol composition. *European Food Research and Technology, 222*, 274–280. https://doi.org/10.1007/s00217-005-0068-0

Delprete, C., & Sesana, R. (2014). Mechanical characterization of kernel and shell of hazelnuts: Proposal of an experimental procedure. *Journal of Food Engineering, 124*, 28-34. https://doi.org/10.1016/j.jfoodeng.2013.09.027

Dursun, İ. (2023). *Kabuk kırma makinaları*. İKSAD Publishing House.

European Food Safety Authority, (2011). Scientific Opinion on the substantiation of health claims related to nuts and essential fatty acids (omega-3/omega-6) in nut oil (ID 741, 1129, 1130, 1305, 1407) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal, 9*(4), 2032. https://doi.org/10.2903/j.efsa.2011.2032

FAO (2020). Food and agriculture organization of the United Nations. FAO Statistics Division. Retrieved March 15, 2023 from https://www.fao.org/faostat/en/#rankings/countries_by_commodity

Ghirardello D., Bertolini M., Belviso S., Bello B. D., Giordano M., Rolle L., Gerbi V., Antonucci M., Spigolon N., & Zeppa G. (2016). Phenolic composition, antioxidant capacity and hexanal content of hazelnuts (Corylus avellana L.) as affected by different storage conditions. *Postharvest Biol. Technol., 112*, 95-104. https://doi.org/10.1016/j.postharvbio.2015.09.039

Güner, M., Dursun E., & Dursun, İ. G. (2003). Mechanical behaviour of hazelnut under compression loading. *Biosystems Engineeering, 85*(4), 485-491. https://doi.org/10.1016/S1537-5110(03)00089-8

Karaosmanoğlu, H. (2022). Geç hasadın Tombul fındığın biyometrik ve renk özellikleri ile aflatoksin düzeyine etkisi. *Harran Tarım ve Gıda Bilimleri Dergisi, 26*(4), 549-559. https://doi.org/10.29050/harranziraat.1138327

Karaosmanoğlu, H. (2023). Farklı ambalaj materyallerinin depolanan fındıkların geometrik ve renk özellikleriyle aflatoksin oluşumuna etkisi. *Anadolu Tarım Bilimleri Dergisi, 38*(2), 331-352. https://doi.org/10.7161/omuanajas.1115743

Moscetti, R., Frangipane, M. T., Monarca, D., Cecchini, M., & Massantini, R. (2012). Maintaining the quality of unripe, fresh hazelnuts through storage under modified atmospheres. *Postharvest Biology and Technology, 65*, 33-38.https://doi.org/10.1016/j.postharvbio.2011.10.009

Pelvan, E., Olgu, E. Ö., Karadağ A., & Alasalvar, C. (2018). Phenolic profiles and antioxidant activity of Turkish Tombul hazelnut samples (natural, roasted, and roasted hazelnut skin). *Food Chemistry, 244*, 102–108. https://doi.org/10.1016/j.foodchem.2017.10.011

Pycia, K., Kapusta, I., & Jaworska, G. (2019). Impact of the degree of maturity of walnuts (Juglans regia L.) and their variety on the antioxidant potential and the content of tocopherols and polyphenols. *Molecules, 24*(16), 2936. https://doi.org/10.3390/molecules24162936

Sun, J., Hu, P., Lyu, C., Tian, J., Meng, X., Tan, H., Dong, W. (2022). Comprehensive lipidomics analysis of the lipids in hazelnut oil during storage. *Food Chemistry. 378*, 132050. https://doi.org/10.1016/j.foodchem.2022.132050

Wang, W., Jung, J., McGorrin, R. J., Traber, M. G., Leonard, S. W., Cherian, G., & Zhao, Y. (2018). Investigation of drying conditions on bioactive compounds, lipid oxidation, and enzyme activity of Oregon hazelnuts (Corylus avellana L.). *LWT-Food Science and Technology, 90*, 526–534. https://doi.org/10.1016/j.lwt.2018.01.002