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Effect of drying methods on the sensory attributes of hazelnut cultivars in different sizes throughout the storage

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ABSTRACT

The main aim of this study was to evaluate the effect of nut sizes and drying methods on the sensory attributes of hazelnut cultivars (*Corylus avellana* L. cvs. Çakıldak, Palaz and Tombul) during the storage. Shelled hazelnut were dried under sun, shadow at room conditions and cold dried at 2 °C and 7 °C and stored at 20±5 °C and 80±5 % relative humidity. Evaluation of sensory attributes was carried out quarterly (harvest, 3, 6, and 9 months). In the Çakıldak cultivar (in 16 mm size), the odor of cold-dried hazelnuts at 2°C was higher than other drying methods in the last two measurements. It was observed that shadow-dried hazelnuts and at 7°C cold, dried hazelnuts had lower rancidity. No significant effect of drying methods was observed on the cultivars' flavor, firmness and color. As a result, it is revealed that drying methods have an effect on the rancidity in hazelnut kernels during storage.

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1. Introduction

In addition to being consumed as dried nut, hazelnut is used as a raw material in the production of many foods such as chocolate, dessert, cake and cream. Therefore, it can be stored for 1-2 years in ordinary warehouses as raw materials. Nutriment quality is lost during storage. It is even stated that there are losses in sensory properties such as taste, flavor and aroma (Turan, 2019; Chen et al., 2021). These losses can be caused by early or late harvest, maturity stage, transportation and storage conditions, and diseases and pests (Borompichaichartkul et al., 2009; Qu et al., 2016; Turan and İslam, 2019). As in all agricultural products, some applications are made with hazelnut to prevent losses and maintain quality in the postharvest period (Güler et al., 2017). At the beginning of these is the reduction of the moisture content, which is necessary for maintaining the quality loss for a long time. Failing to dry hazelnuts to international standards causes product and market loss (Aktaş et al., 2004; Turan and İslam, 2016). For this reason, many drying methods (Bostan, 2000) and technologies (Ceylan and Aktaş, 2008) are used for drying hazelnuts. Researchers have reported that drying methods affect hazelnut bioactive content and sensory properties (Fennema, 1985; Akçin and Bostan, 2019; Wang et al., 2020; Tu et al., 2021).

While hazelnuts are dried by machine in countries such as the USA, Spain and Italy, they are widely dried in the sun in Türkiye. Sun-dried nuts are laid on concrete, wood and grass and dried to the desired humidity level (Bostan, 2000; Turan and İslam, 2019). Drying in the sun is preferred because of its low energy cost. However, due to the rainy season in the hazelnut growing regions, the drying process is very laborious for the producers and increases the drying costs. Machine drying is not common in Türkiye. Especially when machine drying costs are added to sustainable costs, profitability in production decreases. In this context, alternative drying methods should be investigated. Cold drying can be one of these methods. As a result of high drying temperature, loss of color, taste, flavor, vitamin content and structural deterioration are more. However, the losses in products dried at low temperatures may be lower (Hürdoğan et al., 2013). This study aimed to determine the effects of sun, shadow and low-temperature drying methods on the sensory properties of Tombul, Palaz and Çakıldak hazelnut cultivars of different sizes stored under ordinary conditions.

2. Materials and methods

2.1. Plant materials

The plant material of this study was obtained from Tombul, Palaz and Çakıldak (Balık et al., 2016) hazelnut cultivars grown in commercial orchard in the Altinordu, Ordu. After the nuts were separated from the husk manually, each hazelnut variety was first passed through 2 different sorting sieves of 16 mm and 18 mm.

Sun drying was carried out under sun under the weather conditions of the harvest season. Drying in shadow conditions was carried out in an environment with air movement, where the nut were not exposed to sun. Drying at 2 and 7 °C was carried out in a cooler (Arçelik, Türkiye) at

70±5% RH, where temperature control could be achieved at 0-10 °C. Nuts were placed in grids with 10 cm intervals in order not to prevent the air movement created in the cooler. The distance between the grids was 25 cm. A fan assembly was installed to provide cold air movement at a speed of 0.5 m s^{-1} in the environment and the air mobility was continuous. Drying was terminated when the kernel moisture content fell to 6% at all. Afterward, all nuts were immediately transferred to ordinary conditions (to the merchant warehouse). Nuts were stored during the 270 days (9 months) and sensory analyses were performed at 90-day intervals.

2.2. Methods

Approximately 100 g of shelled nuts was taken as a coincidence for each application in each measurement period. The experiment was designed with three replications. Details of the applications are given in Table 1.

2.2.1. Sensory evaluation

The analyses were carried out by 6 panelists aged between 30-45, who had been cultivating hazelnuts for many years, could distinguish the sensory properties of hazelnuts, and had high school and undergraduate education levels, and did not smoke were preferred. In the study conducted on Çakıldak, Palaz and Tombul hazelnut cultivars, each sample was given a code number, and the panelists evaluated the hazelnuts they ate by filling out the form given to them. In the study, sensory characteristics (flavor, rancidity, odor, firmness and color) evaluated according to the hedonic scale. Flavor, odor, firmness and color characteristic in the scale were scored from 0 to 5 (0: Unacceptable, 1: Very Bad, 2: Bad, 3: Acceptable, 4: Good, 5: Very Good) and averaged. The rancidity was described as 0: Excellent 1: Very good, 2: Good, 3: Acceptable, 4: Bad, 5: Very bad.

Table 1. Details of treatments in the study

Çakıldak/Palaz/Tombul							
Sun		Shadow		2 °C		7 °C	
16 mm	18 mm	16 mm	18 mm	16 mm	18 mm	16 mm	18 mm

2.3. Statistical analysis

The normal distribution of data (Kolmogorov-Smirnov) and homogeneity of variance (Levene) tests were checked. ANOVA was performed on the data that met the conditions. Tukey's multiple comparison test was used to determine whether there was a difference between the treatments ($p \leq 0.05$). Statistical analyzes were performed in Minitab® 17 software (Minitab Inc., State College, PA, USA).

Table 2. Effect of drying methods on the flavor of hazelnut cultivars in different sizes throughout the storage

Cultivars	Sizes	Drying methods	Flavor			
			Harvest	90 d	180 d	270 d
Çakıldak	16 mm	Shadow	4.00 ab	3.83 a	4.66 a	4.00 a
		Sun	3.66 b	4.16 a	4.33 a	4.16 a
		2 °C	4.66 a	4.16 a	4.33 a	4.50 a
		7 °C	4.00 ab	3.83 a	4.00 a	4.00 a
	18 mm	Shadow	4.00 ab	3.83 ab	4.00 a	3.83 b
		Sun	3.66 b	3.83 ab	4.33 a	3.83 b
		2 °C	4.33 a	3.67 b	4.33 a	3.83 b
		7 °C	4.16 ab	4.33 a	4.33 a	4.16 a
Palaz	16 mm	Shadow	4.00 a	4.00 a	4.16 a	3.83 a
		Sun	4.16 a	4.00 a	4.00 a	4.00 a
		2 °C	4.33 a	3.83 a	4.16 a	4.16 a
		7 °C	4.66 a	3.66 a	4.00 a	4.16 a
	18 mm	Shadow	4.16 b	3.50 a	3.83 a	3.83 ab
		Sun	4.16 b	4.00 a	3.88 a	3.66 b
		2 °C	4.83 a	4.00 a	4.00 a	4.11 ab
		7 °C	4.66 ab	4.83 a	4.16 a	4.50 a
Tombul	16 mm	Shadow	3.83 ab	4.00 b	4.33 a	4.16 a
		Sun	3.66 b	3.50 c	4.33 a	4.00 a
		2 °C	4.33 a	3.66 c	4.33 a	4.16 a
		7 °C	3.66 b	4.33 a	4.55 a	4.00 a
	18 mm	Shadow	3.33 b	3.83 a	4.16 a	3.66 a
		Sun	4.00 ab	4.00 a	4.33 a	4.00 a
		2 °C	4.16 a	4.50 a	4.00 a	4.33 a
		7 °C	4.66 a	4.00 a	4.16 a	4.16 a

The differences among mean values shown on the same column with the same letter is not significant ($p<0.05$).

3. Results

3.1. Flavor

When Çakıldak nut of different sizes was evaluated, the flavor of the nut (a size16 mm) dried at 2 °C was found to be higher compared to dried only in the sun at harvest. In the evaluation made in the third month, the flavor of the nut (a size 18 mm) dried at 7 °C was higher than those dried only at 2 °C. In addition, in the examinations made in the ninth month, it was determined that the flavor of the nuts dried at 7 °C was higher than the other drying methods.

Table 3. Effect of drying methods on the rancidity of hazelnut cultivars in different sizes throughout the storage

Cultivars	Sizes	Drying methods	Rancidity			
			Harvest	90 d	180 d	270 d
Çakıldak	16 mm	Shadow	0.00 b	0.50 a	0.50 a	0.30 b
		Sun	0.00 b	0.00 b	0.00 b	0.41 b
		2 °C	0.00 b	0.00 b	0.00 b	0.22 b
		7 °C	0.50 a	0.33 a	0.00 b	1.00 a
	18 mm	Shadow	0.00 b	0.00 b	0.00 a	0.50 ab
		Sun	0.00 b	0.00 b	0.00 a	0.83 a
		2 °C	0.00 b	0.50 a	0.00 a	0.50 ab
		7 °C	0.33 a	0.17 ab	0.00 a	0.39 b
Palaz	16 mm	Shadow	0.28 a	0.00 a	0.00 b	0.16 b
		Sun	0.00 a	0.00 a	0.16 ab	0.16 b
		2 °C	0.33 a	0.00 a	0.33 a	0.66 a
		7 °C	0.00 a	0.16 a	0.00 b	0.16 b
	18 mm	Shadow	0.00 b	0.00 b	0.50 a	0.50 bc
		Sun	0.00 b	0.33 a	0.66 a	1.00 ab
		2 °C	0.50 a	0.50 a	0.66 a	1.66 a
		7 °C	0.00 b	0.00 b	0.00 b	0.00 c
Tombul	16 mm	Shadow	0.00 a	0.00 a	0.00 b	0.00 b
		Sun	0.00 a	0.00 a	0.66 a	0.66 a
		2 °C	0.00 a	0.00 a	0.00 b	0.00 b
		7 °C	0.00 a	0.00 a	0.00 b	0.00 b
	18 mm	Shadow	0.50 a	0.00 a	0.00 b	0.50 bc
		Sun	0.00 b	0.00 a	0.00 b	0.00 c
		2 °C	0.00 b	0.00 a	0.16 b	1.16 a
		7 °C	0.16 b	0.00 a	0.50 a	0.66 ab

The differences among mean values shown on the same column with the same letter is not significant ($p<0.05$).

Table 4. Effect of drying methods on the odor of hazelnut cultivars in different sizes throughout the storage

Cultivars	Sizes	Drying methods	Odor			
			Harvest	90 d	180 d	270 d
Çakıldak	16 mm	Shadow	3.83 b	4.00 a	4.00 ab	3.83 b
		Sun	4.00 ab	4.16 a	3.83 b	3.66 b
		2 °C	4.50 a	4.00 a	4.66 a	4.50 a
		7 °C	4.00 ab	4.00 a	3.83 b	3.66 b
	18 mm	Shadow	3.83 a	3.83 a	3.83 a	3.66 b
		Sun	4.00 a	4.33 a	4.00 a	4.00 a
		2 °C	4.33 a	3.66 a	4.00 a	4.00 a
		7 °C	4.16 a	4.16 a	4.16 a	4.16 a
Palaz	16 mm	Shadow	4.33 a	4.16 ab	4.33 a	4.16 a
		Sun	3.66 b	4.50 a	4.16 a	4.16 a
		2 °C	4.33 a	3.83 ab	4.16 a	4.00 a
		7 °C	4.66 a	3.50 b	4.00 a	4.16 a
	18 mm	Shadow	4.16 a	3.50 b	4.00 ab	3.50 b
		Sun	4.16 a	3.50 b	3.50 b	3.66 ab
		2 °C	4.33 a	3.83 ab	4.00 ab	3.66 ab
		7 °C	4.33 a	4.16 a	4.50 a	4.16 a
Tombul	16 mm	Shadow	4.00 a	4.33 a	4.33 a	4.00 a
		Sun	4.00 a	4.50 a	4.00 a	4.16 a
		2 °C	4.50 a	4.50 a	3.83 a	4.00 a
		7 °C	4.00 a	4.00 a	4.33 a	4.00 a
	18 mm	Shadow	3.83 a	4.50 a	4.66 a	4.16 a
		Sun	4.16 a	4.66 a	4.16 ab	4.16 a
		2 °C	4.00 a	4.16 a	3.83 b	3.83 a
		7 °C	4.66 a	4.50 a	4.16 ab	4.16 a

The differences among mean values shown on the same column with the same letter is not significant ($p<0.05$).

When Palaz nuts with a size of 18 mm were examined, it was determined that the flavor of the nuts dried at 2 °C was higher than those dried in the shadow and the sun. Considering the values obtained in the 9th month, it was determined that the flavor of the nuts dried at 7 °C was higher than those dried only in the sun. In the measurements made during the harvest period of 16 mm sized Tombul nuts, the flavor of the nuts dried at 2 °C was higher than those dried at 7 °C and the sun. In the evaluations made in the 3rd month, the flavor of the nuts dried at 7 °C was higher than the other drying methods. When Tombul nuts with a size of 18 mm were evaluated, it was determined that the flavor of the nuts dried at 2 and 7 °C at harvest was higher than those dried in the shadow (Table 2).

3.2. Rancidity

In the examinations of Çakıldak nuts with a size of 16 mm in the harvest period and the 9th month, the rancidity rate of nuts dried in shadow, sun and at 2°C was found to be lower compared to the nuts dried at 7°C. Considering the values obtained in the 3rd month, the rancidity rate of nuts dried in the sun and at 2°C was lower than those dried at 7°C and in the shadow. In the evaluations made in the 6th month, the rancidity rate of the nuts dried in the sun at 2 and 7°C was lower than those dried in the shadow. When Çakıldak nuts with a size of 18 mm were evaluated, the rancidity rate of the nuts dried at 2°C was found to be lower than the dried nuts at 7°C at harvest. Considering the data obtained in the 3rd month, the rancidity rate of the nuts dried in the shadow and in the sun was lower than those dried at 2°C. The evaluations made in the 9th month determined that the rancidity rate of nuts dried at 7°C was lower than those dried only in the sun. In the 6th month examination of 16 mm long Palaz nuts, the rancidity rate of nuts dried at 7°C and shadow was lower than those dried at 2°C. In the evaluations made in the 9th month, it was determined that the rancidity rate of the nuts dried at 7°C and shadow sun was lower than those dried at 2°C. During the harvest period, it was determined that the rancidity ratio of the 18 mm-sized Palaz nuts in shadow, sun and dried at 7°C was lower than those dried at 2°C. In the 3rd month of storage, the rancidity rate of nuts dried in shadow and at 7°C was lower than those dried at 2°C and in the sun. It was determined that the rancidity rate of the nuts dried at 7°C in the 6th month of storage was lower compared to the other drying methods, and in the 9th month, the rancidity rate of the nuts dried at 7°C was lower than those dried in the sun and at 2°C. Tombul nutswith a size of 16 mm had a higher rancidity rate than the others in only sun drying (6th and 9th months). The rancidity rate of 18 mm sized Tombul nuts, dried in the shadow at harvest, dried at 7°C in the 6th month and 2°C in the 9th month, was significantly higher than the others (Table 3).

3.3. Odor

When Çakıldak nuts with a size of 16 mm were evaluated, the odor rate of the nuts dried at 2°C during the harvest period was higher than those dried only in the shadow. Considering the odor changes during storage, nuts dried at 2°C; It was found that the rate of the odor was higher in the 9th month compared to other methods, while it was higher than those dried in the sun and at 7°C in the 6th month. Çakıldak nuts (in the 18 mm sized) odor rate was found the significantly lower in shadow drying only at 9th months. According to the measurements made at the harvest of Palaz nuts with a size of 16 mm, the odor rate of the nuts dried in the sun was lower than the others. However, the odor rate of the nuts dried at 7°C in the 3rd month was measured lower. Considering the odor rate of the Palaz nuts (in the 18 mm sized), the nuts dried in the sun in the 6th month and in the shadow in the 9th month of storage were found to be lower than those dried by the other methods. Whereas, in the 3rd month of storage, sun and shadow drying were measured lower. There was no odor change in the 16 mm sized Tombul nuts during storage. However, in 18 mm sized Tombul nuts, it was determined that different odors in the 9th month of storage (the lowest value was at 2°C drying) (Table 4).

3.4. Firmness

When Çakıldak nuts with a size of 16 mm were evaluated, the firmness rate of the nuts dried at 2 and 7°C during the harvest period was higher than those dried in the shadow and sun. In the examinations made in the 9th month of Çakıldak nuts with a size of 18 mm, the firmness rate of the nuts dried at 7°C was found to be higher than those dried only in the shadow. In addition, drying methods did not have any effect on firmness in Çakıldak hazelnut storage. The measurements made during the harvest period of Palaz nuts with a size of 16 mm determined higher than the firmness ratio of the nuts dried at 7°C compared dried in the shadow and in the sun. In the 6th month of storage, nuts dried at 7°C had higher firmness than nuts dried only at 2°C. The measurements made in the 3rd month of Palaz nuts with a size of 18 mm determined that the firmness ratio of the nuts dried at 2 and 7°C was higher than those dried in the shadow and in the sun. When we look at Tombul nuts with a size of 16 mm, the firmness of the nuts dried at 2°C at harvest and in the 3rd month of storage was determined at the highest level. However, the firmness of 18 mm at Tombul nuts was found to be at a similar level. (Table 5).

3.5. Color

The drying methods did not affect Çakıldak nuts with a size of 16 mm (harvest and storage). However, in Çakıldak nuts with a size of 18 mm, the effect of drying methods was determined only in the 9th month (nuts dried at 7°C had a higher color value). The drying effect was not determined in both Palaz nuts sizes during harvest and storage. The highest color value in 16 mm sized Tombul nuts was determined from the nuts dried at 2°C during the harvest period. However, drying methods had no effect during storage. Similarly, the drying effect was not detected in 18 mm sized Tombul nuts during the harvest period. However, the color change of nuts dried at 2°C in the 6th month of storage (18 mm sized) was significantly lower than those dried in shadow and sun. (Table 6).

4. Discussion

Sensory evaluation is a discipline that measures, analyzes and explains the effects of various properties of foods on the senses of sight, smell, taste, touch and/or hearing (Dermirci Ercoşkun, 2009).

Table 5. Effect of drying methods on the firmness of hazelnut cultivars in different sizes throughout the storage

Cultivars	Sizes	Drying methods	Firmness			
			Harvest	90 d	180 d	270 d
Çakıldak	16 mm	Shadow	3.66 b	3.83 a	4.16 a	3.66 a
		Sun	4.00 b	4.00 a	4.66 a	3.83 a
		2 °C	4.66 a	3.83 a	4.61 a	4.00 a
		7 °C	4.50 a	4.00 a	4.00 a	4.16 a
	18 mm	Shadow	3.83 a	4.16 a	4.33 a	3.66 b
		Sun	4.33 a	4.16 a	4.33 a	3.83 ab
		2 °C	4.16 a	3.83 a	4.16 a	3.83 ab
		7 °C	4.00 a	4.16 a	4.66 a	4.00 a
Palaz	16 mm	Shadow	3.66 c	3.66 a	4.00 ab	3.66 a
		Sun	4.00 bc	4.16 a	4.00 ab	3.83 a
		2 °C	4.33 ab	4.16 a	3.50 b	3.83 a
		7 °C	4.66 a	3.83 a	4.50 a	3.83 a
	18 mm	Shadow	3.94 a	3.50 b	4.00 a	3.50 a
		Sun	4.16 a	3.66 b	4.00 a	4.00 a
		2 °C	4.50 a	4.33 a	3.83 a	4.00 a
		7 °C	4.66 a	4.16 a	3.83 a	4.00 a
Tombul	16 mm	Shadow	3.50 b	3.66 b	3.50 a	3.66 a
		Sun	3.50 b	4.16 ab	3.50 a	3.50 a
		2 °C	4.33 a	4.50 a	3.83 a	4.16 a
		7 °C	3.83 ab	4.33 ab	4.16 a	3.83 a
	18 mm	Shadow	3.33 a	4.00 a	4.00 a	3.66 a
		Sun	4.00 a	4.33 a	4.16 a	4.16 a
		2 °C	4.33 a	4.16 a	3.83 a	4.00 a
		7 °C	4.16 a	4.33 a	4.00 a	4.16 a

The differences among mean values shown on the same column with the same letter is not significant ($p<0.05$).

Table 6. Effect of drying methods on the color of hazelnut cultivars in different sizes throughout the storage

Cultivars	Sizes	Drying methods	Color			
			Harvest	90 d	180 d	270 d
Çakıldak	16 mm	Shadow	4.16 a	4.16 a	4.50 a	4.33 a
		Sun	4.33 a	4.16 a	3.83 a	4.00 a
		2 °C	4.66 a	4.33 a	4.50 a	4.50 a
		7 °C	4.16 a	4.16 a	4.16 a	4.33 a
	18 mm	Shadow	4.00 a	4.16 a	4.33 a	4.16 b
		Sun	4.00 a	4.50 a	4.00 a	4.00 b
		2 °C	4.33 a	4.77 a	4.16 a	4.16 b
		7 °C	4.50 a	4.50 a	4.66 a	4.66 a
Palaz	16 mm	Shadow	4.50 a	4.00 a	4.33 a	4.16 a
		Sun	4.16 a	4.33 a	4.50 a	4.16 a
		2 °C	4.33 a	4.00 a	4.50 a	4.50 a
		7 °C	4.66 a	4.16 a	4.50 a	4.50 a
	18 mm	Shadow	4.00 a	4.16 a	4.33 a	4.00 a
		Sun	4.33 a	3.66 a	4.16 a	4.00 a
		2 °C	4.66 a	4.16 a	4.33 a	4.50 a
		7 °C	4.33 a	4.16 a	4.66 a	4.16 a
Tombul	16 mm	Shadow	4.00 b	4.16 a	4.16 a	4.16 a
		Sun	3.66 b	4.16 a	4.33 a	4.00 a
		2 °C	4.66 a	4.16 a	4.16 a	4.33 a
		7 °C	3.83 b	4.16 a	4.50 a	4.16 a
	18 mm	Shadow	4.00 a	3.83 a	4.50 a	4.00 a
		Sun	4.16 a	4.50 a	4.50 a	4.33 a
		2 °C	4.00 a	4.66 a	3.50 b	4.00 a
		7 °C	4.50 a	4.00 a	4.00 ab	4.16 a

The differences among mean values shown on the same column with the same letter is not significant ($p<0.05$).

Quality in nuts is a feature sought by both producers and consumers. The first thing that comes to mind when talking about quality is the appearance of the nuts. In addition, essential quality parameters consist of sensory characteristics. So much so that consumers demand high taste, aroma and nutritional content in marketable nuts. Each type of nuts has a different sensory quality (Noguera-Artiaga et al., 2019). However, postharvest drying processes (Mokhtarian et al., 2017) or storage time (Güler et al., 2017) can affect sensory properties. In fact, hard-shelled nuts are preserved by drying after being harvested. Some sensory properties may also change depending on this drying process and method. Changes in some sensory properties were detected in hazelnuts that we preserved by applying different drying methods. Like our research findings, Bostan (2000) reported that the shell and inner color of hazelnuts dried on concrete, grass, wood and plastic materials varies depending on the methods. İn this research also stated that the best drying method is drying on concrete, that the hazelnuts dry faster in this process, and this situation significantly affects the sensory properties. Güler et al. (2017) reported that the sensory properties (taste, smell, rancidity, color and firmness) of hazelnuts stored for 18 months by applying different doses of radiation (0.5, 1.0 and 1.5) could vary depending on the storage period. Researchers especially stated that the rancidity is at its highest in the 12th month of storage. Bostan and Güler (2016) determined that the initial brightness of hazelnut kernel decreased during the more extended storage period. Also, emphasizing that this situation differs between cultivars, Palaz and Çakıldak cultivars were determined to darken more than Tombul and Kalınkara cultivars. Considering the drying studies on other nut species, Kashani Nejad et al. (2003) and Ghazanfari et al. (2003) reported significant differences in flavor and firmness of pistachio nuts dried by different methods. They found that especially sun-dried nuts were more delicious than other drying methods. In addition, it was stated that the firmnessdrying method's flavor and firmness decreased with the hot air flow, which created a higher moisture content. Similarly, Mokhtarian et al. (2017) reported differences between the sensory properties of pistachio nuts dried in different methods, especially nuts traditionally dried directly in the sun with stronger flavor and aromatic odor. On the contrary, research findings (Kader et al., 1982) state that the drying method does not affect the sensory quality. According to Kader et al. (1982) stated that depending on the increase in drying temperature, rancidity decreased, and nut firmness and flavor increased. Whereas, Kashani Nejad et al. (2003) stated that the drying method did not have a significant effect on rancidity in pistachio. However, our study found lower rancidity in nuts dried in shadow and at 7 °C. While no significant effect of drying methods on the color was observed in our study, Chen et al., (2020) reported that there is darkening due to rapid moisture loss in nuts that survived at high temperatures in their study on walnuts. Wu et al. (2014) stated that darkening causing color change might be related to moisture content, while Xiao et al. (2017) stated that this may be due to enzymatic/non-enzymatic reactions.

5. Conclusion

It was observed that shadow-dried hazelnuts and at 7 °C cold, dried hazelnuts had lower rancidity. As a result, it is revealed that drying methods affect the rancidity in hazelnut kernels during storage. No significant effect of drying methods was observed in the cultivars' flavor, firmness and color. But, nuts dried in different sizes (16-18 mm) was effective on the sensory properties. More detailed studies are needed to increase the widespread impact of the results and ensure consistency among the findings.

Compliance with Ethical Standards

Conflict of Interest

As the author of article declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Kader Sali: Formal analysis, Data curation **Burhan Ozturk**: Investigation, Conceptualization, Validation, Writing - original draft, Visualization, Review and editing. **Mithat Akgün**: Methodology, Formal analysis, Data curation. **Umut Ates**: Investigation, Conceptualization, Writing - original draft.

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We humbly give consent for this article to be published

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