

## Determination of the Best Drying Temperature of Hazelnut (*Corylus avellana*) after Six Months of Storage

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### Abstract

Drying is one of the most important stages of hazelnut processing and its optimization improves the quality of the final product. The quality of hazelnut is dependent on chemical and organoleptic characteristics of fruit that is affected in the drying process. In present research, samples of Gerd cultivar of hazelnut (*Corylus avellana*) were dried in shelled and in-shell forms using a laboratory dryer in single-layered form, in three temperatures of 40, 50 and 60°C and 1 m/s air velocity, and stored for six months. The time and energy required for drying and qualitative changes of hazelnut (oil content, protein content, acidity content and peroxide value of oil) were evaluated. The results showed that the hazelnuts dried under 60°C required the lowest time and energy for drying and the in-shell hazelnuts dried under this temperature (60°C) had the lowest acidity compared to other treatments. In addition, temperature had a significant effect on the qualitative traits of hazelnut. The results from taste tests showed that consumers prefer the shelled and in-shell hazelnuts dried in 50°C compared to other samples. Based on the results, the 50°C is recommended temperature for drying hazelnuts.

**Keywords:** Acidity Content, Cultivar, Peroxide Value, Protein Content.

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### Introduction

Hazelnut is a rich source of energy and contains 40-60 percents of oil and has a high nutritional value because of high oil content, essential fatty acids, sterols, antioxidants, and minerals (Carlos Bada *et al.*, 2004). In addition to nutritional and health role, hazelnut gives a specific taste to some of the food products (Akkurt *et al.*, 1999). The under-cultivation area and global production rate of hazelnut in 2012 according to FAO's statistics (World Food Organization) has been estimated 600 thousand acres and 914 thousands tones, respectively (Anonymous, 2014). Turkey is the major producer of hazelnuts, producing about 60 percent of the world's hazelnut, of which the main variety is Tombul

(Rasoulzadegan, 1996). Guilan, Ghazvin and Mazandaran provinces have around 93 percent of hazelnut cultivation areas of the country, and they are considered as the most important hazelnut cultivation areas in Iran (Dashtaki, 2011). Hazelnut production of the country has been 21 thousand and 440 tones. Hazelnut has the sixth place in terms of under-cultivation areas and seventh place in terms of production in the world (FAO, 2012). In order to preserve the hazelnuts in warehouses, the water stored in the unit should not be higher than 6 to 8 percent, and air relative humidity storage must not be less than 65%. In this case, if the environment's temperature does not

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exceed 21°C, hazelnuts can be stored up to one year without any decrease or alteration in their taste quality. If the hazelnuts are kept in silos, their ventilation must be perfect and constantly controlled. If stored in a cold place with a temperature equal to 2 to 4°C and relative humidity under 65%, they will remain intact for 2 to 3 years (Darvishian, 1998). It is natural that it is more difficult to keep shelled hazelnuts due to their inherent softness and vulnerability compared to in-shell hazelnuts. In order to prevent rancidity and corruption, they need extra care in a cold temperature around zero (0°C). Water content of hazelnut's kernel when storing should not be more than 4.5%, and the environment's relative humidity must not be higher than 70% (Maghsoudi, 2012). Drying, because of undesirable physical and chemical changes it makes in foods due to heat and water removal, is one of the difficult processes in food industry (Wang, 2005). Peroxide is the initial product of oxidation of fatty substances and generally, the more the unsaturated the oils are, the more ready the oil or fatty material will be for oxidation. Temperature is considered as one of the external factors affecting the oxidation of reaction rate. In temperatures lower than 60°C, the oxidation rate is doubled for each 45°C of temperature increase. While in temperatures higher than 60 °C, the oxidation rate is doubled for each 11°C of increase (Soren *et al.*, 1979). The corruption of fat-containing foods due to oxidation is the greatest concern for dehydrated foods. Oxidative rancidity is the most important fat corruption type. Oxidative corruption of fats result in the development of undesirable taste and smell of the product and destruction of vitamins, essential fatty acids, chlorophylls, carotenes, amino acids, proteins or enzymes (Christopoulos and Tsantili, 2011). Nikzadeh *et al.* (2011) studied the changes in moisture, texture and sensory properties of pistachios under the effect of roasting temperature and storage period. The pistachios were salted and then roasted using the traditional method in three temperatures of 90,

120 and 150°C for 30 minutes. By increasing the roasting temperature, moisture, stiffness and failure force was significantly decreased. In addition, using high roasting temperature resulted in a decrease in the texture's stiffness. The highest overall acceptability was obtained for the samples roasted in 120°C. Soltani Nejad *et al.* (2009) studied the effect of temperature, ascorbic acid and packaging type on the shelf life of fresh pistachios. Their results showed that the best treatment was related to packaging with polypropylene films, keeping in 4°C and density of 10 parts per million of ascorbic acid. Cellophane packages not treated with ascorbic acid kept in warehouse in 25°C had the highest weight decrease and the lowest shelf-life and also, the highest browning rate of internal and external shell. The mentioned research aimed at obtaining the best drying temperature for high storage life of hazelnuts. Also, the effects of different drying temperatures on some qualitative parameters (acidity, peroxide value, protein content and oil content) was studied in order to increase quality of stored hazelnuts.

## **Materials and Methods**

### ***Sample Preparation***

At the harvest time of hazelnuts (*Corylus avellana* gerd cultivar) in July, the hazelnuts required for the research were taken from Rahimabad region of Eshkevarat in Guilan Province. After harvesting the hazelnut fruits, the empty and cracked units as well as theirs with pests and disease symptoms and husks of the hazelnuts were removed. Then, the health samples were put in a sealed plastic bag and transferred to the laboratory. The primary moisture of shelled and in-shell hazelnuts was measured using the oven device. The initial and final weight of each sample (after drying) was measured. The difference between the initial weight and final weight of the samples to a final weight showed the moisture content.

In the next stage, both sample groups were dried using a laboratory drier machine in three different temperatures (40, 50, 60°C) in thin layers. After drying, the samples related to each repetition were put in special polyethylene plastic bags top, which were sewn using a special sewing machine, in order to prevent moisture exchange with surrounding environment. The samples were transferred to a specific warehouse with 15 to 18°C of temperature and relative humidity of 75 to 80 percents, which was similar to the condition of traditional warehouses in Guilan Province’s hazelnut growing areas, for six months of storage duration. Laboratory measurements and taste test were done on the stored samples after six months. The dryer used in experiment had three units which worked simultaneously. Fig. 1 shows different parts of the dryer.

Drying temperatures included 40, 50 and 60°C and displacement velocity of hot air was 1 m/s. In the dryer used in research, input temperature changes were set and recorded using the AT400-K modelAtbin digital thermometer with accuracy of 1°C. Also, weight changes with 1 gram accuracy and the output temperature with accuracy of 0.1°C was transferred from dryer to computer automatically using the data collection system within 30 minute intervals. Weight recording continued until the recorded value was fixed three times consecutively. Displacement velocity of hot air in air output of dryers was measured using an anemometer and the required settings were applied using a fan speed reducer. In this experiment, around 1500 grams of fresh hazelnuts were considered for each experimental treatment in the dryer.

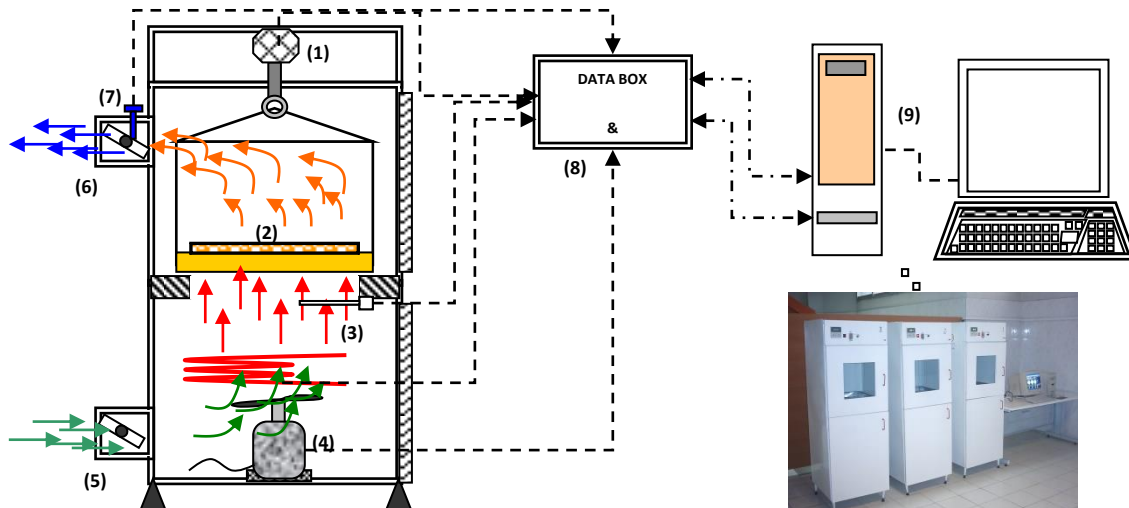


Fig.1. Schematic of the Dryer Used in Research (1) of Load Cell, (2) the Tray Containing the Samples, (3) Air Inlet to Product Sensor, (4) DC Motor, (5) Air Inlet Valve, (6) Air Outlet Valve, (7) Air Outlet Temperature Sensor, (8) Information and Controller Card, (9) Computer

**Percentage and Ratio of Moisture**

Relationship (1) was used in order to determine moisture percentage of hazelnuts based on dry weight (Gazor and Minaei, 2005):

$$M.C = (W_1 - W_2) / W_2 \quad (1)$$

In this relationship:  $W_1$ = weight of sample in each moment of test (g),  $W_2$ = Final Weight of Sample (g),

$M.c$ = moisture of sample in each moment of experiment (d.b%)

**Drying Process Energy**

To calculate the specific energy required for drying one kilogram of hazelnuts in each treatment, the electrical work relationship (Heater’s work+ fan’s work)

was applied. For this purpose, the current passing through the system was measured using an ammeter when the heater was ON first, and the amount of electrical work was obtained considering the active times of the heater within drying time range in terms of kilowatt-hours, using equation (2) (Badiiee, 1992).

$$W=V \times I \times h \quad (2)$$

In this relationship: W= electrical work (KWh), V= alternative current voltage (v), I= electrical current intensity (A), h= time (h). Also, relationship 2 was used to measure electrical work of the fan in dryer. First, the consumed current intensity was measured. The time was considered as the fan-on duration (drying time of the treatment) in the relationship. Electrical work for each treatment was obtained from sum of the two mentioned works. Acidity percentage of hazelnut oil and peroxide value of hazelnut oil were calculated using standard number 4178 and 4179 of Institute of Standards and Industrial Research of Iran (INSO, 2012), respectively. To determine hazelnut samples oil percentage, soxhlet device was used. Nitrogen percentage of hazelnut samples was obtained using Kjeldahl method (Parvaneh, 1992). Nitrogen coefficient for determining protein content was considered 5.3 (Lopez *et al.*, 1997). To determine the taste desirability percentage and appearance of dried hazelnut samples, taste test was performed with presence of 30 hazelnut consumers based on a 5-stage interest test (KashaniNejad *et al.*, 2003). The features based on hazelnut samples that were compared include the shell's appearance, stiffness, sweetness, crispy taste, rancidity, and general acceptance.

## Statistical analysis

SAS Software was used for statistical analysis of the data, LSD test for comparing the significant difference between the averages at a 0.05 significance level, Kruksal-Wallis nonparametric test for taste test and Excel software for drawing the charts.

## Results

The results from variance analysis related to hazelnut's drying period showed that fruit type, temperature rate, interaction of fruit type and temperature rate on drying time of hazelnut, were significant (1% significant level, as seen in Table 1).

Table 2 compares the averages of drying period. Accordingly, the temperature level in in-shell hazelnuts and also shelled hazelnuts affected the drying time. The drying time decreased with an increase of temperature, such that shelled hazelnuts dried in 40°C needed the longest time to dry and the in-shelled hazelnuts dried in 60°C of temperature needed the least time for drying. When the hot air blows on wet hazelnuts, water evaporation degree rises due to the heat and the water content of the fruit is reduced.

Variance analysis results of hazelnut oil acidity percentage after six months of storage showed that type of hazelnut and interaction of hazelnut type and temperature level on acidity content had a significant effect, while the temperature level had no significant effect on the acidity content (Table 1).

**Table 1. Variance Analysis of Hazelnut Type and Temperature on Drying Time, Drying Energy, Acidity, Peroxide Value, Protein Content and Oil Content.**

Changes to resources	Freedom Degree	Mean of squares(MS)					
		Oil Content(%)	Protein Content(%t)	Peroxide value(meq/kg)	Acidity Content(percent)	Drying energy(kj)	Drying time(hr)
Hazelnut type (A)	1	26.34**	1.77 <sup>ns</sup>	0.48 <sup>ns</sup>	28/07**	9081270**	6751.87**
Temperature (B)	2	0.59 <sup>ns</sup>	2.92 <sup>ns</sup>	2.25 <sup>ns</sup>	0.82 <sup>ns</sup>	131100**	163.06**
Type of hazelnut ×Temperature (AB)	2	<sup>ns</sup> 1.30	<sup>ns</sup> 0.69	6.32*	8.27**	50940**	62.14**
Error	12	3.20	0.10	0.25	0.0002	3171.37	0.31
Cv (%)		2.43	2.44	19.00	11.05	3.43	4.002

\*\* (significance in 1% level), \* (significance in 5% level) and ns (No Statistical Difference).

The variance analysis results regarding the energy required for drying hazelnuts showed that the hazelnut type had a significant effect on the drying energy. Additionally, the effect of temperature level and interaction of hazelnut type and temperature level on drying energy was significant as well (Table 1).

**Peroxide Value**

The variance analysis results of peroxide value of hazelnut oil showed that the hazelnut type and temperature level had no significant effects on the peroxide value. However, the interaction of hazelnut type and temperature level on peroxide value had a significant effect (Table 1). By increase of temperature, peroxide value of dried hazelnuts decreased (Fig. 2).

**Table 2. Comparison of Hazelnut Type Average on Drying Period, Drying Energy, Acidity, Peroxide Value**

Qualitative Parameters	Temperature (°C)					
	In-Shell Dried Hazelnuts			Shelled Dried Hazelnuts		
	60°C	50°C	40°C	60°C	50°C	40°C
Drying Period (hr)	2.12e	3e	4.37d	20.25c	25b	29.75a
Drying Energy (Kj)	78435c	91450b	105440a	8936e	11198e	15191d
Acidity Content	0.16a	0.15a	0.14a	0.09b	0.11b	0.14a
Peroxide Value (meq/kg)	6.74ab	7.85ab	9.28a	7.67ab	11.07a	3.63b

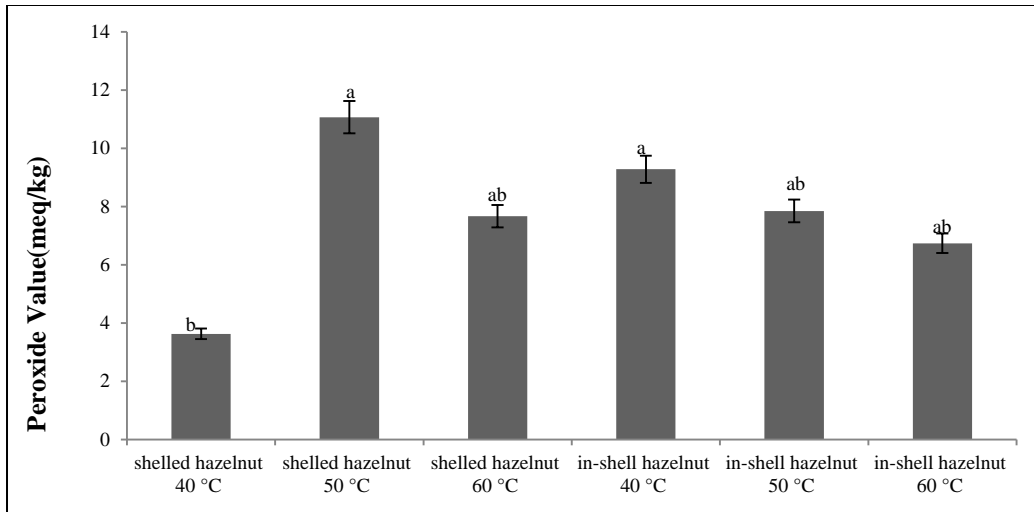


Fig. 2. Average Peroxide Value of Hazelnut Oil in Different Levels of Hazelnut Type and Temperature

**Protein Content**

The results of variance analysis related to protein content of hazelnut after six months of storage showed that the effect of hazelnut type, temperature level and interaction of hazelnut type and temperature level on hazelnut’s protein content was not significant (Table 2).

**Oil Content**

Variance analysis results of oil content data showed that effect of hazelnut type on oil content was significant. The temperature parameter and interaction of temperature and hazelnut type had no significant effect on the oil content (Table 2). According to the results from Fig. 3, in-shell hazelnuts had a higher oil content compared to shelled hazelnuts.

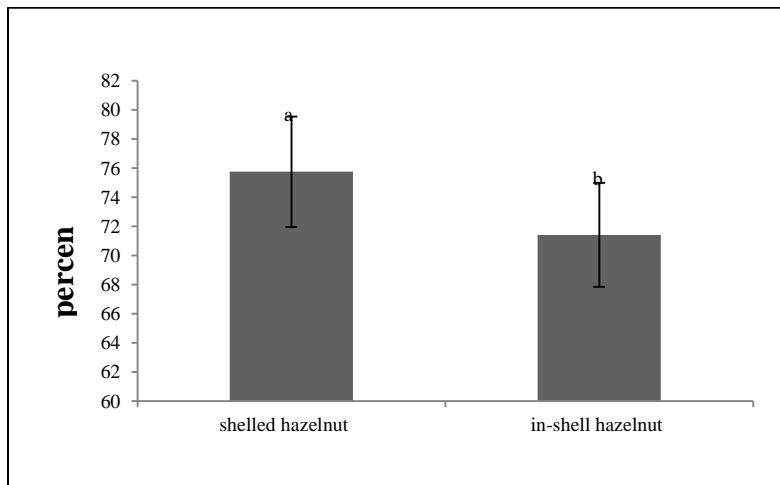


Fig.3. Oil Content average of shell and In-shelled Dried Hazelnuts

**Taste Test**

Kruskal-Wallistest results showed that the effect of temperature level on shell's appearance, sweetness,

stiffness, crispy taste and general acceptability was significant (Table 3).

**Table 3. Average of Taste Test for Each Treatment Based on Testers±SD**

Average of Taste Test	In-shelled Dried Hazelnuts			In-shelled Dried Hazelnuts		
	40	50	60	40	50	60
Shell's Appearance	4±0.31	3.16±0.29	3.16±0.29	3.16±0.29	3±0.63	3.16±0.29
Stiffness	3±0.67	3.66±0.35	3±0.25	3.33±0.42	4.66±0.68	3.16±0.25
Sweetness	3.33±0.41	4.16±0.17	3.5±0.29	3.5±0.29	3.5±0.29	3.5±0.29
Roasted Taste	3.83±0.35	4.5±0.27	3.33±0.50	4.33±0.16	4.5±0.27	3.83±0.42
Change of Taste (Rancidity)	3.33±0.50	4.16±0.19	3.16±0.27	3.33±0.42	3.33±0.35	3.33±0.27
General Acceptability	3.33±0.49	4±0.28	3.33±0.27	2.66±0.45	4.5±0.18	3±0.26

**Discussion**

The moisture reduction process stopped when moisture content of the sample reached up to 5-6% in in-shell hazelnuts and 2-3% in shelled ones. Due to the hard shell, water evaporation takes place later. Consequently, drying of in-shell hazelnuts takes a longer time compared to shelled hazelnuts. According to the results obtained from variance analysis table (Table 2), in-shell hazelnuts dried in 40°C used the highest energy level for drying and were categorized in A statistical class. The shelled hazelnuts dried in 60°C, used the lowest energy level for drying and were categorized in E statistical class. The shelled hazelnuts dried in 50°C also used less energy for drying compared to other treatments and were categorized in E statistical class, which did not have any significant difference with shelled hazelnut treatments dried in 60°C (Table 2). These results were consistent with the results obtained by Pahlavan Zadeh (1998), Tavakkoli Pour (2000) and Afshari Jouybari *et al.* (2012). The results from acidity content average comparison of hazelnut oil in different levels, hazelnut type and temperature level showed that the most acidity content belonged to shelled hazelnuts dried in 60°C and were categorized in A statistical

class. The least acidity content belonged to in-shell hazelnuts dried in 60°C. Considering that the lower the acidity content, the better hazelnut's quality will be, the best drying temperature degree for storage of this product in order to achieve the best acidity content can be attributed to the in-shell hazelnuts dried in 60°C. Results of this research are consistent with the results obtained by Cheraghi Dehdazi and Hamdami (2012) based on effects of different temperatures and storage period on moisture content, dissolved solids and acidity content of Kabkab dates and the researches done by Nikzadeh *et al.* 2009 regarding the effect of roasting temperature at three levels (90, 120 and 150°C) on pistachio oil quality during three months of storage. Data comparison results of the averages showed that in in-shell and shelled dried hazelnuts after six month of storage, peroxide value of the hazelnuts dried in high temperatures has been less than other temperatures. Fat oxidation is related to unsaturated acids. The more the non-saturation of fatty acids is, the more fat oxidation and peroxide value, which is the primary product of fatty material oxidation. These results are consistent with the ones obtained by Bolourch (1979) and

Masoumi and Arzani (2000). By increasing the temperature, the peroxide value of dried hazelnuts decreased. The highest peroxide value occurred in in-shell hazelnuts dried in 50°C. The lowest peroxide value occurred in in-shell hazelnuts dried in 40°C. These results are consistent with the results obtained from the research done by Tavakkoli Pour *et al.* 2008 and Nikzadeh *et al.* 2009. The results of this research showed that temperature changes had no significant effect on protein variations. These results are consistent with the studies done by Omidi *et al.*, 1996 and by Gazor and Minaei (2005) on pistachios. The results obtained from this research showed that in-shell hazelnuts had more oil content compared to shelled ones. According to the research done by Gazor and Minaei, 2005 and Tavakkoli Pour (2000) on pistachio product, the drying temperature has no significant effect on oil content of pistachio in different varieties.. The average and standard deviation of the taste test related to in-shell hazelnuts dried in 50°C of temperature obtained a higher score in the taste test done by the consumers, compared to other temperatures of 40 and 60°C. The shelled hazelnuts dried in 50°C obtained higher scores in total acceptability, roasted taste and stiffness based on consumers and a score similar to other drying temperatures in change of taste (rancidity) and sweetness, though with a lower score in regard to the shell's appearance. These results were consistent with the research results obtained by Nikzadeh *et al.* (2011) on general acceptability of pistachio samples in sensory evaluation, which imply significance of the effect of roasting temperature and storage time on sensory features.

### Conclusions

When drying the in-shell and shelled hazelnuts, the drying period decreased as the temperature increased. In addition, the energy required for drying decreased with an increase in temperature. The acidity content of the

shelled hazelnuts dried in 60° C after six months of storage had the lowest acidity among other treatments. The peroxide value in in-shell dried hazelnuts increased as the temperature increased after six months of storage. In shelled dried hazelnuts, the peroxide value had a decreasing trend with an increase of temperature. The effect of drying temperature on the protein content of in-shell and shelled dried hazelnuts after six months of storage had no significant difference, and in-shell dried hazelnuts had a higher oil content compared to the shelled dried hazelnuts. Considering the results obtained from taste test, the general acceptability of in-shell and shelled hazelnuts dried in 50°C has been more than other temperatures.

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