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Artificial drying of newly harvested Turkish hazelnuts

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ABSTRACT

This study was to investigate the impact of artificial drying on the quality of Turkish hazelnuts by using a horizontal cylindrical type dryer. The hazelnut samples were dried in agitated heated air with a swirl flow in contrast to the conventional drying method. Drying characteristics of the hazelnuts were described as being in the range of 40-55 °C air temperature with constant of dry air velocity 1.0 m/s. Specifying the artificial drying conditions for freshly reaped hazelnut, which has an initial high moisture content ratio, and experimentally researching the effects of drying conditions for hazelnuts were the main objectives of the study. The optimum conditions for drying fresh hazelnuts in an artificial dryer were determined as having maximum moisture content (5-6%) to facilitate long-term storage. The results showed that a normal drying time followed by hot air drying with the shortest drying time to be measured as a 10.5 hours.

KEYWORDS

Artificial dryer;
Hazelnuts;
Artificial drying;
Quality;
Horizontal cylindrical dryer.

INTRODUCTION

Turkey is the one of the main hazelnut (Corylus avellena L.) producers of the world – followed by Italy, the USA and Spain – with about 600.000 tons production per year; 80-90% of this production is exported. Hazelnuts are an important export of Turkey to the world market, and are marketed as natural and processed kernels. The total export revenue of Turkey from hazelnuts and hazelnut products is about two billion US Dollars annually. In the traditional drying method, hazelnuts have an average humidity ratio of 25-30% after dispelling. Newly reaped hazelnuts are spread out as a thin 3-5cm thick layer over a concrete floor under the sun for 2-3 days at an average temperature of 25-32 °C. his traditional and simple drying method doesn't protct the product from dust, unexpected rain, dirt and damage from insects and microorganisms. During the traditional drying process, unpleasant odours, colours and flavours can be formed as hazelnuts may undergo undesirable reactions that degrade quality. For these reasons, artificial hazelnut drying is the current preferred method[1-9]. During summer months; weather conditions are usually cloudy and rainly, so that drying of hazelnuts on the concrete surfaces to reduce the moisture content to 5-6% for long term storage is not sufficiently achieved at the hazelnut production region. Hazelnut to be stored for about 6 months or longer should usually be dried to the moisture ratio of 5-6 %[10,11].

As is well known, the drying process was the first technique of food preservation used by human beings. Drying small grains is an important industrial activity in the field of drying of raw food material[12,13]. Dehydration of vegetables and other food crops by the traditional method of open-air drying is unsatisfactory, as products can easily become infected with bacteria and contaminated by insects, and can deteriorate rapidly in the ambient conditions of high temperatures and humidity of the storage area. Dehydration or drying operations are important steps in storage and processing of grains. Drying of foodstuffs depends on the heat and mass transfer characteristics of the product being dried. Data on the temperature and moisture distribution in the product is vital for equipment and process design, and for quality control methods chosen for appropriate storage and handling practices[1,15,16]. Almost all of the drying of the grain and nut products occurs in environments at which the drying rate is mainly controlled by internal diffusion of moisture. The effect of air velocity on the drying rate is a significant factor when above a critical value. Critical air velocity, at which the desired drying rate is achieved, is given as 0.102 m/s grains[1,17-19].

It can be seen from Figure 1 that drying of grains exhibits a falling moisture rate and constant rate periods whose relative magnitudes depend on the system conditions. In the constant rate periods, the drying rate can be enhanced by an increase in temperature. The presence of the constant rate period provides indications as to whether the dehumidifying is limited to external diffusion, or the diffusion of moisture through the layer at the surface. The influence of temperature is relatively small in the diffusion-controlled process, while its effect is slightly higher in the external diffusion-controlled process. The superficial velocity of the drying medium influences the rate of drying only when external diffusion on the surface of the solid particle is a dominant factor in the drying process. During conventional heating, heat transfer is limited to the inner sections of food because of the low thermal conductivity of food material. Basically, solid foods are porous hygroscopic materials in which moisture is held at higher bound strengths as moisture content decreases[6,7,9,13,14]. For the drying process, the energy balance between water and drying air is given as Equation 1. In this equation, m_w and m_a denote mass flow rates of water evaporated from the sample and water absorbed by drying air, respectively. T_i is the initial temperatures and T_f is final temperatures of the drying air, respectively. L is the latent heat of vaporization for water at 55 °C and C is the specific heat of air.

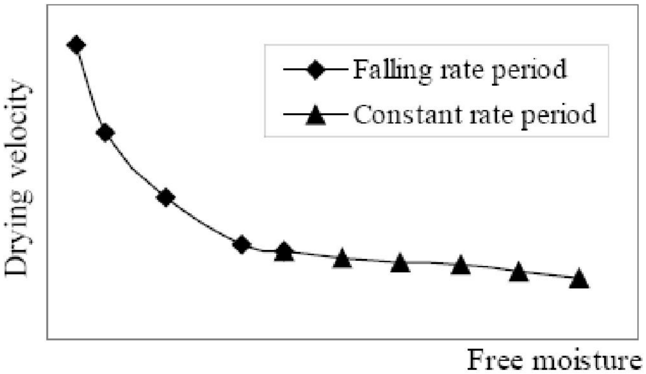

Figure 1 : Drying time versus free moisture (7)

$$m_w L = m_a C (T_i - T_f)$$

Lower temperatures require longer drying times, and the optimal drying air temperature recommended is between 40-55 °C for hazelnuts. The upper temperature limit of 55 °C is recommended for drying hazelnuts. Drying at higher temperatures causes the degradation of hazelnut quality due to increased enzymatic inactivation[2,4,11,20]. In recent years, researchers have started focusing on different grain drying theories and techniques. Boyce proposed a stationary bed model and in this model, a deep bed of grain is represented as a thin layer for the development of a semi-empirical grain drying model. Two adjacent thin layers are coupled through the bulk flow of air over the control volume in the deep bed[21].

Brooker presented the theoretical non-equilibrium grain drying model for a stationary deep bed under cross, concurrent and counter-flow drying conditions. Mixed flow dryers have been recently developed. In mixed flow dryers, the flow direction of grain and air is a combination of counter-flow, cross-flow and concurrent flow[22]. Bakker et al, who reported a set of grain drying models and its simulation in stationary and moving beds of grain, developed a theoretical non-equilibrium model[23]. Srivastava and John reported about the modeling of deep bed drying of grains under unsteady-state conditions, simulating of variation of moisture, grain temperature and air temperature along the bed[24]. The fluidized bed drying of hazelnuts was implemented and a mathematical model for the simulation of simultaneously variable heat and mass transfer in a fluidized bed drying was developed, by Topuz et al, who reported a good agreement between the numerical and experimental results observed[13]. Akpinar tested some crops using the connective cyclone dryer at air temperatures of 60, 70 and 80 °C, and air velocities of 1.0-1.5 m/s[25].

CONSTRUCTION OF EXPERIMENTAL SYSTEMS AND METHODS

The rotary, horizontal and cylindrical artificial dryer was developed at the Erzincan University, Department of Mechanical Engineering's technology laboratory. Figure 2 shows a general view of the dryer which consists of an air heater, a centrifugal fan for generating an air flow, drying chamber, hazelnut entry and exit channels. The drying chamber has a horizontal cylindrical shape. Dimensions of the drying chamber are 560 mm in diameter, 2500 mm in length, with a capacity of 100 kg. The air heater system consists of eight strip electric elements having a total power of 8 kW. The air flow rate is adjusted and flows into the system by means of a centrifugal blower. During the experiments, the drying cylinder was rotated at 4 rpm by means of an electric motor. In the measurement of temperatures, K type copper-constant thermocouples were used with 12 channels. The best quality hazelnut cultivar is grown in the Giresun region of Turkey, therefore the Giresun variety was used in this study. Fresh hazelnut was harvested and pre-sun drying was conducted to remove the outer covering. Hazelnut used in the study was approximately spherical. The moisture content at the start of each experiment was approximately measured as being in the range of 28.2 % on a dry basis. Before placing the samples in the drying unit, the system ran for at least 1 hour, to provide optimum drying conditions. In this study, air velocity was kept constant at 1.0 m/s throughout the experiments, in order not to influence the drying rate by air velocity. Air velocity was measured with a Testo 400 air anemometer at the inlet of the heater unit. During the experiments, a data recorder recorded air temperatures, drying air velocity and the atmospheric conditions automatically at 5-minute intervals. Drying temperatures were selected at 40, 45, 50, 55 °C. At the end of each drying process, 3 kg samples were taken and put into sealed plastic bags, and kept in storage at 0 °C until the quality parameters could be measured. After each drying experiment, the moisture content of hazelnut samples on a wet basis was measured. The drying time for achieving the desired moisture content of 5-6% on the wet basis was significantly reduced. Drying temperatures were very close to the temperatures used in moisture content determination, in which samples were dried at 105 °C in the drying oven (ELE Int. Limited, England model S91-028) by standard methods (TSE 1978). Moisture loss was measured by using a digital balance (Sartorius model MCI-Laboratory LC220S, Germany) with a measurement

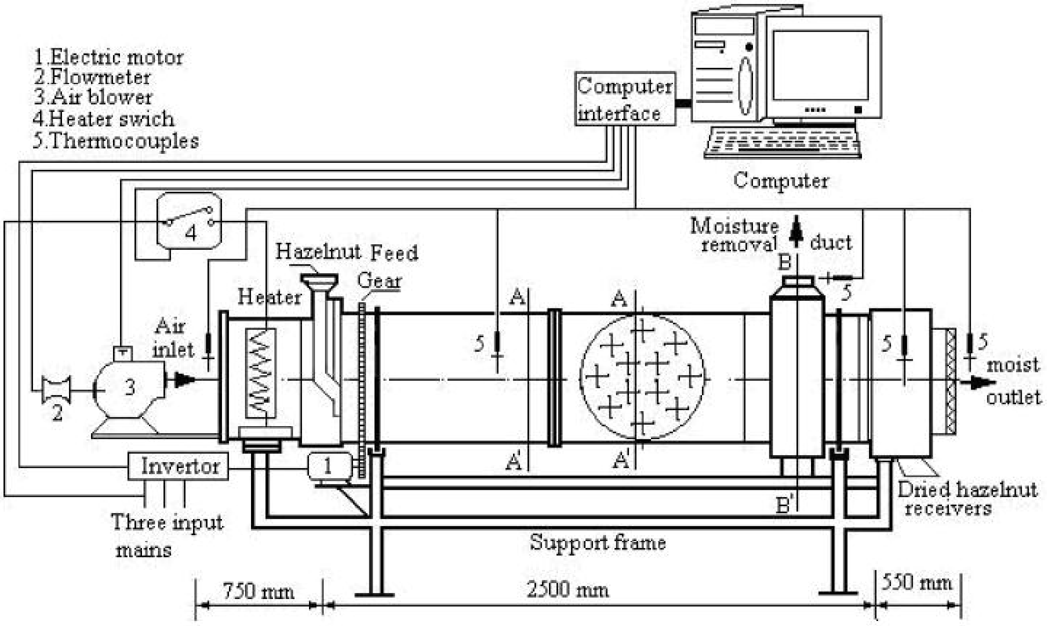

Figure 2 : Schematic diagram of experimental system.

range of 0- 4000 g and an accuracy of 0.01 g. In each experiment, the moisture content as a percentage for each ground sample of 5 grams was determined by using a drying oven at 105 °C. During the drying process, moisture loss was measured at 30-minute intervals in order to determine the drying curves. Equation 2 was used in the calculation of moisture content. In this equation, m is the moisture content percent of the samples, M_1 and M_2 denote the initial and final weights(g) of the sample plus sample plate, respectively, while M_0 is the weight(g) of the empty sample plate[1,9,13,26].

$$m = \frac{M_1 - M_2}{M_1 - M_0} x100$$

RESULTS AND DISCUSSION

At the beginning of the drying experiments, hazelnuts initial moisture content was determined to be 28.2%, and after the drying process, the moisture content was measured at 5-6%. In this study, the following variations were considered in detail.

Drying characteristics of hazelnuts

Four groups of hazelnut samples with the same initial moisture content were dried in the drying cylinder and data was obtained on their drying characteristics. When the moisture values were used in plotting of the drying curves, it was observed that drying time was an independent variable and percent moisture content was a dependent variable. Another result that came from the experiments is that the drying time to reach the desired moisture content of 5-6% is more influenced by drying air temperature in the artificial dryer system in comparison to the conventional drying method. Figure 3 and Figure 4 show the artificial drying characteristics of Giresun high quality hazelnut. Drying processes were varied between 40, 45, 50, 55 °C, and a comparison of the observed significant differences was made. Figure 3 shows the effect of increasing drying air temperature on the fresh hazelnuts during drying process and the variations of moisture content during drying time at drying temperatures of 40, 45, 50, 55 °C. The drying time was varied to achieve moisture content 5-6%, and this was significantly influenced by the drying air temperature. Drying time decreased exponentially with the increase of air temperature and a higher drying temperature resulted in a higher drying rate with decreased drying time periods. During the experiments, in the first 30 min of drying, the moisture was varied from 28.2% to 26.1%, 26.7, %, 27.3 %, 27.5% at air temperatures of 55, 50, 45, 40 °C respectively. At 55 °C air temperature, the initial moisture content of samples of newly harvested hazelnut was reduced from 30% to 5.6% in a drying time of 10.5 hours, in three other samples, initial moisture content was reduced to 7.4%, 10.1%, and 12.9% respectively over the same drying time period. At air temperatures 55, 50, 45 and 40 °C respectively, and a constant air velocity (1m/s), the average drying times determined to reduce the initial moisture content of 28.2%to 5-6% moisture content were 10.5, 13.5, 17 and 19.5 hours respectively. The artificial drying characteristics of Giresun quality hazelnut, with different humidity content showed that the higher the temperature used, the less was the drying time required. There is an inverse relationship between air temperature and drying time; an increase in drying air temperature resulted in a decrease in the drying time.

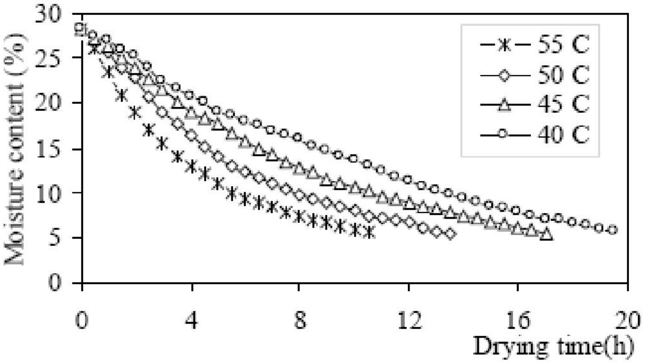

Figure 3 : Initial moisture content versus drying time

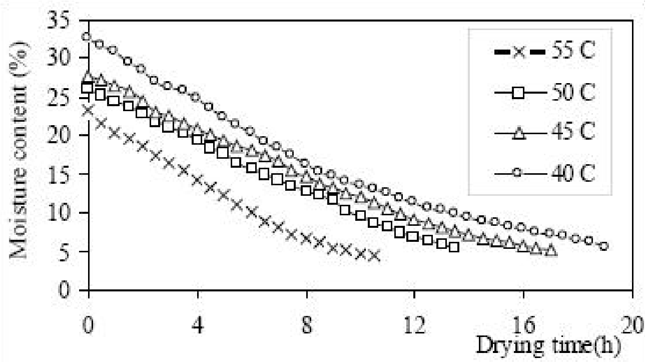

Figure 4 : Hazelnut shell moisture content versus drying time

Figure 4 shows the effect of increasing drying air temperature on the hazelnut shells during the drying process, and the variations of moisture content during drying time at drying temperatures of 40, 45, 50, 55 °C. Although hazelnut initial moisture contents were the same, the hazelnut shell moisture contents were found to be different at the beginning of the drying process; shell moisture content measured differently from hazelnuts moisture content at the beginning of the drying process. The reasons can explain the effect of fast drying and the drying air effect directly with hazelnut shell surface. It was observed that changes in the moisture of shells, like hazelnuts moisture changes, depended on drying temperatures, and drying times reduced at high temperatures.

Quality evaluation

In this study, hazelnut quality was evaluated according to colour, taste and smell by selected taste test assessors. The other factors evaluated were acid levels, anisidine value and oil content. The smell and taste of hazelnut hot effect is deterioration during the drying process but is drawn to the surface of hazelnut shell was observed. Hazelnut quality is mainly based on moisture content and appearance and these criteria are still used in domestic and international markets. Hazelnut with moisture content of 5-6 percent and of a white color is easily marketed. But hazelnut of a scorched, burned, sooty, moldy appearance, and with high moisture content, is sold at discounted prices. Samples dried nuts were analyzed in Sagra hazelnut plant laboratory which the best industrial production of hazelnut processing. Official and chemical laboratory drying analysis results of the four hazelnut samples are given in TABLE 1. There are no significant differences among the hazelnut sample varieties from the point of view of moisture content (MC<5-6 %). Closely with the artificial drying hazelnut values as moisture, free acid and peroxide were similar for compared to natural drying hazelnut quality. Concealed damage in the hazelnuts is defined by the industry as the browning of kernel interior after moderating to high heat processing such as drying, roasting and cooking. The concealed damage disorder is apparently initiated when kernels are exposed to a warm and moist environment. Hazelnuts most likely experience the concealed damage when it rains during harvest and pre-drying periods.

TABLE 1 : Drying analyze report (27).

Results	1st Sample	2nd Sample	3rd Sample	4th Sample
Moisture content	4.5 %	4.4 %	4.3 %	4.1%
Free acid (oleic Acid)	0.09 %	0.09 %	0.09 %	0.09 %
Peroxide	0 meg/kg	0 meg/kg	0 meg/kg	0 meg/kg
Induction Time	22 hrs	22 hrs	22 hrs	22 hrs

CONCLUSION

The results of the artificial drying process for newly harvested hazelnuts covered in this study are given below.

Research was carried out on the effect of initial moisture content, drying time (period), quality of hazelnuts, moisture content, drying characteristics of the artificial dryer.

At the beginning of the drying process, the drying rate was very high due to the high moisture content of hazelnuts, and this decreases with the evaporation of surface moisture towards the end of the drying time.

Experimental study has been shown that hazelnuts exposed to high temperature for a long time may be oxidized. It is observed that a maximum drying temperature of 55 °C is optimal for Turkish hazelnuts based on drying.

The results of chemical laboratory analysis are given in TABLE 1. There are no differences among the hazelnut sample varieties from the point of view of moisture content (MC 5-6 %).

Air temperature and dry air velocity are very important for ensuring the desired quality characteristics of the hazelnut. At the constant air speed, when the drying temperature is higher, drying time is shorter. The conventional open-air drying process took nearly three times longer in comparison to the artificial drying.

Drying process of hazelnut occurred in the falling rate period.

Using a pre-drying process or a graded drying, energy consumption can be reduced.

NOMENCLATURE

m_w	The mass flow rate of evaporated water
m_a	Mass flow rate of air
T_i	Initial temperature of drying air
T_f	Final temperature of drying air
L	The latent heat

C	Specific heat capacity of air.
M_f	Final or equilibrium moisture content
M_i	Initial mass of the as-received samples.
m	Samples moisture content %
M_1	The initial weight of samples plus sample plate
M_2	The final weight of samples plus sample plate
M_0	The weight of empty sample plate

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