

Types of Dryers and Their Effect on the Pistachio Nuts Quality-a Review

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Abstract

This review discusses the performance of existing dryers for pistachio drying process, which is available in the literature. It encompasses sun drying, solar dryer, bin dryer, vertical continuous dryer, funnel cylindrical dryer, vertical cylindrical dryer, continuous mobile and steady tray dryer, drum dryer and continuous belt conveyor dryer. The split nut and shell appearance of pistachio nuts are significantly influenced by the drying methods. The types of dryer used for drying pistachio nuts are critical to the final quality of the product. Although sun drying has a good effect on the final product quality, the negative climatic and environmental conditions must be considered. A combination of bin dryer and sun drying or combination of bin dryer and solar dryer, are recommended as effective drying techniques to prevent adverse quality effect on pistachio nut.

Keywords: Pistachios, Nuts, Drying, Dryer, Moisture, Quality, Processing, Iran

1. Introduction

Pistachio nut (*Pistacia vera* L.) is one of the popular tree nuts in the world. Due to its high nutritional value, the split pistachio nut is an increasingly important nut product consumed either in the form of raw, roasted or salted (Rosengarten, 2004). Pistachio nut grows well in countries with warm-arid climate such as Iran, United States, Turkey, Italy and Syria which represent the major producers and exporters of pistachio nuts in the world (FAO, 2007).

The non-split pistachios are used as raw material for production of wafer, ice cream, chocolate, pistachio halva, pistachio butter, pistachio oil, pistachio baklava and sausage (Ardakani, 2006). They are also used as one of the ingredient of many types of desserts. Pistachio nuts contain 25% protein, 16% carbohydrate and 55% oil (comprises of 80% unsaturated fatty acids) (Rosengarten, 2004). Pistachio nuts are a good source of dietary fiber,

vitamin B-6, thiamin, magnesium, phosphorus and copper (Herber *et al.*, 2008).

Drying is one of the conventional methods used for preservation of most agricultural products. Once pistachio nuts are harvested, the hulls should be removed within a short period of time to prevent shell staining and drying (Avanzato and Vassallo, 2008) (Figures 1 and 2).

During the drying process, nuts undergo reactions that degrade the quality especially in terms of colors and flavours (Kashaninejad *et al.*, 2007). In comparison with other food products, reports on the drying of pistachio nuts and parameters affecting their quality are limited. It is therefore necessary to discuss the different types of dryers and their effect on the quality of the dried product.

2. Current methods of drying pistachio nuts

Post harvest processing is very important to pistachio nut quality. The moment pistachio nuts arrived at the processing plant (Figure 3), the following processes will commence:

- a) Dehulling -to remove hull from nuts;
- b) Trash and blank separation -to remove blank pistachios and trashes such as small branches, remaining shells and leaves;
- c) Stick tight (unpeeled) separation -to remove unpeeled and unripe nuts;
- d) Washing -to clean the nuts by spraying water at high pressures on the pistachios;
- e) Drying -to reduce moisture content of pistachio nuts to 4-6% (Kouchakzadeh, 2011; Nakhaeinejad, 2007;).

The following discussion concentrates on the current drying techniques of pistachio nuts:

(i). Sun drying

Pistachio nuts are spread in thin layers of about 2 to 3 cm thickness on a concrete floor and dry under the sun for 2 days at an average temperature of 26.5 °C and average relative humidity of 18% (Figure 4).

(ii). Solar drying

The shelled and unshelled pistachios are sufficiently dried within 6 hours at temperature between 40 and 60 °C (1.23 m/s of air velocity) of the drying process (Midilli and Kucuk, 2003a).

(iii). Bin drying

In this type of dryer, warm air at an average temperature of 65 ±2°C is used to dry pistachio nuts (Figure 5) (Kashaninejad, 2003).

(iv). Vertical continuous drying

Pistachio nuts are dried in a vertical continuous dryer (Figure 6) for about 10 hours. Drying temperatures for the first (top) and second stages (bottom) were 45° and 40°C, respectively (Kashaninejad, 2003; Rostami and Mirdamadiha, 2004).

(v). Vertical cylindrical drying

Pistachio nuts can be dried in a vertical cylindrical dryer (Figure 7) at a drying temperature of 55 ±2°C for 8 hours.

(vi). Funnel cylindrical drying

Pistachio nuts are dried in a funnel cylindrical dryer (Figure 8), equipped with perforated funnels to adjust the movement and holding time of pistachio nuts in the dryer. The dryer is operated at a temperature of 80°C for 5.5 hours (Kashaninejad, *et al.* 2003).

(vii). Continuous mobile and steady tray dryer

The dryer is operated at a temperature of 70°C for 5 hours (Figure 9).

(viii). Batch drum dryer

The dryer is operated at a temperature of 70°C for 4 hours (Figure 10).

(ix). Continuous belt conveyor dryer

In this dryer, hot air will be blown from the bottom to the top and the moisture content of nuts will decrease to 10-12% in 2.5-3 hours (Figure 11).

3. Quality of dried pistachio nuts

Types of dryers and drying conditions of the process will ultimately influence the quality of pistachio nuts.

Factors such as water activity (FAO, 2001), final moisture content of product (Aktas and Polat, 2007; Gazor, *et al.*, 2009; Omid, 2009; Rafiee *et al.*, 2009; Rafiee *et al.*, 2007; Thompson, 2005; & Zomorodian, 2007), airflow of dryer (Kashaninejad and Tabil, 2009; Gazor *et al.*, 2005b), thickness layer of product (Kashaninejad *et al.*, 2007) and dryer temperature (Gazor *et al.*, 2003; Gazor *et al.* 2005a; Yazdanpanah *et al.*, 2005) are among important parameters that need to be monitored. Several researchers have studied these factors using different pistachio nut drying methods. Owing to the lack of suitable preservation techniques, producers often allowed the nuts to be dried directly under the sun. Although this method produced product of acceptable quality, the nuts are exposed to negative climatic and environmental conditions such as heavy solar radiation, rain, wind, storm, dew and snow. Additionally, the pistachio nuts are also exposed to contaminants from dust, dirt and environmental pollution during drying. Harmful microorganisms and insects can also grow in the dried products causing damages and deterioration during storage due to insufficient drying. If this drying method is to be used, the principal of GMP (good manufacturing practice), GHP (good hygiene practice) and HACCP (hazard analysis critical control points) should be in place.

Fooladi *et al.* (2006) had shown that although there are no significant differences between sun drying, conventional dryers and their combination, the lowest amount of aflatoxin was found in nuts dried using conventional dryers. Studies have proved that sun drying could not significantly reduce the amount of aflatoxin after 60 hours (2.5 days) and hence, the effect of sunlight exposure for more than 60 hours on the reduction of aflatoxin should be further analyzed.

Another conventional drying method that can be used is solar-assisted drying process. Solar-assisted dryer is defined as a drying process that uses the heat supplied by the sun. Drying of solid products using solar energy applications has the advantages of small or negligible installation and energy costs. Furthermore, this drying method can also be performed using solar energy in combination with other renewable energy sources or non-renewable energy sources. On the other hand, solar drying is widely applied in the preservation of agricultural crops such as pistachio, walnut, hazelnut, etc., in order to decrease their moisture contents and to prevent deterioration. Additionally, it is applied in the cities and villages where solar radiation is abundant enough for drying purpose and by this way farmers and producers can decrease drying cost of agricultural products. After harvesting, the pistachio nuts are mostly spread on the ground and generally dried in the open sun. Hence, the producers spend a lot of money to recover the quality of dried pistachio otherwise the quality of the products will be lower than expected. Therefore, drying of pistachio nut has become an increasingly important activity. It is suggested that to increase the quality of pistachio nuts and to decrease the drying time, the solar-assisted convection dryer should be used to replace sun drying (Midilli, 2000 and Midilli 2003b).

Midilli (2001) in their study on the drying behavior and conditions of pistachio nuts using both solar assisted and sun drying had demonstrated that pistachio nuts were dried within 6 hours in solar-assisted dryer at temperatures of 50 ± 10 °C whereas; the samples in the open sun were not sufficiently dried at 28 ± 4 °C during the same period. Hence, he suggested that pistachio nuts at initial moisture content of approximately 29 % can be dried using the solar-assisted convection dryer at 50 ± 10 °C for 6 hours. It is more desirable to dry pistachio nuts using solar-assisted dryer to protect the product from negative influence of the climate and prevent contamination from dust, dirt and harmful insects.

Ghazanfari *et al.* (2003) designed a thin-layer forced air solar dryer in their study on the feasibility of drying pistachio nuts. The maximum temperature of the solar collector reached 56°C, i.e. 20°C above the ambient temperature and the required drying time was 36 hours. During the first day of drying the moisture content decreased to about 21% on wet basis. The final moisture content of the dried nuts was 6% wet basis, which was in the standard range of moisture content. They concluded that the quality of solar dried nuts was better than the conventional heated air due to the slower drying rates. In solar drying of agricultural grains, the rate of water removal depends on the stage of drying of the grains. A large quantity of water could be removed during the initial stage of drying using large volume of fresh air. The diffusion of moisture within the material is the limiting factor and a higher temperature is required for effective removal of moisture. Drying rate is positively and highly correlated to the amount of solar radiation and vapor pressure deficit, but highly and negatively correlated to density and initial moisture content of the hay. A properly managed solar drying system is a suitable alternative for production of good quality dried pistachio nuts. If the temperatures of fossil fuel-based dryers are not precisely controlled, a portion of the dried nuts are discolored, burned, or exposed to various toxic fumes. The maximum recommended air temperature for drying of pistachio nuts is 55°C. Higher temperatures usage are uneconomical as it resulted in cracks formation of the kernels, loss of volatile aromatic components, case hardening, reduction of storage life and germination of kernels. These damages have also been reported for other agricultural products (Ghazanfari and Tabil, 2003).

Kashaninejad *et al.* (2003) reported that sun drying and bin drying techniques resulted in higher percentage of split shell pistachio nuts than other drying methods. Types of drying methods did not have any significant influence on the free fatty acid content, peroxide value and thiobarbituric acid value of pistachio nuts. However, significant differences in the roasted flavour of pistachio nuts were detected. In addition, differences in shell appearance (such as colour) of nuts that are dried using various methods were also significant. The nuts dried in the funnel cylindrical dryer and vertical continuous dryer have the highest and lowest quality, respectively. Shell appearance is one of the most important factors in pricing of raw pistachio for export. Shell staining is a quality defect affecting nut appearance and it can be minimized by avoiding delays in harvesting and the elapse time between harvesting and hull removal (Doster and Michailides, 1995). The cause of shell staining is not yet known, but the high content of phenolic compounds in the hull could be one of the factors. Significant differences were found in the amount of split shell nuts produced using various dryers. Split shell pistachio nuts is also another important criteria affecting the market price. It was reported that the bin drying method produced pistachio nuts with the best quality.

Rostami and Midamadiha (2004) evaluated the effect of various dryers such as batch wagon, continuous cylindrical dryers, and continuous funnel cylindrical and vertical continuous dryers on the quality of dried pistachio nuts. Table 1 summarizes the characteristics of four different types of dryers used in pistachio nut drying. Drying nuts up to 4-6% moisture content, increased nut splitting in batch cylindrical dryer and decreased it in vertical continuous dryer. Continuous cylindrical dryer resulted in the highest percentage of heat injury whereas, the lowest were observed in nuts that were dried in batch cylindrical dryer. Sun drying produces the best nuts in terms of colour and shape uniformity, whereas, pistachio nuts obtained from the continuous cylindrical dryer had the least uniformity. The time required to reduce the moisture content of pistachio nut to 1% was 8.5, 15.1 and 35.5 minutes for the first, second and third hours of drying time, respectively. A higher amount of fuel was needed to dry nuts to a moisture content of 4-6% compared to 10-12%. Drying nuts up to 4-6% (w.b.) moisture level in continuous cylindrical dryer resulted in the best kernel color. Therefore, the types of dryer used for drying pistachio nut are critical as they influence the final quality of the product.

4. Advantages and disadvantages of pistachio dryers

Table 2 compares the advantages and disadvantages of using different types of pistachio nut dryers. Considering the advantages and disadvantages of all the drying methods, it is suggested that the sun drying technique can be used in combination with other methods such as bin dryer or solar dryer. The usage of a solar dryer alone is not advisable because the performance of the dryer depends largely on the prevailing ambient conditions. Monitoring of moisture content during drying is one of the critical control point (CCP) in pistachio processing. Figure 12 shows the drying curves of Fandoghi variety of pistachio nut using a bin dryer. The drying time of pistachio nuts is influenced by the temperature of the bin dryer. Regardless on the types of drying method employed, it is important to ensure that the final moisture content of pistachio nuts should be 4-6% at the end of the drying process. Otherwise, it is necessary to increase the drying time to reach to this standard level. The safety of pistachio nuts depends very much on the final moisture content as the risk of contamination to mycotoxins is higher in high moisture content products (Marin *et al.* 2008).

5. Conclusions

Drying conditions such as temperature of air, velocity of air, time of drying, moisture content of dried pistachio nuts, product thickness layer and type of dryer influence the quality of the final product. Among all the available drying methods, sun drying produces the best final pistachio nut quality; however exposure to negative climatic and environmental conditions hindered its wide usage. Mechanical dryers that consume only fossil fuels or electricity are inappropriate for producers because they are expensive in terms of investment and energy costs, and furthermore skilled personnel are needed for operation and maintenance. Among fossil-based dryers, the bin dryer is considered the best. Split shell appearance, colour and uniformity of pistachio nut are significantly affected by the drying methods used. Therefore, to overcome any adverse effects on the quality, a combination of bin dryer and sun drying or combination of bin dryer and solar drying, are recommended for effective drying of pistachio nuts.

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Table 1. The characteristics of four types of dryers (Source: Rostami and Mirdamadiha, 2004)

Type of dryer	Batch wagon dryer	Continuous vertical dryer	Continuous cylindrical dryers	Continuous Cylindrical Funnel dryer
Depth of sample	25cm	30cm	1.5m	20cm
Air temperature (°C)	60-65	70-75, 60-65 (2dryers)	50-55, 55-60, 60-65, 70-75 (4dryers)	60-65
Capacity (kg)	338	10000	10000	376
Temperature control possibility	Yes	Yes	Yes	Yes
Agitation possibility	Yes	Yes	Yes	No
Air flow changing possibility	No	No	No	No

Table 2. The advantages and disadvantages of pistachio drying methods

Drying method	Advantage	Disadvantage
Sun drying	Good final product quality High product uniformity Increase nut splitting	Negative climate condition Risk of contamination
Solar drying ^a	Good final product quality	Expensive solar radiation equipment
Bin drying ^b	Good final product quality	Low capacity High damage of product
Vertical continuous drying ^c	Less energy required for operation	Negative effect on nut splitting
Vertical cylindrical drying ^c		Low product uniformity
Funnel cylindrical drying ^b	Ability to control movement and holding time	Usage of higher temperature
Continuous mobile and steady tray dryer	Ability to use different drying temperature High product uniformity	Usage of high amount of fuel
Batch drum dryer	High product uniformity	Low capacity
Continuous belt conveyor dryer	Ability to use different drying temperature	Usage of high amount of fuel

^a Middilli, 2001^b Kashaninejad, 2003^c Rostami & Mirdamadiha, 2004



Figure 1. Freshly picked pistachio nut



Figure 2. Dried pistachio nut



Figure 3. Pistachio processing plant



Figure 4. Sun drying of pistachio nut



Figure 5. Wagon bin dryer

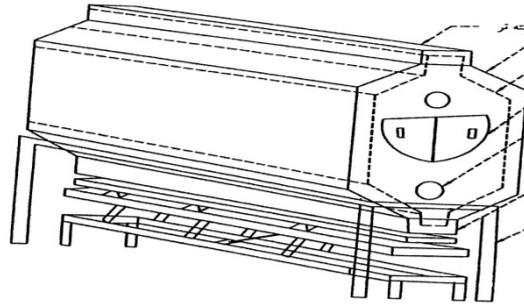


Figure 6. Schematic diagram of a vertical continuous or cross flow dryer
(Source: Rostami and Mirdamadiha, 2004)

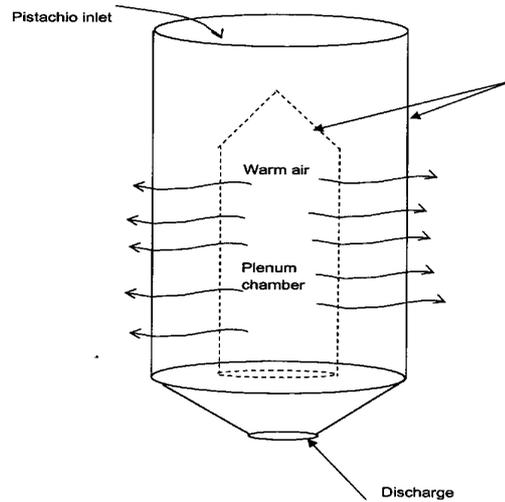


Figure 7. Schematic diagram of a vertical cylindrical or column dryer (Kashaninejad, 2003)

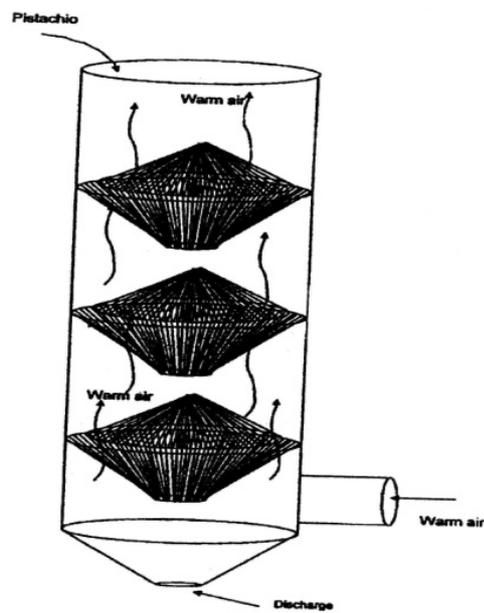


Figure 8. A continuous funnel cylindrical dryer
(Source: Kashaninejad, 2003)



Figure 9. A continuous mobile and steady tray dryer



Figure 10. Batch drum dryer of pistachio nut



Figure 11. Continuous belt dryer

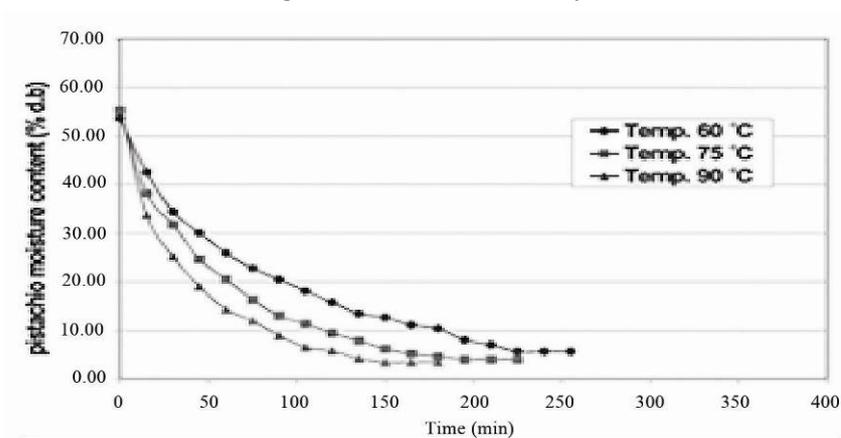


Figure 12. Changes in moisture content during drying of pistachio nut in a bin dryer (Source: Gazor, 2005)