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Comparison of solar drying and open sun drying on texture and color of solar dried persimmon (*Diospyros Kaki L.)* Slices features by instrumental measurement

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Persimmon (*Diospyros kaki L.)* is a highly perishable fruit. Previous studies have shown the feasibility of making a hot-air-dried, sliced-style product from persimmons. However, the texture and color of this type of product has not been explored in Pakistan. In the present study, persimmon slices were dried in the open sun drying and using Flat plate solar collector drying system. The aim was to predict Texture attributes and color from instrumental measurements. During drying, the initial moisture content of persimmon slices was reduced from 85% to less than 10%. Slices took 18 hours to reduce the moisture content from 85% to final moisture content of 9%, while in OSD it took 27 hours to reduce the initial moisture from 85% to final moisture content of 9%. The Analysis of Variance data showed that both texture and color was significantly ($P \leq 0.01$) affected by drying methods. The texture and color of persimmon slice are greatly affected by open sun drying as compared to Flat plate solar collector. All most all the Textural Profile values were affected by drying and showed an increased trend. Springiness (0.47-1.97) and gumminess (0.17-0.99) showed the maximum affect by drying followed by chewiness (0.51-1.89) while cohesiveness (0.29-0.79) and crispness (0.09-0.49) showed minimum effect of drying methods. Flat plate solar collector retained the texture and color attributes of persimmons slice compared to open sun drying. It is recommended to use flat plate solar collector for drying purpose to get texture attributes most desired good color.

Keywords: Color, Persimmons, Slices, Solar Drying, Texture

INTRODUCTION

Fruits are a good source of food and play a vital role in our daily life to fulfill nutritional needs of our body. Different preservation techniques are applied to increase the shelf life of fruits and store them for longer periods of time and use them in off seasons (Celen, 2019). The most ancient technique is sun or solar drying of fruits. This is a quick and efficient technique to preserve the fruits naturally without any application of chemicals (Demiray and Tulek. 2016). Fruits like apples, apricots, plums, grapes, persimmon, figs, pomegranate, muskmelon, peaches, banana and mango are dried in the sun. These dried fruits have a very good market and a high demand due to their taste and aroma (Hanif et al. 2018).

Persimmon belongs to a family called *Ebenaceae*. Persimmon tree is deciduous with

multi or single stem. The tree reaches 25 feet high (Bolek and Obuz., 2014). It is mostly cultivated in China, Brazil, Japan, Pakistan and Korea. Globally, about 400 Species of persimmon are found. In these 400 species the most important species are *DiospyrosVirginiana*, *Diospyros Kaki L* and *Diospyros lotus (*Jia et al. 2020*)*.Persimmon became soft with orange red skin color and flesh having yellow orange color. When it's ready to eat, it is juicy and sweet in taste (Rebecca et al., 2020). Persimmon of the subtropical region is rich in bioactive compounds. The fresh fruit is rich in dietary fiber, Osmotic Phenolics and minerals (Muhammad et al. 2020). Persimmon plays an important role to control diseases like colon diseases, heart diseases, constipation etc (Parka et al. 2006). The eating of persimmon on daily routine helps to limit the fat absorption and reduces cholesterol (Karkasova et al. 2013). It is a fruit which has a high level of nutrients, good color and taste when dried (Safa et al. 2014). Persimmons are cut into circular slices and dried in the sun. After drying the slices becomes just like chips which are very tasty with sweet and leathery texture (Heras et al. 2017). There is good demand in market for dried persimmon slices. Persimmon chips are exported to the world and have a high demand, but due to low quality, color and texture, the products cannot be exported from Pakistan (Mansoor et al. 2019).

In Pakistan and other countries where growers dry persimmons, they commonly and mostly dry it in open sun. This method of drying increases drying time, which can increase chances of microbial attack, deposition of dust and rancidity. The slices thus become contaminated with mycotoxins and hence cannot be exported. The product dried is of low quality with texture and color affected. There is great scope of applying flat plate solar collector drying for achieving good quality solar dried products (Hanif et al. 2015). The current research presents the solar drying of persimmon slices in open sun and with the help of flat plate solar collector to achieve dried persimmon slices to achieve texture and color attributes most desired by consumers.

MATERIALS AND METHODS

The Flat Plate Thermal Solar Collector

The flat plate thermal solar collector used for drying purposes is shown in Figure 1 and 2. The collector is installed at the Department of Agricultural Mechanization, The University of Agriculture Peshawar Pakistan. The latitude of the site is 35.01° and longitude is 72.49° with elevation of 449.37m.The cross sectional area of the solar collector is 8.365m^2 with 0.12 m thick insulation box, glazing of glass (0.08 m) and absorber made of Galvanized, V-corrugated Acryl black painted steel with an area of 8.360m^2. The solar collector is attached with two dryers having volume of 3.2m^3 with capacity of drying 5.0 kg persimmon slices.

Preparation of Drying Process for Persimmon Slices

For the drying process of persimmon first we collected good quality persimmons from the local orchids. Then we washed the persimmon with warm water to remove microbial, dust and other chemical deposition. Persimmons were blanched in hot water at 80 ^{o}C each for five minutes and cut into circular slices of almost equal thickness with the help of a sharp stainless steel knife. After cutting persimmon slices, they were put on a tray. The tray of the drying chamber of the flat plate solar collector was washed so that there is no dust or moisture left on it. After washing and drying the trays in the oven, put the slices on the tray one by one and make rows of slices. At this stage weight the slices before kept in the solar collector, weight must be taken with the help of a sterilized digital weight machine. After the weight has been taken, place the trays in a solar dryer and make sure that the dryer is at the right temperature. After keeping trays in the dryer measure the weight of slices after each hour. When the fruit is completely dry take the trays out of the dryer and carefully pick and pack the slices in polythene bags with special zips to avoid moisture and microbial contamination (Mansoor et al. 2019 and Vilhena et al. 2020).

Moisture Loss

Moisture loss per hour was determined by weighing the slices after each hour. Weight loss was recorded and moisture loss was determined using equation (Hanif et al. 2015).

$$Mc = \frac{Wl}{Wo} x\ 100$$

Where Mc is moisture content, wl is weight lost after each hour of drying, wo is weight before one hour prior to the data taken at the instant time.

Texture Profile Analysis (TPA)

TA-XTPlus100 Texture Analyzer (Stable Micro Systems Ltd., Godalming, UK) with 100 kg load was used for TPA. A TA-11stainless steel cylindrical probe (25.4 mm diameter) was used for

the test. The probe speed was kept at 1.55 mm.S^{-1}, and the probe was given compression up to 50% strain. TPA was done on fresh and dried persimmon slices (Seenadeera et al. 2020 and Celen, 2019).

Color Determination

Chroma meter (CR-300) made by Minolta Corporation, Japan). A Minolta calibration plate YCIE=94.5, XCIE=0.3160, YCIE=0.330 and a Hunter Laboratory standard color plates (L*=97.51, a*=-0.18, b*=+1.67) were used to standardize the instrument using a D65 illuminant. L*(lightness), a*(redness, + or greenness, -), and b*(yellowness, +or blueness,-) values of fresh and dried persimmon were determined (Cho et al. 2017 and Milczarek et al. 2019).

Statistical Analysis

An ANOVA (Analysis of variance) was done to determine the effect of two drying methods on the mean values of the instrumental measurements. The probability value of $P \leq 0.01$ was chosen to indicate a significant difference between two drying methods. The analysis of Tukey's Least Significant Difference (T's LSD) was applied to interpret difference of dried slices from each other, and a difference of $p \leq 0.01$ between the two methods was considered significant (Ji-Hyeong et al. 2017 and Olsen et al. 2017).

RESULTS

Moisture Loss

Moisture Loss per hour by persimmon slices during drying by Flat plate solar collector (FPSC) is given in Figure 2 while that open sun drying (OSD) is given in Figure 3. During drying, the initial moisture content of persimmon slices was reduced from 85% to less than 10%. In FPSC the slices took 18 hours to reduce the moisture content from 85% to final moisture content of 9%, while in OSD it took 27 hours to reduce the initial moisture from 85% to final moisture content of 9%.

Texture Profile Analysis (TPA)

The results of texture profile analysis of the fresh and dried slices dried by FPSC and OSD are given in Table 1. The analysis of variance (ANOVA) showed that all the attributes showed a significant difference ($p \leq 0.01$). The type of drying also showed significant ($p \leq 0.01$) effect on the TPA values. All most all the TPA values were affected by drying and showed an increased trend. Springiness (0.47-1.97) and gumminess (0.17-0.99) showed the maximum affect by drying followed by chewiness (0.51-1.89) while cohesiveness (0.29-0.79) and crispness (0.09-0.49) showed minimum affect by drying methods.

Color Determination

The results of instrumental color analysis of the fresh and dried slices dried by FPSC and OSD are given in Table 2. The ANOVA (Analysis of Variance) showed that color is significantly ($p \leq 0.01$) affected by drying methods. The minimum values for Lightness (20.6$\pm$0.02), Redness (-0.112$\pm$0.007) and Yellowness (0.9$\pm$0.01) were recorded for persimmon slices dried in OSD followed by slices dried at FPSC with Lightness (41.7$\pm$0.01), Redness -0.226$\pm$0.002) and Yellowness (1.7$\pm$0.09). The results showed that during solar drying by FPSC the color values are 47% affected while in OSD the color was more than 60% affected solar dried persimmons.

Table 1: Instrumental texture attributes of persimmon slices before drying (fresh) and dried at flat plate solar collector (FPSC) and Open Sun Drying (OSD)

TPA Attribute	Fresh	FPSC	OSD	Mean	Probability > F value / p-value
Hardness	0.69	1.47	1.39	1.18a	0.0139
Cohesiveness	0.29	0.79	0.67	0.58c	0.0080
Springiness	0.47	1.97	1.19	1.21a	0.0078
Gumminess	0.17	0.98	0.99	0.71b	0.0041
Chewiness	0.51	1.90	1.89	1.43a	0.0400
Adhesiveness	0.61	1.87	1.65	1.38a	0.0078
Crispness	0.09	0.49	0.43	0.34d	0.0027
Resilience	0.23	1.33	1.19	0.92b	0.0412
Mean	0.38c	1.35a	1.17b		

LSD Value for TPA attributes 0.23, LSD Value for Drying methods= 0.01

Table 2: Instrumental Color Analysis of persimmon slices before drying (fresh) and dried at flat plate solar collector (FPSC) and Open Sun Drying (OSD)

Drying Method	Hunter Color Value		
	Lightness (L)	Redness (a)	Yellowness (b)
Fresh	77.6±0.03a	-0.373±0.005a	1.9±0.04a
FPSC	41.7±0.01b	-0.226±0.002b	1.7±0.09b
OSD	20.6±0.02c	-0.112±0.007c	0.9±0.01c

LSD Value for TPA attributes 0.0024

Figure 1: The Flat Plate Solar Collector Assembly

Figure 2: The Flat Plate Solar Collector with drying chamber

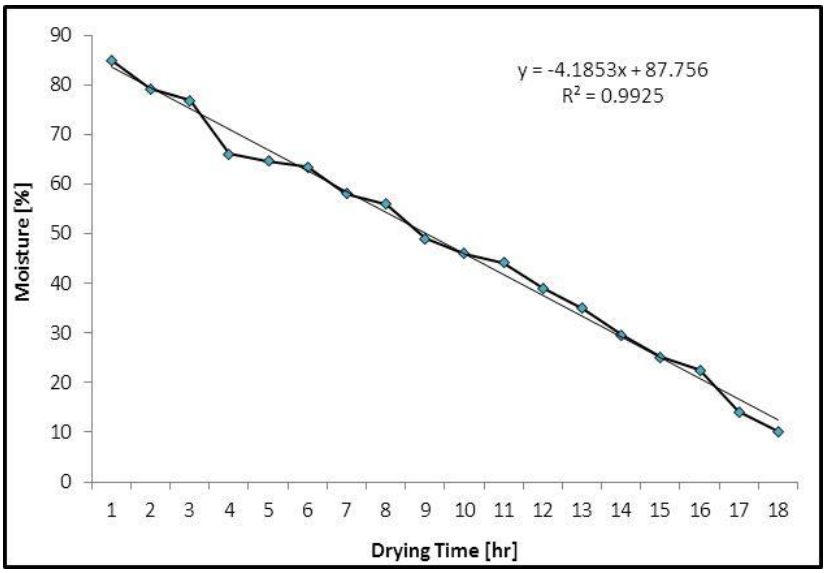

Figure 3: Moisture Loss per Hour by persimmon slices during solar drying by FPSC

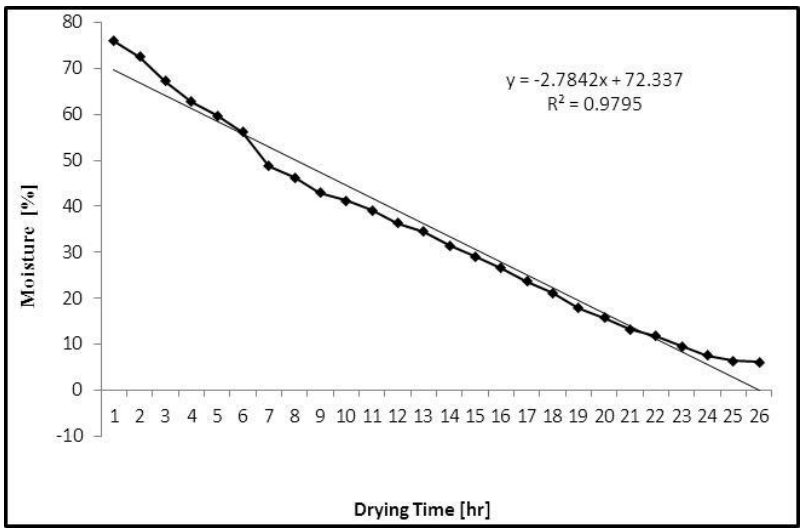

Figure 4: Moisture Loss per Hour by persimmon slices during OSD

DISCUSSION

The reason for quick drying by FPSC is that there was a controlled drying environment set at 45 to 55 ^{o}C while in ambient environment the temperature fluctuated with time from 23 to 34 ^{o}C as thus increased drying time for OSD method. Another reason is that in the FPSC drying chamber the relative humidity remained in the range of 10 to 15%, which facilitate the drying by allowing the air to absorb more moisture from the persimmon slices while in OSD the humidity remained high i.e. in between 55 and 60%, causing a decrease in the drying process and hence increased drying time. If we consider the moisture loss on dry basis, so persimmon slices got 0.23 g.cm^{-2}.hr^{-1} of drying rate in FPSC while in OSD it gained 0.35 g.cm^{-2}.hr^{-1} of drying rate. The results of FPSC are in accordance with findings of Hanif et al. (2015) who dried persimmons using FPSC, which took 19 hours of drying time with almost similar drying conditions. Parka et al. (2006) dried persimmons in open sun and it took 34 hours of drying, which are slower than the

drying performed in this research. This may be due to the fact that the slice size was more as compared to our research. The results of drying are in line with the findings of Bölek and Obuz. (2014) who reported the same drying characteristics and drying time for persimmons. Hanif et al. (2018) reported the results in line with the findings of this research. They also stated the same fact that controlled temperature and humidity causes decrease in drying time and increases quality of solar dried products.

The reason for the change in texture is due to the fact water activity is decreased by loss of moisture from the slices causing an increasing trend in TPA. This fact is also stated by Mansoor et al. (2019) in their results of TPA. Their results are also in accordance with the findings of this research. The results are also in line with the findings of Rebecca et al.(2020) who reported a significant effect of drying methods on TPA of persimmon chips. The results are also in line with the findings of Olsen et al. (2017) who reported an increasing trend of TPA attributes in persimmon chips with drying methods as compared to fresh persimmon slices. Ji-Hyeong et al., (2017) also reported results in line with the findings of this research who reported increasing trend in TPA with drying process. Muhammad (2020) also reported results of TPA trends in line with the TPA analysis of the research.

The reason for the change in color occurs due to oxidation of minerals and other chemical changes occurred during drying. The results are in line with the findings of Mansoor et al. (2019) who reported that color is affected during solar drying of persimmons. Muhammad (2020) reported his results in accordance with the findings of this research. He reported more 50% change in color during solar drying of persimmons. Rebecca et al., (2020) also reported a significant decrease in all the three color values. They also reported the results that open sun drying causes more damage to color as compared to oven or flat plate solar collector drying. Olsen et al. (2017) reported that the color was affected by solar drying. Open sun dried persimmon chips have color attributes more affected than

CONCLUSION

Persimmons took more drying time during open sun drying compared to solar drying flat plate solar collector. Texture is highly affected by open sun drying and is recommended to use Flat plate solar collector instead of open sun drying to achieve texture attributes most desired by consumers. The color of persimmon slice is greatly affected by solar drying. Flat plate solar collector retained the color attributes of persimmons slice compared to open sun drying. It is highly recommended to use flat plate solar collector for drying purpose to get achieve texture attributes most desired by consumers with good color that will increase chances of export.

CONFLICT OF INTEREST

The authors have declared that the present study was performed in the absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Asif Ali Mirani Co-supervised the research, Mansoor Khan Khattak supervised the research, Muhammad Hanif designed and performed the experiment, Inam Ul Haq wrote the manuscript, Rafi Uddin performed the treatment analysis, Kaleemullah helped in collection of data, Muhammad Ramzan and Akhtar Ali helps in review and collection of literature. All authors read and approved the final version.

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