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COMPARISON OF DRYING PROCESS AND PRESERVATIVES ON DRYING KINETICS, TEXTURE AND ANTIOXIDANTS RETENTION IN MULBERRY FRUITS

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ABSTRACT

The objective of the study was to compare drying processes (open sun, Hot Air of Solar Collector and Micro wave) and preservatives (potassium meta bisulphate, Sodium benzoate and control) on drying kinetics, texture and antioxidants retention of three species (Morus alba, Morus nigra and Morus. *Morus laevigata*) in the mulberries. Mulberries were pretreated with preservatives and subject to selected drying processes. Drying kinetics, texture and antioxidant retention were determined before and after each drying process. The results were analyzed using three factorial completely randomized design and means were compared at $p = 0.05$. The statistical analysis of the data showed that different drying process showed a significant ($p < 0.05$) Effect on drying kinetics, texture and antioxidant retention in mulberry fruits. Preservatives showed a significant effect on drying kinetics while it showed a nonsignificant effect on the texture and antioxidant retention. High moisture lost hr^{-1} (5.4%) was recorded in the microwave while minimum (1.8%) was recorded in open sun drying. Good textured dried mulberries with optimum hardness (313g) and stiffness ($141 g.mm^{-1}$) were found in hot air dried samples. Similarly, more antioxidants (52%) retained in samples dried with hot air followed by microwave (47%) while the minimum (41%) was recorded in open sun drying. It was concluded that hot air drying is the best drying process to get valuable dried quality mulberries with good texture and more antioxidants.

Keywords: Drying Process, Preservatives, Mulberries, Texture, Antioxidants

INTRODUCTION

Horticultural plants, including mulberries have been an indispensable part of human life for ages. Ever since ancient times, their fruits, seeds, even roots and branches have been used to meet personal and social needs such as severing food, curing diseases and beautifying the planet (Erturk *et al*., 2010; Canan *et al*., 2016; Hricova *et al*., 2016; Yazici and Sahin, 2016).

Mulberries belong to the *Moraceae* family, are small, cylindrical, juicy, safe to eat fruit that consists of a bunch of drupes. They are a rich resource of carbohydrates, proteins, potassium, minerals, vitamins, phenolics, flavonoids, anthocyanins and important antioxidants (Ercisli and Orhan, 2007; Ercisli *et al*., 2010). They have a good aroma and sweet agreeable taste, and are consumed as fresh or dried form. However, they have a very short shelf life and degraded quickly due to their high moisture content (Masood *et al*. 2008).

To preserve these mulberries, they are dried in open air and consumed in the extreme winter season in particular Asian countries, including Pakistan, Turkey, Iran, Uzbekistan etc. This method is very old and unhygienic, uncontrolled and not safe from the attack of microbes and pests. Almost 40% of the fruit is lost due to contamination and pest attack (Ali *et al*. 2016). The food industries of the world are at present looking for new advanced, alternative of open sun drying, inexpensive, hygienic and controlled preservation technology that yielding in good quality of dried fruits having minimum alteration in the quality attributes of dried fruits (Katsube *et al.* 2009). Additionally, the development of alternative technologies for dehydration and processing of fruits is necessary to reduce losses and obtain best quality value added fruits. Thus development of new drying technologies which are energy efficient and providing a base for quality drying is the goal of modern researchers (Hanif *et al.* 2016).

To develop new dehydrators and overcome the conventional open sun drying of fruits, numerous researchers have analyzed the dehydration of mulberries and other fruits. Luchai *et al*. (2013) studied the drying kinetics and quality attributes of mulberry (*Morus alba. L*) dried by a solar air heater and open sun, pretreated with different preservatives. They reported that hot air drying using solar air heater is quick and the quality of mulberries was very good as compared to sun drying. Akbulut and Durmus (2009) conducted experiments on white mulberry (*Morus alba. L*). They dried mulberries in the sun and a hot air provided by a 2.04 m^2 solar air heater. They reported good kinetics and quality for samples dried by a solar collector. Katsube *et al.* (2009) studied the impact of drying process on quality attributes of mulberry (*Morus alba. L*). They reported that there is a significant difference found in between sun dried, solar dried and oven dried samples. Solar dried and oven drying give much better results of antioxidants as compared to sun drying. Tasar *et al.* (2007) studied hot air drying of mulberries at temperatures lower than 50ºC is the best practice to maintain phenolics, flavonoids and antioxidants.

There are little data on different drying methods applied to different mulberry species under different preservatives and their effect on the drying kinetics and quality parameters such as texture and antioxidants retention. Thus the aim of the study was to find and compare different drying methods (Open sun, hot air by solar collector, and microwave), preservatives (control, Potassium meta bisulphate and Sodium benzoate) and species (*Morus alba. L, Morus nigra. L and Morus laevigata*) in the mulberries. The effects of the process variables over the proficiency of drying kinetics, texture and antioxidants retention of mulberries were determined.

MATERIALS AND METHODS

Mulberries: Three main species of mulberries grown in Peshawar, Pakistan namely White Mulberry (*Morus alba. L*), Black Mulberry (*Morus nigra L.*) and Himalayan Mulberry (*Morus laevigata*) were selected from the mulberry orchards of the newly developmental agricultural farm of the University of Agriculture Peshawar and stored at 1ºC. Prior to drying each fruit is selected on the basis of size and more than 90% maturity. Mulberries were washed for 30 seconds with water at room temperature and dried with the help of tissue paper. The early characteristics of the mulberries were as given in Table 1.

Table 1. Initial Characteristics of the Mulberries prior to Drying.

Species	Moisture content (%)	Total soluble solids (%)	Water activity	Antioxidant capacity (DPPH)
White Mulberry (*Morus alba L.*)	85.01	11.50 ºBrix	0.98	118 $mg.g^{-1}$
Black Mulberry (*Morus nigra L.*)	83.76	12.11 ºBrix	0.97	171 $mg.g^{-1}$
Himalayan Mulberry (*Morus laevigata*)	85.85	11.12 ºBrix	0.98	134 $mg.g^{-1}$

Experimental Procedure: Before drying all the varieties were pretreated separately with 2% solution of Potassium Meta bisulphate (PMBS) and 1% solution of Sodium benzoate (SB) were used for achieving high quality and less degradation. One of the treatments was also considered as control without any pretreatment. After pretreatment with preservative, mulberries were subjected to be dehydrated until the moisture content becomes less than 20%. The drying conditions were as shown in Table 2. In sun drying, mulberries were put on clean trays and covered with polyethylene sheet. In a hot air drying, mulberries were placed in a dryer connected with a solar air heater that provided hot air for drying. The solar collector assembly is as shown in figure 1. In microwave drying, samples were subjected in a microwave oven (Model, JT-359 Whirlpool Ch). Weight lost data was recorded after each hour with the help of electronic balance. All measurements were performed three times.

Table 2. Drying Conditions of Mulberries at Different Drying Process.

Drying Methods	Temperature	Humidity	Time taken by drying
Open Sun	30 + 10	45-78%	48 hr
Hot air (solar collector)	50+5	10-15%	23 hr
Microwave	50+1	>10%	16 hr

Moisture Content (wet basis): Moisture content at each hour of drying was determined according to the procedure described by The Association of Official Analytical Chemists (AOAC) using equation 1.

$$Mc = \frac{mw}{mt} * 100 \quad (1)$$

Where Mc is moisture content (% wb),
mt is the total mass (g) while mw is water mass (g).
All the samples were dried for 8 hr per day.

Drying rate: Before drying rate, moisture ration was determined using equation 2 given by Hanif *et al*., (2016).

$$MR = a^{*}\exp^{(-k*t)} \quad (2)$$

Where MR is moisture ratio
t is drying time (hr)
a and *k* are constants to be fitted in the graph of DR and MR.
Drying rate was calculated as derivatives of MR over time using equation (3) given by Hanif *et al*., (2016).

$$DR = \frac{dMR}{dt} \quad (3)$$

Where DR id drying rate ($kg_{water}.\ kg._{dry\ solid}{}^{-1}$)
t is drying time (hr)

Texture Analysis: Two bite compression tests were performed using texture profile analyzer (Model, TPA-XT2 Stable Micro-Sys.UK) having a 5 mm cylindrical probe with 1.5 mm thickness. Samples were subject to a constant compression speed of 0.45 $mm.s^{-1}$ at room temperature. The parameters analyzed before and after drying were hardness (g) and stiffness ($g.mm^{-1}$).

Antioxidants Analysis: Antioxidants before drying and retained in the samples after drying were determined using 2,2- diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity assay of mulberries. Measurements were made with 1.5 ml of DPHH added to different aliquots of ethanol and reacted for 2 hours at 25°C. The absorbtance spectrum was measured at 500 nm with a spectrometer (Model, Hitachi –UK-1900, UK). The sample mass to inhibit 50% DPPH was determined.

The determinations were expressed as the percentage of antioxidants retention and calculated using equation 4 given by Anabel *et al*. (2017).

$$AAR = 100 - \left(\frac{AAo - AAt}{AA0} * 100\right) \quad (4)$$

Where AAR is Antioxidants Retention (%)
AAo is the initial and AAt is the final antioxidant retention capacity (%).

Statistical Analysis: Analysis of variance (ANOVA) was determined using three factorial completely randomized designs. Drying methods, preservatives and varieties were considered as three different factors. Results were expressed as mean+ SD. Means were compared using LSD at α= 5%. The effect on quality parameters were considered at 5% significance level.

RESULTS AND DISCUSSIONS

Moisture loss and drying rate: Percent moisture lost per hour from the mulberries is given in table 3. The analysis of variance showed that drying method significantly ($p < 0.05$) affected the moisture loss per hour while the preservatives and varieties had a nonsignificant effect on mulberries. Maximum moisture of 5.40% was lost from samples dried by microwave followed by hot air drying with 3.75%, while a minimum moisture lost of 1.81% was recorded for open sun drying method. In species, black mulberries (*Morus nigra L.*) shown more moisture lost per hour as compared to the other two species. The reason for high moisture lost at microwave drying is a uniform drying environment and minimum relative humidity due to which the air had more capacity to extract moisture from the mulberries. On the other hand hot air provided by solar collector had temperature and humidity fluctuations causing relatively slow moisture lost. Samples dried in the open sun showed a minimum moisture loss due to uncontrolled drying environment. The air was humid causing it to take less moisture uptake from the mulberries. The results are in accordance with the findings of Akbulut and Durmus (2009) and Akpinar (2008) who reported their results that hot air drying is 45% quicker than sun drying. Katsube *et al*. (2009) and Duygu (2011) also reported a decrease in drying time of 73% by mulberries dried by oven as compared to sun drying. The results that black mulberries (*Morus nigra L.*) lost more moisture were also reported by Taser *et al*. (2007).

The drying rate of the mulberries is given in table 4. The analysis of variance showed that drying method significantly ($p < 0.05$) affected the drying rate of mulberries while the preservatives and varieties showed a nonsignificant effect. **A** maximum drying rate of 0.046 $kg_{water}.kg._{dry\ solid}^{-1}$ was recorded for samples dried by microwave followed by hot air drying with 0.041 $kg_{water}.kg._{dry\ solid}^{-1}$ while the minimum drying rate of 0.028 $kg_{water}.kg._{dry\ solid}^{-1}$ was recorded for open sun drying method. In Varieties, black mulberries (*Morus nigra L.*) showed more 0.047 $kg_{water}.kg._{dry\ solid}^{-1}$ drying per kg of dry matter because of high moisture lost per hour. The results of drying rate are related with moisture lost per hour. These results are in accordance with the findings of Abdullah (2009) and Hanif *et al*. (2016) who reported their results that hot air drying is gives higher drying rates then open sun drying. These results are also in accordance with the findings of Doymaz (2004).

Table 3. Moisture lost per hour from different species of mulberries as affected by different drying methods and preservatives.

	Drying Methods			
	Open Sun	**Hot Air**	**Microwave**	**Mean**
Preservative	***Morus alba L.***			
Control	1.81	3.74	5.41	**3.65**
PMBS	1.79	3.71	5.37	**3.62**
SB	1.80	3.73	5.39	**3.64**
	Morus nigra L.			
Control	1.87	3.82	5.49	**3.73**
PMBS	1.89	3.80	5.41	**3.70**
SB	1.86	3.81	5.44	**3.70**
	Morus laevigata			
Control	1.76	3.71	5.38	**3.62**
PMBS	1.78	3.69	5.33	**3.60**
SB	1.76	3.70	5.34	**3.60**
Mean	**1.81c**	**3.75b**	**5.40a**	

LSD= 0.23, Means followed by different alphabets are significantly (α < 0.05) different from each other.

Table 3. Moisture lost per hour from different varieties of mulberries as affected by different drying methods and preservatives.

	Drying Methods			
	Open Sun	Hot Air	Microwave	Mean
Preservative	***Morus alba L.***			
Control	0.029	0.041	0.047	**0.039**
PMBS	0.026	0.040	0.046	**0.037**
SB	0.024	0.041	0.046	**0.037**
	Morus nigra L.			
Control	0.031	0.042	0.049	**0.041**
PMBS	0.032	0.041	0.048	**0.040**
SB	0.031	0.040	0.047	**0.039**
	Morus laevigata			
Control	0.029	0.039	0.048	**0.039**
PMBS	0.025	0.041	0.045	**0.037**
SB	0.026	0.040	0.039	**0.035**
Mean	**0.028**^{c}	**0.041**^{b}	**0.046**^{a}	

LSD= 0.015
Means followed by different alphabets are significantly (α < 0.05) different from each other

Texture: Statistical analysis of the data showed that the values of hardness (g) and stiffness (g.mm^{-1}) were only affected by drying methods while there was no significant effects of preservatives and the species on the overall texture of the dried mulberries. The means of hardness (g) of the dried mulberries as compared with fresh are as shown in figure. 1. While that of stiffness is shown in figure 2. The results showed that the mulberries become harder and stiffness increases if we dry them in microwave oven. Less hard mulberries were obtained during sun drying while leathery and gently hard dried mulberries were obtained from hot air drying. The reason is slow and controlled drying by the help of hot air having minimum enthalpy and optimum capacity of gaining moisture from the samples. The results are in accordance with the finds of Enabel *et al.* (2016) who reported more hardness is samples dried by oven as compared to fresh.

Antioxidants Retention: Statistical analysis of the data showed that the values Antioxidants retention (%) was only affected by drying methods while there was no significant effects of preservatives and species on antioxidants retained in dried mulberries. The means of data as compared with fresh are as shown in figure. 3. More antioxidants of 52% retained in mulberries dried by hot air drying using solar air heater followed by 47% in microwave drying while a minimum of 41% antioxidants was recorded in samples dried in an open sun drying. The fact that minimum antioxidants retained in open sun drying is the ultraviolet rays in the sunlight. These ultraviolet rays degraded the antioxidants and reduce their amount in dried mulberries. The results are in accordance with the findings of Doymaz (2004) who reported the reduction in percent of antioxidants in open sun dried mulberries as compared to fresh. Taser *et al.* (2007) also reported reduction in antioxidants percentage as compared with hot air drying.

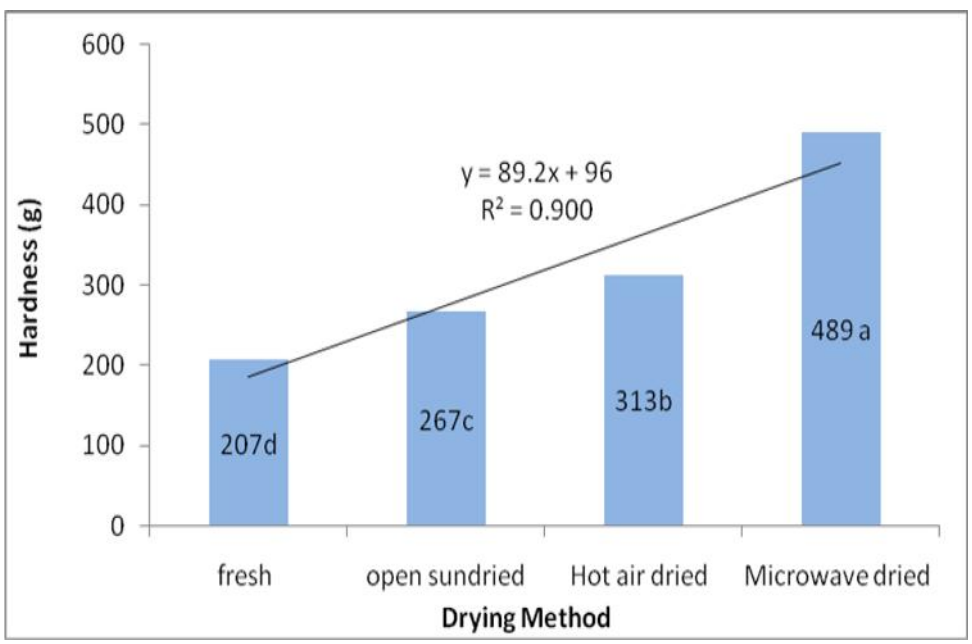

Figure 1. Comparison of hardness (g) of mulberries under different drying methods

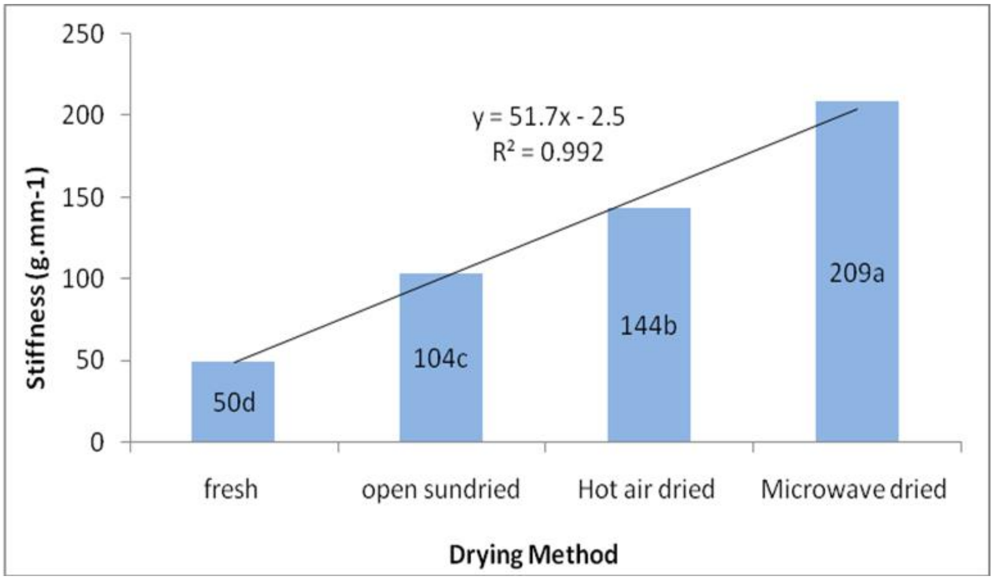

Figure 2. Comparison of hardness (g) of mulberries under different drying methods

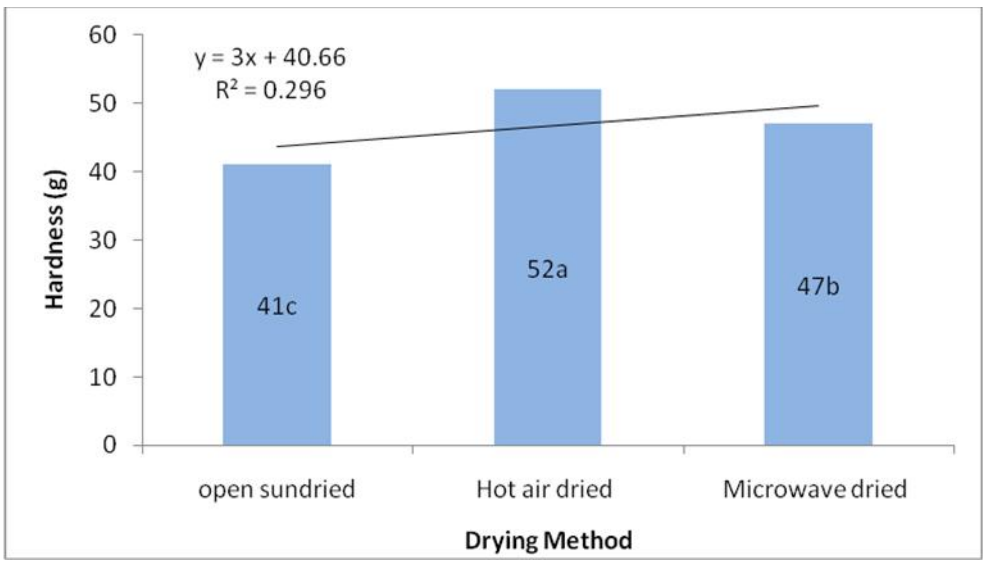

Figure 3. Comparison of Antioxidants retained in mulberries under different drying methods

Conclusion: In food processing, drying process play a vital role in determining the final quality of dried products, particularly in terms of texture and antioxidants retention. Therefore, it is essential to select an optimal dehydration process. In this study, different drying process showed a significant Effect on drying kinetics, texture and antioxidants retention. Preservatives showed a significant effect on drying kinetics while it showed a nonsignificant effect on the texture and antioxidants. Although, microwave drying is fast, but it does not help to maintain a good texture and more antioxidants. From the study it was concluded that hot air drying using a solar collector is the best drying process to get valuable dried mulberries with good texture and more antioxidants.

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