Research Article

Effect of Drying Methods on Physiochemical Characteristics and Mineral Composition of Mulberry Fruits

Ishtiaq Ahmad[1]*, Muhammad Nafees[1], Maryam[2], Irfan Ashraf[3], Ambreen Maqsood[4] and Muhammad Saqib[5]

[1]Department of Horticultural Sciences, The Islamia University of Bahawalpur, Bahawalpur; [2]Department of Botany, Government Sadiq College Women University, Bahawalpur; [3]Department of Forestry, Range and Wildlife Management, The Islamia University of Bahawalpur, Bahawalpur; [4]Department of Plant Pathology, The Islamia University of Bahawalpur, Bahawalpur; [5] Department of Agronomy, The Islamia University of Bahawalpur, Bahawalpur, Pakistan.

Abstract | Mulberry fruits (*Morus alba* and *M. nigra*) are highly nutritious that can be used to mitigate malnutrition of human beings, however have very low shelf-life. The present study was aimed at evaluation of different drying methods to improve shelf-life of dry mulberry fruits for their sustainable availability in the market for human consumption. For this purpose, common drying methods *viz.*, sun drying, shade drying and oven drying were applied on freshly harvested black and white mulberry fruits to evaluate the significant drying method with minimal nutritional losses. The fruit samples were collected from mulberry plants growing at the experimental area, The Islamia University of Bahawalpur, Pakistan. Analysis of variance showed significant effect of drying methods on fruit quality of mulberry ($p \leq 0.05$). There was significant difference ($p \leq 0.05$) in fresh and dry fruit weight, fruit width and area, and Cu contents of both the species in spectrophotometer. Reduction in fruit weight, fruit area and moisture percentage were significantly higher in oven dry method, followed by sundry with minimum reduction in shade dry method. The depletion in Cu and Fe contents was statistically high in oven drying method, followed by shade dry and sun drying, respectively; however, Zn and Mn contents were not significantly affected by any of drying method. Cu contents were significantly higher in black mulberry; however, Fe, Mn and Zn were similar in both species. This study concluded that sundry is better than all other methods with significantly less reduction in studied minerals.

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***Correspondence** | Muhammad Nafees, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan; **Email:** ishtiaq@iub.edu.pk
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Introduction

Three species of mulberry, white (*Morus alba* L.), black (*M. nigra* L.) and red (*M. rubra* L.) are well known for their delicious fruits, consumed as fresh and in dried form throughout the world (Bae and Suh, 2007; Okatan, 2018). Mulberry fruits possess some very useful and desirable medicinal properties and can be used as a remedy for dental problems, as anthelmintic, expectorant, hypoglycemic and emetic preparations in human care (Ercisli and Orhan, 2007). Besides, mulberry fruits are used in juices, paste, mar-

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malade and wine production (Doymaz, 2004). These are useful against type III diabetes mellitus, inflammation of throat and strengthening of teeth (Darias-Martin *et al*., 2003). Leaves and fruit of mulberry are used as animal feed, bears and drinks. Mulberry is commercially grown in China, Japan and India for sericulture purposes (Singhal *et al*., 2010).

Mulberry fruits have very short harvesting span and a shelf-life of three to six days (Wang *et al*., 2013). Due to high moisture contents, these are considered most sensitive to storage. Different drying methods are being developed for improvement in storage period, preservation and value addition (Doymaz, 2004). Sun drying of fruits is in use since prehistoric times despite certain drawbacks such as long drying time, pollutions of different kind, product deterioration and other unwanted damages (Doymaz, 2005). Preservation and drying techniques minimize wastage and ensure efficient utilization of fruits, even in off-season (Parakash and Datta, 2004). Dried fruits are excellent source of minerals required in enzyme activity and thus control various metabolic activities in human body. Some minerals are essential component of diet for proper body functioning and enzyme activity in humans but cannot be synthesized by human body (Simsek and Aykut, 2007; Abolhasani and Ansarifar, 2015). Different fruits are excellent source of essential minerals and have profound effects on human metabolism for different nutritional composition; moreover, various wild fruit species are highly nutritive with wide range of use in the human diet (Bosnjakovic *et al*., 2012).

Drying of fruits is rated as an important post-harvest process for overall food security, despite an accompanied high-energy consumption and some quality concerns. Thus, researchers and industrialists are always in search of new drying techniques (Doymaz, 2005; Abolhasani and Ansarifar, 2015). Sharma *et al*. (2004) used microwave energy for quality improvement and drying of fruits and vegetables. Sun light is an economical natural resource of energy, which is commonly used, in drying fruits (Doymaz and Ismail, 2010) but high product quality is obtained in drying under vacuum (Muthukumaran *et al*., 2008). Little information is available on effective drying methods in relation to morphological and nutritional quality of dried mulberry fruits. The aim of this research was to evaluate the effect of different drying methods on morphological qualities and mineral composition of fruits of different species of mulberry. This information would help to identify the best drying method for mulberry fruits that could be applied to reduce loss of mineral contents on one hand and increasing their shelf-life on the other hand for consumption by the human beings.

Materials and Methods

There were two commercial mulberry fruit species, selected in this research activity with three drying methods and three replications as mulberry plants and drying method. Data were analyzed with two factors (mulberry species and drying method) factorial experiment under completely randomized design with computer software Statistics 8.1. Least significant difference among mean values was calculated using Tukey's Test. Moreover, graphs were prepared and standard error bars were assigned with computer program MS Excel 2007.

White and black mulberry fruits were collected from the field areas, Bagdad-ul-Jadid Campus of Islamia University of Bahawalpur, Pakistan. The full ripened fruits (30) were picked from each three plants of selected species within human reach by moving around the trees, and immediately carried to Fruit research laboratory department of Horticulture, Faculty of Agriculture & Environment, The Islamia University of Bahawalpur for further analysis.

Fruits (90) of each species from three plants were polled and 30 best fruits were selected, rinsed in distilled water and spreaded odrying trays. Three fruit trays were placed in laboratory at room temperature for 10 days for shade drying. Sun drying sample trays were placed on terrace of the building of Islamic learning, Bagdad-ul-Jadid campus and were exposed to direct sunlight with daily monitoring where average temperature and relative humidity ranged between 40-43°C and 60-70%, respectively with bright sunny days during the drying period for 10 days. Another three trays of fruit samples from each species were kept in incubator at 65°C for 24 hours. Average of 30 fresh and dried fruit samples were subjected to measure fruit weight (g), length (cm), and width (cm), surface area (cm^2) and moisture content (%). The dry fruit samples were crushed in pistol mortal to fine powder to compare effect of drying method on mineral level in these dry fruits.

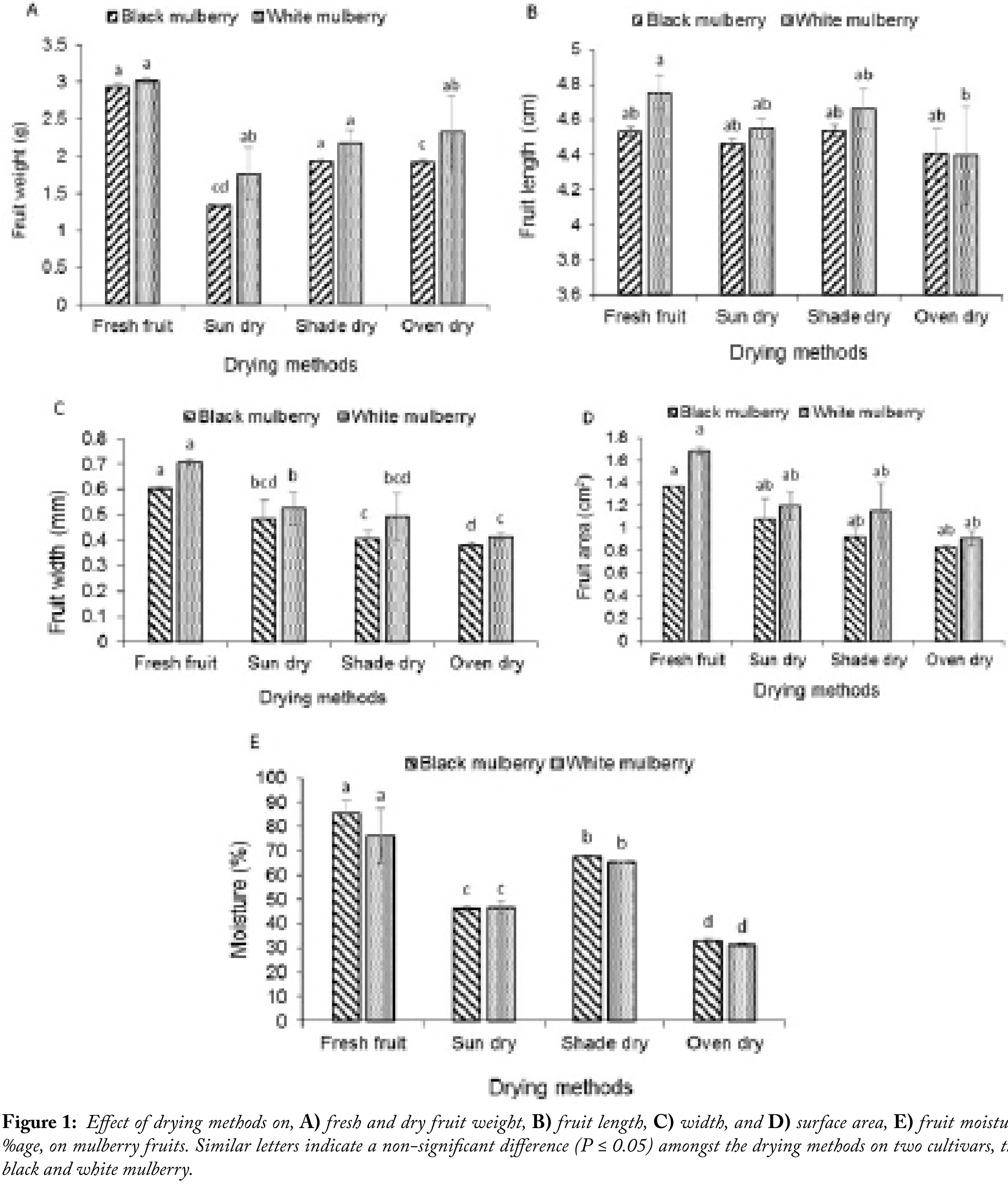

Figure 1: *Effect of drying methods on,* **A)** *fresh and dry fruit weight,* **B)** *fruit length,* **C)** *width, and* **D)** *surface area,* **E)** *fruit moisture %age, on mulberry fruits. Similar letters indicate a non-significant difference ($P \leq 0.05$) amongst the drying methods on two cultivars, the black and white mulberry.*

Stock solution preparation for spectrophotometric analysis

The powdered fruit samples of 0.5 g were poured in burning cup with 15 ml concentrate H_2SO_4 and placed over night for digestion and then 0.2 ml H_2O_2 was added to the contents and heated gently on a hot plate, followed by vigorous heating till drying to approximately 1–2 ml. After cooling, the digested samples were transferred to flasks and diluted up to 100 ml with deionized double distilled water, filtrated through Whatman No.42. An atomic absorption spectrophotometer (Analyst 700, Perkin Elmer, USA), equipped with standard burner, air acetylene flame and hollow cathode lamps as the radiation source, was used for the analysis of iron (Fe), copper

(Cu), manganese (Mn) and zinc (Zn) contents in mg / 0.5 g powdered fruit samples (Hussain *et al*., 2005; Imran *et al*., 2007; 2008; Hussain and Khan, 2010).

Results and Discussion

Effect of drying method on morphological traits

Statistically, there was a significant effect of drying method on dry fruit weight, fruit width, surface area and fruit moisture content ($p \leq 0.05$) in both species. Moreover, interaction effect of drying methods and species was also significantly different on all studied morphological traits. Fruit weight in sun dry, shade dry and oven dry fruits varied significantly with high value in freshly harvested samples that was at par with rest of the fruit drying lots, however, fresh fruit weight of both selected species was non significantly different (Figure 1A). Dry fruit weight differed significantly with the drying method and the mulberry species with highest value in shade drying trays, followed by sun drying and oven drying respectively. However, highest dry fruit weight was recorded in white mulberry as compared to black mulberry, (Figure 1B). Lowest dry fruit weight was recorded in case of oven dried mulberry fruits of both species. A significantly high fruit length was recorded in fresh fruits (≥ 3 cm) that were at par with sun and shade dried mulberry fruits, while minimum fruit length was recorded in oven dry fruits. Besides, in interaction effect, fresh white mulberry had highest fruit length which was statistically similar to drying methods, except for oven dried fruits (Figure 1C). Fruit width and surface area was significantly affected by drying method in both the species. There was highest fruit width and area (0.65 cm and 1.52 cm^2) in fresh white mulberry fruits, followed by sundried fruits which were at par with shade dried and oven dried fruits (Figure 1D). Moreover, white mulberry on the average had a larger fruit width (0.53 cm) as compared to black mulberry (0.47 cm). Interaction effect was also significantly different with least width in black mulberry fruits dried in oven which was at par with shade dry fruits. Besides, fruit area was significantly high in white mulberry fruits as compared to black mulberry (Figure 1E). Fruit drying method and cultivar type had a statistically significant effect on moisture percentage with the highest value (80.87%) recorded in fresh fruits, followed by shade dried and sun dried mulberry fruits, while least moisture content (32.02%) was demonstrated in oven dried fruits (Figure 1F). Statistically there was no effect of species on the moisture percentage, however, the interaction effect was significantly different with high moisture (85.63%) recorded in fresh fruits of black mulberry, which was equal to fresh white mulberry fruits. However, there was no significant difference between species in shade dry fruits of the both mulberries. Least moisture percentage was recorded in oven dry fruits of white and black mulberries.

Effect of drying methods versus species on mineral contents in mulberry fruits

There was a statistically significant difference of drying method on the Fe, Zn, Cu and Mn contents of fruits however, the both species of mulberry had statistically same quantities of these minerals except copper. Highest iron contents were recorded in fresh mulberry fruits which was at par with sun dried and shade dried fruits, however, least amount of Fe was recorded in oven dried fruits (Figure 2A). High levels of Fe were recorded in fresh fruits of black mulberry which was at par with sundry and shade dry fruits except for oven dry black mulberries. Zinc and Mn concentrations were not significantly different in fruits of the both species dried under different drying methods, however, interaction effect were statistically different in species with drying methods, except fresh white mulberries with least Zn contents (Figure 2B). High contents of Mn were recorded in fresh black mulberry fruits which was statistically similar for all drying methods in the both species except for oven drying (Figure 2C). Copper contents were significantly affected by drying method. High level of Cu was recorded in fresh mulberry which was similar to sundry mulberry followed by oven dry mulberry which was at par with shade dry mulberries. Significantly high level of Cu (0.484 mg / g) was recorded in black mulberry followed by white mulberry (Figure 2D). The interaction effects of Cu were also significantly different with high levels of Cu in fresh black mulberry fruits and sundry fruits which was followed by fruits of the both species dried with other drying methods (Figure 2D).

In this study, high fruit weight was recorded in freshly harvested fruits. Dry fruit weight was highest in shade dried fruits and least fruit weight was demonstrated by oven dried samples which shows that oven drying is the best method for drying mulberry fruits. Moreover, fresh and dry fruit weight and volume was

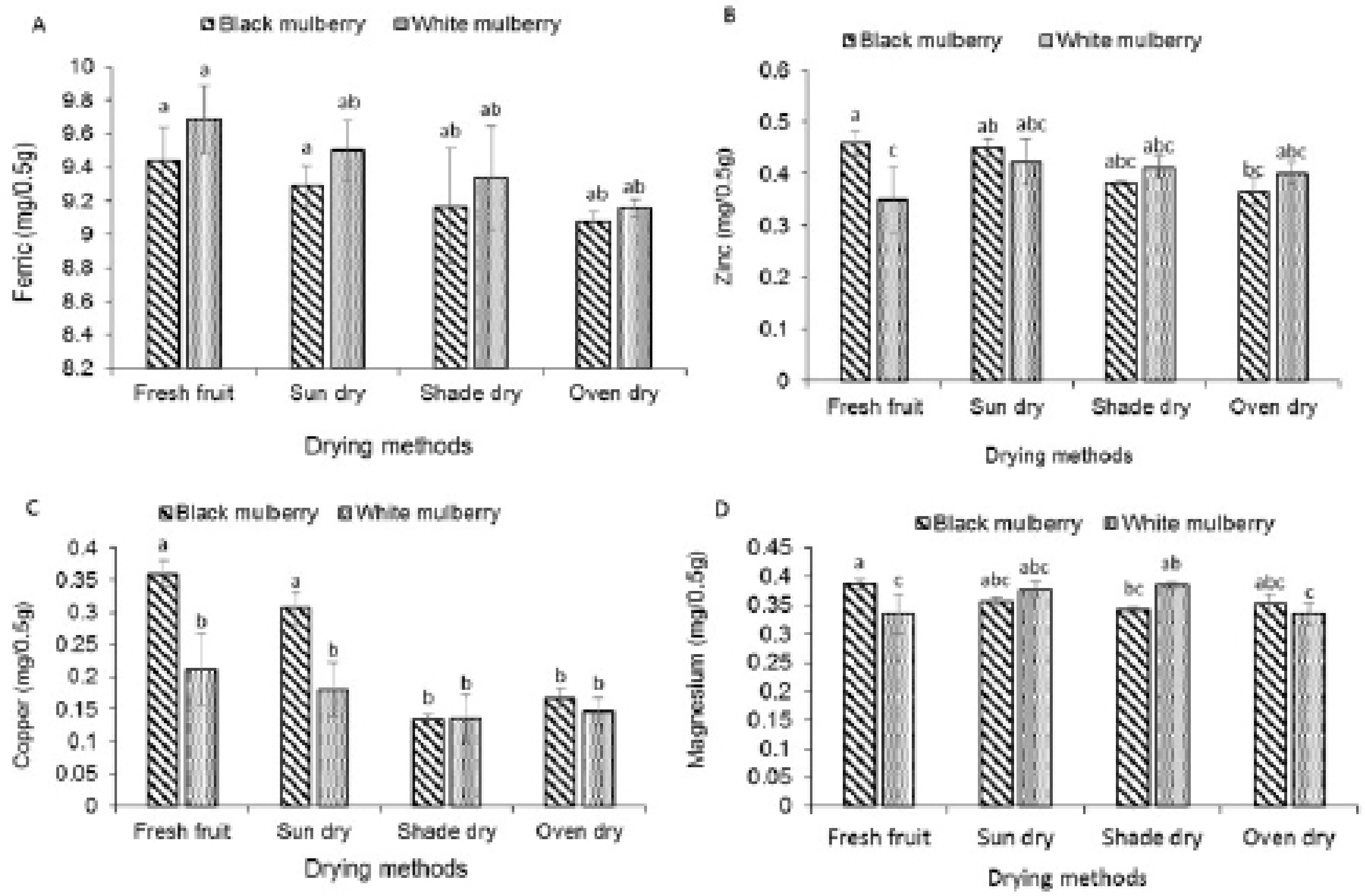

Figure 2: *Effect of drying methods on,* **A)** *Fe,* **B)** *Zn,* **C)** *Mn and* **D)** *Cu, contents in black and white mulberry fruits. Similar letters showed non-significant difference (P ≤ 0.05) among cultivars for different mineral contents affected by drying methods.*

higher for white mulberries which indicated that the tested cultivars responded differently to the drying methods. These results are in agreement with the findings of Karlidag *et al.* (2012). Fruit length, width and area were higher in shade dried mulberry fruits as compared to oven dried mulberries. High fruit moisture contents were recorded in white mulberries dried in shade with least moisture contents in oven dried mulberries. The methods used in this research are equally important as discussed by Leon *et al.* (2002) that open sun drying of fruits and vegetables are commercially adoptable being a cheap source of drying, however, environmental contamination, insect infestation and slow processing (Aghbashlo *et al*., 2008) may be controlled by replacing sun drying technique with solar and hot air drying (Doymaz and Ismail, 2011; Adedeji *et al*., 2008; Sacilik *et al*., 2006; Kingsly *et al*., 2007).

Results of this study showed that both the mulberry species had same quantities of minerals except copper. There was no depletion of Fe, Zn and Mn contents in sun dried and shade dried fruits; however, least amount of these minerals was recorded in oven dried mulberry fruits. High Fe contents were recorded in fresh black mulberry fruits. The high amount of Fe is nutritionally important that can be used to overcome iron deficiency as well as to treat anemia.

Copper contents were significantly affected by drying methods with least contents in oven dried and higher levels in black mulberry. Zinc, manganese and copper contents were found higher in shade dried mulberry fruits. Mulberry fruit drying is used to extend supply window because its harvest season is short, however nutritional status is maximum in fresh fruits. Shade dried fruit samples had higher concentration of Cu followed by fresh, oven and sun-dried fruits, respectively. Dried berry fruits had more Cu contents as compared to fresh berries, however, least concentration of Cu was recorded in sundry fruits. Zinc and Mn contents were improved with shade drying method. Results are in line with the findings of Koyuncu *et al.* (2014) who stated that iron, copper and Zn are main mineral components in dried mulberries with high contents of K in fresh mulberries. Depletion of Cu and other minerals in dried mulberry fruits may be due to high temperature and prolonged exposure to heat and light (Watada *et al*., 1996). The drying process increases the cost of production and results in reduction of product quality because of biochemical changes which may be controlled by reducing the drying time (Sharma *et al*., 2004), and thus improve the product quality (Yongsawatdigul *et al*., 1996). Shade and sun drying methods are cheaper techniques with maximum hazards to quality. However, hot air and microwave drying also has limitations for their high energy consumption, long drying times, low energy efficiency and higher cost of production (Abolhasani and Ansarifar, 2015).

Conclusions and Recommendations

This study revealed that mineral contents in fruits can be well preserved in shade drying techniques, followed by sun-drying. The depletion of minerals was higher in oven drying method. Based on the results of this study, it is suggested that shade and sun-drying techniques are required to be studied in detail in order to maintain quality of dried fruits, while oven conditions also need improvement to minimize mineral depletion to ensure sustainable supply of mulberry in fruit industry at global scale to reduce malnutrition in human beings.

Novelty Statement

The main objective of the current study is to minimize the loses in fruits through preserving after drying.

Author's Contribution

Ishtiaq Ahmad: Executed the field work.
Muhammad Nafees: Perceived the idea.
Maryam and Irfan Ashraf: Laboratory analysis.
Ambreen Maqsood: Statistical analysis.
Muhammad Saqib: Write up.

Conflict of interest
The authors have declared no conflict of interest.

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