Comparison of drying characteristics and quality of tender mulberry leaves (Morus alba) using five different drying methods

Shubhajit Sarkhel, Dronachari Manvi and Ramachandra CT

DOI: https://doi.org/10.22271/plants.2022.v10.i1a.1360

Abstract
The value-added forms of mulberry leaves (Morus alba) significantly help to reduce blood sugar, cardiovascular diseases, inflammation levels, cholesterol and fighting against heart disease. This research is aimed at studying the suitable method for drying of tender mulberry leaves for the production of mulberry tea. To select a suitable drying technology for drying of tender mulberry leaves for retention of biochemical quality parameters, open sun (31 to 35 ºC), shade (21 to 25 ºC), tray (50 ºC), vacuum (45 ºC) and solar tunnel drying (55 ºC) methods were chosen. The drying characteristics, colour properties and biochemical quality parameters were determined at NABL accredited laboratory as per ISO/IEC 17025:2005. In comparison to the other four drying methods, shade drying is the ideal way for drying tender mulberry leaves since shade dried leaves retain all biochemical and colour qualities of fresh leaves, making them acceptable for mulberry tea production.

Keywords: Blood sugar, drying, instant mulberry tea, shade drying, solar tunnel drying, vacuum drying

1. Introduction
In this modern era, the continuous price increment of medicine emboldens the consumers to shift towards herbal products. Mulberry plant has been used as a medicine particularly in China, Korea and Japan. The mulberry leaves contain protein, ash, fiber, crude fat, carbohydrate, phenolics and some flavonoids (Srivastava et al. 2006 and Jia et al. 1999) [27, 15]. It also comprises a large number of bioactive components such as DNJ (1-Deoxynojirimycin), phenolic, flavonoid, and GABA (γ-amino butyric acid), which have active pharmacokinetic principles for example the ability to suppress hyperglycemia, have stronger anti-oxidative properties, and have anti-fatigue function, respectively (Bajpai and Rao, 2014; Iqbal et al. 2012 and Flaczyk et al. 2013; Chen et al. 2016) [6, 11, 9, 7]. The value-added products developed from mulberry leaves are mulberry tea, smoothie, salads, nutritional masala biscuits, capsules, oil, dietary supplement etc. Among them, the mulberry tea or herbal tea is the most popular health drink. The hygroscopic mulberry powder in which water is added, in order to reconstitute it into a cup of mulberry tea. The drying is the primary unit operation for the processing of instant mulberry tea. But the high drying temperature affects the phenolic acid and flavonol content of the mulberry leaves (Przeor et al. 2019) [21]. Another noticeable point by using commercials dryers (hot air dryer) i.e. are long drying time even at high temperature. Hence, it is essential to find out a solution to overcome the problems associated with conventional drying, the proposed investigation undergone to select a suitable drying technology for drying of tender mulberry leaves without affecting nutritional parameters for the development of instant mulberry tea.

2. Materials and methods
2.1. Sample collection and preparation
The fresh and tender mulberry leaves (V 1 or Victoria-I variety) were collected from mulberry garden, Department of Sericulture, University of Agricultural Sciences, GKVK, Bangalore located in the Northern part of Bangalore, India. The leaves were separated from the stalk, thoroughly washed with tap water and subjected to different drying methods.

2.2. Drying of mulberry leaves using different drying methods
The harvested mulberry leaves were dried with five methods viz. shade drying (25 ± 4 ºC), sun
drying (31-35 °C), vacuum tray drying (45 °C and vacuum chamber pressure of 75-80 Kpa), solar tunnel drying (50-60 °C) and tray drying (50 °C) until a constant weight was reached (Pujari et al. 2019; Tan et al. 2015; Shang et al. 2017; Simate et al. 2017 and Phoungchandang et al. 2008) [22, 28, 23, 25, 20]. Five hundred grams of fresh mulberry leaves were taken for each drying treatment. When the constant weight of each tray reached, the dried mulberry leaves were grounded into the powder manually. The powder was sieved using ISS 500 (0.5 mm) sieve to get a fine dust and samples were kept into an airtight plastic package for further bio-chemical analysis.

2.3. Determination of drying characteristics
The initial moisture content of the fresh mulberry leaf was determined by using a hot air oven (Murthy et al. 2013) [16]. The moisture content was calculated using the following equations:

\[
\text{Moisture content (% db)} = \frac{W_1 - W_2}{W_2} \times 100 \quad \ldots (1)
\]

Where,
\( W_1 \) = Initial weight of the sample, g
\( W_2 \) = Final weight of the sample, g

The moisture ratio (MR) was calculated for five different drying methods by using the following equation (Ertekin and Yaldiz, 2001) [8].

\[
\text{Moisture Ratio (MR)} = \frac{M_t - M_e}{M_0 - M_e} \quad \ldots (2)
\]

Where,
\( M_t \) = Moisture content at specific time t (kg)
\( M_e \) = Equilibrium moisture content (kg)
\( M_0 \) = Initial moisture contents (kg)

2.4. Proximate analysis of dried mulberry leaves
Proximate analysis of the samples, which include moisture content (IS 4333 2002, RA:2012) [14], ash (IS 1155 1968, RA:2010) [12], crude protein (AOAC 984.13, 20th edition 2016), fat (AOAC 2003.06, 20th edition 2016), and crude fiber (AOAC 962.09, 20th edition 2016) and carbohydrate (IS 1656 2007, RA:2009) [13], was determined according to the methods set forth by the Association of Analytical Chemist (AOAC) and Indian standards (IS). All the experiment was conducted at Pesticide Residue and Food Quality Analysis Laboratory (NABL Accredited Laboratory as per ISO/IEC 17025:2005), University of Agricultural Sciences, Raichur, Karnataka, India.

2.5. Determination of colour by using Minolta chromameter
The colour changes in the sample were determined by a Minolta CR-200b Chroma Meter (Minolta, Japan). Minolta chromameter converts all colours within the range of human perception into a common numerical code with \( L^* \), \( a^* \), \( b^* \) colour notations. The colour of mulberry leaves before and after drying was determined to understand the changes in colour due to drying (Pankaj et al. 2013) [19]. The colour differences \( \Delta E \) were calculated from the \( L^* \), \( a^* \), \( b^* \) parameters, using the Hunter–Scotfield equation:

\[
\Delta E = \sqrt{(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2} \quad \ldots (3)
\]

Where,
\( \Delta a \) = Difference of redness and greenness
\( \Delta b \) = Difference of yellowness and blueness
\( \Delta L \) = Difference of brightness

2.6. Statistical analysis
Results were reported as means ± standard deviation (SD) for triplicate determinations. The standard error of mean, critical difference, and co-efficient of variation was determined by using simple CRD at a level of significance of \( P<0.05 \).

3. Results and discussion
3.1. Drying characteristics
In order to calculate the drying characteristics, the tender mulberry leaves were dried from initial moisture content of 360-370 % to final moisture content of 4-30 % (d.b) by different drying methods. The results on drying characteristics of mulberry under drying time, final weight after drying (final weight) and drying temperature are shown in Table 1. To reduce the post-harvest loss, to identify best drying method and to retain biochemical quality parameters. The moisture content versus drying time were presented in Fig.1. The drying curves shows a faster rate of moisture removal in vacuum tray drying followed by tray drying, solar tunnel drying, sun drying and shade drying. This outcome may be attributed to high temperature (varying 50 to 65 °C) as compared to shade drying. It can be seen from Fig.1 the drying time is not uniformly shortened with the drying temperature. Overall, there was no marked constant rate drying period observed during the drying process and drying of tender mulberry leaves took place in falling rate period. The increase in drying temperature reduced total drying time. The vacuum tray dryer taken lowest drying time, the similar results obtained by Shravya et al. (2019) [24] for vacuum drying of guava leaves (Psidium guajava L.), the results displayed that at 50 °C of drying temperature, vacuum dryer took 4 hours 20 min to reach a constant weight and shade drying taken highest drying time to reduce the moisture, similar results were found by Ordonez et al. (2015) [18] experimented on shade drying of Stevia rebaudiana (Bertoni) leaves, the leaves were dried at 29.7 °C (70% RH) and the moisture content present into the leaves was reduced to 7.72 % (w.b.). Low moisture content in tender mulberry leaves helps for extraction of bioactive compounds and encouraged to safe guard the product from the microbial attack and prevents spoilage. The Fig. 2 shows the relationships between the moisture ratio and drying time.

| Table 1: Drying characteristics of tender mulberry leaves |
|---------------------------------|
| Drying Methods     | Initial weight (g) | Final weight (g) | Drying time (min) | Drying temp (°C) |
| Sun Drying          | 500               | 110              | 1170             | 31-35            |
| Shade Drying        | 500               | 140              | 1200             | 21-25            |
| Tray Drying         | 500               | 115              | 810              | 50               |
| Vacuum Tray Drying  | 500               | 121              | 540              | 45               |
| Solar Tunnel Drying | 500               | 112              | 660              | 55               |
3.2. Proximate analysis

The proximate analysis was calculated for sun dried, shade dried, tray dried, vacuum tray dried and solar tunnel dried samples as shown in Table 2. The moisture content significantly affects the shelf life of dried leaves. High moisture content in samples promotes the water activity correspondingly increase the chance of microbial growth (Sospedra et al. 2010)[26]. The solar tunnel, vacuum tray, sun and shade dried samples showed lower moisture content therefore shelf life was more compared to tray dried samples. The increase in ash content is the indication of the presence of heat resistance and low volatile minerals. The ash content of vacuum and shade dried samples was comparatively decent. Because of the removal of water during the drying process, the ash content significantly increased and simultaneously the nutrient content also increased. Basically, the ash content epitomizes the total minerals present in the dried samples (Agoreyo et al. 2011)[1]. The fat content in shade dried samples was minimum thus the shelf life of shade-dried samples is higher due to fewer chances of oxidative rancidity (Ojo et al. 2014)[17]. Mulberry leaves have very good potential activity to improve digestion because it contained an excessive amount of dietary fibres which helps to bulk of stool for digestion improvement (Ojo et al. 2014)[17].

![Drying rate curves of mulberry leaves in different drying methods.](image1.png)

![Moisture ratio versus drying time of mulberry leaves in different drying methods.](image2.png)
shade dried leaves contained comprehensive amount of fiber which is significantly high compared to other dried samples. A high reduction of protein content was observed in the vacuum tray dryer. This was due to the capability of the dryer to concentrate energy which causes the denaturation of the protein (Hassan et al. 2007) [10].

Table 2: Proximate composition of mulberry leaves in different drying methods

| Sl No. | Drying treatments           | Moisture (% d.b.) | Ash (%) | Fat (%) | Fiber (%) | Protein (%) | Carbohydrate (%) |
|-------|-----------------------------|-------------------|---------|---------|-----------|-------------|------------------|
| 1     | Sun drying                  | 6.29              | 16.99   | 3.41    | 9.96      | 20.41       | 42.31            |
| 2     | Shade drying                | 7.41              | 9.74    | 2.19    | 12.26     | 32.36       | 36.04            |
| 3     | Tray drying                 | 10.07             | 9.13    | 3.23    | 9.93      | 26.91       | 40.73            |
| 4     | Vacuum tray drying          | 5.79              | 15.7    | 4.11    | 11.33     | 19.11       | 43.96            |
| 5     | Solar tunnel drying         | 2.46              | 10.07   | 3.44    | 10.42     | 19.81       | 53.8             |
| 6     | S.Em±                        | 0.0088            | 0.0455  | 0.0174  | 0.0141    | 0.0218      | 0.0413           |
| 7     | CD at 5%                     | 0.0264            | 0.137   | 0.0525  | 0.0426    | 0.0656      | 0.1244           |
| 8     | C.V.%                        | 0.2735            | 0.7376  | 1.0633  | 0.2625    | 0.1834      | 0.1903           |

Conversely, Shade-dried samples have the highest protein content compared to other dried samples. Different drying treatments had no effect on the carbohydrate content of mulberry leaves as shown in Fig. 3. It can be established that as compared to other drying methods, the shade drying showed better results in nutritional composition retention and can be compatible for drying of mulberry leaves due to the economic advantages.

3.3. Colour values
The L, a*, b* (lightness, redness and yellowness, respectively) were the determining parameters for colours. The high temperature during drying is the reasons of colour degradation in dehydrated products (Arabhosseini et al. 2010) [5]. The comparison of colour parameters of dried mulberry leaves by different methods as shown in Table 3. Overall, when compared with fresh leaves, a smaller decrease in L* values of all the dried leaves was observed. Further, the solar tunnel dried leaves showed a large decrease in L* value. The total colour difference ∆E, which is a combination of parameters L*, a* and b* values, is a colorimetric parameter extensively used to characterize the variation of colours in food during processing.

Table 3: Comparison of colour parameters of dried mulberry leaves

| Sl No. | Different Drying Methods     | L     | a*    | b*    | ∆E     |
|-------|------------------------------|-------|-------|-------|--------|
| 1     | Fresh Leaves                 | 49.50 | -11.92| 25.96 |        |
| 2     | Sun Drying                   | 43.38 | -7.10 | 21.37 | 9.04   |
| 3     | Shade Drying                 | 44.43 | -8.85 | 22.64 | 6.79   |
| 4     | Tray Drying                  | 41.03 | -3.98 | 22.17 | 12.21  |
| 5     | Vacuum Tray Drying           | 46.53 | -6.91 | 23.46 | 6.33   |
| 6     | Solar Tunnel Drying          | 40.25 | -4.56 | 21.18 | 12.75  |
| 7     | S.Em±                        | 0.6239| 0.035 | 0.1138|        |
| 8     | CD at 5%                     | 1.8538| 0.1041| 0.3381|        |
| 9     | C.V.%                        | 2.8239| 0.9706| 0.9984|        |
The results suggested that the change in $\Delta E$ of four dried leaves were lesser as associated with solar tunnel dried leaves ($\Delta E= 12.75$). Degradation of certain bioactive compounds in the leaf tissues might be related to decreasing bioactivity of the leaves (Wanyo et al. 2011)\(^{(29)}\). As the colour of shade and vacuum dried samples appear to be more like a fresh leaf ($\Delta E= 6.79$ and 6.33), this may imply that this drying method can better preserve bioactive compounds and activities than does the solar tunnel drying. It can be concluded that as compared to other drying methods the shade drying showed better retention of colours and can be compatible for drying of mulberry leaves.

4. Conclusion

The drying is the most important unit operation for the production of instant mulberry tea. Drying methods influenced the proximate composition and colors of mulberry leaves. Better nutrient retention was found in shade and vacuum drying methods. Hence, either shade drying or vacuum drying can opt as processing methods when proximate composition and colors are under consideration. The protein content was found to be the highest in shade-dried mulberry leaves followed by vacuum dried mulberry leaves and least in vacuum dried mulberry leaves. Shade drying was the best drying method of mulberry leaves that preserved the maximum bioactive compounds and colors activity. Therefore, for the processing of instant mulberry tea the shade drying method is most preferable.

5. Acknowledgments

This paper and the research behind it would not have been possible without the exceptional support of College of Agricultural Engineering, University of Agricultural Sciences, Bangalore. We are extremely thankful to Department of sericulture and Department of processing and food engineering, University of Agricultural Sciences, Bangalore for providing information’s related with this article.

6. References

1. Agoreyo BO, Akpiroroh O, Orukpe OA, Osaweren OR, Owabor CN. The effects of various drying methods on the nutritional composition of Musa paradisiaca, Dioscorea rotundata and Colocasia esculenta. Asian Journal of Biochemistry. 2011;6(6):458-464.
2. AOAC. 20th edition, Crude Fat in Foods, Cereal Grains, and Forages-Randall/Sixtce/Hexanes Extraction-Submersion Method, AOAC international, 2016, 2003, 06.
3. AOAC. 20th edition, Fiber (crude) in animal feed and pet food. Ceramic fiber filter method, AOAC international, 2016, 962, 09.
4. AOAC. 20th edition. Protein (Crude) in animal feed and pet food. Copper catalyst kjeldahl method, AOAC international, 2016, 984, 13.
5. Arabhosseini A, Padhye S, Huisman W, Ton VBV, Joachim M. Effect of drying on the color of Tarragon. Food and Bioprocess Technology. 2010;4(7):1281-1287.
6. Bajpai SK, Rao AVB. Quantitative determination of 1-Deoxyxojirimycin in different Mulberry Varieties of India. Journal of Pharmacognosy and Phytochemistry. 2014;3(3):17-22.
7. Chen H, He X, Liu Y, Li J, He Q, et al. Extraction, purification and anti-fatigue activity of $\gamma$-aminobutyric acid from mulberry (Morus alba L.) leaves. Scientific reports 2016;6:18933.
8. Ertek C, Yaldiz O. Thin layer solar drying of some different vegetables. Drying Technology. 2001;19(3):583-596.
9. Flaczyk E, Kobus-Cisowska J, Przeor M, Korczak J, Remiszewski M, Korbas E, Buchowski M. Chemical characterization and antioxidative properties of Polish variety of Morus alba L. leaf aqueous extracts from the laboratory and pilot-scale processes. Agricultural Sciences. 2013;4(5B):141-147.
10. Hassan SW, Umar RA, Matazu IK, Maishanu HM, Abbas AY, Sani AA. The effect of drying method on the nutrients and non- nutrients composition of leaves of Leptadenia hastata (Asclepiadaceae). Asian J Biochem 2007;2(3):188-192.
11. Iqbal S, Younas U, Sirajuddin C et al. Proximate composition and antioxidiant potential of leaves from three varieties of mulberry (Morus sp.): A comparative study. International Journal of Molecular Sciences 2012;13(6):6651-6664.
12. IS 1155 1968, RA. Food grains, Starches and Ready to Eat Foods. Indian Standard Specification for wheat aita- Determination of Ash Content. Bureau of Indian Standards (BIS) 2010.
13. IS 1656 2007, RA. Milk-cereal based complementary foods- Determination of total carbohydrate. Bureau of Indian Standards (BIS). 2009.
14. IS 4333 2002, RA. Method of Analysis for Foodgrains - Determination of Moisture Content. Bureau of Indian Standards (BIS). 2012.
15. Jia Z, Tang M, Wu J. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem. 1999;64:555-559.
16. Murthy RH, Lokesh G, et al. Leaf quality evaluation of ten mulberry (Morus) germplasm varieties through phytochemical analysis. International Journal of Pharmaceutical Sciences Review and Research 2013;21(1):182-189.
17. Ojo A, Abiodun OA, Odedeji JO, Akintoyese OA. Effects of Drying Methods on Proximate and Phytochemical Properties of Fufu Flour Fortified with Soybean. British Journal of Applied Science and Technology. 2014;4(14):2079-2089.
18. Ordonez YBM, Amaro DLC, Campos MRS, Ruiz JCR. Studies on drying characteristic, nutritional composition, and antioxidant properties of Stevia rebaudiana (Bertoni) leaves. Int. Agrophys. 2015;29(1):323-331.
19. Pankaj B, et al. Colour measurement and analysis in fresh and processed food. Food and bioprocess technology 2013;6(1):36-60.
20. Phoungchandang S, Tochip L, Srijesdaruk V. White Mulberry Leaf Drying by Tray and Heat Pump Dehumidified Dryers. World Journal of Agricultural Sciences. 2008;4(5):844-851.
21. Przeor M, Flaczyk E, Beszterda M, Szymandera-Busza KE, Piechocka J, Kmiecik D, et al. Air-drying temperature changes the content of the phenolic acids and flavonols in white mulberry (Morus alba L.) leaves. Ciencia Rural 2019;49(11):e20190489.
22. Pujari AK, Jadhav NR. Design and development of anti-diabetic tablet formulation containing spray dried extract of mulberry leaves. International Journal of Pharmaceutical Science and Research. 2019;10(3):1501-1509.
23. Shang HM, Zhou HZ, Li R, Duan MY, Wu HX, Lou YJ. Extraction optimization and influences of drying methods...
on antioxidant activities of polysaccharide from cup plant (*Silphium perfoliatum* L.). PloS one 2017;12(8):0183001.

24. Shravya K, Renu R, Srinivas M. Study on Drying Characteristics of Guava Leaves. J Food Process Technol 2019;10(4):1000-785. 10.

25. Simate IN, Cherotich S. Design and Testing of a Natural Convection Solar Tunnel Dryer for Mango. Journal of Solar Energy. 2017;1:1-10.

26. Sospedra I, Soriano JM, Manes J. Assessment of the microbiological safety of dried spices and herbs commercialized in Spain. Plant Foods for Human Nutrition 2010;65(4):364-368.

27. Srivastava S, Kapoor R, Thathola A, Srivastava RP. Nutritional quality of leaves of some genotypes of mulberry (*Morus alba*). Int J Food Sci Nutr 2006;57(5-6):305-313.

28. Tan JJY, Lim YY, Siow LF, Tan JBL. Effects of drying on polyphenol oxidase and antioxidant activity of *Morus alba* Leaves. Journal of Food Processing and Preservation. 2015;39(6):2811-2819.

29. Wanyo P, Sirithon S, Naret M. Improvement of quality and properties of dried mulberry leaves with combined far-infrared radiation and air convection in Thai tea process. Food and Bioproducts Processing 2011;89(10):22-30.