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

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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 continues 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 (ɣ-aminobutyric 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-1 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 ºC), vacuum tray drying (45 ºC and vacuum chamber pressure of 75-80 Kpa), solar tunnel drying (50-60 ºC) and tray drying (50 ºC) 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:

$$\text{Moisture content (\% db.)} = \frac{W1 - W2}{W2} \times 100 \quad \dots (1)$$

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].

$$\text{Moisture Ratio (MR)} = \frac{M_t - M_e}{M_0 - M_e} \quad \dots (2)$$

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 ΔE were calculated from the L^*, a^*, b^* parameters, using the Hunter–Scotfield equation:

$$\Delta E = \sqrt{(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2} \quad \dots (3)$$

Where,
Δa = Difference of redness and greenness
Δb= Difference of yellowness and blueness
ΔL= 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 intial 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 ºC) 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 vaccum 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 ºC 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 ºC (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 (ºC)
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

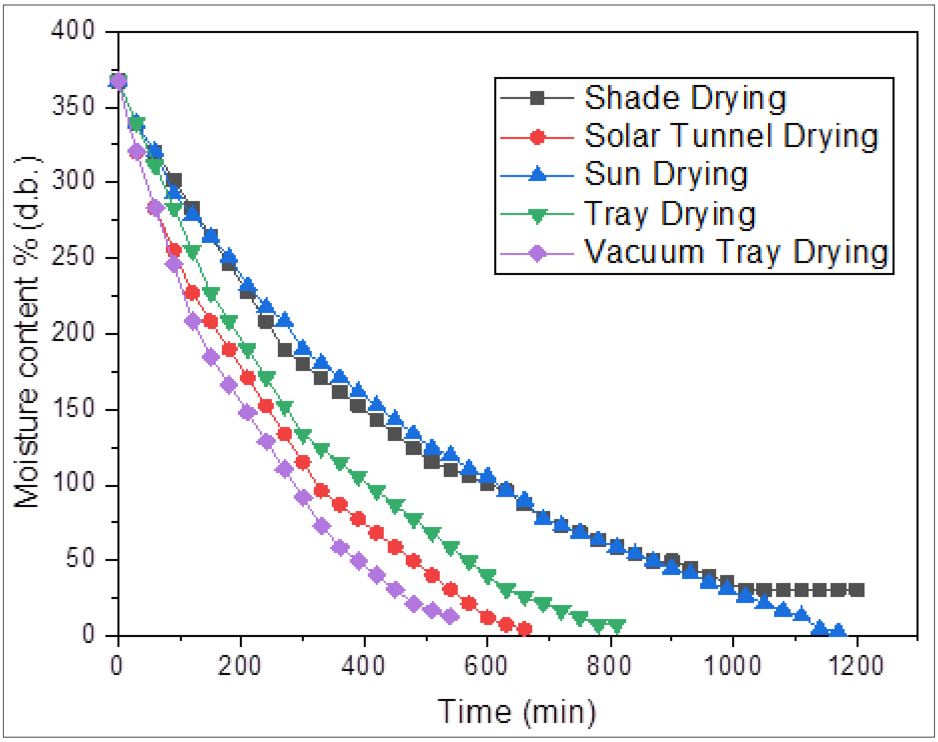

Fig 1: Drying rate curves of mulberry leaves in different drying methods.

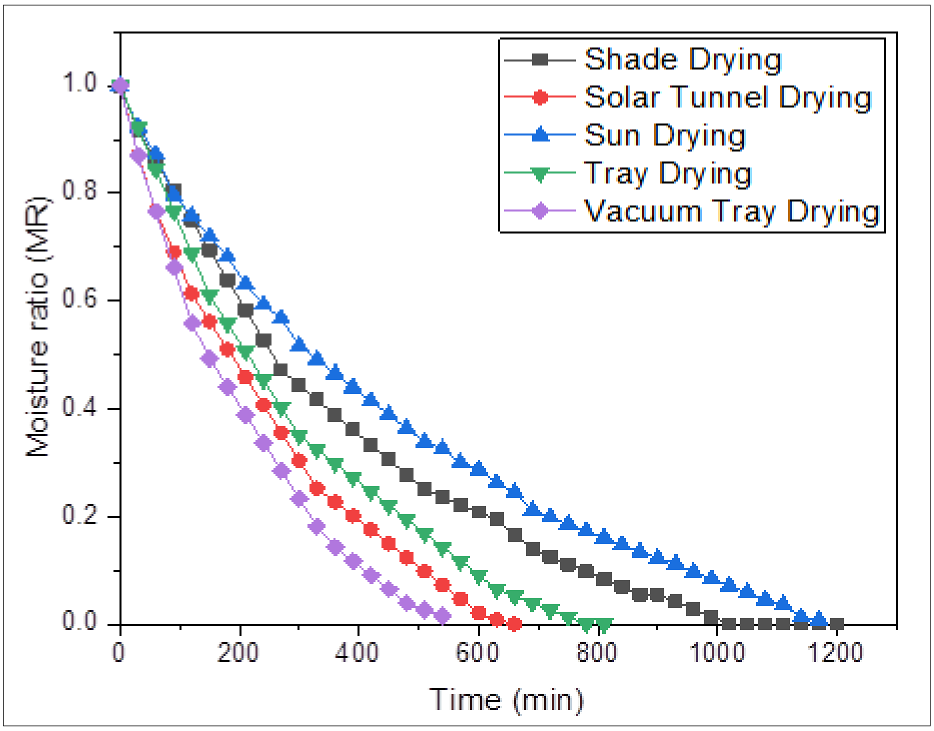

Fig 2: Moisture ratio versus drying time of mulberry leaves in different drying methods.

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]. The shade dried leaves contained comprehensive amount of fiber which is significantly high compare 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

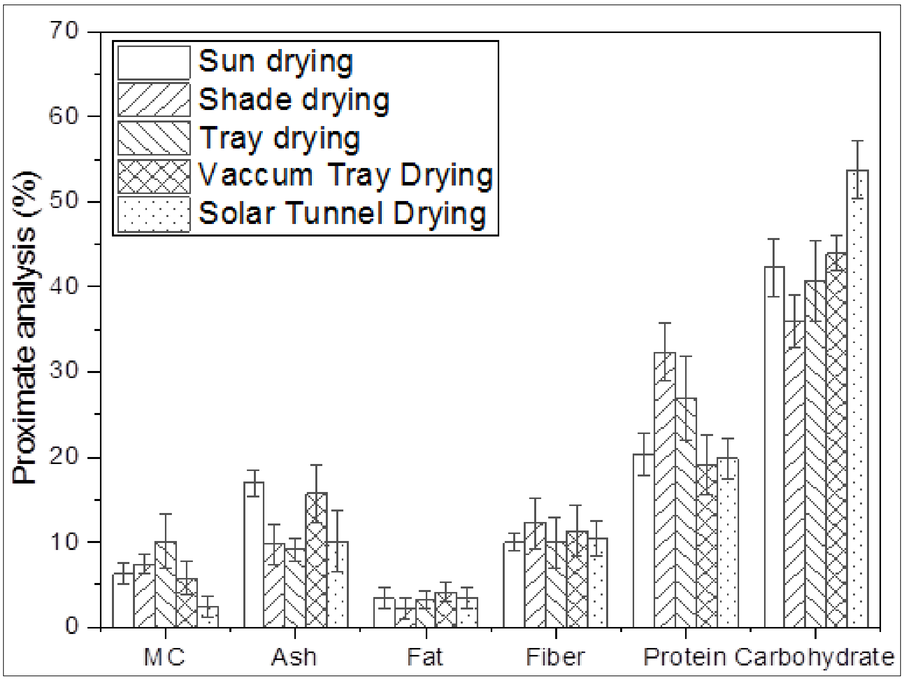

Fig 3: Proximate composition of dried mulberry leaves under different drying methods

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 ΔE, 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	Colours			
		L	a*	b*	ΔE
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 ΔE of four dried leaves were lesser as associated with solar tunnel dried leaves (ΔE= 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 (ΔE= 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.

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