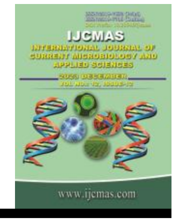
Int.J.Curr.Microbiol.App.Sci (2023) *12*(12): 229-250

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 12 Number 12 (2023)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2023.1212.026

Drying Characteristics of Mulberry Leaves

Manish Kumar Choudhary*

Department of Processing and Food Engineering, College of Technology and Engineering Maharana Pratap University of Agriculture and Technology, Udaipur, India

**Corresponding author*

Keywords

Mulberry Leaves
Morus alba,
Bioactive compounds,
Drying methods,
Phytochemicals

Article Info

Received:
05 October 2023
Accepted:
30 November 2023
Available Online:
10 December 2023

ABSTRACT

Mulberry (*Morus alba*) contains a variety of bioactive compounds. The phytochemicals present in mulberry leaves are philobatannins, saponin, tannins, alkaloids, phenol, antioxidant, carotenoids, lutein, zeaxanthin and flavonoids. Drying is the most common and traditional method for preservation of food. The drying methods, drying air temperatures and drying time had significant effects on quality of the dried product. Mulberry leaves were dried in three different drying methods: tray, heat pump and fluidized bed drying with four levels of temperatures such as 40, 50, 60 and 70ºC.The drying characteristics such as moisture content, drying rate, moisture ratio, moisture diffusivity was studied and quality parameters such as colour, protein content, ash content, dehydration ratio, water activity, total phenol and flavonoids were determined. The drying rate increased with drying air temperatures for all drying methods. The time required for drying was minimum in case of fluidized bed dryer for all temperatures. The effective moisture diffusivity ranged between 5.92×10^{-11} to 1.24×10^{-10} m^2/s in tray drying, 6.08×10^{-11} to 1.01×10^{-10} m^2/s in heat pump drying and 9.85×10^{-11} to 2.42×10^{-10} m^2/s in fluidized bed drying. The moisture diffusivity increased with air temperature for tray, heat pump and fluidized bed dryer. Total phenol and flavonoid were found maximum *i.e.*, 1033.33 mg GAE/ 100 g and 605.30 mg RE/ 100 g.

Introduction

Mulberry is a fast-growing woody plant that has a deep root system and belongs to moraceae family. it is easily propogated and grows rigorously in fertile soils it is originaly come from temperate zone of Asia and now spread across the world adopting itself well in our tropical climate.

Mulberry leaves have become more and more popular due to their many advantages, such as fewer side effects, better patient tolerance, relatively low cost and acceptance due to a long history of use, especially plantal medicines provide rational means for the treatment of many diseases that are obstinate and incurable in other system of medicine (Yun *et al.,* 2016).

Mulberry leafs consists minerals,vitamins, dietry fibers, amino acids, phytosterols, flavonoids and other functional component , mainly 1-DNJ (1-Deoxinojirimycin) which act as an anti-diabitic drug. In many countries the preparations from mulberry leaves are used as medicine for increasing the immunity of the human body. Traditional medicines are used by about 60 percent of the world's populace (Seth and Sharma, 2004). These are not only used for primary health care in rural areas of developing countries, but also in developed countries as well where modern medicines are predominantly used. In rural India, 70 per cent of the population is dependent on the traditional system of medicine. India is the biggest manufacturer of medicinal plants and it is referred to as the botanical garden of the world (Seth and Sharma, 2004).

The uses of mulberry are widespread in the food and flavor industry. It is used as a preservative in beverages, confectionaries and pan mixtures. Bakery products such as cookies, mathri, mulberry flavored salty breads and pastry uses mulberry in their preparation. Curries in Indian cuisine, pickles, and pulses also include mulberry as their indispensable part. The aromatic compounds of mulberry have taken a place in perfumery industry. In cosmetic industry, the mulberry oil is an essential ingredient of ointments and lotions (Malotra and Vijay, 2004).

Mulberry has been well known as an ayurvedic plant since ancient times. In India, it is highly regarded as a gastrointestinal medicine and as an antiseptic. It is mixed with salt and hot water, and taken after meals to relieve intestinal pain or colic, and to improve digestion. Mulberry is also a traditional medicine for treating cholera and fainting spells. Westerners often use it to treat coughs and throat problems (Nadarni, 1976). Mulberry is also present in mouthwashes and toothpastes because of its antiseptic properties, and is valued for the following problems: flatulence, indigestion, polyuria, asthma, bronchitis, common cold, toothache, various other gastrointestinal disorders, pain in throat, arthritic and rheumatic pains, and migraine. It is also used as an aphrodisiac, to enhance virility and prevent premature ejaculation (Rajeswari *et al.,* 2011). Mulberry leaves can be crushed and used for skin infection. Mulberry roots are diuretic (Chahal *et al.,* 2017).

Drying is the process in which the food product exposes to heat so the water activity reduces and allowing longer periods of storage with minimal packaging requirements. In case of convective drying, heat transfer coefficients are high, and the process time is short. In India, plants are dried either in sun or shade relying upon the requirements. However, traditional drying methods, akin to drying within the shade or in sun, have several drawbacks due to the inability to handle the massive capacity of mechanical harvesters and to attain the high-quality standards required for medicinal plants.

The present research study involves the use of various dryers to dry mulberry leaves, and emphasizes the production of value-added products that retain its natural aroma, flavour, nutritional properties and provide a longer shelf life. The drying characteristics such as moisture content, drying rate, dehydration ratio, and moisture diffusivity were determined and the quality parameters of the developed product were also studied. The present research work was carried out with specific objectives that include to study the drying characteristics of mulberry leaves in selected dryers. And also to evaluate the quality of developed dried product.

Materials and Methods

Selection of Raw Material

Fresh mulberry leaves used for drying procured from Udaipur Rajasthan. The insect infested, ruined, discolored, decayed, and wilted leaves were separated before further processing.

Sample Preparation

The stalks of the leaves were cut from the branches and the leaves were then separated and washed thoroughly three to four times with tap water to remove dust and dirt. After cleaning and washing the leaves were placed on draining table for about one hour before further processing in tray, fluidized bed and heat pump dryer.The dried leaves were ground in grinder and screened to uniform size.

Initial Moisture Content of MulberryLeaves

The initial moisture content of the mulberry leaves was determined by hot air oven drying method as discussed by AOAC, 2010. Approximately 10 g of sample was placed in fully rinsed, dried and pre-weighted moisture boxes. The initial weight of each sample was recorded. The moisture boxes were put in the oven at 105ºC temperature for 24 hours. Then the samples were taken out, cooled in the desiccators and then weighted using an electronic balance having capacity 200 g and least count of 0.001 g. Initial and bone dried weights were used to calculate the initial moisture content which was expressed as g water per g dry matter. The initial moisture content of mulberry leaves was determined by following formula,

$$\text{Moisture Content } (db)\% = \frac{W_1 - W_2}{W_1} \times 100$$

W_1 = Mass of the original sample, (g)
W_2 = Mass of the sample after drying, (g)

Experimental Plan

The experiments were planned to study the drying for mulberry leaves in tray, fluidized bed and heat pump dryer (Fig. 3.1). The drying of leaves was conducted in three dryers at four different temperatures. The air velocity was kept constant at 2 m/s. Four-level of drying temperatures(40. 50, 60 and 70ºC) as independent variables in drying process with moisture content, drying rate, moisture ratio, and moisture diffusivity were taken as dependent variables. The quality of dried leaves was evaluated on the basis of color, phytochemical content, protein content, ash content and on sensory parameters.

Drying Methods

The drying experiment method adopted for this research work was tray, fluidized bed and heat pump drying. The detailed description of the different drying is given below. About 100 g of mulberry leaves were taken and dried in tray, fluidized bed and heat pump dryer available in Department of Processing and Food Engineering, College of Technology and Engineering, Udaipur. The air flow rate was kept constant at 2 m/s. The samples were weighed at various intervals until the constant weight was achieved.

Tray dryer

A convective tray dryer was used to carry out drying experiments. The specifications of the tray dryer are given in Appendix A-1. The dryer has insulated box and one door at the front for placing and removing the food material. The air velocity of the fan can be regulated using a rotary knob. The air enters the plenum chamber and is heated by the heating unit, then flows through the food material, absorbs the moisture and moist air leaves the dryer. The dryer has trays of 340X270 mm size made of stainless steel. Approximately 100 g of mulberry leaves were placed on each tray. The air is heated by 2.5 kW heater, which can be regulated by a thermostatic controller. The fan sucks atmospheric air into the dryer, which is working on single phase current flows 50 Hz AC. The basic working principle of tray dryer is the continuous circulation of hot air. In the tray dryer, moisture is removed from the product that are placed in the tray by a forced convectional heating. The moist air removal is conducted partially but in a simultaneous fashion.

Fluidized bed dryer

The Sherwood Scientific Ltd., Cambridge, England manufactured the fluidized bed dryer. Air enters into the chamber through a mesh filter which is attached at the bottom of the dryer. The electric heater has an output of 2 kW power to build PID based controller that used to regulate the temperature up to 200ºC.

The fluidized bed dryer was run idle with no load for about 30 minute to achieve constant drying conditions. Approximately 100 g of mulberry leaves were placed in the plenum chamber and dried at 40, 50, 60 and 70ºC temperature. The weight of the sample was taken using top-pan electronic balance (Adair Dutt, ± 0.001 g), during the drying process until the moisture content of the sample reduced up to a safe level. Then, the dried mulberry leaves were transferred into air tight pouches and stored in desiccators. Drying experiments were repeated in a similar manner at different air temperatures.

Heat pump dryer

The heat pump is an efficient heating and cooling generating system. Heat pump drying system consists of an evaporator, condenser, compressor, fan and, a drying chamber with trolleys of trays. In this system, water is removed from the product without external ventilation, because the system is closed with air recirculation. Dry hot air is drawn from the condenser and blown through the drying chamber containing wet material. The hot humid air leaving from the drying chamber is sent to the evaporator to be cooled to below the dew point temperature, causing condensation to remove the moisture from the air. The cool dry air from the evaporator is pumped back into the condenser to increase to the desired temperature. The hot air is then returned to the drying chamber, which completes the cycle.

Analysis of Drying Data

The observed data were used to determine various drying parameters such as moisture content, average moisture content, drying rate and moisture ratio.

Drying rate

The moisture loss data were recorded and analyzed during the drying experiments to determine the moisture content of sample after a certain time interval. The drying rate was calculated by estimating the change in moisture content that occurred in each time interval and expressed as g water / g dry matter-min.

$$R = \frac{W_1 - W_2}{\mathrm{T} \times \mathrm{DM}}$$

Where,

DM = Dry matter, Kg
R = Drying rate, g water / g dry matter- min
W_1 = Initial weight of sample, Kg
W_2 = Weight of sample after time, Kg
t = Time interval, min

Moisture ratio

For finding out the moisture ratio (MR) during drying the following expression was used,

$$MR = \frac{(M - M_e)}{(M_O - M_e)}$$

Where,
MR = Moisture ratio, (% db)
M = Moisture content after θ time, (% db)
M_O = Initial moisture content, (% db)
M_e = Equilibrium moisture content, (% db)

Moisture diffusivity

In drying, diffusivity is used to signify the flow of moisture of material. Moisture is transferred especially by molecular diffusion in the falling rate period of drying. The diffusivity can be affected by case hardening, moisture content and temperature of material. The moisture diffusivity was calculated by equation as proposed by Crank (1975).

When the food products with uniform moisture content is assumed as one-dimensional moisture flow, the solution of Flick's equation for infinite plate shape is

$$MR = \left[\frac{M - M_e}{M_O - M_e}\right] = \sum_{n=1}^{\infty} \frac{4}{\beta_n^2} exp\left[-\frac{\beta_n^2 D_{eff}}{r_c^2}\right] = \frac{8}{\pi^2} exp\left[-\frac{\pi^2 D_{eff} t}{L^2}\right]$$

Where,
MR = Moisture ratio, dimensionless
M = Final moisture content, g of water / g of dry matter
M_O = Initial moisture content,g of water / g of dry matter
M_e = Equilibrium moisture content, g of water / g of dry matter
β = Roots of Bessel moisture content
D_{eff} = Diffusion coefficient
L = Slab thickness, mm
n = Positive integer
t = Time (h)

A general form of above equation could be written in semi-logarithmic form, as follows.

$$\ln MR = A - Bt$$

The slope B can be calculated by plotting in (MR) versus time according to above equation. The effective moisture diffusivity was derived from the slope.

Quality Evaluation

A very well-known fact is that quality is crux of food processing. The dried leaves were evaluated on the basis of color, protein content, ash content, water activity, phytochemical content and sensory aspects.

Color

Color is important for the consumer to judge quality based on its fundamental aesthetic value, and food is no exception. The overall objective of food color is to make it attractive and recognizable. There are several color scales that are used in a Hunter Lab Colorimeter such as L*, a* and b*, which represent the color of the surface. The values obtained as L* are the lightness coefficient, which ranges from 0 (black) to 100 (white), a* is purple-red (positive a* value) and blue-green (negative a* value) and b* that represents yellow (positive b* value) or blue (negative b* value) color (McGuire, 1982).

The color of mulberry leaves powder was measured using a Hunter Lab Colorimeter by using a glass cup provided with in it as sample. A cylindrical glass sample cup, 6.35 cm in diameter and 4 cm deep, was inserted into the light port of 3.175 cm diameter. The L*, a* and b* values were measured for all dried samples of mulberry leaves and replicated three times. The device was first calibrated with a black and a white standard plate.

Water activity

The water activity (a_w) of a food is a measure of the availability of the moisture and thus can often be more informative about its likely stability. Water activity may be defined as follows:

$$a_w = \frac{P}{P_0}$$

Where P is the vapour pressure of the food and P_0 is the vapour pressure of pure water.

A digital water activity meter was used for measuring water activity of the dried mulberry leaves powder. The samples were filled in the sample cup and the sample cup kept in contact with sensor probe of water activity meter and values of water activity were recorded.

Dehydration ratio

Dehydration ratio was calculated by taking the weights of the sample before and after drying as:

$$\text{Dehydration ratio} = \frac{\text{Weight of sample before drying}}{\text{Weight of sample after drying}}$$

Phytochemical analysis

Total Flavonoid Content

The total flavonoid content was estimated using the method as reported by Zhishen *et al.,* 1999. 0.5 ml of aliquot was taken and volume made up to 5 ml with distilled water. Then the extract was mixed with 0.3 ml of sodium nitrite (1:20). The solution was then incubated at room temperature for 5 minutes. 0.6 ml of 10 % aluminum chloride was added to mixture. Again, the solution was incubated at room temperature for 6 minutes. 2 ml of sodium hydroxide (1N) was added to the mixture with concentration of 4%. Volume was made up using 2.1 ml of distilled water. The absorbance was taken at 510 nm. The flavonoids were expressed as mg RE/ 100 g.

Statistical Analysis

Analyses of variance (ANOVA) was conducted with CRD as suggested by Gomez and Gomez (1984) to determine whether significant effect exists on different type of drying methods, and temperature on the quality of dehydrated mulberry leaves.

Results and Discussion

The results obtained during the drying of mulberry leaves under various drying methods and their effect on active ingredients is presented. The weight of leaves during convective tray drying, fluidized bed drying and heat pump drying was recorded periodically and moisture content was calculated by using mass balance equations. Drying characteristics of mulberry leaves under three different drying methods have been discussed below. The quality evaluation of mulberry was done on the basis of phytochemical content, protein content, colour and water activity.

Initial Moisture Content

The initial moisture content of mulberry leaves was determined by oven drying method as described in Section 3.3. The average initial moisture content of mulberry leaves was found to be 71.3 per cent (wb).

Drying of Mulberry Leaves

Effects of drying air temperature on drying time

The fresh mulberry leaves were dried in tray, fluidized bed and heat pump dryer. The initial moisture content, final moisture content, time required to dry mulberry leaves along with per cent reduction in drying time for various drying air temperatures is shown in Table 4.1.

The reduction in the drying time with increase in air temperature is quite evident. It can be seen from Table 4.1 that minimum drying time was recorded for fluidized bed dryer for all four-temperature studied and maximum drying time was obtained in tray drying of mulberry leaves. For the tray dryer when the temperature increased from 40ºC to 50ºC,60ºC and 70ºC, the initial moisture content of the product i.e., 248.43 per cent (db) is reduced to final moisture content in the range of 7.83 to 8.64 in the drying time for 330 minutes, 270 minutes, 240 minutes and 210 minutes respectively. The percent reduction in drying time when drying temperature increased from 40ºC to 50ºC, 60ºC and 70ºCwere 18.18 per cent, 27.27 per cent and 36.36 per cent respectively. In case of heat pump dryer, the drying time was obtained as 300 minutes, 240 minutes, 210 minutes and 180 minutes for drying air temperaturesof40ºC, 50ºC, 60ºC and 70ºC respectively and the initial moisture content (248.43 per cent in dry basis) was reduced to the final moisture content in the range of 7.77 to 8.25 per cent (db). With increase in temperature from 40ºC to 50ºC, the reduction in drying time was 20 per cent and that for 60ºC the time reduction was 30 per cent and for 70ºC the reduction in time was 40 per cent when compared withtime required for 40ºCin case of heat pump dryer.For the fluidized bed dryer when the temperature increased from 40ºC to 50ºC,60ºC and 70ºC, the required drying time was obtained as 210 minutes, 180 minutes, 150 minutes and 120 minutes respectively. The percent reduction in drying time when air temperature increased from 40ºC to 50ºC, 60ºC and 70ºC were 14.28 per cent, 28.57 per cent and 42.85 per cent respectively for fluidized bed dryer (Table 4.1).

The variation in moisture content with time in tray, heat pump and fluidized bed dryers for various temperatures are presented in Fig. 4.1 to Fig. 4.3. It can be seen that as the drying temperature increased, the drying curves exhibited steeper slope indicating that the drying rate increased with temperature. This result into substantial decrease of drying time, as also shown in the Table 4.1.So, it can be inferred that the moisture reduction depends on drying air temperature. The reduction in moisture content was slow at lower temperature and it took more time as compared to drying at higher temperatures for all three modes of drying. These observations are in line with the findings for drying of spinach leaves reported by Ankita and Prasad, (2013). It is clearly evident from Fig. 4.1 to 4.3 that the drying time decreased with drying air temperature. Hence, it can be inferred that the drying air temperature has pronounced effect on the removal of moisture content. For drying of mint leaves by Doymaz (2006), Sharma *et al.,* (2005) and drying kinetics of onion by Kadam *et al.,* (2011) similar results were also obtained.

Effects of drying method on drying time

At each drying temperature (40ºC, 50ºC, 60ºC and 70ºC), the change in moisture content of mulberry leaves with elapsed drying time, were noted and were presented in Fig. 4.4- 4.8. The time required for drying was minimum for fluidized bed dryer for all temperatures and maximum for tray dryer, the observation is in line with the findings reported by Gur *et al.,* (2014) for corn. The maximum time was required for tray dryer at air temperature 40ºC (330 minutes) and the minimum was for fluidized bed dryer at temperature 70ºC (120 minutes). The drying time required in case of heat pump dryer was less than that required for tray drying. These findings are also in conformity with the results reported by Phoungchandang*et al.,* (2008) for drying of white mulberry leaves.

At 40ºC air temperature,the drying time was reduced 9.09 per cent for heat pump dryer and 36.36 per cent for fluidized bed dryer when compared with time required in tray dryer. For drying air temperature of 50ºC, the per cent reduction in time was obtained as 11.11 pr cent for heat pump dryer and 33.33 per cent for fluidized bed dryer as compared to tray dryer at same temperature. When comparing heat pump and fluidized bed dryer with tray dryer at 60ºC air temperature, the percent reduction in time was obtained as 12.5 per cent and 37.5 per cent respectively. At 70ºC air temperature,the drying time was reduced by 14.28 per cent for heat pump dryer and by 42.85 per cent for fluidized bed dryer as compared to tray dryer for same drying air temperature.

Effects of air temperature on drying rate

The drying rate of mulberry leaves were estimated from the reduction in the moisture content in a given time interval and expressed as g water removal/ g dm-min. The effect of air temperatures on drying rate are shown in Fig. 4.9 – 4.11. It can be inferred that increasing the drying temperature resulted in decrease of the total drying time and an increase of the drying rate. The maximum drying rate was observed at initial stage of drying for all air temperatures and the drying rate decreased as time elapsed. It is quite evident from the Figs. that initial drying rate was higher for higher drying air temperatures. The initial drying rate was found to be0.100 g w/g dm- min for 70ºC air temperature for tray dryer, 0.052 g w/ g dm-min for70ºC for heat pump dryer and 0.102 g w/ g dm-min for 70ºC for fluidized bed dryer.

It was obvious from these curves that the higher the drying temperature, the greater the drying rate, so the highest values of drying rate were obtained for 60ºC air temperature for all drying methods. These results areinsupport of the findings of research done on some aromatic plants and mint leaves by Akpinar (2006), Doymaz*et al.,* (2006) and Kadam *et al.,* (2011) respectively.

Effects of temperature and drying method on moisture ratio for drying of mulberry leaves

The values of moisture ratio during drying of mulberry leaves in different dryers at various temperatures was determined as per procedure mentioned in Section 3.6.2. For different drying temperatures, the variation in Moisture Ratio (MR) with respect to time are presented in Fig. 4.12 – 4.14. It can be seen from the Figs. that moisture ratio values decreased with drying time. It can be inferred bythecontinuous decrease in moisture ratio that diffusion has governed the internal mass transfer of mulberry drying. Demir *et al.,* (2004) reported that the moisture ratio decreased rapidly at the high drying air temperatures. Experimental results showed that drying air temperature was effective parameter for the drying of mulberry leaves. These results were in good agreement with earlier results reported by Silva *et al.,* (2008) for coriander leaves and stems, Aghbashol *et al.,* (2009) for carrots, Premi *et al.,* (2010) for drum stick leaves and Porntewabancha and Siriwongwilaichat (2010) for lettuce leaves.

Effect of temperature and drying method on moisture diffusivity for drying of mulberry leaves

The moisture loss data were analysed and moisture ratios at various time intervals were determined as per procedure explained in Chapter III. The ln (MR) values were plotted with drying time in order to find out moisture diffusivity in drying of mulberry leaves.

Table.4.1 Drying time for mulberry leaves in different dryers

Drying Methods	Temperature (ºC)	IMC (%db)	FMC (%db)	Time (min)	Reduction in time (%)
Tray drying	40	248.4321	8.0836	330	-
	50	248.4321	7.7700	270	18.18
	60	248.4321	8.6411	240	27.27
	70	248.4321	7.8397	210	36.36
Heat pump drying	40	248.4321	8.1200	300	-
	50	248.4321	8.0487	240	20
	60	248.4321	8.2578	210	30
	70	248.4321	7.7700	180	40
Fluidized bed drying	40	248.4321	8.2229	210	-
	50	248.4321	10.5574	180	14.28
	60	248.4321	8.3275	150	28.57
	70	248.4321	7.8048	120	42.85

Table 4.2 Regression coefficient for drying rate equation with respect to moisture content

Drying methods	Drying air temperature (ºC)	R^2
Tray drying	40	0.9903
	50	0.9825
	60	0.9764
	70	0.9789
Heat pump drying	40	0.9816
	50	0.9781
	60	0.9820
	70	0.9860
Fluidized bed drying	40	0.9923
	50	0.9942
	60	0.9928
	60	0.9930

Table 4.3Moisture diffusivity values duringmulberry leaves drying

Drying methods	Drying air temperature (ºC)	Moisture diffusivity (m^2/s)	R^2
Tray drying	40	5.92×10^{-11}	0.9882
	50	8.03×10^{-11}	0.9808
	60	1.05×10^{-10}	0.975
	70	1.24×10^{-10}	0.994
Heat pump drying	40	6.08×10^{-11}	0.9877
	50	6.93×10^{-11}	0.9869
	60	8.35×10^{-11}	0.9873
	70	1.01×10^{-10}	0.9787
Fluidized bed drying	40	9.85×10^{-11}	0.9895
	50	1.23×10^{-10}	0.9955
	60	1.71×10^{-10}	0.9883
	70	2.42×10^{-10}	0.9891

Table 4.4Colour value L*, a* and b* under various process parameters

Drying Methods	Temperature (ºC)	L* value	a* value	b* value
Tray drying	40	48.27	3.95	24.82
	50	53.49	2.86	28.17
	60	54.78	1.34	22.98
	70	56.84	1.30	24
Heat pump drying	40	45.91	4.39	25.24
	50	48.52	4.25	26.23
	60	47.4	4.17	20.81
	70	48.63	4.14	20.87
Fluidized bed drying	40	47.79	4.45	27.52
	50	48.47	3.46	25.48
	60	51.80	1.53	26.50
	70	57.30	1.20	23.53

Table 4.5 ANOVA for a* value for dried mulberry leaves powder

Source	Sum of square	df	Mean Square	F-value	p-value	
Model	27.26	5	5.45	36.26	<0.0001	Significant at 1 per cent level
A-Drying temperature, ºC (Numeric type)	8.64	1	8.64	57.45	<0.0001	Significant at 1 per cent level
B-Type of dryer, (Categoric type)	14.86	2	7.43	49.41	<0.0001	Significant at 1 per cent level
AB	6.45	2	3.22	21.43	0.0002	
Residual	1.65	11	0.1504			
Lack of fit	1.28	6	0.2140	2.89	0.1318	Not significant
Pure Error	0.3698	5	0.0740			
Cor Total	28.92	16				

Fit Statistics

Std. Dev.	0.3878	**R^2**	0.9428
Mean	3.24	**Adjusted R^2**	0.9168
C.V. %	11.98	**Predicted R^2**	0.8251
		Adeq Precision	16.2083

High value of coefficient of determination R^2 obtained for response variable indicated that the developed model for a*value accounted for and adequately explained optimum variation. The 2-Dimensional representation of the variation in a* value with drying temperatureand types of dryer is shown in Figure 4.18.

Table 4.7 ANOVA for water activity values for dried mulberry leaves powder

Source	Sum of square	Df	Mean square	F-value	P-value	
Model	0.0056	5	0.0011	24.09	<0.0001	Significant at 1 per cent level
A-Drying temperature, ºC (Numeric type)	0.0037	1	0.0037	79.38	<0.0001	Significant at 1 per cent level
B-Type of dryer, (Categoric type)	0.0012	2	0.0006	12.40	0.0015	Significant at 1 per cent level
AB	0.0012	2	0.0006	12.65	0.0014	
Residual	0.0005	11	0.0000			
Lack of Fit	0.0004	6	0.0001	4.78	0.0535	Not significant
Pure Error	0.0001	5	0.0000			
Cor Total	0.0062	16				

Fit Statistics

Std. Dev.	0.0068	**R^2**	0.9163
Mean	0.1855	**Adjusted R^2**	0.8783
C.V. %	3.69	**Predicted R^2**	0.6482
		Adeq Precision	16.5330

High value of coefficient of determination R^2 obtained for response variable indicated that the developed model for water activityvaluesaccounted for and adequately explained optimum variation. The 2-Dimensional representation of the variation in water activity values with drying temperature and types of dryeris shown in Figure 4.22.

Table 4.9 ANOVA for total flavonoid for dried mulberry leaves powder

Source	Sum of square	Df	Mean square	F-value	P-value	
Model	2.880×10^{05}	6	48000.42	41.24	<0.0001	Significant at 1 per cent level
A-Drying temperature, °C (Numeric type)	87081.54	1	87071.54	74.81	<0.0001	Significant at 1 per cent level
B-Type of dryer, (Categoric type)	1.874×10^{05}	2	93679.71	80.49	<0.0001	Significant at 1 per cent level
AB	4302.70	2	2151.35	1.85	0.2074	
A^2	11212.60	1	1121.60	9.63	0.0112	
Residual	11638.25	10	1163.82			
Lack of Fit	6461.72	5	1292.34	1.25	0.4068	Not significant
Pure Error	5176.53	5	1035.31			
Cor Total	2.996×10^{05}	16				

Fit Statistics

Std. Dev.	34.11	**R^2**	0.9612
Mean	249.47	**Adjusted R^2**	0.9379
C.V. %	13.68	**Predicted R^2**	0.8337
		Adeq Precision	21.4537

High value of coefficient of determination R^2 obtained for response variable indicated that the developed model for total flavonoid accounted for and adequately explained optimum variation. The 2-Dimensional representation of the variation of total flavonoid with drying temperature and type of dryer is shown in Fig. 4.26.

Table 4.10 Optimization for all process parameters

S. No	Type of dryer	Drying temperature (°C)	a* value	Water activity	Total phenol (mg GAE/ 100g)	Flavonoids (mg RE/ 100g)	Desirability
1	Fluidized bed dryer	53	2.66	0.176	370.09	820.69	0.668
2	Heat pump dryer	45	4.23	0.201	325.73	823.64	0.458
3	Tray dryer	46	3.66	0.241	246.53	599.19	0.375

Fig. 4.1 Variation in moisture content with time for different drying air temperatures in tray drying of mulberry leaves

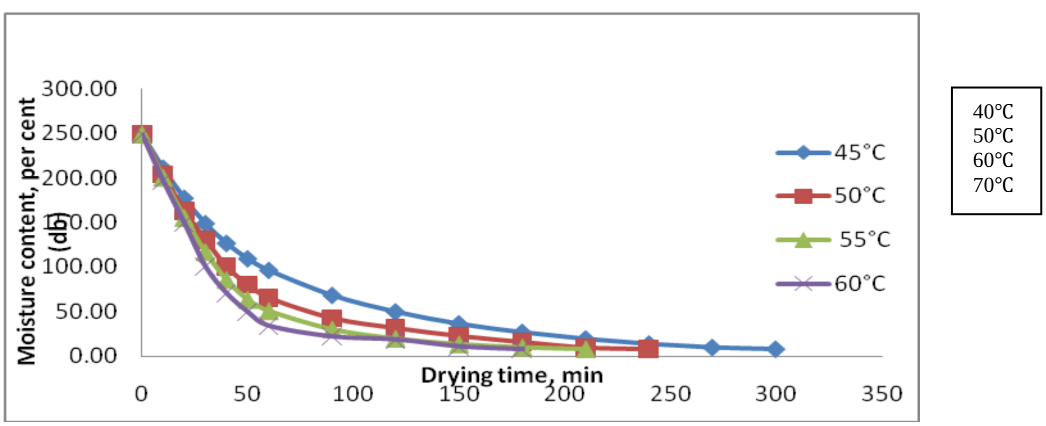


Fig. 4.2 Variation in moisture content with time for different dryingair temperatures in heat pump drying of mulberry leaves

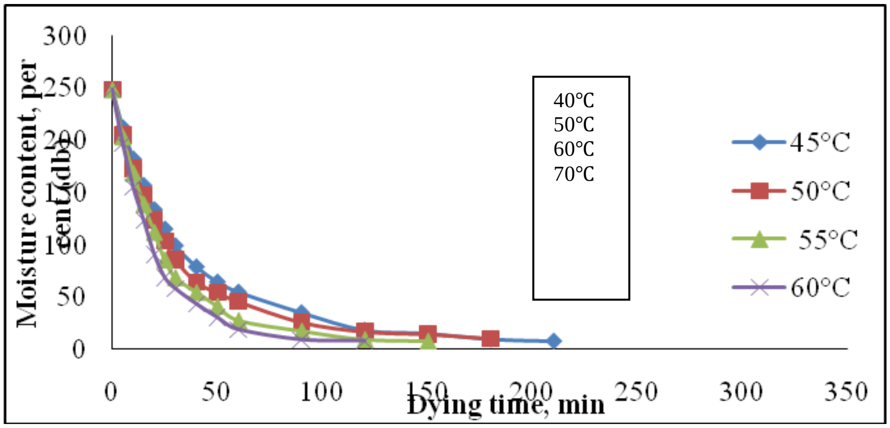


Fig. 4.4 Variation in drying time under different drying methods for 40, 50, 60 and 70°C air temperature

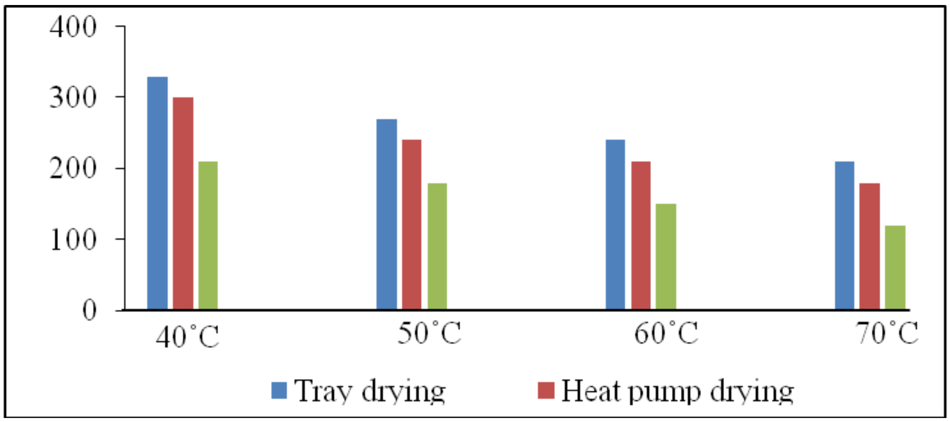


Fig. 4.5Variationin drying time with moisture content at 40°C air temperature for different drying methods

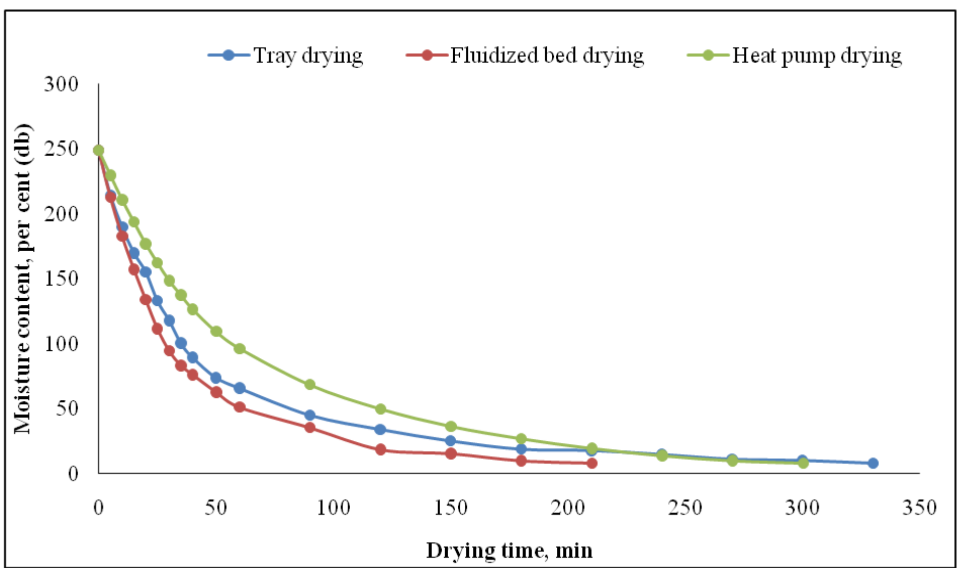


Fig. 4.6Variationin drying time with moisture contentat 50ºC air temperature for different drying methods

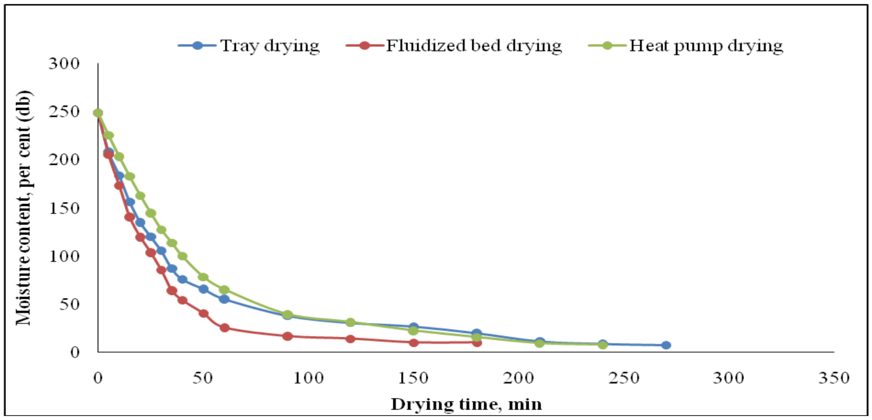


Fig. 4.7Variationindrying time with moisture content at 60ºC air temperature for different drying methods

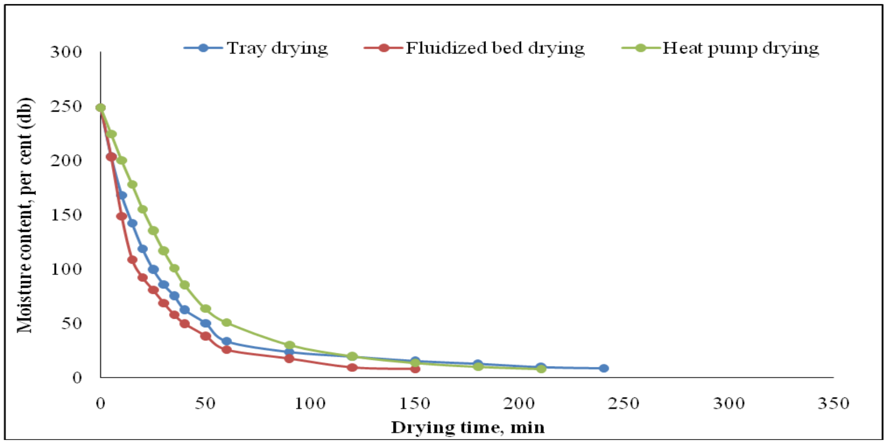


Fig. 4.8Variationin drying time with moisture content at 70ºC air temperature for different drying methods

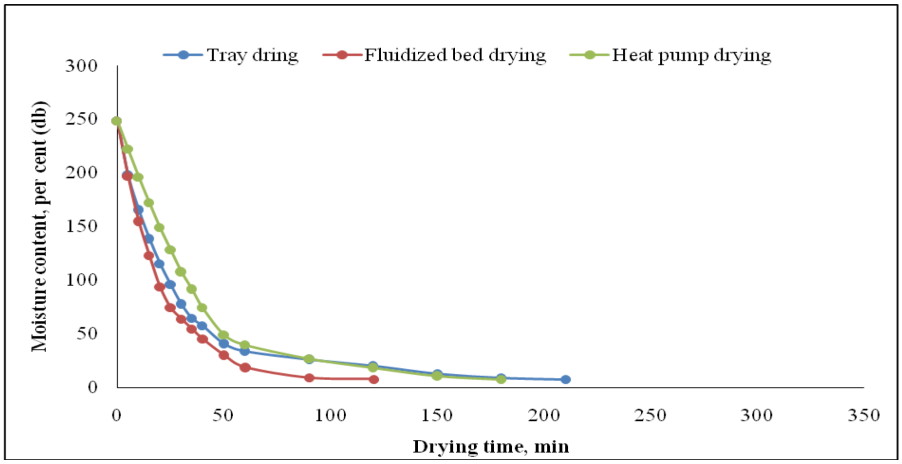


Fig. 4.9Variation in drying rate with moisture content for different air temperatures in tray dryer

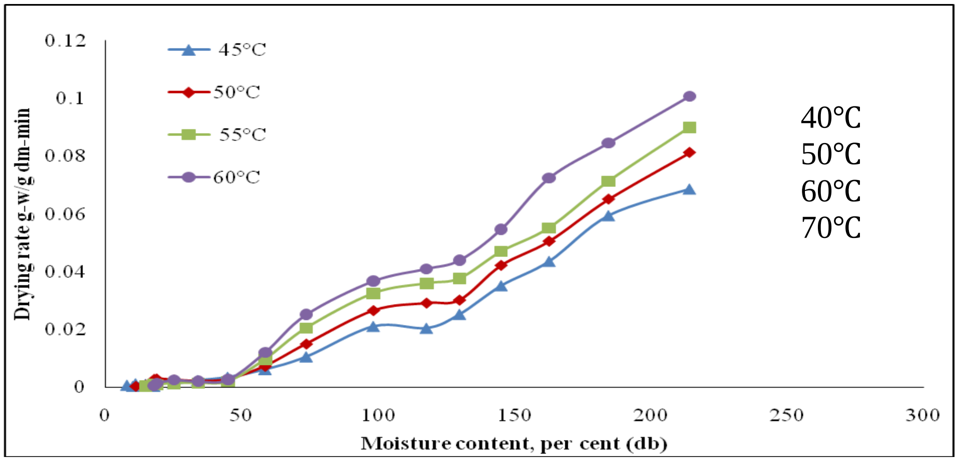


Fig. 4.10Variation in drying rate with moisture content for different air temperatures in heat pump dryer

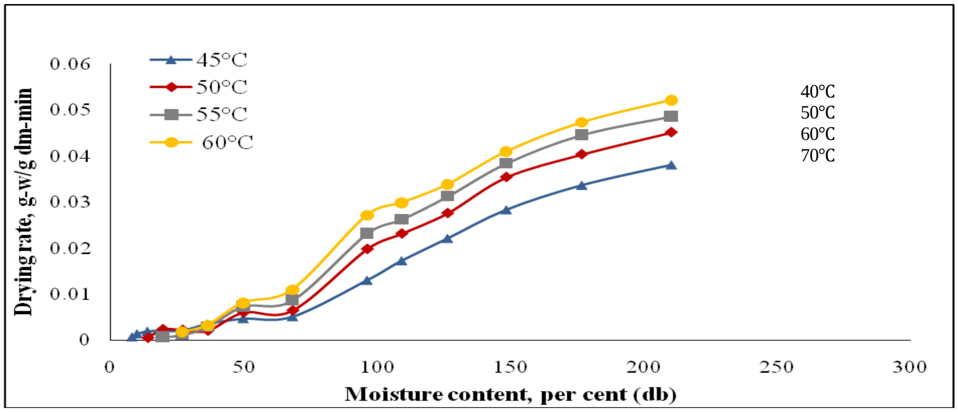


Fig. 4.11Variation in drying rate with moisture content for different air temperatures in fluidized bed dryer

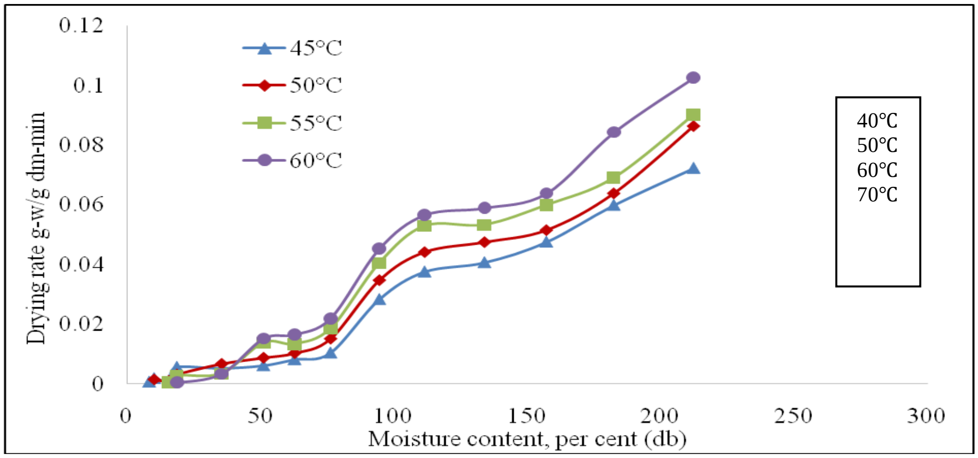


Fig. 4.12Variation in moisture ratio with drying time at various air temperaturesfor tray dryer

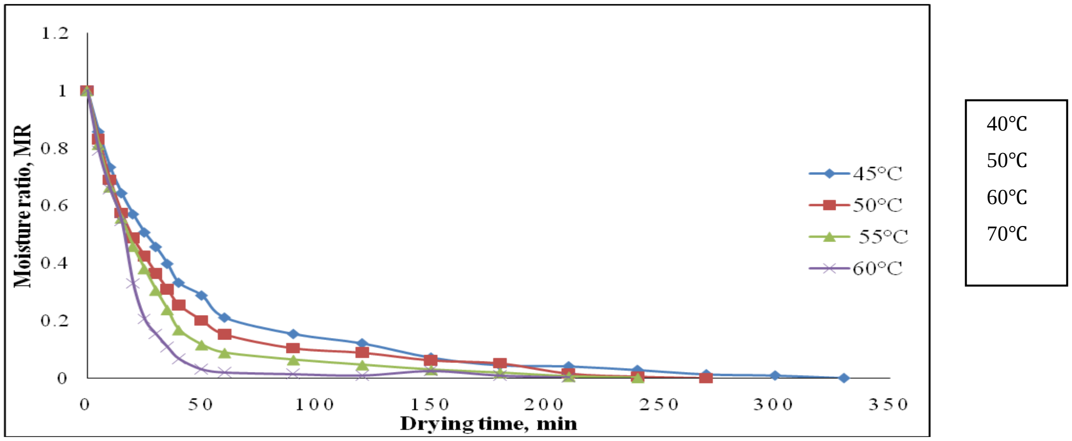


Fig. 4.13Variation in moisture ratio with drying time at various air temperatures for heat pump dryer

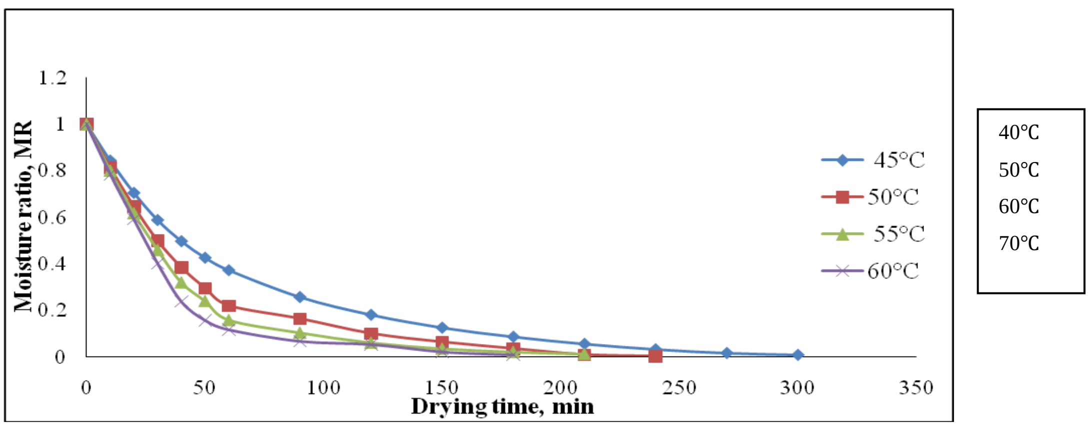


Fig. 4.14Variation in moisture ratio with drying time at various air temperatures for fluidized bed dryer

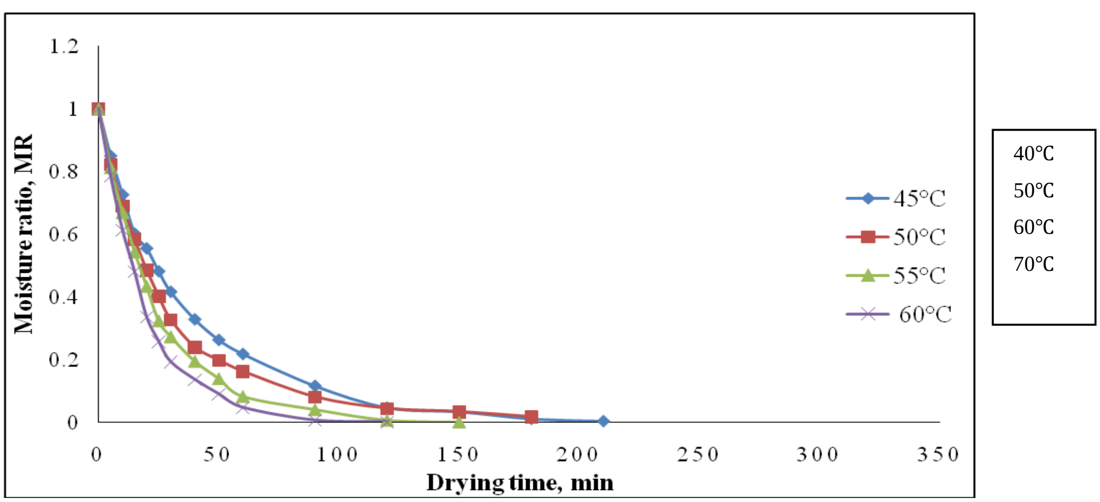


Fig. 4.15 Various in ln(MR) with drying time for different air temperatures in tray dryer

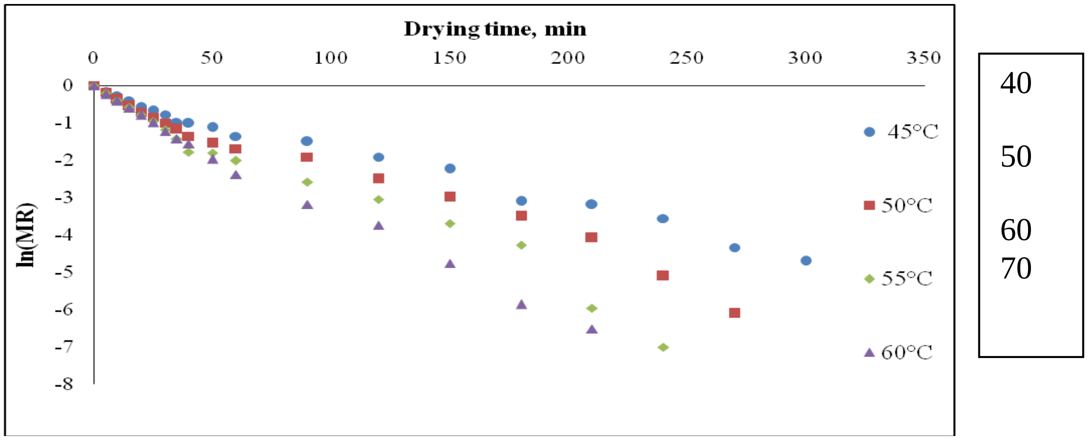


Fig. 4.16 Various in ln (MR) with drying time for different air temperatures inheat pump dryer

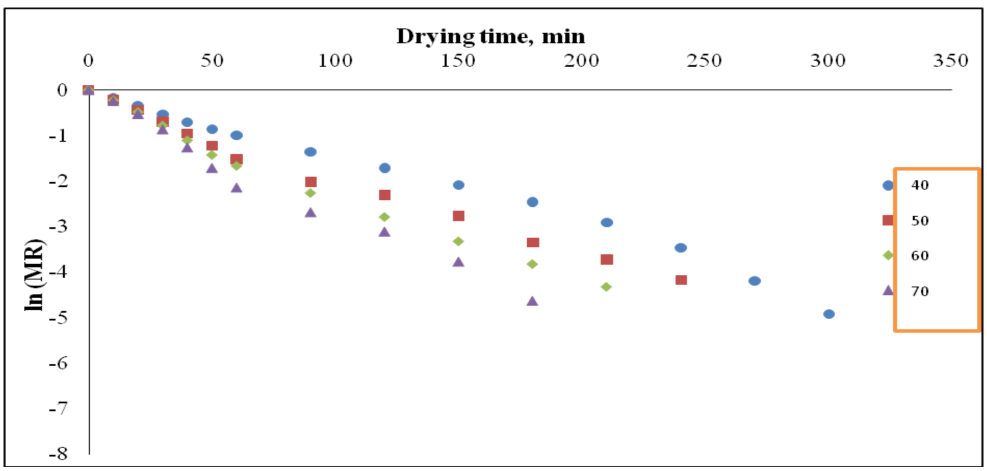


Fig. 4.17 Various in ln (MR) with drying time for different air temperatures influidized bed dryer

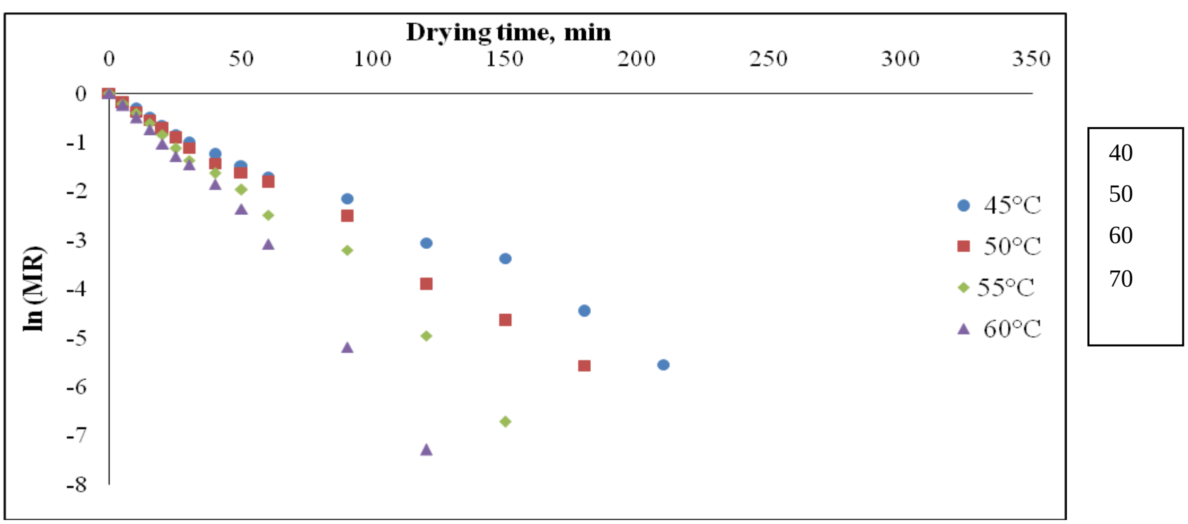


Fig. 4.18 Variation in a* value with drying air temperature and type of dryer

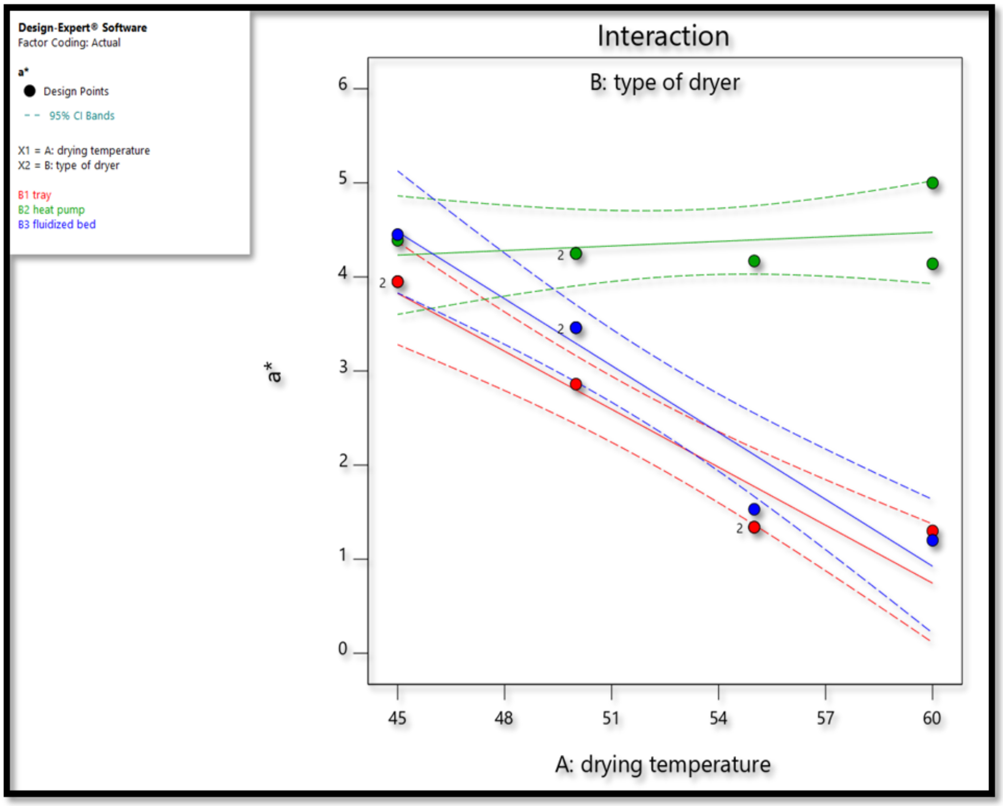


Fig. 4.19 Water activity of mulberry leaves dried in tray, heat pump and fluidized bed dryer for different air temperatures

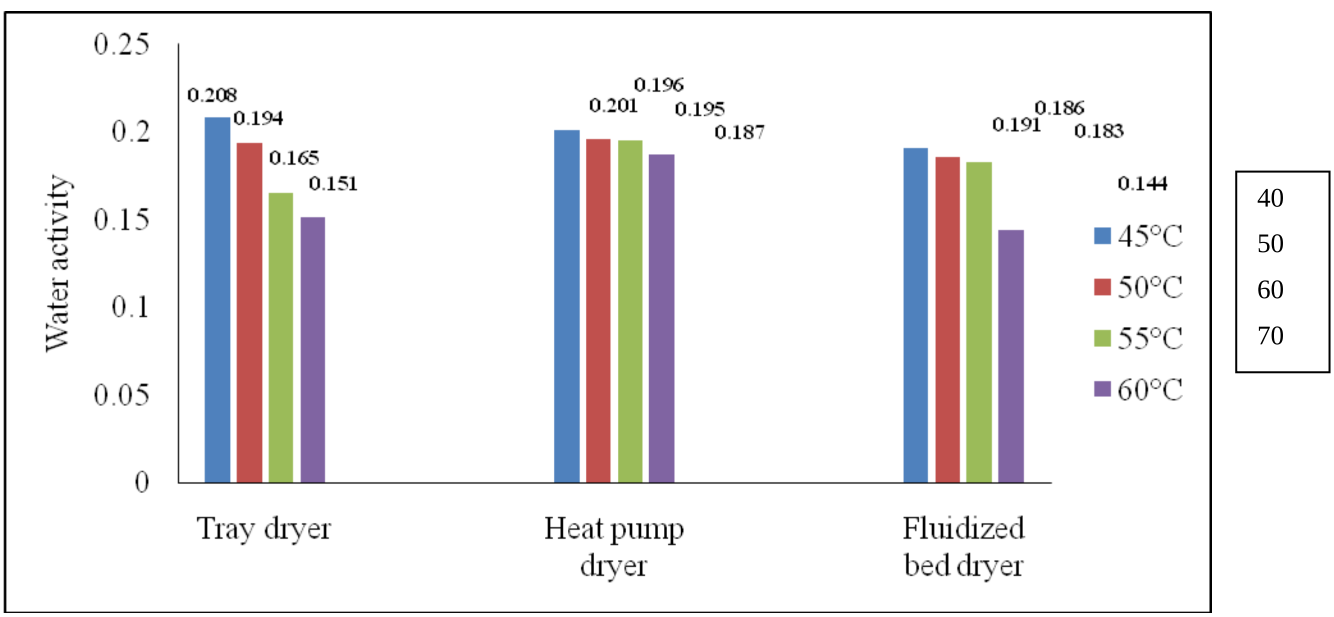


Fig. 4.20 Variation in water activity with drying air temperature and type of dryer

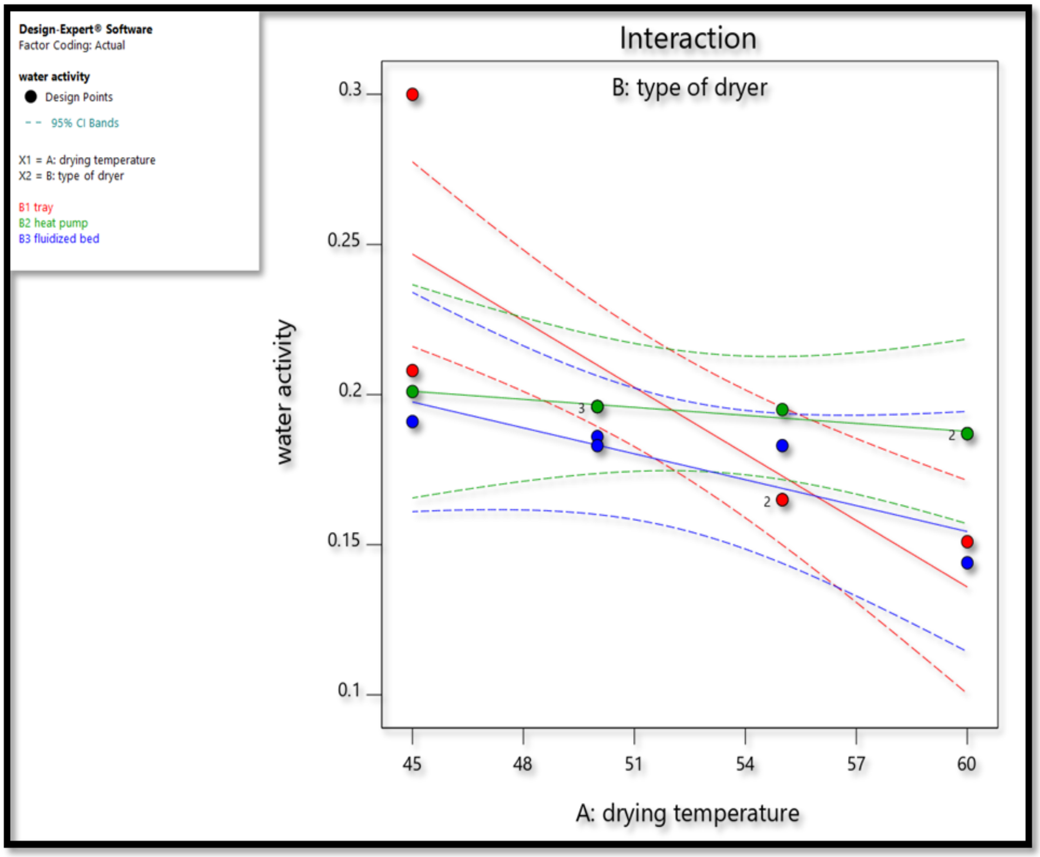


Fig. 4.21 Total flavonoids content of mulberry leaves dried in tray, heat pump and fluidized bed dryer for different air temperatures

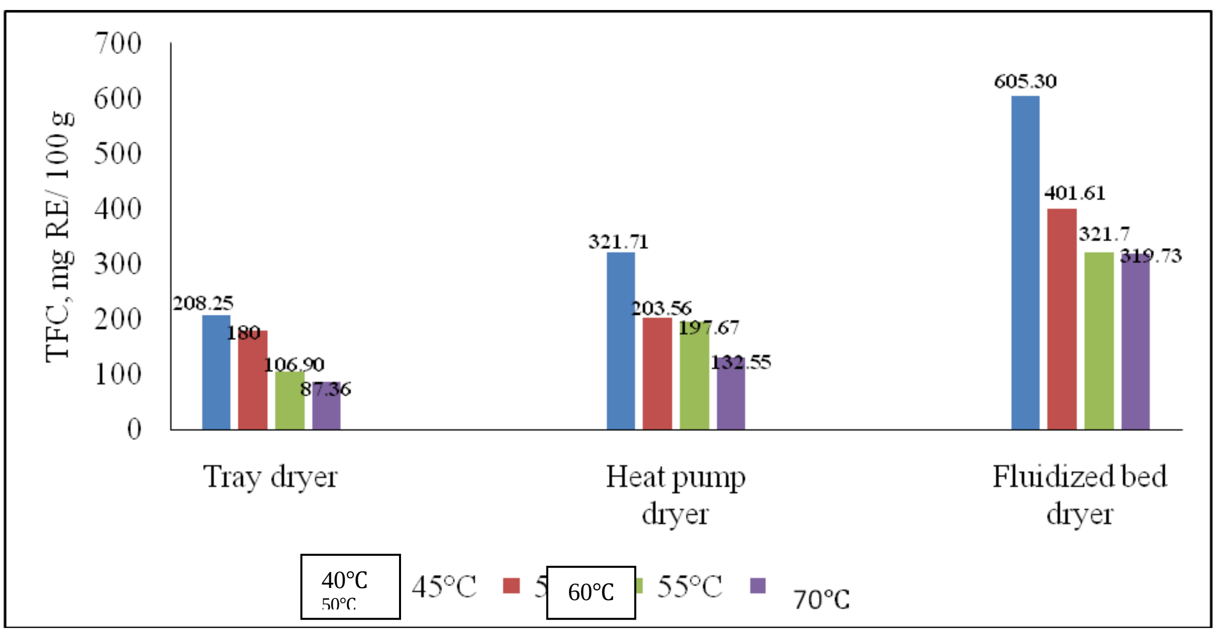
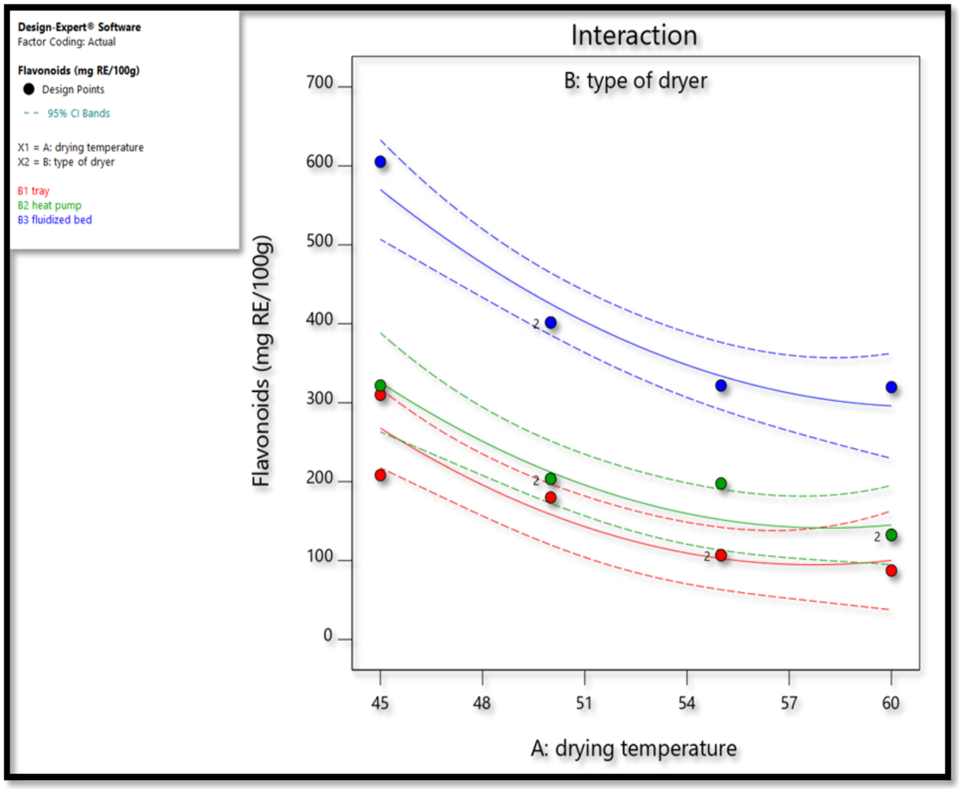
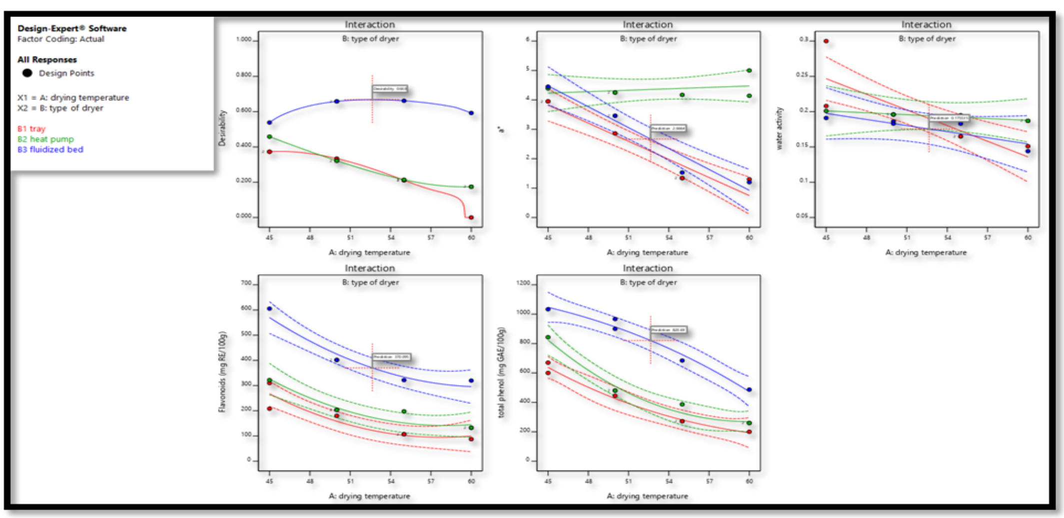


Fig. 4.22 Variation in flavonoids with drying air temperature and type of dryer



The regression actual equation describing the effects of total flavonoid for process variables on in terms of temperature is given as:

Fig. 4.23Optimization for all parameter



The variation in ln (MR) with drying time of mulberry leaves are presented in Fig. 4.15 - 4.17. The curve for the variation in ln (MR) with the drying time for each case process variable was linear with inverse slope. It can be seen that straights lines fitted satisfactory with coefficient of determination R^2 greater than 0.97. The slope becomes steeper with increase in temperature for all drying methods.

Moisture diffusivities were calculated from the slopes of the respective straight lines as suggested by Doymaz, 2004; Maskan*et al.*, 2002and are presented in Table 4.3.

It can be seen that moisture diffusivity increased with temperature for all drying methods. The reason may be with increase in drying temperature the product temperature increased and since moisture diffusion is an internal process, it dependson product temperature (Singh and Heldman, 2001). Similar trends were also reported by Derya and Mehmet (2010) for onion slices, as the effective diffusivity (Deff) values (m^2 /s) for 50°C and 70°C drying process were 7.468 x 10^{-10} and 1.554 x 10^{-9} m^2/s respectively.

Quality Analysis

Colour values L*, a* and b*

The colour of fresh and dried mulberry leaves were measured with the help of colorimeter as described in the Section 3.8.1. The colour values such as L*, a* and b* of fresh mulberry leaves were found to be 24.71, -2.05, 8.24 respectively. These colour values were observed to increase after drying under all the process parameter. The L* values of tray dried product increased and ranged between 48.27 to 56.84. The L* values for sample dried in heat pump dryer varied between 45.91 to 48.63 and for fluidized bed dryer, the L*values were found between 47.79 to 57.30. The a*values were found to decrease with temperature. It was varied from maximum value of 3.95 to minimum value of 1.20 at 45ºC in tray drying and60ºC in fluidized bed drying method respectively.

The observed data for L*, a* and b* values under varying processing parameters are presented in Table 4.4. It can be inferred from Table thatL*, a* and b* values during the drying was found to be dependent on the drying temperature.

As a* value represents the green colour and the priority is to conserve the green colour of the powder so a* value was considered for statistical analysis. Polynomial Equation 4.2, 4.3 and 4.4were used to fit the experimental data presented in Table 4.4. Equation 4.2, 4.3 and 4.4gave the predicted a* value as a function of drying temperature for tray, heat pump and fluidized bed dryer respectively. The data for a* value was analysed stepwise regression analysis as shown in Table 4.5. The R^2 value was calculated by least square technique and found to be 0.9428for a*value, showing good fit of model. The Model F-value of 36.26fora* value implies the model is significant ($P<0.0001$). The linear terms (A and B) are significant ($P<0.001$). The lack of fit F value is non-significant which indicates that the developed model is adequate for predicting the response.

High value of coefficient of determination R^2 obtained for response variable indicated that the developed model for a*value accounted for and adequately explained optimum variation. The 2-Dimensional representation of the variation in a* value with drying temperatureand types of dryer is shown in Figure 4.18.

Water activity

Water activity was measured to ascertain the storage stability of the dried mulberry leaves powder using a water activity meter. The water activity of dried mulberry leaves ranged between 0.144 to 0.208 which indicated the stability of the product as if the water activity less than 0.61 the product is stable for storage (Barbosa-Canovas and Vega-Mercado, 1996). Water activity of dried leave samples was observed to decrease with increase in air temperature from 40 to 70ºC for all drying methods. The lowest water activity at highest air temperature may be due to higher evaporation rate influencing the moisture content and consequently water activity of product (Kaur and Singh, 2014).

Polynomial Equation 4.5, 4.6 and 4.7were used to fit the experimental data presented above. Equation 4.5, 4.6 and 4.7 gave the predicted water activity as a function of drying temperature for tray, heat pump and fluidized bed dryer respectively. The data for water activity was analysed stepwise regression analysis as shown in Table 4.7.The R^2 value was calculated by least square technique and found to be 0.9163for water activity value, showing good fit of model to the data. The Model F-value of 0.0056forwater activity value implies the model is significant. The linear terms (A and B) are significant. The lack of fit F value is non-significant which indicates that the developed model is adequate for predicting the response. Moreover, the predicted R^2 of 0.6482 for water activityis in reasonable agreement with adjusted R^2 of 0.8783. This reveals that the non-significant terms have not been included in the model. Therefore, this model could be used to navigate the design space.

Phytochemical content

Total flavonoid content

The Total Flavonoid Content (TFC) of fresh and dried mulberry leaves were measured as described in Section 3.8.6.2. Total flavonoid content of fresh leaves was found to be 663.96 mg RE/ 100g.Total flavonoid content at 40ºC was maximum (605.30 mg RE/100g) for fluidized bed dried sample and lowest values (87.36 mg RE/ 100g) was for tray dried sampleat70ºC. It was observed that with increasing temperature in dryer, flavonoid content exhibited decreasing trend. This trend is in harmony with study by Rababah *et al*. (2015) who observed effects of drying process on total phenolics, antioxidant activity and flavonoid contents of common plants. This decreasing trend is might be due to exposure of product to drying temperature and prolonged drying time. According to Rabhabh *et al.* (2015) heating may breakdown some phytochemicals which affect cell wall integrity and cause a migration of some flavonoid component. In addition, the loss in flavonoids may due to breakdown or leakage by chemical reactions includes oxygen, enzymes and light.

The values of total flavonoid during the drying were found to be dependent on the drying temperature and type of dryer. Polynomial Eqn. 4.11, 4.12 and 4.13were used to fit the experimental data presented in Table 4.14. Eqn. 4.11 to 4.13 gave the predicted; total flavonoid as a function of drying temperature for tray, heat pump and fluidized bed dryer respectively. The data for total flavonoidwas analysed stepwise regression analysis as shown in Table 4.9. The quadratic model was fitted with the experimental data and statistical significance for linear and quadratic terms was calculated for total flavonoid as shown in Table 4.9. The R^2 value was calculated by least square technique and found to be 0.9612 showing good fit of model to the data. The Model F-value of 41.24 implies the model is significant ($P<0.0001$). The linear terms (A and B) are significant ($P<0.0001$). The lack of fit F value is non-significant which indicates that the developed model is adequate for predicting the response. Moreover, the predicted R^2 of 0.8337is in reasonable agreement with adjusted R^2 of 0.9379. This reveals that the non-significant terms have not been included in the model. Therefore, this model could be used to navigate the design space.

Optimization of Process Parameters

The optimization of process parameters for tray, heat pump and fluidized bed drying process of mulberry leaves was done on the basis of drying temperature and prominent quality attributes like colour value (a* value), water activity, total phenols and flavonoid content. On comparing the data on the basis of above-mentioned parameters the best results were found for fluidized bed dryer at 52.648ºC, practically it is difficult to set the dryer at 52.648ºC so the temperature is rounded to 53ºC. It showed highest total phenols and flavonoid content (*i.e.*, 820.690 mg GAE/ 100g, 370.095 mg RE/ 100g), lowest water activity (0.176) and 2.666of a* value. Among the three drying techniques the product obtained after fluidized bed drying was found to be superior quality and hence is most acceptable.

References

Cavuldak OA, VuralN, AkayMA,AnliRE. Optimization of ultrasound-assisted water extraction conditions for the extraction of phenolic compounds from black mulberry leaves (Morus nigraL.). Journal of Food Process Engineering2019;42:e13132

Chabow,MaY,KaptsoGK,KwawE,ChenoRW,XiaoL et al. Process analysis of mulberry (Morus alba) leaf extract encapsulation :effects of spray drying conditions on bioactive encapsulated powder quality. Food Bioprocess Technology 2019;12:122-146

Chan EW, Lye PY, and Wong SK .Photochemistry, pharmacology, and clinical trials of Morus alba .Chinese *Journal* of Natural Medicines 2016;14:17-30.

Cui H, Lu T, Wang M, Zou X, Zhang Y, Yang Xet al.Flavonoids from Morus albaL. leaves: Optimization of extraction by response surface methodology and comprehensive evaluation of their antioxidant, antimicrobial, and inhibition of α-amylase activities through analytical hierarchy process. Molecules (Basel, Switzerland) 2019;24:2398.

Datta KR.Mulberry cultivationand utilization in India.Proceedings of the FAO electronic conference on mulberry for animal production (Morus1-L). Vol. 147, FAO animal production and health paper, Rome, Italy 2000:45-62.

LiuC,WangCH,LiuJ,XuL,XiangW,WangYC.Optimization of Microwave-Assisted technology for extracting 1-deoxynojirimycin from mulberry tea by Response Surface Methodology. Food Science and Technology Research2014;20:599-605.

Phoungchandang S,TochipL, SrijesdarukV. White mulberry leaf drying by tray and heat pump dehumidified dryers. World Journal of Agricultural Sciences 2008;4:844-851

Przygonski K,WojtowicE.The optimization of extraction process of white mulberry leaves and the characteristic bioactive properties its powder extract. HerbaPolonica, International Journal edited by the Institute of Natural Fibres and Medicinal Plants2019;65:12-19.

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;10:1501-1509.

Srivastava S, Kapoor R,ThatholaA,SrivastavaRP. Nutritional Quality of Leaves of Some Genotypes of Mulberry (Morus Alba). International *Journal* of Food Sciences and Nutrition2006;57:305-313.

YigitD,AkarF,BaydasA,BuyukyildizM. Elemental composition of various mulberry species. Asian Journal ofChemistry 2010;22:3554-3560.

Zhang PQ, Zhang LH, Zong W. Optimization of high hydrostatic pressure extract 1-deoxynojirimycin from mulberry leaves with response surface methodology. BioTechnology, an Indian Journal 2014;10:13132-13137.

ZhangDY,WanY,XuJY,WuG.Ultrasound extraction of polysaccharides from mulberry leaves and their effect on enhancing antioxidant activity.Carbohydrate Polymers 2015;137:473-479

How to cite this article:

Manish Kumar Choudhary. 2023. Drying Characteristics of Mulberry Leaves. *Int.J.Curr.Microbiol.App.Sci.* 12(12): 229-250. **doi:** https://doi.org/10.20546/ijcmas.2023.1212.026