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Effect of Drying Methods on Quality Characteristics of Medicinal Indian Borage (*Coleus aromaticus*) Leaves

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Abstract

Indian Borage (*Coleus aromaticus*) leaves are very rich in medicinal qualities. Due to low keeping quality, heavy quantities of *Coleus* leaves go as waste every year. If proper drying methods are scientifically standardized, the leaves can be processed both at garden and orchard level and the grower can earn more profit. The present study is an attempt to assess the effect of selected drying methods on the quality characteristics of the leaves. The drying methods considered were hot air drying (50°C -80°C), fluidized bed drying (50°C -80°C), and microwave drying(180-900W). The dependent parameters were total drying time, therapeutic quality (total phenolics, antioxidant property), and sensory property (shape, colour, aroma and overall acceptability). Effect of power level and temperature on quality characteristics of dried products has been analyzed to determine the optimum drying conditions. Considering the total drying time, therapeutic and sensory attributes of the dried leaves, it is proposed to dry the leaves at 60°C and 540W in hot air dryer and microwave dryer respectively to obtain an acceptable product. Overall analysis of the drying behaviour and quality characteristics of dried leaves indicated that the microwave drying could preserve maximum therapeutic quality followed by hot air drying. As the leaves lost most of the medicinal components for which these are valued in a fluidized bed drying, the scope of fluidized bed drying for preservation of leaves was ruled out.

Keywords: Drying methods; Total phenolics; Antioxidant activity; Sensory evaluation

Introduction

Coleus aromaticus (Benth, Family: Laminaceae), commonly known as Indian/country borage is an important aromatic herb of the family Laminaceae which is routinely grown as a traditional medicinal herb in India and South East Asia .The leaves are mainly used for the treatment of stomach disorder, asthma, epilepsy and renal diseases. These are reported to have anti-oxidant and anti-microbial properties [1-3]. The fresh or dried leaves are also used for culinary purposes in most of the countries for flavouring, seasoning and as condiment and spice for different food preparations. Unlike various culinary herbs such as mint and curry leaves, the *Coleus* leaves are rarely sold in markets. In the kitchen, its leaves are used in small quantities and added to mutton and fish curries to mask the strong smell.

Dehydration is an essential method of preserving the leaves with minimum spoilage. Standardization of drying parameters is vital for producing good quality leaves which can be further used in food, pharmaceutical industries to produce spices and different drugs. Thus controlled and appropriate drying of the leaves appears to be the only alternative measure for preserving the aromatic qualities of the leaves. However, studies on the drying characteristics of *Coleus* leaves are scarce in the literature. Most of the conventional thermal treatments such as sun drying and shade drying result in low drying rates in the falling rate period which leads to undesirable thermal degradation of the finished products. In addition to long time and environmentally dependent process, sun and shade drying is not recommended from the hygienic point of view. These also have disadvantages like inconsistent quality standards, contamination problems, low energy efficiency which are not desirable for the food industry.

As compared to other conventional drying techniques, microwave drying, fluidized bed drying and hot air drying systems offer opportunities as less drying time, uniform energy and high thermal conductivity with high quality of finished product [4]. Since heating takes place only in the food material and not in the surrounding medium, microwave processing can reduce energy costs. Shorter heating times also lead to greater nutrient retention, better quality characteristics such as texture and flavor, as well as increased production. The use of a continuous microwave system for blanching has been proposed as a means of reducing production time and energy costs during processing. *Coleus* leaves are a store house of vitamins and minerals. They also contain an immense variety of bio-active non-nutritive health promoting factors such as antioxidants, total phenolics and dietary fibres. Their higher moisture content renders them perishable and seasonal availability limits their utilization all round the year. Hence, there is a need to preserve this nature's gift through proper processing techniques for safe storage with efficient nutrition retention. The drying kinetics of food is a complex phenomenon and requires simple representations to predict the drying behavior and to optimize the drying parameters [5,6]. However systematic studies of effect of drying methods on quality parameters of *Coleus* leaves are lacking. Therefore, the objectives of the present work were to study the effect of different temperatures and power levels on quality parameters of dried *Coleus aromaticus* leaves in hot air, fluidized bed and microwave drying techniques.

Materials and Methods

Sample preparation

Fresh, healthy and matured *Coleus* leaves were collected in bulk

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from the medicinal garden of Orissa University of Agriculture and Technology, Bhubaneswar and washed thrice thoroughly in clean cool water to remove the dirt and dust present. Then petioles were removed. The depetioled leaves were subjected to drying experiment as explained in details below. After wiping the surface water the drying was carried out by various methods e.g. hot air drying (50°C-80°C), fluidized bed drying (50°C -80°C) and microwave drying (180-900W). The drying was carried out in a continuous manner. The final dried sample leaves were analyzed for different therapeutic qualities such as total phenolics, antioxidant property and sensory properties [7]. This analysis was made for fresh leaves before drying and so also for dried leaves. The data collected have been compiled and analyzed for interpretation.

Moisture content was measured by the gravimetric method using an electric convection oven. Three 30 g leaf samples were dried at 105°C for 24 h to determine initial moisture content. The initial moisture content of the *Coleus* leaves was 16.03 kg of moisture per kg dry matter. For the mass determination, a digital balance of 0.0001 g accuracy (ANAMED, M7000 series) was used.

Drying techniques

Hot air drying (HAD): Thin-layer drying experiments under controlled conditions were conducted for *Coleus* in a convective dryer (IIC, Model TD-12) at 50, 60, 70, and 80°C (40-60% relative humidity). The experimental dryer (tray dryer) consists of a centrifugal blower, an electrical resistance air heating section, the measurement sensors and the displaying unit. A door was provided in front of the chamber for placing and removing the sample tray. The blower and heater of dryer were switched on for 30 minutes prior to each experimental run for the drying air to reach stable temperature. The air velocity was continuously measured using an anemometer (Lutron AM-4201). After attaining the desired drying air temperature, samples of about 1.4 kg/m^2 were loaded onto the drying trays in single layer. The sample tray was removed from the dryer and weighed regularly, initially at intervals of 15 mins, then onwards at 30-min intervals. The drying tests were terminated when the weights of the samples got stabilized, which was assumed to be the stage of dynamic equilibrium. All the experiments were carried out at 1.2 m/s air velocity. The drying operation started with an initial moisture content of about 1603.29% (db) and continued until no further changes in their mass was observed.

Fluidized bed drying (FBD): A fluidized bed dryer (SMST, SM Scientech, Calcutta) was used in the present investigation. The drying system was allowed to run for about 30 min to achieve steady conditions before the fresh leaves were put into fluidized bed dryer. After noting down the initial moisture content subsequent observations on weight was taken initially at 5 min then 10 min thereafter at 15 minutes interval. The drying runs of leaves were conducted at temperatures of 50, 60, 70 and 80°C similar to those at hot air dryer. The air velocity was increased till all the samples came to the fluidized state. Sample of 50 g weight was used in each run. As the samples started losing moisture, the air velocity was monitored to obtain the complete fluidization till the end of experiment. The air velocity was in the range of 14.8 to 16.2 m/sec in order to achieve the complete fluidization of the leaves. The relative humidity of the drying air was not regulated and varied from 22 to 38%.

Microwave drying (MWD): A programmable domestic microwave oven (LG Intellowave3850w2G031A) with maximum output of 900 W at 2450 MHz was used for the drying experiments. The dimensions of the microwave cavity were 215 mm by 350 mm by 330 mm. The oven had a fan for air flow in the drying chamber and cooling of magnetron. The moisture from drying chamber was removed with this fan by passing it through the openings on the top of the oven wall to the outer atmosphere. The oven was fitted with a glass turntable (30 cm diameter) and had a digital control facility to adjust the microwave output power by the 20% decrements and the time of processing. The microwave oven had the capability of operating at five different microwave output power levels: 180, 360, 540, 720 and 900 W. The fresh leaf material with a density of 1.4 kg/m^2 was uniformly spread on the tissue paper over the turntable inside the microwave cavity, for an even absorption of microwave energy. Three replicates were carried out for each experiment according to preset time schedule based on the preliminary tests. Depending on the drying conditions, moisture loss was recorded at 30 sec or 1 min intervals drying at the end of power-on time by removing the turn-table from the microwave, and periodically placing the leaf sample, on the digital balance [8] and the data analyzed was an average of these results. The reproducibility of the experiments was within the range of ±5 %. All weighing processes were completed in less than 10 s during the drying process. The microwave power was applied until the mass of the sample reduced to a constant level which corresponded to moisture content of about 0.06±0.01 kg of moisture per kg dry matter.

Quality analysis

Microwave assisted extraction (MAE): For estimation of total phenolics (TP) and total antioxidant property (TAA), the samples were required to be extracted. This was carried out by closed system of microwave assisted extraction by Multiwave 3000-801V (Anton Par) following the method suggested by Eskilson et al. Methanol: water (6:4) was used as a solvent was taken in each vessel of the extraction unit. The initial temperature and pressure was 27°C to 34°C and 2.6 bars to 3.7 bars respectively. The temperature was maintained at 80°C during the process of extraction. After cooling the temperature was between 30°C to 40°C and pressure was 4.8 to 5.0 bars.

Estimation of total phenolics (TP): The amount of the total phenolics in the extract was determined according to the Folin-ciocalteau procedure modified by [9]. The absorbance was measured at 765 nm using Perkin-Elmer UV visible spectrophotometer. The total phenolics in the test sample were calculated from the standard curve, and were expressed as Gallic Acid Equivalent (GAE) per gram of sample. Methanol: water (6:4v/v) was taken in the place of plant sample as blank.

Evaluation of total antioxidant activity (TAA): Total antioxidant activity was estimated using phospho-molybdenum method as suggested by [10]. The assay is on the reduction of MO (VI) to MO (V) by the extract and subsequent formation of a green phosphate complex at acid pH. Phospho-Molybdenum Reagent was prepared as per the standard procedure. The tubes are capped and incubated in a boiling water bath at 95°C for 90 min. After that the samples were cooled to room temperature the absorbance of the aqueous solute was measured at 695 nm against a blank in a Perkin–Elmer UV-visible Spectrophotometer. Standard curve was prepared taking different concentration of ascorbic acid. The antioxidant activity of sample was expressed as equivalent of ascorbic acid (μM/g of sample).

Sensory analysis: Sensory characteristics (shape, colour, aroma and overall acceptability) of dried leaf samples were determined as an average score of the ten-member consumer panel. (9-point Hedonic scale following the procedure of ISI (1997)). It was speculated that the market value of the product would be influenced by the colour and the texture of the leaves where as the aroma would establish the consumers' preference. Like denoted flatness and dislike denoted distortedness for shape and intensity of greenness for colour. Average of the scores obtained was calculated and analyzed. Fresh leaves were included as control samples.

Colour analysis (Surface colour): The Surface colour of leaves obtained from different drying conditions was measured by Hunter Lab colorimeter (Colour Flex) to record the L*, a* and b* value. The total color change i.e total chromatic aberration value (ΔE) was calculated by Equation,

$$(\Delta E) = [(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2]^{1/2}.$$

The L, a and b values correspond to the values of samples at different drying temperature, whereas the values of L_0, a_0 and b_0 are related to the fresh leaf samples.

Statistical analysis: Analysis of Variance carried out for quality characteristics and total chromatic aberration for individual drying methods by using the statistical software GENSTAT (Trial version). The significance of the results was tested using critical difference technique.

Results

Effect of drying methods on yield and drying time of leaves

The data on yield of dry leaves obtained by drying fresh *Coleus* leaves using different methods are given in (Table 1). It was evident from the data that there was a remarkable reduction in weight after drying the leaves by all the methods. The initial moisture content was 1603.28% db. The final moisture content of the samples ranged between 6.206 to 6.889% db, 6.325 to 6.591% db and 6.059 to 6.553% db respectively for hot air drying (HAD), fluidized bed drying (FBD), and microwave drying (MWD). The corresponding drying time required for these processes were 300 to 540, 150 to 270, and 5 to 13 minutes. The wide variation in drying time could be explained by the individual drying principle lying behind each method. The drying time requirement of FBD was less by about 2 and 3 hours in comparison to HAD irrespective of temperature. DT for microwave is drastically less and it is because of the obvious reasons of high rate of mass transfer at the higher temperature generated due to electromagnetic field.

Hot air drying

The time taken for drying the leaves by hot air drying at 50, 60, 70 and 80°C was 540, 420, 360, 300 min respectively (Table 1). The experimental results for the hot air drying showed that the drying air temperature had a significant effect on the moisture content. It is also obvious that air temperature is the most important factor affecting the drying rate. Similar results were reported by [11].

Methods of drying	Temperature, Power level (°C, Watt)	Final moisture content,% (d.b)	Total Drying time(min)
HAD	50	6.206	540
	60	6.681	420
	70	6.766	360
	80	6.889	300
FBD	50	6.251	270
	60	6.325	210
	70	6.417	180
	80	6.591	150
MWD	180	6.059	13
	360	6.399	6.5
	540	6.398	6
	720	6.5	5.5
	900	6.553	5

Table 1: Drying time and yield of leaves at different temperature and power level.

Effect of drying air temperature on colour indices

The mean surface colour values obtained L (Lightness), a (+redness, -greenness), b(+yellowness, -blueness) of leaves dried at different temperature are results of colour parameters obtained are presented in the (Table 2). Results indicated significant loss in L, a, b values in the dried leaves in comparison to fresh ones. Reduction in 'L' and 'b' values and increase in 'a' values indicated that hot air drying produced brownish (dark green) products. It is verified from results that the degree of colour change was dependent on drying air temperature. Rudra et al. [12], opined that high temperature could lead to the replacement of magnesium in the chlorophyll by hydrogen, thereby converting chlorophylls to pheophytins. However, the rate of change varied with the temperature. The greatest loss was observed at 80°C. The statistical analysis of overall colour change ΔE indicated that there was no significant difference in colour parameters of the samples dried at 60 and 70°C.

Effect of drying air temperature on quality parameters and sensory evaluation

(Table 3) shows the change in therapeutic and sensory qualities of *Coleus* leaves dried at different temperatures. The total phenolics (TP) and antioxidant (TAA) values of the fresh leaves were 1180 mg/100g and 516 μM/g respectively. Both the components reduced with drying, but the loss in antioxidant values is more than that in the total phenolics values irrespective of temperature. However, the retention of both the components was found to be highest at 60°C and no significant difference was observed between the values at 60°C and 70°C. Overall analysis of the low values of quality at 50°C and 80°C may be attributed due to the longer drying time and high temperature respectively. Similar trend has been observed in sensory qualities. No significant different could be observed between values at 50, 60, 70°C. All the scores at 80°C were significantly less than those at lower temperature. Among all sensory properties, the aroma got higher score for all the samples. Irrespective of the temperature, the colour of the samples was dark which is supported by increasing +a values.

The results of the quality characteristics of dried leaves suggested that although there was loss in the quality characteristics during hot air drying, a considerable amount is still preserved in the samples dried at 60°C.Therefore, 60°C may be the limiting temperature for hot air drying of *Coleus* leaves and it may be extended up to 70°C at the time of requirement.

Fluidized bed drying

It was observed that there was a substantial reduction in drying time in FBD as compared to that of the HAD irrespective of the temperature. The DT required 50, 60, 70 and 80°C were 270, 210, 180, 150 min respectively. The TP and TAA values for the leaves were found to be 181, 165,162,145mg/100g and 68, 56, 48, 42 μM/g respectively.

While analyzing the components, it was found that, there was a drastic reduction in TP and TAA values which are actually the vital components of leaves. It was also noticed that the dried leaves lost their contour quickly and the shrinkage was quite high. This may be due to the vigorous and continuous motion of leaves in fluidized state. The sensory scores for all the parameters were observed to be less than

Drying Methods	Temperature, Power level (ºC,Watt)	L	a	b	ΔL^2	Δa^2	Δb^2	ΔE^2	ΔE
Fresh	-	37.06	-7.10	19.55	-	-	-	-	-
HAD	50	36.08	2.04	16.7	0.9604	83.539	8.1225	92.6225	9.624[a]
	60	36.62	2.03	15.55	0.1936	83.356	16.000	99.5505	9.977[ab]
	70	35.04	2.28	14.22	4.0804	4.0804	28.4089	120.4737	10.976[b]
	80	34.55	3.16	13.31	6.3001	105.26	38.9376	15.5053	12.268[c]
MWD	180	31.1	-0.25	8.2	35.5216	46.922	128.8225	211.266	14.535[d]
	360	34.45	-0.61	12.65	6.8121	42.1201	47.61	96.5422	9.825[c]
	540	36.16	-2.12	15.78	0.81	24.8004	14.2129	39.8233	6.310[a]
	720	35.23	-2.48	16.26	3.3489	21.344	10.8241	35.5174	5.959[a]
	900	35.11	-1.77	14.88	3.8025	28.4089	21.8089	54.0203	7.349[b]

*The values having same superscript in a column for individual drying are not significantly different at $p<0.05$

Table 2: Effect of drying temperatures (HAD) and power levels (MWD) for colour parameters.

Drying Methods	Temperature, Power level (ºC,Watt)	Total phenolics (mg/100g)	Antioxidant (µM/g)	Sensory Evaluation			
				Colour	Shape	Aroma	Overall Acceptability
HAD	50	455[ab]	151[ab]	6.0[ab]	5.5[ab]	7.0[ab]	6.0[a]
	60	615[c]	198[c]	6.5[b]	6.0[b]	7.5[b]	7.0[b]
	70	493[bc]	167[bc]	6.0[ab]	6.0[b]	7.0[ab]	6.0[a]
	80	338[a]	139[a]	5.5[a]	5.0[a]	6.5[a]	5.5[a]
FBD	50	181[a]	68[a]	5.0[a]	4.0[a]	5.0[a]	4.5[a]
	60	165[b]	56[b]	5.0[b]	4.0[a]	5.0[a]	4.5[a]
	70	162[b]	48[bc]	4.0[b]	3.0[b]	4.0[b]	3.5[b]
	80	145[c]	42[c]	3.0[c]	2.5[b]	3.0[b]	3.0[b]
MWD	180	335[a]	205[a]	6.0[a]	6.5[a]	6.5[a]	6.0[a]
	360	436[ab]	281[b]	8.0[bc]	7.5[bc]	8.0[bc]	8.0[bc]
	540	692[c]	377[c]	8.5[c]	8.0[c]	8.5[c]	8.5[c]
	720	553[bc]	287[b]	8.0[bc]	8.0[c]	8.0[bc]	8.0[bc]
	900	372[a]	181[a]	7.5[b]	7.0[ab]	7.5[b]	7.5[b]

*The values having same superscript in a column for individual drying are not significantly different at $p<0.05$

Table 3: Quality Analysis of the leaves dried at different temperature and power level.

Drying Methods	Parameters	Drying Time(min)	Total phenolics, (mg/100g)	Antioxidant (µM/g)	Sensory Evaluation			
					Colour	Shape	Aroma	Overall Acceptability
HAD,ºC	60	420	615	198	6.5	6.0	7.5	7.0
MWD,W	540	6	692	377	8.5	8.0	8.5	8.5
FBD*, ºC	50	270	181	68	5.0	4.0	5.0	4.5

* Not recommended

Table 4: Summary for optimum parameters for different drying methods.

5. However, among the drying temperature within the experimental range the sample at 50°C showed relatively better results. Since, the leaves lost their medicinal components for which they are valued, the scope of fluidized bed drying for preservation of leaves was ruled out and further analysis of this drying system was not done.

Microwave drying

The drying time requirement at 180, 360,540,720,900 W was 13, 6.5, 6, 5.5 and 5 min respectively in (Table 1). As the microwave output power was increased, the drying time of samples was significantly decreased. By working at 900W instead of 180W, the drying time was shortened by 60%. For comparison no literature is available on drying of *Coleus* leaves. However, the drying times obtained in the microwave drying system were extremely low compared to HAD and FBD and the results obtained using different drying methods in the previous studies for different leaves [13]. Since, the initial moisture contents of *Coleus* leaves used in drying experiments were same (1609.23% dry basis); the difference in drying time requirements was considered to be mainly due to the difference in the drying rates.

Effect of power level on colour indices of dried leaves

Mean surface colour values of fresh and dried under different power levels are shown in (Table 2). Lightness (+L), greenness (-a) and yellowness (+b) of fresh leaves were found to be 37.06, -7.10 and 19.55 respectively. After microwave drying all the three values decreased but the reduction in L values was not significant. Though the -a values reduced significantly, still these were within the greenness range and then same was with the +b values for which the product obtained was of yellowish green colour. On the contrary, the sample obtained from hot air drying the lightness was decreased and the redness was increasing resulting in dark green brown colour. For hot air drying at 60 to 70°C ΔE of dried leaves was not significantly different ($p<0.05$). Both drying temperature yielded positive 'a' value, thus redness appeared. Insignificant effect of drying temperature in this range on the colour of hot air dried product was observed in a previous study of drying for mint leaves [14].

The greatest loss in brightness values was observed in 180 W energy applications 'L'. This could be due to longer drying period (13 min). Analyzing ΔE values, it was observed that the colour of the samples dried at 540W and 720W is close to those of fresh leaves. No significant difference in ΔE could be observed between the samples dried at 540 and 720W. These results are in consistent with [14] for spinach leaves. In comparison to the microwave drying, the hot air drying yielded darker leaves with less greenness and more yellowness. As a result, ΔE values of the air dried samples were significantly higher than those of the microwave dried one ($p \leq 0.05$), except for the samples dried at 180W.

Effect of power level on quality parameters and sensory evaluation

Total phenolics content and total antioxidant value (TAA) for fresh leaves were found to be 1180 mg/100 g and 516 μM/g respectively on dry weight basis. From (Table 3) it was observed that the total phenolics and antioxidant content varied with change in microwave output powers because of its temperature sensitivity. The retention of both total phenolics and antioxidant content was more in samples dried at 540W output power, than those obtained at rest of the power levels. This may be due to the relatively long drying time or higher temperature development, which facilitated for removal of volatile compounds. Statistical analysis indicated that the therapeutic values (TP and TAA) of the dried samples were significantly less than that of fresh leaves. However, a considerable amount was still preserved in samples dried at 540 W. These values are very close to the values obtained from samples dried at 720W (TP is non significant at 5%). It was observed that 540W yielded products with highest sensory score for all parameters .The change in these parameters was insignificant when the power level was increased from 540 to 720W.The sensory characteristics obtained at 180 W power level was at par with HAD samples ,though the retention of therapeutic values were much higher.

Overall analysis indicated that HAD tended to reduce the TAA values to a greater extent in comparison to MWD, though phenolic values remained comparable. The results of sensory evaluation agreed to [15] in which an improvement was observed in microwave dried mushroom product over hot air dried product. From sensory evaluation, the mean sensory scores for different quality attributes of dried leaves are presented in (Table 3). The aroma and color of microwave dried samples were observed to be better as compared to a hot air dried samples. So samples had better overall acceptability in comparison to hot air dried samples. According to [16], high moisture bio-products undergoing microwave drying have the advantage, as if pushes liquid into the surface and the liquid is usually converted into the vapor. This process results in drying without causing surface overheating phenomena. Therefore, in terms of surface colour degradation, preservation of the product colour was good. It is estimated that the products are subjected to high temperature with the increasing power levels during microwave drying. Therefore, the product colour is adversely affected in the drying processes either at high microwave powers or for longer drying period. In the present study, the low sensory scores in colour at 180W microwave powers are supported by the results obtained in the previous research above. (Hunter lab colour values) Samples dried at higher power level appeared slightly darker in greenness as compared to fresh samples, but the product still looked excellent for use.

Conclusion

The time required for drying of leaves at 50, 60, 70 and 80°C was 540, 420, 360, 300 min respectively for HAD and although there was loss in the quality characteristics during HAD, a considerable amount is still preserved in the samples dried at 60°C.Therefore, 60°C may be the limiting temperature for hot air drying of *Coleus* leaves. There was a substantial reduction in drying time in fluidized bed drying as compared to that of the hot air and microwave drying techniques irrespective of the temperature. But the leaves lost most of the medicinal components for which these are valued. Hence, the scope of fluidized bed drying for preservation of leaves was ruled out and further analysis of this drying system was not done. The time required for drying of leaves at 180, 360, 540, 720 and 900W was 13, 6.5, 6.0, 5.5 and 5min respectively for MWD and this drying can be successfully used to dry *Coleus* leaves with maximum preservation of aroma. So keeping in view the drying time and sensory attributes of the leaves, it is proposed to dry the leaves at 540W in a microwave dryer to obtain an acceptable product with higher retention of therapeutic components. In absence of the availability of commercial microwave drying, hot air drying may be adopted for large scale drying of leaves. However, selection of drying method is dependent on specific use of end product and the economic consideration.

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