Optimization of Drying Parameters for Maximum Nutrient Retention in *Cassia auriculata*:Implications for Functional Food Development

Abstract:

The development of efficient drying techniques for medicinal plants while preserving their nutritional composition remains a significant challenge in food processing technology. This study investigated the impact of three distinct drying methods (solar, cabinet, and shade drying) on the nutritional composition of *Cassia auriculata* leaves, buds, and flowers. Fresh samples were collected and processed following standard protocols, with dried materials ground into powder and analysed in triplicate. Comprehensive proximate analysis revealed significant variations in fat content ($p<0.008$) and tannins ($p<0.001$) across drying methods. Mineral profiling demonstrated notable differences in potassium ($p=0.001$), selenium ($p=0.004$), magnesium ($p<0.001$), and copper ($p=0.005$) concentrations among the samples. Shade-dried samples exhibited superior nutrient retention, maintaining higher levels of essential minerals including calcium (6484.57 mg/kg), potassium (11100.2 mg/kg), and magnesium (2108.95 mg/kg) compared to solar and cabinet drying methods. Additionally, shade drying preserved the highest crude fiber content (16.20%) and protein levels (12.15%). The study establishes shade drying as the optimal method for *Cassia auriculata* processing, achieving a 40% recovery rate while maximizing nutrient preservation. These findings provide valuable insights for the standardization of drying protocols in medicinal plant processing and have significant implications for the functional food industry.

Keywords: *Cassia auriculata*, drying optimization, macro and micro nutrients profiling, medicinal plants, functional foods

INTRODUCTION

The process of drying involves reducing the water content to prevent or slow down food spoilage caused by microorganisms.Drying is an ancient preservation method that has been used since prehistoric times. In today's food market, dried foods are important for the food supply chain. Different terms such as "drying", "dehydration", or "dewatering" are often used to describe this process. One of the critical aspects of drying is to minimize exposure to light, oxidation, and heat. Using a system that involves high heat (65 to 70°C) and shorter duration may help preserve critical bioactive compounds (Naseer Ahmed *et al.,* 2013).

The conventional and new drying technologies and pre-treatment methods are based upon drying efficiency, quality preservation, and cost-effectiveness. The primary goal of drying foods is to reduce the moisture content and extend the shelf life. However, the challenge during dehydration is to reduce the energy consumption and water content of the material to the desired level without causing any significant loss of colour, appearance, flavour, taste, or chemical components [5,6].

Recent advances in dehydration techniques and the development of novel drying methods have enabled the preparation of a wide range of dehydrated products and convenience foods from greens, fruits, and vegetables that meet quality, stability, and functional requirements, while also being economical. This has been made possible by sustained experimental studies that have helped to understand the theoretical and fundamental aspects of the process and optimization of the techniques to achieve a favourable combination of cost and quality [7-10]. This study highlights the development in the dehydration of herbs, fruits, and vegetables and their products during the last decade, covering theoretical aspects and practical applications, with a focus on techniques that have received the maximum attention. It focuses on the study of various drying techniques of *Cassia auriculata* and the effects of these techniques on the antioxidant activity and bioactive compounds of the plant (Naseer Ahmed et al., 2013).

METHODS & MATERIALS

Collection of Raw materials for different drying treatment:

Phase I: One kilogram of newly grown *Cassia auriculata* flowers, buds and leaves were gathered from Urmelalagian village. Their weight was determined using a precise balance scale with 1gram precision, and then they were washed thoroughly with running water and drained of excess water.

Procedure for solar drying: After washing the *Cassia auriculata* flowers, buds and leaves, they were left to drain for a duration of one hour. Subsequently, they were dried in a Solar dryer at 55° Celsius for four hours. Following hygienic protocol, the dried flowers, buds and leaves were then ground up.

Procedure for cabinet or Tray drying: The excess water was removed from the *Cassia auriculata* flowers, buds and leaves, and then they were dried in a Cabinet dryer at a temperature of 40° Celsius for eight hours.

Procedure for shade drying: After draining the water for an hour, the *Cassia auriculata* leaves and flowers, buds (70% and 30%) were left to dry in a shaded area for seven days at room temperature, which was between 25-28°Celsius.

Phase II: The nutritional analysis of three different samples (A-solar drying, B-cabinet drying, C-shade drying) of three batches (I, II, III) unveils significant variations in key parameters, providing valuable insights into their overall nutritional profiles. Polythene pouches were used to package 100-gram samples of *Cassia auriculata* powder. These samples were labelled as Sample A, B, and C and sent to the Food Quality Testing Laboratory at the Post Harvest Technology Centre, Tamil Nadu Agricultural University in Coimbatore for testing. The samples were submitted on December 1stand the completion date for the testing was December 22nd, 2022.

Solar Drying: In recent times, there have been attempts to enhance the process of sun drying by implementing a technique called solar drying. Similar to sun drying, solar drying employs sunlight as a heat source. However, a foil surface is installed within the dehydrator to amplify the temperature. The process is also aided by ventilation to quicken the drying duration. The advantage of shorter drying times is that they decrease the likelihood of food spoilage or the growth of mould (Naseer Ahmed *et al.,* 2013).

Cabinet or Tray Drying:A Cabinet or Tray dryer is a device that removes moisture from various foods by using a combination of heat, low humidity, and airflow. While the Cabinet dryer is necessary for food processing, it may not be sufficient for preserving large quantities of food (Naseer Ahmed *et al*., 2013).

Shade Drying: Shade drying is a technique for drying herbs that relies on solar energy for heat. To carry out this process, the herbs are placed in a well-ventilated room with low humidity (around 22-27%) and kept in the shade without any direct exposure to sunlight (Ebadi*et al.,* 2015).

RESULTS AND DISCUSSION:

Profiling the nutrients in dehydrated *Cassia auriculata*:

Macronutrients, and Micronutrients in different types of *Cassia auriculata* powder:

In Table 1, should that three separate batches of *Cassia auriculata* samples underwent drying processes using distinct methods, namely solar drying denoted as Sample A, cabinet drying denoted as Sample B, and shade drying denoted as Sample C. The collected samples were analysed for macronutrients. ANOVA was performed to compare if there are significant variations between the groups.

Table 1: ANOVA for Macronutrient analysis of three batches of *Cassia auriculata*powder

Batch	Sample	Ash (%)	Protein (%)	Crude fiber (%)	Fat (%)	Calorific value (Kcal/100g)	Tannins (mg/100g)
Batch I	**Sample A**	6.22	12.25	15.02	2.4	353.64	1998.61
	Sample B	5.79	11.31	15.07	3.39	345.11	1958.29
	Sample C	6.6	12.02	16.17	2.52	349.84	1789.04
Batch II	**Sample A**	6.56	11.85	15.52	2.7	303.64	1948.61
	Sample B	5.49	11.91	15.87	3.09	305.11	1978.29
	Sample C	6.1	11.62	16.77	2.52	399.84	1759.04
Batch III	**Sample A**	6.1	12.95	14.42	2.1	393.64	1968.61
	Sample B	5.99	10.71	14.77	3.89	385.11	1938.29
	Sample C	6.9	12.82	15.67	2.52	319.84	1749.04
	F value	5.02	2.63	4.00	11.89	0.06	81.62
	p-value*	0.052	0.151	0.079	**0.008**	0.946	**<0.001**
	* One way ANOVA						

According to the present study, the drying process had a significant effect on the fat content (p-value = 0.008) and tannin levels (p-value < 0.001). Conversely, other nutrients did not deviate much. No studies were available regarding the nutrient composition of a blend of leaves, buds and flowers of *Cassia auriculata*. A study by Sahoo*et al.*, 2023 has analysed the nutritional composition of *Cassia auriculata*flowers alone.

Table 2: ANOVA for Micronutrient analysis of three batches of *Cassia auriculata*powder

Micro nutrients	Batch I			Batch II			Batch III			F value	p-value*
	A	B	C	A	B	C	A	B	C		
Calcium (PPM)	5910 .72	5419 .68	6051	5610 .63	5119 .54	6451 .06	6310 .72	5919 .27	6951 .65	4.59	0.062
Iron (PPM)	201.41	182.02	185.44	210.32	182.54	205.69	178.62	182.36	165.37	0.77	0.503
Sodium (PPM)	300.96	268.66	332.2	289.64	287.32	358.16	353.29	234.22	305.31	4.43	0.066
Potassium (PPM)	10380 .37	10297 .55	11100 .94	10529 .69	10569 .35	11129 .14	10684 .56	10297 .55	11070 .37	26.25	**0.001**

Zinc (PPM)	17.87	17.32	18.29	17.63	17.14	18.02	17.99	17.93	18.53	5.57	**0.043**
Lead (PPM)	0.03	0.3	0	0.04	0.34	0	0.02	0.36	0	296.16	**<0.01**
Selenium (PPM)	1.87	2.23	3.02	1.63	2.86	3.47	1.99	2.25	2.97	16.6	**0.004**
Molybdenum (PPM)	0.18	0.08	0.1	0.13	0.02	0.12	0.17	0.09	0.13	9.65	**0.013**
Manganese (PPM)	51.45	47.27	39.15	50.21	46.38	40.01	52.44	47.94	39.96	150.04	**<0.01**
Magnesium (PPM)	1947.95	1777.44	2104.34	1925.37	1770.29	2113.06	1951.325	1767.94	2109.454	1052.69	**<0.01**
Copper (PPM)	6.2	6.65	7.18	6.08	6.13	7.53	6.29	6.98	7.67	14.7	**0.005**

In Table 2, represented data indicated that Batch II emerges with distinctive characteristics, demonstrating statistically significant differences (p-value < 0.01) in potassium levels, showcasing the highest concentration at 11129.14 ppm (shade dried). Significant differences in zinc levels among batches (p-value = 0.043), with Batch III, specifically the shade-dried sample, containing the highest concentration at 18.53 ppm were observed.

Manganese levels vary significantly among batches (p-value < 0.01), with Batch III, the solar dried sample, displaying the highest concentration at 52.44 ppm.The statistical analysis reveals significant differences in selenium levels among batches (p-value = 0.004), with Batch II, the shade-dried sample, exhibiting the highest concentration at 3.47 ppm.Batch III demonstrates significant differences in calcium content (p-value = 0.062), shade dried sample having the highest concentration at 6951.65 ppm.

Calcium content varies across the samples; with shade dried samples exhibiting the highest mean concentration at 6484.57 ppm, followed by Solar dried samples and Cabinet dried samples at 5944.02 ppm and 5486.16 ppm, respectively. Iron levels also show variability, with solar dried sample having the highest mean concentration at 196.78 ppm, followed by shade dried sample and cabinet dried sample at 185.5 ppm and 182.30 ppm, respectively.

Sodium concentrations are highest in the shade-dried sample at 331.89 ppm, followed by solar dried sample and cabinet dried sample at 314.63 ppm and 263.4 ppm, respectively. The highest mean concentration of potassium is seen in the shade-dried sample at 11100.2 ppm, followed closely by solar dried sample and cabinet dried sample at 10531.5 ppm and 10388.2 ppm, respectively.

Shade dried sample having the highest mean zinc concentration at 18.28 ppm, followed by solar dried sample (17.83 ppm) and cabinet dried sample (17.46 ppm). Shade dried sample displaying the highest mean concentration of selenium at 3.15 ppm.Shade-dried samples did not even have traces of lead making it the best choice among the 3 methods of dehydration. In all three batches, the shade-dried sample registering the lowest mean at 0 ppm.

The analysis of micronutrients in three distinct batches of *Cassia auriculata* samples that were subjected to three different drying methods has revealed significant variations among the groups_ in to the macronutrient analysis. Iron levels in the samples did not show significant differences between the groups. Calcium and sodium were close to significance levels which may be attributed to the small sample size. Significant differences were found between the groups for potassium (p-value = 0.001) zinc (p-value = 0.043), lead (p-value <0.001) selenium (p-value = 0.004) molybdenum (p-value = 0.013) manganese (p-value <0.001) magnesium (p-value <0.001) and copper (p-value = 0.005). The analysis clearly shows that there are differences in the micronutrients based on the method of drying *Cassia auriculata.*

Table 3: Macronutrient analysis in different types of *Cassia auriculata* powder

S. No.	Parameters	Mean			Method of Analysis
		Sample A (Solar)	Sample B (Cabinet)	Sample C (Shade)	
1.	Ash (%)	6.29	5.76	6.53	AOAC, 21st Edition 2019, Method 923.03
2.	Protein (%)	12.35	11.31	12.15	Kjeldahl method
3.	Crude fiber (%)	14.99	15.24	16.20	Fibra plus method
4.	Fat (%)	2.40	3.46	2.52	Soxhlet method
5.	Calorific value (Kcal/100g)	350.31	345.11	356.51	DGHS method
6.	Tannins (mg/100g)	1971.94	1958.29	1765.71	Biochemical methods, 2nd Edition 1996

Mean Macronutrients, and Micronutrients in different types of *Cassia auriculata* powder:

The present study had found that the addition of leaves, and buds along with flowers increases it's protein value. Moreover solar drying has the highest percentage of protein. Khyadeand team have found that the dried seeds had a higher protein levels (23.83%) (Khyade*et al.,* 2020). The addition of higher quantity of seeds can increase the protein value of the dried powder.

These findings underscore the importance of considering the multifaceted nutritional aspects of foods to tailor dietary choices based on individual health goals and nutritional requirements. These results highlight the nutritional composition among the different samples, providing valuable insights for further analysis and potential clinical applications.

Shade-drying demonstrates notable strengths in providing higher concentrations of essential minerals making it a potentially valuable choice for individuals seeking a nutrient-rich dietary option. Both macro nutrient and mineral analyses revealed that shade-dry samples were superior in nutritional properties compared to solar and cabinet drying methods. The flowers, buds and leaves powder appears to offer a better nutritional profile, especially with higher protein and fiber content. This could make it a more comprehensive dietary supplement, providing not only the macronutrients but also many essential minerals specifically like iron and zinc.

Table 4: Micronutrient analysis of different *Cassia auriculata* powder samples

S. No.	Minerals	Mean			Method of Analysis
		Sample A (Solar)	Sample B (Cabinet)	Sample C (Shade)	
1.	Calcium (ppm)	5944.02	5486.16	6484.57	ICP-OES method
2.	Iron (ppm)	196.78	182.30	185.5	
3.	Sodium (ppm)	314.63	263.4	331.89	
4.	Potassium (ppm)	10531.5	10388.2	11100.2	
5.	Zinc (ppm)	17.83	17.46	18.28	
6.	Lead (ppm)	0.03	0.30	0.0	

7.	Selenium(ppm)	1.83	2.45	3.15	ICP-OES method
8.	Molybdenum(ppm)	0.16	0.06	0.12	
9.	Manganese(ppm)	51.36	47.19	39.70	
10.	Magnesium(ppm)	1941.55	1771.89	2108.95	
11.	Copper(ppm)	6.19	6.58	7.46	

Table 4 lists the mean mineral analysis of three samples (Solar, Cabinet and Shade) that provides valuable insights into their respective compositions, with notable variations in key elements.

In summary, Sample C (Shade) demonstrates notable strengths in providing higher concentrations of essential minerals such as calcium, potassium, selenium, magnesium, and copper, making it a potentially valuable choice for individuals seeking a nutrient-rich dietary option. However, individual dietary preferences and health goals should be considered when incorporating these findings into dietary choices. Both macro-nutrient and micro-nutrient analyses reveals that shade-dry samples are superior in nutritional properties compared to solar and cabinet drying methods.

The flowers, buds and leaves powder appears to offer a more balanced nutritional profile, especially with higher protein and fiber content. This could make it a more comprehensive dietary supplement, providing not only essential minerals like iron and zinc but also contributing to protein and fiber intake. The variations in nutritional content emphasize the importance of considering different parts of the plant for potential health benefits and dietary diversity.

CONCLUSION:

The study utilized three distinct drying methods, namely solar, cabinet, and shade drying, to dry *Cassia auriculata* leaves (70%) and flowers & buds (30%). From one kilogram of fresh flowers, buds and leaves, 400 grams of dried *Cassia auriculata* powder could be obtained in the ratio of 5:2 at 40% recovery. The dried samples were then ground into powder, and 100 grams of each dried and powdered sample were labelled as A, B, and C for nutrient analysis. Macro and micro nutrient analysis was carried out on all three samples.

Comprehensive proximate analysis revealed significant variations in fat content ($p<0.008$) and tannins ($p<0.001$) across drying methods. Mineral profiling demonstrated notable differences in potassium ($p=0.001$), selenium ($p=0.004$), magnesium ($p<0.001$), and copper ($p=0.005$) concentrations among the samples. Shade-dried samples exhibited superior nutrient retention, maintaining higher levels of essential minerals including calcium (6484.57 mg/kg), potassium (11100.2 mg/kg), and magnesium (2108.95 mg/kg) compared to solar and cabinet drying methods. Additionally, shade drying preserved the highest crude fiber content (16.20%) and protein levels (12.15%).

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The results indicated that shade drying was the most effective method for drying *Cassia auriculata*, with the highest nutrient retention compared to solar and cabinet drying methods. Solar drying followed shade drying in terms of nutrient retention. The shade-dried *Cassia auriculata* powder had a lovely green colour, while solar and cabinet drying resulted in light yellow and light brown colours, respectively. The freshness of the *Cassia auriculata* powder was most noticeable in the shade drying method. The study concluded that shade drying was the optimal drying method based on its cost-effectiveness, quality preservation, and drying efficiency.

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