

ORIGINAL ARTICLE

Physicochemical characterization of tamarind pulp powders obtained by foam mat drying at different temperatures

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Abstract

This study evaluated the physicochemical properties of tamarind (*Tamarindus indica* L.) pulp powders obtained by foam mat drying at temperatures ranging from 60 °C to 85 °C. Analyses included ascorbic acid, titratable acidity, soluble solids, color (L^* , a^* , b^* , chroma, hue), water, ash, proteins, lipids, carbohydrates, and fibers. Higher drying temperatures increased soluble solids and carbohydrates, while lipids and ash reached maximum values at moderate temperatures (65 °C to 75 °C) before decreasing. Ascorbic acid, titratable acidity, and color parameters declined continuously with increasing temperature, indicating thermal sensitivity. Protein content remained stable, demonstrating thermal resistance. Foam mat drying proved to be a viable technique to produce tamarind pulp powder with preserved nutritional value, especially at 65 °C, which maintained adequate levels of lipids, minerals, and proteins. The powders obtained under these conditions have potential application in beverages, bakery products, and snacks, contributing to the development of new functional foods.

Keywords: Drying process; Functional properties; Nutritional composition; Color parameters; Ascorbic acid; Thermal sensitivity.

Highlights

- Soluble solids and carbohydrates increased with higher drying temperatures
- Ascorbic acid, acidity, and color parameters decreased due to thermal sensitivity
- Foam mat drying is a viable technique to produce quality tamarind pulp powder



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1 Introduction

Tamarind (*Tamarindus indica* L.) is a fruit native to India and Africa that has adapted well to Brazil, especially in the North and Northeast regions. Its soft, thick, brownish pulp has an acidic and sweet flavor. Tamarind is rich in soluble fiber, sugars, tartaric, citric, and malic acids, as well as phenolic compounds, with antioxidant potential (Amaral et al., 2022; Azad, 2018; Bowe & Haq, 2010).

Fruit trade and industrialization are common practices globally. According to the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, 2023), Brazil is the world's third largest producer of fruits, with an annual production of 41 million tons. Twenty-one fruits produced in the country generated R\$76.1 billion in production value, representing an increase of 16.7% compared to the previous year. Given the growing demand for new foods with high nutritional and functional value, tamarind is a fruit that should be widely explored. Furthermore, with the rising costs of conventional foods and the often insufficient supply, tamarind emerges as a viable alternative due to its rich nutritional composition, functional properties, and adaptability to Brazilian regions (Amaral et al., 2022; Silva et al., 2020). Its potential for the production of a variety of industrial products, such as powdered pulp and juice concentrate, places it in a strategic position in the market (Azad, 2018; Vieira et al., 2011).

In this context, agroforestry systems play a fundamental role in environmental, economic, and social sustainability, especially on small rural properties. In the Brazilian state of Goiás, the inclusion of tamarind in these systems represents a viable alternative for diversifying production and increasing family income, since its fruits are in high demand in the local market, whether for fresh consumption or for the production of pulp and derivatives. In addition, tamarind contributes to soil and biodiversity conservation, promoting the circulation of nutrients and reducing the need for chemical inputs (Camargos et al., 2013). Investing in the exploration of this fruit cannot only diversify the food supply, but also add value to national agricultural production.

Understanding the composition of a food matrix is essential for the development and application of more appropriate processing technologies. This allows for improving food stability during storage, transportation, and marketing. Drying, in particular, is an important technique in this process, with the aim of reducing water activity, which inhibits several undesirable reactions (Fellows, 2022; Fennema et al., 2017).

Considering the current trends for nutritious and quick-to-prepare foods, the dehydration of fruit pulp for use in instant beverages emerges as an interesting alternative, with great economic potential, replacing similar artificial products currently on the market.

However, little information is available on the use of foam bed techniques in the dehydration of tamarind pulp as a preservation method, as well as on the impact of these processes on the chemical composition of the pulp. Foam mat drying presents several advantages compared to simple convection drying. While conventional hot air drying is often associated with long processing times, high energy consumption, and degradation of heat-sensitive compounds, foam mat drying promotes faster moisture removal due to the increased surface area created by foam formation. This method allows the drying process to occur at relatively lower temperatures and shorter times, which helps to preserve bioactive compounds, color, and flavor. Additionally, the use of foaming agents improves powder solubility and rehydration capacity, resulting in a final product with superior quality and functionality compared to powders obtained by simple convection drying (Cól et al., 2021; El-Salam et al., 2021). Therefore, this study aimed to evaluate the kinetics of foam bed drying of tamarind pulp and to investigate the effects of this process on the chemical composition of the dried pulp.

2 Material and methods

2.1 Raw material

The tamarinds in Figure 1 were purchased from the State Supply Center (Centrais Estaduais de Abastecimento - CEASA) in the city of Anápolis, Goiás, Brazil. The fruits were transported to the Laboratory

of Drying and Storage of Vegetable Products of the State University of Goiás, Central Campus - Anápolis, in plastic packaging made of low density polyethylene and stored under refrigeration (7 ± 1 °C) in a Biochemical Oxygen Demand (B.O.D.) incubator until processing. Subsequently, they were manually selected, eliminating fruits with damaged skins, diseases, and green ones. The fruits were sanitized with a sodium hypochlorite solution (100 mg L^{-1}) for 15 minutes. After sanitization, the fruits were rinsed and sent for pulp extraction. To extract the tamarind pulp, the fruits were peeled and immersed in filtered water, in a ratio of 1:1.5 (w/v) (1 kg of fruit to 1.5 L of water), for two hours to hydrate at room temperature (23.17 ± 1.66 °C). After hydration, the fruits were manually pulped, using a common stainless steel sieve, in order to separate the pulp from the seed. The foam was prepared by adding 2% (w/w) Emustab® (Brazil) and 2% (w/w) albumin as foaming agents to the tamarind pulp, which were homogenized using a domestic mixer for 15 minutes until a stable foam was formed. No modified starches, gum arabic, or other drying aids were added. The drying process was carried out in a tray dryer (Marconi/MA035/5, Brazil), with forced air circulation, at temperatures of 60 °C, 65 °C, 70 °C, 75 °C, 80 °C, and 85 °C until constant weight was achieved. The dried foams were then ground, sieved (60 mesh), and stored in hermetically sealed polyethylene packages until analysis.



Figure 1. Tamarinds purchased from CEASA, in the city of Anápolis, Goiás, Brazil.

2.2 Physicochemical properties of tamarind *in natura* pulp and powder

The physicochemical properties of the pulp and powders resulting from the drying of tamarind pulp in a foam bed were analyzed at the Food Research Center of the Federal University of Goiás and at the Post-Harvest Laboratory of the State University of Goiás. The reagents used in the characterization analyses of the tamarind pulp, *in natura* and the powder, are of analytical grade and provided by both the State University of Goiás and the Federal University of Goiás. All analyses were performed in triplicate, and the results are expressed as mean values $\pm$ standard deviation.

2.2.1 Soluble solids

The soluble solids contents were determined by refractometric reading, with a portable digital refractometer (Reichert, Brix/RI-Chek, United States), as described by the Association of Official Analytical Chemists (2016) and expressed in °Brix at 25 °C.

2.2.2 Water content

The initial water content of the tamarind foam was determined according to the Association of Official Analytical Chemists (2016), using an oven with air circulation, at 105 °C until reaching constant mass. The water content of the samples was estimated using Equation 1.

$$U(\%) = \left(\frac{m_u - m_s}{m_s} \right) \times 100 \quad (1)$$

where: m_s is the dry mass (kg), m_u is the wet mass (kg), and U is the water content, in % d.b.

2.2.3 Color

The instrumental color parameters were obtained by reflectance, with a colorimeter (Konica Minolta, CR-400), with CIE L^* , a^* , and b^* scale. From the values obtained, the Chroma and Hue angle were calculated. The L^* coordinate indicates how dark (0) and how light (100) the product is; the a^* coordinate is related to the intensity from green (-a) to red (+a); and the b^* coordinate is related to the intensity from blue (-b) to yellow (+b). The Chroma indicates the saturation or intensity of the color (0 to 60), while the Hue angle (°Hue) is the angle formed between the a^* and b^* coordinates, with which the real color of the sample is obtained (0 to 360°).

2.2.4 Proteins

Protein content was determined using the Kjeldahl method, and nitrogen content was multiplied by a factor of 6.25, resulting in crude protein content (Association of Official Analytical Chemists, 2016).

2.2.5 Ethereal extract

The ether extract was determined using the hot extraction method in a Soxhlet extractor, with petroleum ether P.A (Association of Official Analytical Chemists, 2016).

2.2.6 Ashes

To determine the ash content, the gravimetric method was used, with a muffle furnace at 550 °C, until a constant mass and light ash were obtained (Association of Official Analytical Chemists, 2016).

2.2.7 Total dietary fiber

The determination of total dietary fiber content was performed using the non-enzymatic gravimetric method, according to the method described by Li & Cardozo (1992), modified by Guerra et al. (2004).

2.2.8 Carbohydrates

The carbohydrate content was estimated by the difference method, subtracting the values of water, ether extract, protein, fiber, and ash from one hundred (Association of Official Analytical Chemists, 2016).

2.2.9 Titratable acidity

Titrate acidity was determined by titration with NaOH (0.1 mol L⁻¹). The results will be expressed as a percentage (%) of tartaric acid (Association of Official Analytical Chemists, 2016).

2.2.10 Ascorbic acid

To determine the ascorbic acid content, the methodology described by Benassi & Antunes (1988) was used, by means of oxidative titration, with 2,6-dichlorophenolindophenol at 0.02%. The results were expressed in mg of ascorbic acid per 100 mg of sample.

3 Results and discussions

As shown in Figure 2, the raw pulp had a relatively darker color, $L^* = 41.23$, with a slight tendency towards red, $a^* = 8.79$, and yellow, $b^* = 19.12$, reinforced by the yellowish tone of the Hue angle, $^{\circ}\text{Hue} = 65.96$, and a moderate color saturation, $C = 21.06$ (Figure 2). The color of tamarind is derived mainly from the yellow flavonoid pigments and anthocyanins (Silva et al., 2014).

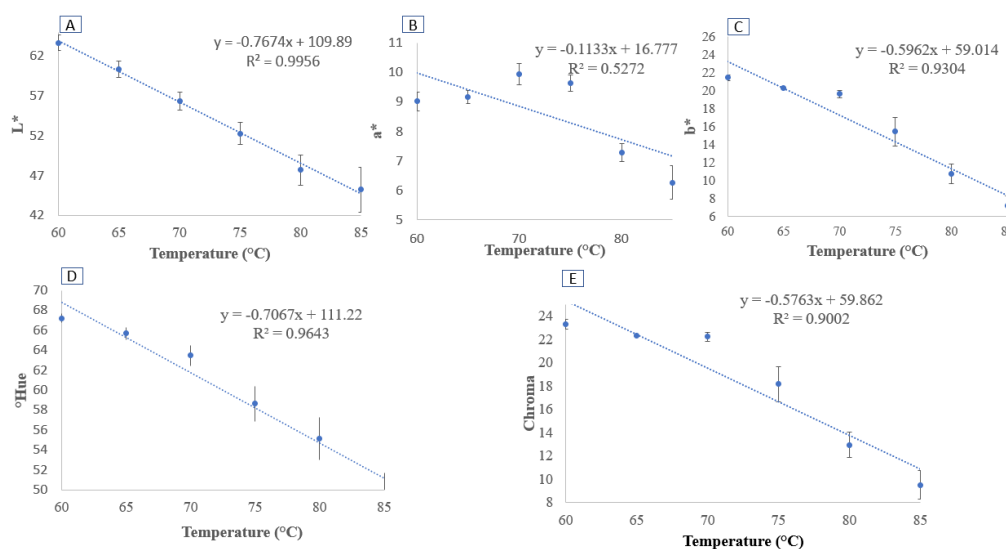


Figure 2. Relationship between temperature and luminosity (L^*) (A), a^* (B), b^* (C), Hue angle ($^{\circ}\text{Hue}$) (D), and Chroma (E) with linear regression adjustment.

Silva et al. (2008), when studying tamarind pulp, found a darker pulp, $L^* = 27.87$, and an orange hue, $^{\circ}\text{Hue} = 73.53^{\circ}$. The tamarind pulp studied by Obulesu & Bhattacharya (2011) was lighter, $L^* = 65.5$, and more greenish yellow, $a^* = -6.5$, and $b^* = 27.5$. Table 1 presents the average values for the color parameters of the fresh pulp and the dried tamarind pulp in a foam bed at the temperatures studied.

Table 1. Mean values $\pm$ standard deviation of luminosity (L^*), a^* , b^* , Hue angle ($^{\circ}\text{Hue}$), and Chroma of the fresh pulp and tamarind pulps dried in a foam bed.

Treatments	L^*	a^*	b^*	$^{\circ}\text{Hue}$	Chroma
Pulp	41.23 ± 0.28	8.79 ± 0.89	19.12 ± 1.80	65.96 ± 0.45	21.06 ± 2.01
60 °C	63.68 ± 0.99	9.03 ± 0.31	21.47 ± 0.32	67.19 ± 0.45	23.29 ± 0.41
65 °C	60.34 ± 1.03	9.18 ± 0.22	20.30 ± 0.07	65.69 ± 0.60	22.30 ± 0.02
70 °C	56.35 ± 1.12	9.96 ± 0.36	19.62 ± 0.44	63.46 ± 1.03	22.23 ± 0.40
75 °C	52.26 ± 1.39	9.65 ± 0.28	15.45 ± 1.59	58.66 ± 1.75	18.17 ± 1.50
80 °C	47.69 ± 1.85	7.29 ± 0.31	10.73 ± 1.10	55.13 ± 2.10	12.97 ± 1.06
85 °C	45.23 ± 2.83	6.26 ± 0.56	7.18 ± 1.12	49.75 ± 1.94	9.53 ± 1.21

Table 2 shows the variance analyses for the color parameters as a function of the foam mat drying temperature of tamarind pulp. For all parameters analyzed, the influence of temperature is highly significant ($p < 0.01$), indicating that changes in this treatment have a statistically relevant impact on the dependent variables and low values of the coefficient of variation ($< 6\%$), indicating good precision and experimental control.

Table 2. Analysis of Variance (ANOVA) for the variables L*, a*, b*, Hue Angle, and Chroma as a function of the foam bed drying temperature of tamarind pulp.

Analysis of Variance Table						
		MS				
	DF	L*	a*	b*	°Hue	Chroma
Temperature	5	157.1917**	6.8769*	101.6755**	130.7543**	98.3102**
Error	12	2.789,056	0.1293	0.8921	2.159,172	0.8685
CV (%)		3.09	4.19	5.92	2.45	5.12

Mean square values (MS); degrees of freedom (DF); coefficient of variation (CV%); **significant at 1% probability by the F-test;

*significant at 5% probability by the F-test.

It can be seen in Figure 2 that the tamarind pulp powder presented a strong negative linear relationship between temperature and color parameters, and the high R^2 values, above 88%, indicate a good fit of the models, with the exception of the a* parameter.

In Figure 3, it is possible to observe a progressive change in the color of the dried tamarind pulp as the temperature increases. As the temperature rises, the pulp becomes darker and less saturated, presenting lower L* and Chroma values. At the same time, there is an intensification of the red color and a reduction in the °Hue value, as shown in the results. This phenomenon occurs due to the degradation of the pigments present in the pulp and the Maillard reactions, which are influenced by the drying heat (Fellows, 2022; Fennema et al., 2017). These changes result in a change in the color of dried foods as a function of the increase in temperature. This behavior was also observed by Silva et al. (2008) in dried tamarind pulps, by El-Salam et al. (2021) in papaya pulp dried in a foam bed and by Yang et al. (2024) in dried apricots by different drying methods.



Figure 3. Tamarind pulps dried on a foam bed at temperatures of 60 °C, 65 °C, 70 °C, 75 °C, 80 °C, and 85 °C, from left to right.

When comparing the result of the L* parameter of the raw pulp with the results of the drying temperatures, increases were noted that may be related to the addition of the Emustab® additive and the foam formation process. When incorporating air, the color change was favored, making the sample lighter. This behavior was also observed by Cól et al. (2021) when drying *bacaba* pulp in a foam bed. The presence of copper, iron and oxygen ions, the oxidation of ascorbic acid (vitamin C) to dehydroascorbic acid (DHA) is accompanied by the formation of hydrogen peroxide. This last compound degrades anthocyanins, which implies the loss of color of

the food. Thus, the modification in the L^* parameter and $^{\circ}$ Hue with the increase in drying temperatures may be related to the oxidative process of anthocyanin caused by the degradation of ascorbic acid (Castro et al., 2017).

The parameter a^* maintains relatively stable values between 60 °C and 75 °C, with an increase at 70 °C, followed by a reduction from 80 °C and 85 °C (Table 1 and Figure 2). This decrease may be associated with the degradation of compounds responsible for the reddish coloration, such as carotenoids and anthocyanins. While the progressive reduction of the parameter b^* , with increasing temperature, reaching the lowest value at 85 °C (Table 1 and Figure 2), suggests degradation of yellow pigments and possible oxidative reactions (Castro et al., 2017; Patras et al., 2010; Rodriguez-Amaya, 2019).

$^{\circ}$ Hue increased at 60 °C, presenting a yellowish hue, but decreased after 70 °C, indicating a change in Hue values to more reddish tones (Table 1 and Figures 2 and 3). The reduction at 85 °C may be associated with the loss of color precursor compounds. Chroma also increased at 60 °C and 65 °C, but decreased above 70 °C, reaching its lowest value at 85 °C (Table 1 and Figure 2), making the pulp less vibrant and more opaque with increasing temperature. This suggests color fading, a possible decrease in the manipulation of chromophore compounds, and a reduction in the visual intensity of the color of the dry pulp (Pandiselvam et al., 2023). In addition to the individual regression analyses, a joint evaluation of the color parameters was carried out using percentage variations ($\Delta\%$) relative to the fresh pulp baseline (Figure 4). This approach highlights the multivariate response of tamarind pulp color to drying temperatures. The heatmap shows that temperatures above 80 °C led to the most pronounced changes, with marked decreases in b (yellow component) and Chroma (saturation), together with lower Hue values, consistent with pigment degradation and Maillard reactions. These results suggest that drying at 85 °C, and even at 80 °C under stricter preservation criteria, should be excluded from the recommended operating range. In contrast, the interval of 60 °C to 75 °C ensured better color stability while still allowing adequate drying performance.

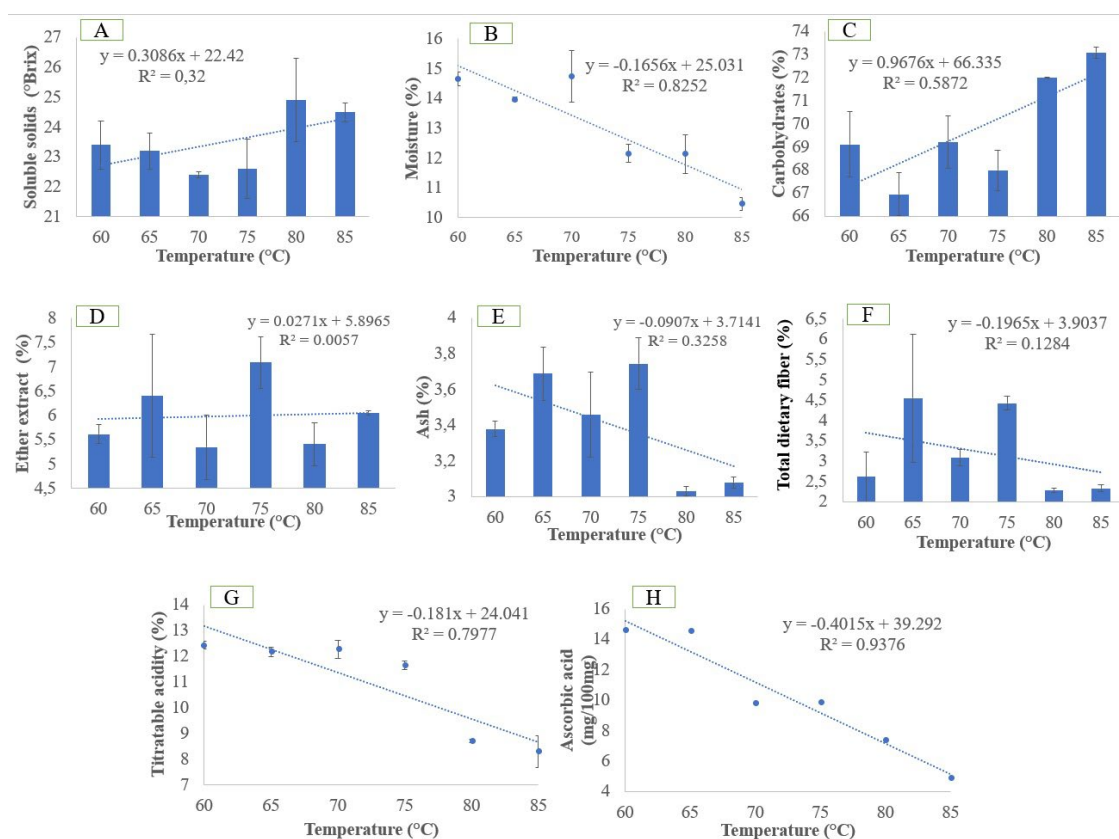


Figure 4. Relationship between the temperature of soluble solids (A), water (B), carbohydrates (C), ether extract (D), ash (E), total dietary fiber (F), titratable acidity (G) and ascorbic acid (H) with linear regression adjustment.

Soluble solids (SS), expressed in °Brix, reached their maximum content at 80 °C (24.9 ± 1.401 °Brix) (Table 3 and Figure 4A), followed by a reduction at 85 °C. The root mean square (QS) value was 2.9263 (Table 4), which strongly indicates that temperature had a significant effect on dissolved solids. This behavior can be explained by the increase in solids during drying, when water was removed. However, the decrease in SS at high temperatures may be related to the thermal degradation of soluble compounds, such as monosaccharides. Sousa et al. (2020) demonstrated that, with increasing pulp drying temperature, there is an increase in soluble solids to a certain extent, while higher temperatures lead to a loss of soluble solids. Almeida et al. (2020) extracted potato flour from a fluidized bed and investigated the effect of temperature on material properties, finding that total solids were higher when temperature was applied.

Table 3. Mean content and standard deviations of moisture content (U), soluble solids (SS), carbohydrates (CHO), proteins (PTN), ether extract (LIP), ash (MIN), total dietary fiber (TDF), titratable acidity (TA), and ascorbic acid (AA) of the fresh pulp and tamarind pulps dried in a foam bed.

Treatments	U	SS	CHO	PTN	LIP	MIN	TDF	TA	AA
	(%)	(°Brix)	(%)	(%)	(%)	(%)	(%)	(%)	(mg/100mg)
Pulp	75.924 ± 0.04	22.3 ± 0.15	19.272 ± 0.05	1.799 ± 0.03	0.186 ± 0.01	0.821 ± 0.02	2.000 ± 0.03	3.136 ± 0.11	26.67 ± 4.63
60 °C	14.654 ± 0.23	23.4 ± 0.81	69.101 ± 1.41	4.632 ± 0.71	5.622 ± 0.19	3.379 ± 0.04	2.613 ± 0.61	12.424 ± 0.15	14.634 ± 1.51
65 °C	13.969 ± 0.07	23.2 ± 0.61	66.949 ± 0.91	4.436 ± 0.77	6.408 ± 1.26	3.688 ± 0.14	4.550 ± 1.57	12.168 ± 0.18	14.563 ± 0.08
70 °C	14.741 ± 0.87	22.4 ± 0.1	69.206 ± 1.14	4.147 ± 0.35	5.352 ± 0.66	3.458 ± 0.23	3.095 ± 0.20	12.266 ± 0.34	9.804 ± 0.17
75 °C	12.160 ± 0.30	22.6 ± 1.00	67.980 ± 0.86	4.606 ± 0.75	7.090 ± 0.53	3.743 ± 0.14	4.422 ± 0.16	11.644 ± 0.17	9.852 ± 0.04
80 °C	12.139 ± 0.65	24.9 ± 1.40	72.006 ± 0.00	5.125 ± 0.30	5.416 ± 0.44	3.032 ± 0.02	2.283 ± 0.05	8.709 ± 0.07	7.389 ± 0.09
85 °C	10.471 ± 0.21	24.5 ± 0.32	73.085 ± 0.25	5.057 ± 0.15	6.059 ± 0.04	3.081 ± 0.03	2.332 ± 0.09	8.288 ± 0.62	4.878 ± 0.03

Table 4. Analysis of Variance (ANOVA) for the chemical variables as a function of the drying temperature of tamarind pulps dried in a foam bed.

Analysis of Variance Table										
	MS									
	DF	SS (°Brix)	U (%)	CHO (%)	PTN (%)	LIP (%)	MIN (%)	TDF (%)	TA (%)	AA (mg/100mg)
Temperature	5	2.9263*	8.6628**	16.2529**	0.4531 ^{ns}	1.3548*	0.2651**	3.1851**	10.0591**	94.5000**
Error	12	0.6877	0.1971	0.8249	0.3145	0.4108	0.0171	0.4909	0.0990	1.0000
CV (%)		3.51	3.41	1.30	11.98	10.70	3.86	21.81	2.88	4.32

Mean square values (MS), degrees of freedom (DF), coefficient of variation (CV%), soluble solids (SS), moisture (U), carbohydrates (CHO), proteins (PTN), ether extract (LIP), ash (MIN), total dietary fiber (TDF), total titratable acidity (TA), and ascorbic acid (AA). **significant at 1% probability by the F-test. *significant at 5% probability by the F-test; ^{ns}not significant by the F-test.

The raw pulp has a high moisture content (Table 3), which is expected, and with increasing drying temperature, moisture content reduces, reaching 10.47% at 85 °C (Table 3), indicating a highly significant effect of temperature on this variable ($p < 0.01$) (Table 4), which confirms the linear regression of moisture content with increasing temperature, showing a sharp decline and a strong correlation ($R^2 = 0.8252$) (Figure 4B).

The carbohydrate content also showed an increasing trend with increasing temperature and reached a maximum value at 85 °C ($73.085\% \pm 0.253\%$) (Table 3 and Figure 4C). This effect is evident with increasing temperature,

as the water content of the samples decreased from 75.924% in the pulp to 10.471% at 85 °C. This increase may be due to the accumulation of natural sugars in the water vapor. According to Santos et al. (2019), drying is a common method of food preservation because the removal of water reduces water activity, inhibits microbial growth, and slows down enzymatic and chemical reactions. These results corroborate the data of Dionello et al. (2009) who showed that drying fruits such as pineapple in the range of 70 to 80 °C promotes sugar absorption, while at higher temperature, sugars decompose through the Maillard reaction and caramelization.

Temperature had no significant effect on protein content, showing little variation and indicating relative thermal stability (Tables 3 and 4). This suggests that, during foam drying, the proteins present in tamarind pulp are less sensitive to heat compared to other constituents, and that this difference in content is due to the concentration of the components after drying. Justus et al. (2020) evaluated the physical and chemical stability of Okara protein hydrolysates microencapsulated by spray drying and observed that the hydrolysates maintained their antioxidant capacity and physical integrity during storage, indicating that the proteins present exhibited thermal stability during the drying process, as well as in the present study. Meneses et al. (2018) showed that proteins in tropical fruits are generally stable at moderate drying temperatures.

The mean value of the ether extract content indicated that heating caused a significant effect (Table 4), with a small variation between temperatures (Table 3), with an increase compared to the pulp, due to the concentration of the components after drying. At high temperatures (above 60 °C), the ether extract content may undergo lipid degradation, such as oxidation or molecular degradation, and its concentration due to water loss during drying may have caused this variation between temperatures. Therefore, thinking only about the preservation of this isolated component, drying at a temperature of about 75 °C is considered the best to preserve the lipids of the tamarind pulp dried using the foam bed method. The ash content showed a small variation between temperatures, with a slight increase (Table 3). In Table 4, the results show a mean square (MS) of 0.265188, and it is classified as highly significant ($p < 0.01$) in the effect of temperature on this parameter, meaning that temperature changes significantly affect the ash content. The regression shows a slight reduction (Figure 4E), but without a clear trend.

The mineral content of dried tamarind pulp increased with increasing drying temperature from 60 °C to 65 °C. However, at higher temperatures, the mineral content begins to decrease and reaches the lowest value at 85 °C (Table 3), suggesting that temperature may influence the volatilization of some minerals, but with a less significant effect. Therefore, it can be inferred that for mineral preservation, the optimum drying temperature should be 75 °C, at which the lowest loss of ash content occurs. Total dietary fibers had a slight concentration with drying (Table 3), confirming the significant effect ($p < 0.01$) of temperature (Table 4). Drying of tamarind foam showed a slight reduction trend (Figure 4F), which may indicate some thermal degradation of the fiber.

The ascorbic acid content (Table 3 and Figure 4H), as well as the titratable acidity (Table 3 and Figure 4G), obtained a negative linear relationship with temperature, with high R^2 values, above 79%, indicating a good fit of the models, probably because both are volatile, showing greater preservation at lower temperatures and an accelerated reduction from 70 °C (Silva et al., 2008). Gonzaga et al. (2021) stated that the reduction in titratable acidity and ascorbic acid levels with increasing temperature may be related to the oxidation of organic acids during the drying process, as shown in Table 3, since tamarind pulp is rich in organic acids such as tartaric, citric, malic, and ascorbic (Vieira Neto, 2002).

Conclusion

Foam mat drying proved to be a viable technique to obtain tamarind pulp powder with preserved nutritional and physicochemical quality. The best results were obtained at 65 °C to 70 °C, a temperature range that ensured color stability, high carbohydrate and soluble solids content, and adequate preservation of lipids, minerals, and proteins. At higher temperatures (≥ 80 °C), significant deterioration of color and ascorbic acid was observed. Therefore, the recommended drying range for tamarind pulp is 65 °C to 70 °C. It is also essential that the dehydration process be conducted in accordance with good manufacturing practices, as this is a critical requirement in food processing plants.

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Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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