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Comparison of powdered and fresh jambu (*Acmella oleracea*)

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ABSTRACT

Jambu, *Acmella oleracea* (L.), is a low-growing herb plant, with cylindrical, fleshy, decumbent and branched stem varying from 20 to 30 cm in height. It is an abundantly cultivated and consumed vegetable in the northern region of Brazil and usually consumed in preparations of typical foods of the Amazon region. So, this work aimed to compare the chemical composition and physical chemistry of powdered and jambu leaf mass. *Acmella oleracea* plants were selected, sanitized and their leaves were crushed (without adding water). The mass was dried in an oven with forced air circulation under different conditions of temperature (60, 70 and 80 °C) and relative humidity (13.09, 8.14 and 5.45%, respectively), in two layer thicknesses (0.5 and 1.0 cm). The physical, chemical, physicochemical parameters moisture content, water activity, ash, protein, lipids, pH, total titratable acidity and color were analyzed in powdered and fresh leaves. Contrast test was used to evaluate the interaction between the layer thicknesses at 5% level of significance. Considering the contrasts, the parameters total soluble solids, ash, protein and lipids do not differ from those in the fresh sample, demonstrating that these parameters are not modified or degraded with the drying conditions. The pH and color parameters differed from those of the fresh material, due to degradation, which can be linked to the rise in temperature sensitivity. The moisture content and water activity also differed and were reduced, contributing to conservation of the material. Contrast analysis made it possible to conclude that the physicochemical composition did not undergo modifications through the use of drying. In addition, a powdered material with reduced water activity was obtained.

1. Introduction

Jambu, *Acmella oleracea* (L.), is a low-growing herb plant, with cylindrical, fleshy, decumbent and branched stem varying from 20 to 30 cm in height. Its inflorescence is a yellow-colored terminal globose capitulum with hermaphrodite flowers. Its leaves and yellow flowers cause a slight tingling and numbness in the tongue due to the presence of spilanthol, which is an alkylamide with various bioactivities of plant protection, including analgesic action (Nascimento et al., 2013; Aguiar et al., 2014; Homma et al., 2014; Veryser et al., 2014).

The plant is a herb abundantly cultivated and consumed in the Northern region of Brazil, especially in the Pará state. It is usually consumed in food preparations that are typical of the Amazon Region, such as '*pato no tucupi*', '*tacacá*', '*frango no tucupi*' and '*peixe no tucupi*' (*pato*, *frango* and *peixe* are words for duck, chicken and fish; *tucupi* is a yellow sauce extracted from wild manioc; *tacacá* is a soup made with jambu, tucupi, dried shrimps and yellow peppers) (Borges et al., 2013; Aguiar et al., 2014).

An important chemical property of the plant has aroused the interest of the pharmaceutical industry, due to the presence of the active ingredient known as spilanthol (Borges et al., 2012). Spilanthol is an alkylamide with several plant protection bioactivities, because it has antibacterial, antifungal and analgesic action (Veryser et al., 2014).

This plant species shows that it can be well appreciated in cooking, as it has benefits for the pharmaceutical industries due to its potential characteristics of vitamins, calcium, iron, among others that are effective for human health (Santos et al., 2019).

Some studies on jambu properties can be found in the literature, such as Barbosa et al. (2016b), who evaluated the occurrence, extraction, chemistry and biological activity of spilanthol, a chemical compound present in jambu, besides technological studies such as: Barbosa et al. (2015), who investigated freeze-drying of jambu; Araújo et al. (2015), who evaluated the mathematical modeling and effective diffusivity of

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fresh jambu leaves during drying; Gomes et al. (2018), who evaluated the drying kinetics of crushed mass of jambu, its effective diffusivity and activation energy; and Barbosa et al. (2016a), who evaluated the microbiological and sensory quality of jambu (*Acmella oleracea L.*) after freeze-drying. However, these studies have not investigated the potential of obtaining jambu powder through convective drying.

The major changes in the Brazilian vegetable market have favored the increase in the number of prepared or semi-ready products for greater practicality of consumption. According to Barbosa et al. (2016a), the increasing interest of consumers in healthier products, made of plant raw materials, and the need for improving postharvest technologies to preserve quality in the long term, given the need for transport and commercialization in several markets, cities or even countries, demonstrates the need for simple and inexpensive processes that allow extremely perishable raw materials to be preserved. One alternative is to use the technology of artificial drying and, for this process, the vegetable needs to be put under controlled conditions of temperature and relative humidity.

Given the above, this study aimed to produce powder from jambu leaf mass through convective drying at different temperatures, characterize the chemical and physicochemical composition of the fresh mass and dehydrated powders, and to compare the chemical composition between powdered and fresh jambu leaf mass.

2. Material and methods

2.1. Obtaining the raw material

Jambu plants were purchased in the municipality of Macapá, AP, Brazil, and taken to the Food Laboratory of the Brazilian Agricultural Research Corporation – Embrapa (Macapá – AP). Botanical identification was carried out by the Institute of Scientific and Technological Research of Amapá (IEPA), and the exsiccate was deposited in the *Amapá's Herbarium* (HAMAB) collection under the code *Acmella oleracea* (L) R.K. Jansen F.P. Gomes 001.

2.2. Jambu processing and drying

Jambu plants were selected, sanitized and its leaves were separated and shredded (with no addition of water) in a food processor to obtain a homogeneous mass.

For the drying conditions of the work in question, a bibliographic survey was carried out and it was found that the usual temperatures for drying in an oven with forced air circulation were within the range from 40 to 80 °C, according to studies by Kaya and Aydin (2009), Sagrin and Chong (2013), Goneli et al. (2014), Martins et al. (2015), and Lima-Corrêa et al. (2017). This mass was dried in a forced air circulation oven under different conditions of temperature (60, 70 and 80 °C), with relative humidity of 13.09, 8.14 and 5.45%, respectively, and layer thicknesses of 0.5 and 1.0 cm. The overall workflow is represented in Figure 1.

The dehydrated material was ground in a mill and stored in laminated packages composed of one layer of transparent PET (transparent low-density polyethylene) and one layer of metallized PET (metallized polyethylene terephthalate).

2.3. Physical and physicochemical characterization of jambu leaf mass and powder

The ground mass of fresh leaves and the dehydrated powders were analyzed, in triplicate, for the physicochemical parameters: moisture content (%); pH (potentiometer); inorganic residue (%), lipids (%) and proteins (%), according to the methodology of Instituto Adolfo Lutz (2008). Water activity at 25 °C was determined in Lab Touch hygrometer - aw brand Novasina. The color in a portable Konica Minolta color meter, obtaining the parameters: lightness ($L^* = 0$ black and $L^* = 100$ white), Coordinates a* ($+a^* =$ red and $-a^* =$ green) and b* ($+b^* =$ yellow and $-b^* =$ blue), Hue angle or Color tone ($h^o = 0°$ = red; 90° = yellow; 180° = green; 270° = blue and 360° = black), chromaticity (C*) (Purity degree: 0 – impure color and 60 – pure color) and total color difference (ΔE^*) (Lawless and Heymann, 2003).

2.4. Statistical analysis

The obtained data were statistically compared by Tukey and contrast tests at 0.05 probability level, using the program Sisvar 5.6 (Ferreira, 2014).

The physical, chemical and physicochemical parameters of the powders compared to the crushed mass of jambu leaf mass before drying were evaluated considering the interactions between the temperatures and the layer thickness of the material on the tray.

The contrast test was applied to the data of chemical and physicochemical characterization of crushed jambu leaf mass and powders, with the interaction between the temperatures and layer thickness at 5% significance level according to Table 1.

3. Results and discussion

3.1. Characterization of ground jambu leaf mass

The results of physicochemical characterization and color are presented in Table 2. The high moisture content obtained in this study may be related to the grinding stage applied to the leaves, which ruptured cellular structures and, consequently, released water from the leaves. However, Chitarra and Chitarra (2005) highlight that water constitutes 80–95% of the composition of vegetables and is responsible for the turgidity of tissues, giving them good appearance.

Behavior similar to that found in this study was observed by Oliveira and Soares (2012) for Amazonian vegetable leaves, with moisture

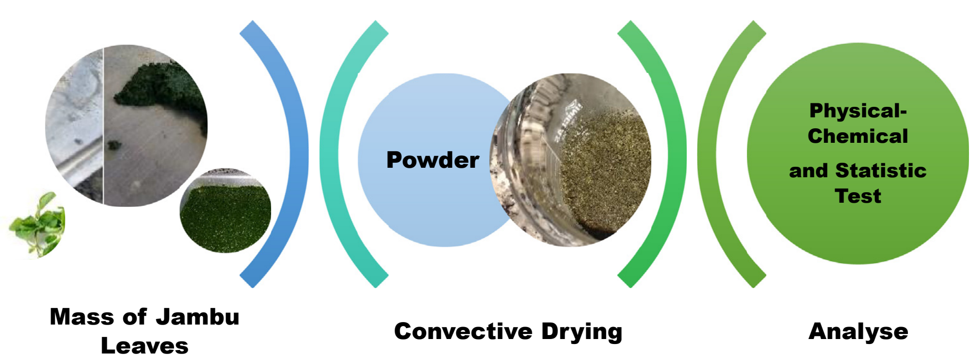

Figure 1. Schematic representation of the production stages of jambu powder from the crushed mass of the leaves.

contents of 90.20% for basil and 87.16% for fresh coriander. Aguiar et al. (2014) studied iron availability in jambu (*Spilanthes oleracea L.*) and found moisture content of 88.6% (w.b.), and Silva (2015) studied minimally processed jambu (*Spilanthes oleracea* L.), its bioactive compounds and physicochemical, microbiological and sensory characterization and reported moisture content of 89.60%.

The color parameters of lightness (L*), coordinated a* and coordinated b* characterize the material with dark color, tending to greenish and yellow. The hue angle (hº) or tonality also indicated green color, and chromaticity (*C**) had low intensity.

In plant tissues, acidity is attributed to organic acids that are dissolved in cell vacuoles and the pH ranges from 5 to 7 (Chitarra and Chitarra, 2005). Silva (2015) reported pH of 6.1 and oxalic acid content of 0.10% for fresh jambu leaves. Values of pH in the range from 5.02 to 6.72 and TTA from 0.11 to 0.27% citric acid were reported by Viana et al. (2015) when studying the composition of the unconventional vegetables 'beldroega' (*Portulaca oleracea*), 'bertalha' (*Basella rubra*), 'caruru' (*Amaranthus viridis*) and 'peixinho' (*Stachis lanata*).

The inorganic content of jambu leaf mass was lower than that observed by Cavalheiro et al. (2014) for different varieties of olive leaves. Higher results than that of the present study were also reported for different unconventional vegetables by Viana et al. (2015), who found ash content from 4.33 to 20.56%.

Like Aguiar et al. (2014), who quantified 3.08% of protein in jambu and considered jambu a basic source of plant protein, the present study obtained similar results. Cavalheiro et al. (2014) quantified protein contents from 7.10 to 12.24% for different varieties of olive leaves, while Viana et al. (2015) described protein contents of 29.34% in 'azedinho' leaves and 12.82% in 'beldroega' leaves.

Jambu is a hypocaloric and hypolipidic vegetable because it has a low lipid concentration of 0.25% (Aguiar et al., 2014). Cavalheiro et al. (2014) quantified lipid contents from 1.30 to 8.14% for different varieties of olive leaves. Viana et al. (2015) quantified values that were 2.16, 3.75, 1.92 and 2.62% higher than that of this study for 'azedinho', 'beldroega', 'caruru' and 'peixinho' leaves, respectively.

3.2. Characterization of jambu powders

The moisture content showed no difference at the different temperatures for the layer thickness of 0.5 cm, while for the thickness of 1.0 cm only the temperature of 60 °C showed difference, an increase in moisture content under this drying condition. Considering the thickness of 1.0 cm, the moisture content tended to decrease with the increase in temperature (Table 3). Water activity (Aw) showed a downward trend with the increase in temperature, with the highest Aw at 60 °C, and did not differ between the study thicknesses only for the temperature of 70 °C. For the 1.0 cm thickness, there was a difference with the increase in temperatures, which was not observed in the 0.5 cm thickness.

The behavior of reduction in moisture content through the drying treatment is explained by considering that the increase in temperature causes a reduction in the relative humidity of the environment, resulting in this reduction in the equilibrium moisture content. This affects water activity, which is directly proportional to the moisture content; the lower the water activity, the lower the availability of water for microbiological, enzymatic and chemical reactions in the food, thus making the product more stable (Damodaran et al., 2010). Oliveira and Soares (2012) when studying Amazonian vegetables reported higher moisture contents for dehydrated basil (8.78% w.b.) and dehydrated coriander (16.71% w.b.) and Couto et al. (2009) when studying the characterization of the leaf powder of *Eugenia dysenterica* D C. ('cagaita' or 'cagaiteira'), found moisture content of 8.15% (w.b.).

The pH of the powders did not show a trend of behavior with the increase in temperature. Differences were found in ash percentages between the layer thicknesses (0.5 and 1.0 cm), except at the temperature of 80 °C. For the 1.0 cm thickness, there was a reduction in ash percentage with the increase in temperature and, for the 0.5 cm thickness, this same behavior was observed at temperatures of 60 and 70 °C.

The inorganic residue of jambu powders described by the present study was higher than those reported by Barni et al. (2009) for the leaf powder of *Ipomoea pes-caprae*, a plant popularly known as "salsa-da-praia" (12.51%), Modesti et al. (2007) for cassava leaf flour (6.83%) and Oliveira and Soares (2012), who found values of 9.27% for dehydrated basil and 12.97% for dehydrated coriander.

In relation to the macronutrients, lipid contents did not show a specific behavior with the increase of treatment temperature and did not differ between thicknesses. The percentage of proteins did not differ with the temperature change for the 0.5 and 1.0 cm layer thickness. Considering the temperatures of 60 and 70 °C, there was a reduction with the increase in drying thickness.

Dehydrated jambu, as well as dehydrated basil (3.41%) and dehydrated coriander (2.60%) (Oliveira and Soares, 2012) are hypocaloric and hypolipidic because they have low lipid concentration. Modesti et al. (2007) reported higher lipid contents for cassava leaf flour (12.0%).

Regarding protein content, dehydrated jambu is an interesting source of this macronutrient, as is dehydrated basil (20.88%), dehydrated coriander (15.14%) (Oliveira and Soares, 2012) and cassava leaf flour, with 34% protein (Modesti et al., 2007).

For the color parameters of jambu powders, there was no difference with the temperature increase for the 1.0 cm thickness. For the 0.5 cm thickness, only the temperatures of 60 and 70 °C differed from each other. The temperature of 80 °C was the only one with no difference between thicknesses. It is observed that the increase in drying temperature caused a tendency of reduction in lightness, characterizing

Table 1. Definitions of treatments and interactions of the contrast test for the chemical, physical and physicochemical composition of the crushed mass of jambu leaf mass before and after drying.

Treatments	Temperature (°C)	Thickness (cm)	Interactions of Treatments
1	60	0.5	
2	60	1.0	1 + 2 vs 7
3	70	0.5	3 + 4 vs 7
4	70	1.0	5 + 6 vs 7
5	80	0.5	
6	80	1.0	1 + 3 + 5 vs 7
7	fresh		2 + 4 + 6 vs 7

Vs: Versus.

Table 2. – Mean values and standard deviations of the physicochemical composition of the ground mass of jambu leaf mass before drying.

Determination	Results (g $100g^{-1}$)
Moisture content (% w.b.)	92.99 ± 0.8
Inorganic residue (%)	1.44 ± 0.07
Proteins (%)	3.35 ± 0.2
Lipids (%)	1.14 ± 0.1
Aw (25 °C)	0.96 ± 0.0
pH	6.25 ± 0.07
TSS (°Brix)	4.00 ± 0.1
TTA (% of tartaric acid)	0.61 ± 0.04
Lightness (L*)	20.22 ± 0.4
Green Intensity (-a*)	-1.98 ± 0.6
Yellow Intensity (b*)	6.64 ± 0.5
Hue Angle (h°)	107.19 ± 4.4
Chromaticity (C*)	6.62 ± 0.6

Aw: Water activity. TSS: Total soluble solids. TTA: Total titratable acidity. Mean and standard deviation obtained from the mean of triplicates.

Table 3. Mean values of physical, chemical and physicochemical characterization and color parameters: L*, a*, b*, hº and C* of jambu powders subjected to drying under different conditions of temperature and thickness.

Determination	Thickness (cm)	Temperature (°C)		
		60	70	80
Moisture content (% w.b.)	0.5	3.68aB	3.72aB	3.76aA
	1.0	6.13aA	4.64bA	4.19bA
Aw (25 °C)	0.5	0.29aB	0.25bA	0.24bA
	1.0	0.34aA	0.25bA	0.18cB
pH	0.5	5.98bA	6.19aA	5.99bA
	1.0	6.04bA	6.15aA	6.03bA
Inorganic residue (%)	0.5	16.99bA	16.49cB	17.42aA
	1.0	16.61bB	17.06aA	17.42aA
Lipids (%)	0.5	8.09abA	8.85aA	6.64bA
	1.0	7.17aA	7.25aA	7.74aA
Proteins (%)	0.5	28.56aA	28.42aA	28.32aA
	1.0	27.62aB	27.36aB	27.62aA
Lightness (L*)	0.5	38.23aB	36.47bB	36.96abA
	1.0	41.22aA	39.15bA	37.83bA
Green intensity (a*)	0.5	-1.85aA	-1.50bA	-1.04cA
	1.0	-1.28aB	-1.16aB	-0.69bB
Yellow intensity (b*)	0.5	14.90abB	14.32bA	15.00aA
	1.0	15.55aA	14.20bA	13.81bB
Hue angle (hº)	0.5	97.07aA	95.98bA	93.98cA
	1.0	94.69aB	94.68aB	92.85bB
Chromaticity (C*)	0.5	15.02aB	14.40aA	15.04aA
	1.0	15.60aA	14.25bA	13.82bB
ΔE*	0.5	19.82aB	17.98bB	18.75abA
	1.0	22.83aA	20.41bA	19.07bA

Aw: Water activity. ΔE: total color difference. Means followed by the same letters, lowercase in rows and uppercase in columns between the two thicknesses, do not differ by Tukey test at 0.05 significance level.

darkening of the material, possibly due to the degradation of heat-sensitive chemical components, responsible for the color.

Based on the color parameters lightness (L*), which comprises the range from 0 (dark) to 100 (white), the coordinate a*, which ranges from positive values corresponding to red color (+a) to negative values characterizing the green color (-a), the coordinate b*, which describes the intensity from yellow (+b*) to blue (-b), chromaticity (*C**) (Purity: 0 – impure color and 60 – pure color) and color variation, defined as very different, ΔE > 3, different, 1.5< ΔE < 3, and little different, ΔE < 1.5 (Adekunte et al., 2010), the dehydrated jambu maintained the characteristics already shown by the mass crushed leaves (fresh), greenish to yellow color and low color intensity.

Considering the contrasts analyzed, the parameters total soluble solids, ash, proteins and lipids did not differ from the values found in the fresh sample, demonstrating that these parameters did not change or degraded with the drying conditions (Table 4).

The pH showed difference at 5% significance level for the interactions of the same temperature and at 1% significance level for the interactions of the same thickness. For the total titratable acidity, there was only difference at the 1% level in the interactions of the same thickness, demonstrating that the changes in the process temperature degraded this property.

In general, the physicochemical composition did not undergo major changes with the use of drying as a method of conservation of jambu, except only for pH, which showed an increase, hence favoring conservation. This increase may be related to the concentration of organic acids present in the raw material, resulting in the removal of water from the product.

Water activity showed a difference at 5% significance level for all contrast interactions. This demonstrates that the powders differ for this characteristic in comparison to the fresh sample.

Reduction of water activity is the basis for the conservation of this raw material, which had high moisture content in its fresh form, minimizes degradation reactions., microbiological nature or even metabolic reactions of the plant. Water activity is an important property for the processing and for the control of conservation and storage conditions of foods.

Of the color parameters evaluated, hue angle (h*) was the only one that showed no difference in all contrasts. Chromaticity (C*) and coordinate b* showed differences at 5% significance level for all contrast interactions. The coordinate a* showed no difference at 5% significance level in the interaction contrasts of the same temperature and different layer thicknesses. For the interactions of the same thickness and different temperatures, the coordinate a* showed difference at the 1% significance level. Lightness differed in the interactions of the same temperature and was altered with the change in thickness.

The contrast interactions of the color parameters demonstrate that there was degradation of constituents responsible for the color of jambu, including chlorophyll. This is due to the sensitivity of these compounds to heat, characterizing a darker-colored product.

The study showed that at higher temperatures and lower thickness, the jambu powder had the lowest values of moisture content and water activity. For the lipid and protein parameters, under the studied conditions, there were no significant indications of degradation. When it

Table 4. Mean square (MS) of contrast analysis of variance.

Contrasts	Aw	TSS	pH	TTA	Ash	Protein
1x2 vs 7	0.009293**	0,000000^{ns}	0,064560**	0.034901^{ns}	0.579713^{ns}	0.001752^{ns}
3x4 vs 7	0.009293**	0,000000^{ns}	0,064560**	0.034901^{ns}	0.579713^{ns}	0.001752^{ns}
5x6 vs 7	0.009293**	0,000000^{ns}	0,064560**	0.034901^{ns}	0.579713^{ns}	0.001752^{ns}
1 × 3 × 5 vs 7	0.004715**	0,000075^{ns}	0,012247*	0.527439*	0.358821^{ns}	1.569383^{ns}
2 × 4 × 6 vs 7	0.004715**	0,000075^{ns}	0,012247*	0.527439*	0.358821^{ns}	1.569383^{ns}
Contrasts	**Lipids**	**L***	**a***	**b***	**C***	**h***
1x2 vs 7	2.782755^{ns}	21.233472**	0.008450^{ns}	1.626006**	1.644089**	0.018050^{ns}
3x4 vs 7	2.782755^{ns}	21.233472**	0.008450^{ns}	1.626006**	1.644089**	0.018050^{ns}
5x6 vs 7	2.782755^{ns}	21.233472**	0.008450^{ns}	1.626006**	1.644089**	0.018050^{ns}
1 × 3 × 5 vs 7	1.467086^{ns}	0.595469^{ns}	0.330625*	1.170003**	1.292011**	3.441025^{ns}
2 × 4 × 6 vs 7	1.467086^{ns}	0.595469^{ns}	0.330625*	1.170003**	1.292011**	3.441025^{ns}

Aw: water activity. TSS: Total Soluble Solids. TTA: Total Titratable Acidity. L: Lightness. a*: Green axis coordinate (-a) to red (+a). b*: Yellow axis coordinate (+b*) to blue (-b). h° Hue Angle. C*: Chromaticity. * significant at the level of 1%. ** significant at the level of 5%. ns: Not significant.

comes to color, it is noted that for a lower temperature (60 °C) there was less degradation, with greater pigment retention and more vivid colors. Therefore, the conditions studied were favorable to the conservation of the powders.

4. Conclusion

The parameters of the analysis of total solids, inorganic residues, proteins and lipids did not show significant difference in the drying conditions, being healthy for the production of powdered jambu; while the parameters of water activity and moisture content decreased.

The contrast analysis allowed to conclude that the physical-chemical composition did not change with the use of drying. In addition, a powder material with reduced water activity was obtained.

Declarations

Author contribution statement

Francileni P. Gomes: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Osvaldo Resende: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Elisabete P. Sousa: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Leandro F. Damasceno: Performed the experiments; Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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