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Stability of cactus-pear powder during storage

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Key words:
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conservation

ABSTRACT
The stability of cactus-pear powder, obtained by the process of spray drying for 40 days, was evaluated under controlled conditions of relative air humidity (83%) and temperature (25 and 40 °C). The whole pulp was characterized with regard to its physico-chemical parameters: pH, total titratable acidity, soluble solids, water content, total solids, ashes, reducing sugars, total sugars, non-reducing sugars, luminosity, redness, yellowness and water activity. The stored samples in powder were evaluated every 10 days for water content, water activity, total titratable acidity and color (luminosity, redness and yellowness). The whole pulp was slightly acidic and perishable, due to the high water content. During storage, the packages did not prevent water absorption, thus increasing water content and, consequently, water activity. Yellowness oscillated along the storage time, but the predominance of the yellow color was not affected.

Palavras-chave:
Opuntia ficus indica Mill.
desidratação
conservação

Estabilidade do figo-da-índia em pó durante o armazenamento

RESUMO
A estabilidade do figo-da-índia em pó obtido pelo processo de secagem por aspersão durante 40 dias foi avaliada em condições controladas de umidade relativa (83%) e temperatura (25 e 40 °C). A polpa integral foi caracterizada quanto aos parâmetros físico-químicos: pH, acidez total titulável, sólidos solúveis totais, teor de água, sólidos totais, cinzas, açúcares redutores, açúcares totais, açúcares não-redutores, luminosidade, intensidade de vermelho, intensidade de amarelo e atividade de água. As amostras em pó armazenadas foram avaliadas a cada 10 dias de acordo com o teor de água, atividade de água, acidez total titulável e cor (luminosidade, intensidade de vermelho e intensidade de amarelo). Verificou-se que a polpa integral se apresentou pouco ácida e perecível devido ao elevado teor de água. Durante o armazenamento as embalagens não evitaram a absorção de água, aumentando, assim, o teor de água e, consequentemente, a atividade de água; a intensidade de amarelo sofreu oscilações durante o armazenamento, porém a predominância da cor amarela não foi afetada.

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Introduction

Cactus pear (*Opuntia ficus indica* Mill.) is a sweet, slightly acidic, succulent fruit, rich in vitamins (A and C) and minerals (calcium and magnesium) and can be consumed fresh or processed in various forms. According to Mobhammer et al. (2006), the use of this fruit is extended to the field of natural food dyes, since the pulp in powder presents itself as a water-soluble, yellow-orange dye.

Drying is one of the most used post-harvest technologies to solve problems such as overproduction/excess of offer and high perishability of fruits (Chong & Law, 2011). Resende et al. (2012) claimed that, for the commercial production of fruit pulp and distribution in distant markets, drying is an advantageous process for fruit pulps, since mass and volume are reduced, which decrease the costs with package and storage.

Spray drying is the transformation of a liquid food into the form of sprayed-dried particles in a hot drying medium (Goula & Adamopoulos, 2005). At the end of the process, it is essential to know the properties of the powder in order to evaluate the influence of drying parameters on the characteristics and stability of the end product (Toneli et al., 2008).

The shelf life of a dehydrated food depends on extrinsic factors, such as size and properties of the package, environmental conditions of storage, transport and handling, and also on intrinsic factors, such as food chemical composition and type and concentration of additives (Cano-Chauca et al., 2005).

This study aimed to evaluate the stability of cactus pear pulp in powder, stored in laminated packages for 40 days under controlled conditions of temperature (25 and 40 °C) and relative air humidity (83%).

Material and Methods

The raw materials used in the study were whole pulps of cactus pear, from the municipality of Boqueirão-PB, and maltodextrin with dextrose equivalent (DE) equal to 10, donated by the company Corn Products.

The formulation containing whole pulp and maltodextrin (Mor Rex®) was elaborated with a concentration of 35%. The formulation was manually homogenized and then analyzed for the parameters pH, total titratable acidity, total soluble solids, water content, total solids, ashes, reducing sugars, total sugars, non-reducing sugars, lightness, redness, yellowness and water activity, following the methodologies described by IAL (2008).

The formulated pulp was dehydrated in a spray dryer (Model LM MSD 1.0 - Labmaq), using a pneumatic nozzle with diameter of 1.2 mm, pumping flow rate of the formulated pulp of 0.5 L h^{-1}, compressed-air flow rate of 0.3 L min^{-1} and temperature of the drying air of 190 °C.

The powder was subjected to accelerated storage under controlled conditions of temperature and relative humidity. The samples were placed in flexible laminated packages containing approximately 8 g of the powder in each, which were sealed using a mechanical sealing machine. Then, three packages containing the samples were placed in hermetic glass containers with solutions saturated by potassium chloride (KCl), which provide an environment with controlled relative humidity of 84.34% at the temperature of 25 °C and 82.32% at the temperature of 40 °C. These containers were placed in BOD chambers at temperatures of 25 and 40 °C.

At the beginning of the storage (time zero) and every 10 days, for 40 days, the stability of the samples in powder was monitored through the determination of quality parameters: water content, water activity and total titratable acidity, using the methodologies described by IAL (2008). Color was determined using a MiniScan XE Plus spectrophotometer (HunterLab®), in which the parameters lightness, redness and yellowness were determined.

The statistical analysis of the experimental data was performed using the computational program ASSISTAT version 7.5 Beta (Silva & Azevedo, 2006). The design was completely randomized, in a 2 x 5 factorial scheme, with 2 temperatures (25 and 40 ºC) and 5 storage times (0, 10, 20, 30 and 40 days) with 3 replicates. Means were compared by Tukey test at 0.05 probability level.

Results and Discussion

The characterization data of cactus pear pulp are shown in Table 1, which shows the mean results and standard deviations found in the determination.

The mean pH value of the whole pulp was 5.59, which classifies it as a slightly acidic food, while the total titratable acidity of the pulp was, on average, 0.07% of citric acid, which is much lower than that reported by Souza et al. (2007), 0.63%.

The total soluble solids (TSS) are compounds dissolved in fruit pulp mainly formed by sugars, which provide sweet or acidic flavor (Almeida et al., 2009). The TSS value observed in the whole pulp was 11.07 °Brix.

The whole pulp of cactus pear showed values of 89.97% (wet basis) and 13.03 for water content and total solids, respectively; thus, these values were similar to those established by Oliveira et al. (2007) for the pulp of branches of 'mandacaru' (*Cereus jamacaru*), 88.36% (wet basis) and 6.66.

The pulp showed mean ash content of 0.30%, which is lower than that reported by Lima (2006), ranging from 1.16 to 1.50% for the pulp of 'facheiro' (*Pilosocereus pachycladus*) extracted from the region of the storing parenchyma.

The contents of reducing, total and non-reducing sugars were 8.51% glucose, 12.13% glucose and 3.66% sucrose, respectively, which were similar to those observed by Oliveira et al. (2011) for reducing sugars (7.27% glucose) and total sugar

Table 1. Mean values of physico-chemical characterization of the whole pulp

Parameters	Mean and standard deviation
ph	5.59 ± 0.010
Total titratable acidity (% citric acid)	0.07 ± 0.000
Total soluble solids (ºBrix)	11.07 ± 0.000
Water content (% wet basis)	86.97 ± 0.350
Total solids (%)	13.03 ± 0.350
Ashes (%)	0.30 ± 0.020
Reducing sugars (% glucose)	8.51 ± 0.210
Total sugars (% glucose)	12.13 ± 0.000
Non-reducing sugars (% sucrose)	3.66 ± 0.170
Lightness (L*)	17.26 ± 0.120
Redness (+a*)	11.12 ± 0.070
Yellowness (+b*)	25.98 ± 0.160
Water activity (a_w)	0.976 ± 0.001

(13% glucose), for the pulp of 'palma' (*Opuntia ficus-indica* (L.) Mill.) fruits, cultivated in the Sertão of Sub-middle São Francisco.

The pulp showed mean values of 17.26 for lightness (L*), 11.12 for redness (+a*) and 25.98 for yellowness (+b*). The observed mean value of yellowness was very expressive, because the pulp showed an orange color. Lisbôa et al. (2012), studying whole pulp of cactus pear, observed values of 26.29, 12.20 and 37.75 for the same parameters, respectively.

Water activity in the pulp was equal to 0.976, which classifies the whole pulp of cactus pear as a food with high water content; thus, it can easily suffer microbiological contamination (Ribeiro & Seravalli, 2007).

The mean values of water content (%, wet basis) of cactus-pear powder, stored at temperatures of 25 and 40 °C and mean relative humidity of 83%, are shown in Table 2.

The water content increased significantly along the storage time for the studied temperatures and this increase was more evident at the temperature of 40 °C; from 3.37 to 7.25% (wet basis) at 25 °C and from 3.37 to 8.36% (wet basis) at 40 °C, i.e., increases of 115% and 148%, respectively. The samples stored at both temperatures were statistically different by Tukey test at 0.05 probability level, from the time of 10 days on, indicating that temperature significantly influenced the absorption of moisture. However, the results show that the type of package used, or its closure, was not efficient at preventing the absorption of moisture by the samples. Thus, the produced sample in powder is a hygroscopic product. Endo et al. (2007) also observed differences between the water contents of passion fruit juice in powder stored in laminated packages for 120 days, in environments at temperatures of 30 and 40 °C and relative humidity of 84%.

The mean values of water activity of the powder, stored at temperatures of 25 and 40 °C and at mean relative humidity of 83%, are shown in Table 3.

The water activity of the samples stored at both temperatures increased gradually along the storage time. This increase was statistically significant between the initial time, 10 and 20 days, with statistically equal values between 20 and 30 days and between 30 and 40 days, at the temperature of 25 °C, and significant differences between the means of 30 and 40 days, compared with the others at the temperature of 40 °C. At the end of the storage time, the samples at the temperatures of 25 and 40 °C showed increases in water activity of 35 and 34%, respectively, which are due to the directly proportional relationship between relative humidity and water activity,

Table 2. Mean* values of water content (%, wet basis) of cactus-pear powder at different temperatures along the storage

Storage time (day)	Water content (%, wet basis)	
	25 °C	40 °C
0	3.37 eA	3.37 eA
10	4.42 dB	4.82 dA
20	5.07 cB	5.86 cA
30	6.14 bB	7.29 bA
40	7.25 aB	8.36 aA

LSD for columns = 0.19; LSD for rows = 0.26; OM = 5.60%; CV% = 3.64
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

Table 3. Mean* values of water activity in cactus-pear powder at different temperatures, along the storage

Storage time (day)	Water activity	
	25 °C	40 °C
0	0.260 dA	0.260 cA
10	0.300 cA	0.281 bcB
20	0.328 bA	0.301 bB
30	0.346 abA	0.332 aA
40	0.352 aA	0.348 aA

LSD for columns = 0.01; LSD for rows = 0.02; OM = 0.31%; CV% = 5.39
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

according to the equation of water activity mentioned in Ordoñez (2005). Different results were reported by Lee et al. (2013), who observed physical-chemical stability of powders of red-pulp and white-pulp dragon fruits dried in spray dryer, with addition of maltodextrin (DE 9-12) and stored for 25 days under temperature (25 °C) and relative humidity (33%) at which water absorption by the samples was minimal, because the relative humidity of the environment and the water activity of the samples were similar.

In general, temperature did not influence water activity, because the values of water activity of samples stored at 40 °C were statistically lower than those of samples at 25 °C for 10 and 20 days, and statistically equal at the other times. Moreira et al. (2011), studying 'cupuaçu' pulp in powder, observed no variation in water activity after 90 days of storage; however, the obtained values were higher than those in the present study, between 0.63 and 0.69.

The mean values of total titratable acidity of the powder stored at controlled conditions of temperature (25 and 40 °C) and relative humidity (83%) are shown in Table 4.

The mean values of total titratable acidity of the samples stored at both temperatures suffered small oscillations along the storage time. At the temperature of 25 °C, there were no significant differences between acidity at the initial time, or at the two final times (30 and 40 days), while at the temperature of 40 °C there was significant difference only at the time of 20 days.

Since the observed differences occurred, in most cases, between the intermediate times and there was no significant difference between the values of the other times, acidity did not suffer alterations related to the studied storage time and to the effect of temperature, corroborating the data of water activity. In other words, there was no evidence of microbiological contamination. Oliveira et al. (2015) analyzed the stability of pulp of *Cereus jamacaru* in powder, obtained through spray drying with addition of maltodextrin and different dextrose

Table 4. Mean* values of total titratable acidity of cactus-pear powder at different temperatures, along the storage

Storage time (day)	Total titratable acidity (% citric acid)	
	25 °C	40 °C
0	0.32 cA	0.32 bA
10	0.36 aA	0.31 bB
20	0.35 abA	0.36 aA
30	0.31 cA	0.31 bA
40	0.33 bcA	0.32 bA

LSD for columns = 0.02; LSD for rows = 0.03; OM = 0.33%; CV% = 7.38
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

equivalents (10 and 14), stored in laminated packages for 50 days at relative humidity of 57.7% and temperature of 25 °C. These authors observed that the samples of both dextrose values remained stable along the storage; in the comparison between dextrose equivalents, the values were higher in the sample with DE = 14.

According to the lightness of cactus-pear powder stored at 25 °C (Table 5), this variable was statistically different from the other times only at 20 days; thus, representing an isolated behavior and showing tendency of stability during the 40 days of storage. The sample stored at 40 °C also showed tendency of stability along the storage time.

In the statistical comparison between the samples stored at both temperatures, temperature did not influence sample lightness; the package, in turn, protected the product against alterations caused by light incidence. Loureiro et al. (2013) stored 'buriti' (*Mauritia flexuosa*) in powder at mean temperature of 26 ºC and humidity of 78% for 90 days and observed that sample lightness did not suffer influence of the storage time.

The mean values of redness (+a*) of the samples in powder stored under controlled conditions are shown in Table 6.

There was a reduction in redness and, for the temperature of 25 °C, there were no significant differences between the time zero and the times of 20 and 30 days; however, at the time of 40 days, the parameter redness showed significant decrease in relation to the time zero. For the temperature of 40 °C, there was an isolated significant decrease of redness at the time of 20 days, remaining constant from 30 days until the end of the storage time. In general, the redness of the samples stored at 25 and 40 °C along the storage time remained stable. According to the results of redness between both temperatures, there were differences between the times of 10, 20 and 40 days, but without representing a consistent tendency of higher values, whether at 25 or at 40 °C. Alexandre et al. (2014) analyzed the stability of Surinam cherry in powder and observed that the decrease in redness between the time zero and the final time (60 days) was equal to 30.29%. This decrease was related to the transparency and permeability of the package.

The mean results of yellowness (+b*) of cactus-pear powder along the storage time at each isolated temperature are shown in Table 7.

For the temperature of 25 °C, there was no significant alteration between the initial time and 30 days of storage; at 30 days, there was a difference in relation to 10, 20 and 40 days, which shows the tendency of reduction in yellowness along the storage time. For the temperature of 40 °C, only the initial time differed statistically from the others and there was a tendency of decrease in yellowness.

In the comparison between both temperatures, there was a significant difference at 30 days; thus, no significant influence of storage temperatures was observed. Lisbôa et al. (2012) stored cactus-pear powder in laminated package at temperatures of 25 and 40 °C and relative humidity of 83% and observed that yellowness remained constant at 25 °C and decreased at 40 °C.

Table 5. Mean* values of lightness of cactus-pear powder at different temperatures, along the storage

Storage time (day)	Lightness	
	25 °C	40 °C
0	68.86 aA	68.85 abA
10	68.91 aA	69.16 abA
20	64.36 bA	64.36 bA
30	69.23 aA	68.06 bB
40	68.86 aA	69.32 aA

LSD for columns = 0.89; LSD for rows = 1.25; OM = 68.07; CV% = 1.40
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

Table 6. Mean* values of redness of cactus-pear powder at different temperatures along the storage

Storage time (day)	Redness	
	25 °C	40 °C
0	7.55 bA	7.55 abA
10	8.44 aA	7.90 aB
20	7.51 bA	6.86 cB
30	7.01 bcA	7.01 bcA
40	6.79 cB	7.27 abcA

LSD for columns = 0.47; LSD for rows = 0.66; OM = 7.39; CV% = 6.78
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

Table 7. Mean* values of yellowness of cactus-pear powder at different temperatures along the storage

Storage time (day)	Yellowness	
	25 °C	40 °C
0	42.08 aA	42.08 aA
10	40.28 bcA	40.06 bA
20	39.11 cA	39.89 bA
30	42.00 aA	40.52 bB
40	40.67 bA	40.45 bA

LSD for columns = 0.84; LSD for rows = 1.18; OM = 40.71; CV% = 2.21
LSD - Least significant difference; OM - Overall mean; CV - Coefficient of variation
* Means followed by the same letter, lowercase in the columns and uppercase in the rows, do not differ statistically by Tukey test at 0.05 probability level

Conclusions

1. The whole pulp was slightly acidic and with predominance of the yellow color.

2. Laminated packages did not prevent the increase in water content and water activity in the samples. Total titratable acidity did not change along the studied storage time.

3. Lightness remained almost constant from the beginning to the end of the storage time and there was a predominance of the yellow color.

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