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Production and sensory evaluation of dried mango[1]

Elaboração e avaliação sensorial da manga-passa

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HIGHLIGHTS:

The concentration and temperature of the dehydrating solution influenced water loss and water activity during osmotic dehydration.
The increase in the convective drying temperature did not influence the color and appearance of the dried mangoes.
The combination of osmoconvective dehydration can be used for slices of mango cv. Espada with excellent sensory acceptance.

ABSTRACT: The objective of this study was to determine the best osmotic dehydration (OD) condition for slices of mango cv. Espada through a factorial experiment, evaluating water loss and water activity during the process, and then perform convective drying at different temperatures to sensorially evaluate the obtained dried mango. An experiment was conducted in a 2^3 factorial experiment, with three central points, to evaluate the influence of thickness (1; 1.5 and 2 cm), sucrose concentration (35; 45 and 55 °Brix) and temperature (30, 40 and 50 °C) on water loss and water activity during the process. Convective drying was carried out in a tray dryer at temperatures of 50, 60 and 70 °C, with an air speed of 1.5 m s^{-1}. The optimal OD condition was found for slices with 1 cm thickness, sucrose concentration of 55 °Brix and temperature of 50 °C. Dried mangoes produced at temperatures of 50 and 60 °C were the most accepted among the tasters for the attributes of color, appearance, odor and taste, intensity of hardness, preference and purchase intention, and can be a promising alternative for utilization of Espada mango.

Key words: *Mangifera indica*, osmotic dehydration, convective drying

RESUMO: Objetivou-se neste estudo determinar a melhor condição de desidratação osmótica (DO) das fatias de manga cv. Espada através de planejamento fatorial, avaliando perda de água e atividade de água durante o processo, e realizar a secagem convectiva em diferentes temperaturas para avaliar sensorialmente as mangas-passas obtidas. Foi realizado um planejamento experimental fatorial 2^3, com três pontos centrais, para avaliar a influência da espessura (1; 1,5 e 2 cm), concentração de sacarose (35; 45 e 55 °Brix) e temperatura (30, 40 e 50 °C), sobre a perda de água e atividade de água durante o processo. A secagem convectiva foi realizada em secador de bandejas nas temperaturas de 50, 60 e 70 °C, com velocidade do ar de 1,5 m s^{-1}. A melhor condição da DO foi encontrada para as fatias com 1 cm de espessura, concentração de sacarose de 55 °Brix e temperatura de 50 °C. As mangas-passas elaboradas nas temperaturas de secagem de 50 e 60 °C foram as mais aceitas entre os provadores para os atributos de cor, aparência, odor e sabor, intensidade de dureza, preferência e intenção de compra, podendo ser uma alternativa promissora de aproveitamento da manga Espada.

Palavras-chave: *Mangifera indica*, desidratação osmótica, secagem convectiva

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Introduction

Osmotic dehydration is a partial drying method capable of reducing the water content by soaking the fruits in a concentrated solution containing one or more solutes, resulting in significant release of water from the product to the surrounding medium (Souraki et al., 2013). This technique can be used as a pretreatment, followed by complementary processes such as hot-air drying or freezing, freeze drying and microwaving, among others (Nikbakht et al., 2014; Perussello et al., 2014). This technique can be used as the main treatment in the dehydration of mango, apple, pineapple, Prata banana and guava (Porciuncula et al., 2013; Ganjloo et al., 2014). Combined drying methods promote advantages in the packaging and storage processes, also contributing to the development of new food products (Castro et al., 2018).

Dried mango can be an alternative to reduce postharvest losses, enable consumption in the off-season and add value to the fruit. Dried mango production by osmotic dehydration followed by convective drying usually requires low investment in equipment, and this product can be produced on a small scale and its conservation is at room temperature. It results in a product with smaller dimensions, better color, softer and more acceptable, both for direct consumption and for the incorporation in ice cream, cereal bars, yogurts, cheeses, among other products (Soares & José, 2013). However, there are few studies with osmotic dehydration followed by convective drying of mango cv. Espada, and there are no studies on the specific conditions proposed here.

Thus, the objective of this study was to determine the best condition of osmotic dehydration of slices of mango cv. Espada through a factorial experiment, evaluating water loss and water activity during the process and then perform convective drying at different temperatures to sensorially evaluate the dried mango obtained.

Material and Methods

Mango (*Mangifera indica* L.) fruits cv. Espada purchased at EMPASA/Campina Grande, PB, Brazil, from the metropolitan region of João Pessoa, were used in this study. The fruits were selected according to the maturity degree from 15 to 17 °Brix, using a portable refractometer for measurement. The fruits were pre-washed with running water in order to remove dirt and other foreign materials. After washing, they were sanitized by immersion in sodium hypochlorite solution at 100 mg L^{-1} and, soon after, were rinsed to remove excess chlorine solution.

The washed and sanitized mangoes were peeled manually with a stainless-steel knife and cut longitudinally, close to the seed, into slices of 1, 1.5 and 2 cm thickness perpendicular to the fibers. These parts were sliced with 5 cm length and 2 cm width. To study the effect of the three independent variables (slice thickness, sucrose solution concentration and temperature) on the dependent variables (water loss and water activity) in the osmotic dehydration process of mango slices, a complete 2^3 factorial experiment was carried out with three repetitions at the central point, totaling 11 trials, with the objective of determining the best process condition. The values of the encoded and decoded levels of the three independent variables are shown in Table 1.

Table 1. Matrix of 2^3 factorial experiment with three repetitions at the central point, for osmotic dehydration of mango in sucrose solution

Trials	Slice thickness (cm)	Sucrose concentration (°Brix)	Temperature (°C)
1	-1 (1)	-1 (35)	-1 (30)
2	+1 (2)	-1 (35)	-1 (30)
3	-1 (1)	+1 (55)	-1 (30)
4	+1 (2)	+1 (55)	-1 (30)
5	-1 (1)	-1 (35)	+1 (50)
6	+1 (2)	-1 (35)	+1 (50)
7	-1 (1)	+1 (55)	+1 (50)
8	+1 (2)	+1 (55)	+1 (50)
9	0 (1.5)	0 (45)	0 (40)
10	0 (1.5)	0 (45)	0 (40)
11	0 (1.5)	0 (45)	0 (40)

Based on the study of the effects of osmotic dehydration considering the thickness, sucrose concentration and temperature on mango slices, the best process condition that occurs with the highest water loss and the lowest water activity was determined in order to obtain a slightly processed product with longer shelf life.

The water activity (a_w) of mango slices was determined in an Aqualab 3TE hygrometer (Decagon Devices) at 25 °C, periodically at time intervals of 0, 15, 30, 60, 120, 180, 240, 300 and 360 min, totaling 6 hours of osmotic dehydration. At each interval, excess sucrose was removed from the mango slices with absorbent paper.

Water loss (WL) was calculated using Eq. 1, cited by Ito (2007).

$$WL(\%) = \frac{(Mw_0 - Mw_t)}{M_0} 100 \qquad (1)$$

where:

M_0 - initial mass of the product, g;
Mw_0 - initial water content in the product, g; and,
Mw_t - water content in the product at time t, g.

Convective drying of osmo-dehydrated mango slices under the best process condition in the design was performed in a tray dryer at temperatures of 50, 60 and 70 °C, maintaining constant air velocity at 1.5 m s^{-1}, measured with an anemometer. During drying, the trays with the mango slices were weighed, initially at time intervals of 5 min, followed by intervals of 15, 30 and 60 min at the end of the process, until a water content of 10-13% w.b. was obtained in the dried mango samples.

The microbiological analyses performed in the dried mango samples stored were: coliforms at 35 °C (MPN g^{-1}), thermotolerant coliforms (MPN g^{-1}), *Staphylococcus aureus* (CFU g^{-1}), molds and yeasts (CFU g^{-1}) and *Salmonella* sp., according to the requirement of Resolution RDC nº. 331, which approves the Regulation on microbiological standards for food (Brasil, 2019). Microbiological procedures are the protocol described by the FDA (1995).

Sensory evaluation of dried mango samples was applied to an untrained team of 80 tasters of both sexes within a sample group (students, professors and staff). Before starting the tasting, the free and informed consent form was applied to the judges (over 18 years of age) according to the project approved by the ethics committee with human beings, under nº 0566.0.133.000-11. Three samples of dried mango were offered to the judges in disposable white plastic plates, coded with three-digit numbers, accompanied by water and salt crackers and mineral water at room temperature, to wash the palate between the samples. The tests were applied in individual cabins, in refrigerated environment under artificial white light.

The acceptance test for the attributes color, appearance, odor and flavor was applied using a structured nine-point hedonic scale (1 = Liked extremely to 9 = Disliked extremely). In addition, the intensity scale for the texture/hardness attribute using the seven-point hedonic scale (1 = Very hard to 7 = Very soft), the preference test and purchase intention test were also applied. Sensory tests followed the methodology of AOAC (2018).

The results of osmotic dehydration were analyzed in Statistica 10.0 software to obtain the Pareto chart and contour curves. The data obtained in the sensory tests of the dried mango, obtained from osmotic dehydration under the optimized condition followed by convective drying at three temperatures, were evaluated by ANOVA and the means were compared by Tukey test at $p \leq 0.05$ using Assistat 7.7 Beta software (Silva & Azevedo, 2016).

Results and Discussion

By analyzing Table 2, it can be observed that, for the regression, $F_{calculated}$ was higher than $F_{tabulated}$ and the ratio between them was approximately 1.98 for the 95% confidence level, so it is possible to affirm that the proposed model for water loss was significant. Mendes et al. (2013), when studying the conditions for osmotic dehydration of orange, using sucrose as a dehydrating agent, followed by drying in a tray dryer at 60 ºC, with a factorial design, found that the linear model for water loss was statistically significant and not predictive, with R^2 equal to 0.88. For the model to be predictive, $F_{calculated}$ needs to be at least four times higher than $F_{tabulated}$.

Table 3 shows that the $F_{calculated}$ value was higher than the $F_{tabulated}$ value, so it is possible to affirm that the proposed model for water activity was significant. Rodríguez et al. (2013) worked with osmotic dehydration of nectarines, noting that water activity was affected by the effects of process time, temperature, fruit/solute ratio and osmotic solution concentration.

Table 2. Analysis of variance for the water loss of mango slices

	SS	DF	MS	$F_{calculated}$	$F_{tabulated*}$
Regression	1188.629900	7	169.804271	12.25	6.16
Residual	41.566391	3	13.855464		
Lack of fit	0.009000	1	0.004500	0.0002	19
Pure error	41.557	2	20.778695		
Total	1230.196	10			

* - Tabulated F values at $p \leq 0.05$; SS - Sum of squares; DF - Degrees of freedom; MS - Mean square

Table 3. Analysis of variance for the water activity of mango slices

	SS	DF	MS	$F_{calculated}$	$F_{tabulated*}$
Regression	0.0023	7	0.0003	4.64	4.35
Residual	0.0002	3	0.0001		
Lack of fit	0.000205	1	0.0000	17.61	19.3
Pure error	0.000005	2	0.0000		
Total	0.002484	10			

* - Tabulated F values at $p \leq 0.05$; SS - Sum of squares; DF - Degrees of freedom; MS - Mean squares

The coded models proposed to represent water loss and water activity in osmotic dehydration of mango in sugar solution, obtained from the regression, are described in the Eqs. 2 and 3, with coefficients of determination $R^2 \geq 0.91$, indicating the ability of the model to explain 91% of the variations of the observed data.

$$WL = 21.55 - 1.72L + 7.84C + 8.11T - 3.25LC - 0.78LT + 2.67CT \quad R^2 = 96.62\% \quad (2)$$

$$a_w = 0.95 + 0.005L - 0.010C - 0.008T + 0.006LC + 0.0005LT - 0.006CT \quad R^2 = 91.54\% \quad (3)$$

where:
L - slice thickness;
C - sucrose concentration; and,
T - temperature of dehydration.

Figure 1 shows the Pareto chart for water loss (Figure 1A) and water activity (Figure 1B) of mango slices. It is observed that temperature was the variable that most influenced the water loss of the osmo-dehydrated slices; this is evident when observing the values of the estimated effect of each linear factor evaluated, as the temperature has a higher absolute value when compared with the variables thickness and concentration, respectively. It is also observed that only thickness had a decreasing effect on the response. On the other hand, the variables concentration and temperature showed positive estimated effects, indicating that the higher the sucrose concentration and the dehydration temperature, the greater the water loss. Similar behavior was observed by Ferreira et al. (2020) in papaya cubes subjected to osmotic dehydration at different concentrations of sucrose (40 and 50 °Brix) and temperatures (50 and 60 °C) followed by convective drying (50, 60 and 70 °C), and by Assis et al. (2017) who osmotically dehydrated apple cubes with sucrose or sorbitol at different temperatures.

High temperatures seem to promote water loss more quickly, as well as better mass transfer on the surface of the product. For water activity, it is observed that concentration was the factor with the greatest influence. The negative sign represents decreasing effect of the factors on water activity, meaning reduction in water activity with increase in sucrose concentration and dehydration temperature. This influence is attributed to the high concentration of the solution, which causes a high pressure gradient between the fruit and the osmotic solution, favoring greater loss of water and tending to equilibrium with the osmotic medium (Castro et al., 2018). This relationship of influence of osmotic concentration on fruit water loss during osmotic dehydration was also verified by Germer et al. (2011), who studied osmotic dehydration of peaches as a function of temperature and concentration of sucrose syrup.

Figure 2 corresponds to the contour curve for water loss (Figure 2A) and water activity (Figure 2B) in the optimized region of the factorial design.

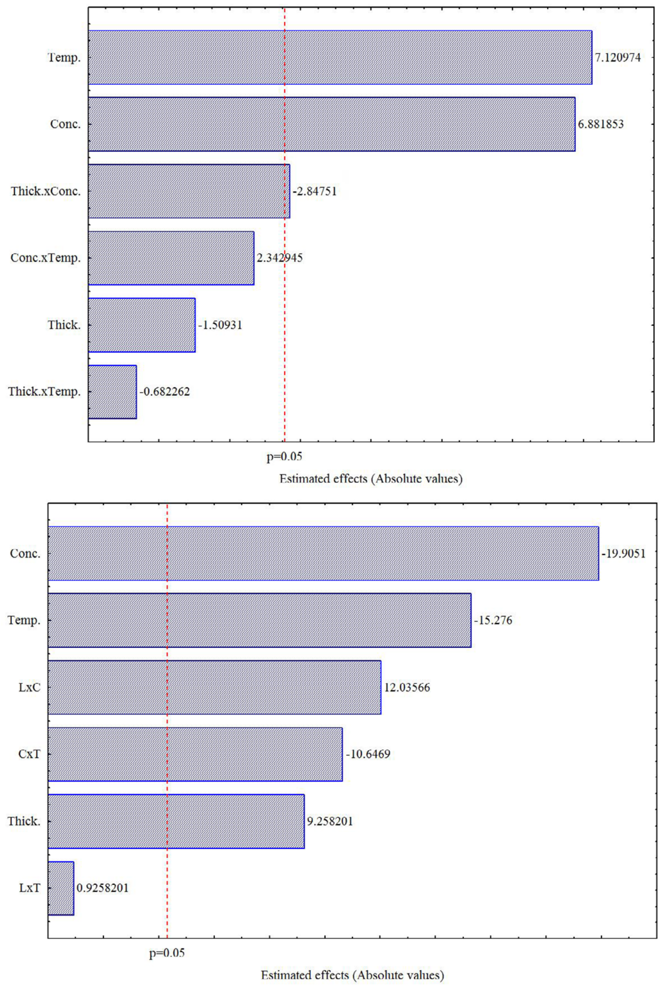

Figure 1. Pareto chart for water loss (A) and water activity (B) of mango slices

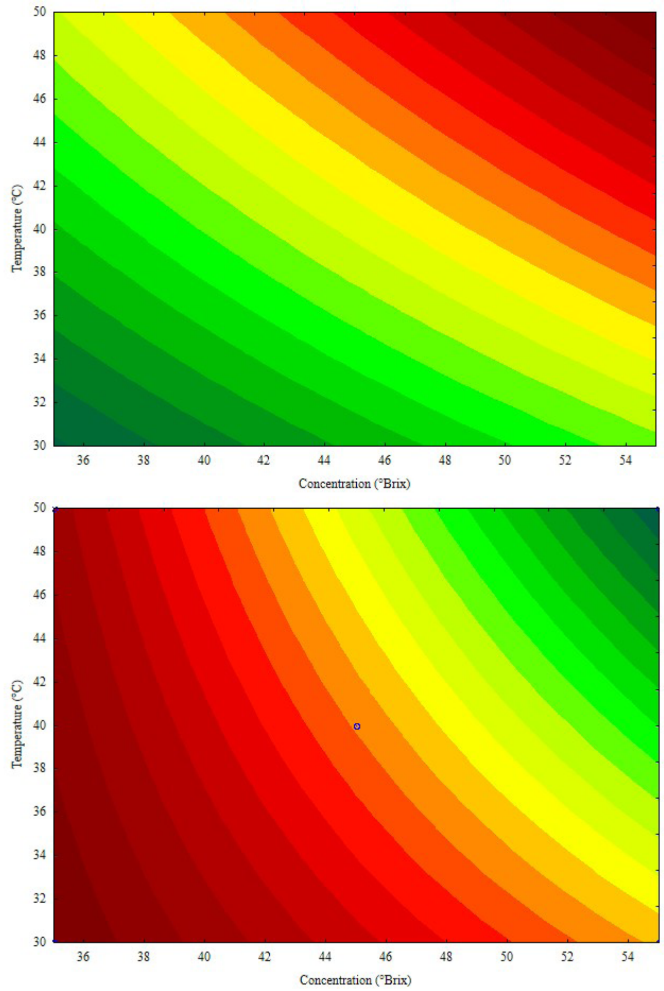

Figure 2. Contour curve for water loss (A) and water activity (B) under the best condition of the factorial design, as a function of sucrose concentration and drying temperature

The higher water loss and lower water activity resulted in the most concentrated osmotic solution at the highest temperature, and the exchange of free water for sucrose in mango slices occurs more rapidly with the smallest thickness of the slice. Therefore, the best condition of osmotic dehydration process was: osmotic solution concentration of 55 °Brix, solution temperature of 50 °C and slice thickness of 1.0 cm.

Table 4 presents the results of microbiological analyses of dried mango slices obtained at different drying temperatures. All the results of the microbiological attributes comply with the current Resolution. The bacteria of the coliform group are indicators of unsatisfactory hygiene conditions in the production and/or handling of food and, as the values are below the recommended by the legislation, it is possible to affirm that the processing of dried mango followed the standards recommended by the Good Manufacturing Practices.

Table 5 presents the results of the acceptance test for the dried mango obtained at different temperatures for the attributes color, appearance, odor and flavor. It is observed that all the scores attributed were between the terms "liked slightly" to "liked moderately", which demonstrates good acceptance of all samples by consumers, as they were above 5 (Queiroz et al., 2007). There were no significant differences between the mangoes dried at different temperatures (50, 60 and 70 °C) for color and appearance. This result can be justified

Table 5. Average acceptance of the attributes color, appearance, odor and flavor of dried mango dehydrated at three temperatures

Temperature (°C)	Means			
	Color	Appearance	Odor	Flavor
50	7.44 a	7.41 a	7.72 a	7.98 a
60	7.36 a	7.24 a	7.17 ab	7.46 a
70	6.94 a	6.86 a	6.98 b	6.50 b

Means followed by equal letters in the columns do not differ statistically by Tukey test at $p \leq 0.05$

Table 4. Microbiological attributes of mango slices dehydrated at three temperatures

Parameters	50	60	70	Resolution (MPN g^{-1})
		(°C)		
Coliforms at 35 °C (MPN g^{-1})	< 3.0	< 3.0	< 3.0	< 3.0
Thermotolerant coliforms (MPN g^{-1})	< 3.0	< 3.0	< 3.0	< 3.0
Staphylococcus aureus (CFU g^{-1})	< 1 x 10^{1}	< 1 x 10^{1}	< 1 x 10^{1}	< 1 x 10^{1}
Molds and yeasts (CFU g^{-1})	3 x 10^{1}	< 1 x 10^{1}	< 1 x 10^{1}	< 1 x 10^{3}
Salmonella sp.	Absent	Absent	Absent	Absent

by the use of osmotic dehydration before convective drying, which maintained color and appearance. For the odor, there was significant difference only between the temperatures of 50 and 70 °C and, for the flavor, there was difference between the temperature of 70 °C and the others.

Therefore, the mangoes dried at 50 and 60 °C had the highest acceptance in the opinion of the tasters, without significant differences between these treatments for all attributes evaluated. Good acceptance was also verified by Sanjinez-Argandoña et al. (2018) for the mango cv. Palmer cut into pieces and subjected to osmotic dehydration (sucrose solution at 60%; 40 °C/2 hours) followed by convective drying at 50 °C with air velocity of 1.6 m s^{-1}, obtaining acceptance level greater than 70% for color, odor, flavor, texture and overall appearance.

The influence of osmotic dehydration on dried mango acceptance was evaluated by Garcia-Paternina et al. (2015) in two types of dried mango cv. Tommy, without osmotic treatment (control) and with osmotic treatment (sucrose at 65 °Brix/60 min at 37-40 °C) combined with convective drying (70 °C). It was verified that osmotic dehydration contributed to the maintenance of nutritional quality and color of the product, and the products obtained from osmotic dehydration with pretreatment were more preferred by judges (80%) and with greater purchase intention.

Figure 3 shows the sensory profile attributed to the intensity of hardness of the dried mango obtained in osmo-convective drying at temperatures of 50, 60 and 70 °C. It can be observed that the greater acceptance for mangoes was obtained at the temperature of 50 °C, justified by the lower hardness (score 3.91 between the terms "slightly hard" and "neither hard nor soft"), followed by 60 °C (score 2.96 between the terms "hard" and "slightly hard") and lastly at 70 °C (score 1.75 between the terms "very hard" and "hard"). In the process of convective drying of the mangoes, the time-temperature binomial should be low because it prevents the formation of a rigid film, avoiding the diffusion of free water and leading to rubbery aspect in its texture. Regarding resistance during chewing, there was no mention of displeasure by the tasters regarding the dried mangoes obtained at 50 and 60 °C.

Alves et al. (2018) sensorially evaluated the texture in strawberries dehydrated in sucrose solutions from 60 to 80 °Brix for 2 hours followed by convective drying at 60 °C and obtained the lowest value of texture in products with the lowest sucrose concentration.

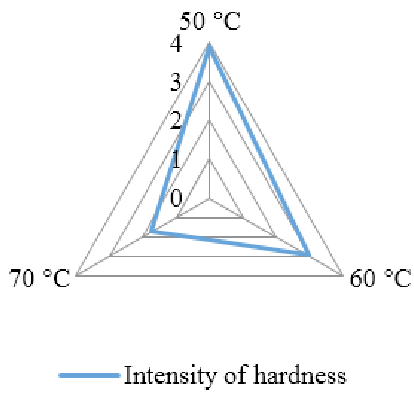

Figure 3. Sensory profile attributed to the intensity of hardness of dried mangoes dehydrated at three temperatures

Figure 4 shows the percentage values obtained in the preference test of dried mangoes, obtained at drying temperatures of 50, 60 and 70 °C. It was observed that the dried mango obtained with drying at 50 °C was preferred by the tasters, with 62%, followed by the dried mango obtained at 60 °C with 24% preference by the tasters, and finally the dried mango produced at 70 °C, preferred by only 14% of the tasters, probably because its texture is considered very hard, but with acceptable color, taste, odor and appearance. Lower drying temperatures were also verified as preferred for the texture parameter by Dourado et al. (2012) in the sensory evaluation of dried banana slices subjected to different drying temperatures, with the preference of consumers for dried bananas obtained at the temperature of 85 °C for the attributes color, aroma and flavor and at 65 °C for texture.

Figure 5 shows the results for the intention to purchase dried mangoes produced at temperatures of 50, 60 and 70 °C, with a five-point scale ranging from "certainly would buy" to "certainly would not buy". It was found that the purchase intention decreased with the increase in drying temperature. The dried mangoes treated at 50 °C had a higher percentage of purchase intention for the term "certainly would buy". For the dried mangoes produced at 60 and 70 °C, the highest percentages were for the terms "possibly would buy" and "certainly would not buy", respectively. However, it is also

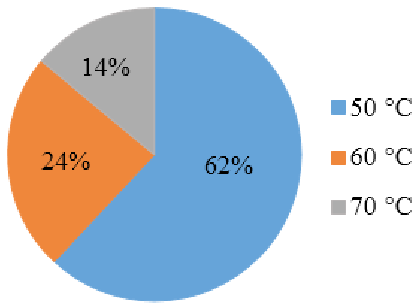

Figure 4. Preference test of dried mangoes dehydrated at three temperatures

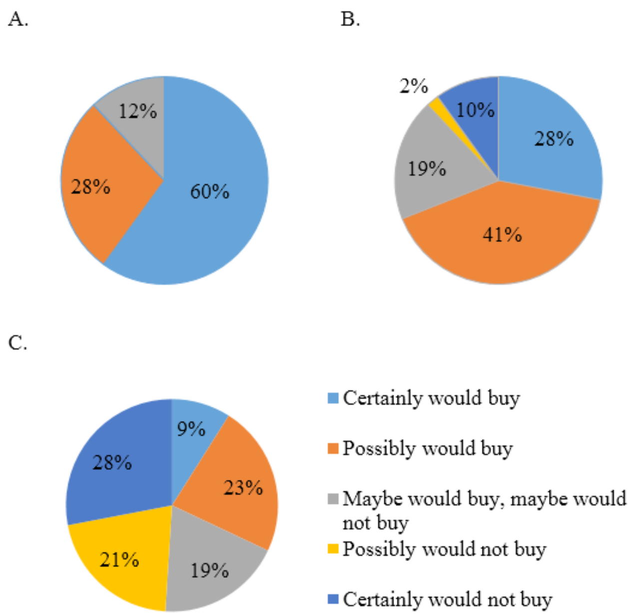

Figure 5. Purchase intention for dried mangoes dehydrated at three temperatures: (A) 50 °C; (B) 60 °C; and (C) 70 °C

noted that the dried mangoes produced at 60 °C were a good option to buy, because 69% of the tasters attributed scores between the terms "possibly would buy" and "certainly would buy", while for the mangoes dried at 70 °C only 32% attributed these terms, but this value was higher than the percentage of rejection ("certainly would not buy").

High purchase intention was also verified by Silva et al. (2015) for dried cagaita prepared by combining osmotic dehydration (45 to 65 °Brix) and convective drying (50 to 70 °C), with the highest frequencies for the scores "certainly would buy" and "probably would buy".

Conclusions

1. The best condition of the osmotic dehydration of mango was slices with thickness of 1.0 cm, sucrose concentration of 55 °Brix and osmotic solution temperature of 50 °C.

2. Dried mangoes produced at drying temperatures of 50 and 60 °C were the most accepted among the tasters for the attributes of color, appearance, odor and flavor, intensity of hardness, preference and purchase intention.

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