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Mango dehydration: influence of osmotic pre-treatment and addition of calcium chloride

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Abstract - Mango (*Mangifera indica* L.) can be characterized as a greatly accepted fruit due to its sensory attributes of flavor and aroma. However, it has a large production during the harvest season and requires preservation through processing. Osmotic pretreatment, followed by drying, provides products with higher quality and stability. The present study explored the effects of osmotic pretreatment with and without addition of calcium chloride in the nutritional characteristics and sensorial acceptance of dehydrated mango. Four different osmotic treatments were applied in mango slices followed by drying. Drying without osmotic treatment was considered control. Dried samples pre-treated with calcium had lower sugar content and higher retention of acids in the fruit. The increase of sucrose and glucose content during osmotic treatment contributed to maintaining nutritional quality and color of the product when compared with control treatment. Products dehydrated with osmotic pre-treatment were the most preferred, presenting higher purchase intention. The combination of osmotic pretreatment with convective drying provided higher acceptance of dehydrated mango due to its higher quality.

Index terms: drying, osmodehydration, quality, *Mangifera indica* L. cv. Palmer.

Desidratação de manga: influência do pré-tratamento osmóticoe da adição de cloreto de cálcio

Resumo - A manga (*Mangifera indica* L.) pode ser caracterizada como uma fruta de grande aceitação devido a seus atributos sensoriais de sabor e aroma. Porém, apresenta grande produção nos meses de safra, sendo necessária sua conservação por meio do processamento. O pré-tratamento osmótico, seguido da secagem, proporciona produtos com maior qualidade e estabilidade. O presente estudo explorou os efeitos do pré-tratamento osmótico, com e sem adição de cloreto de cálcio, nas características nutricionais e na aceitação sensorial de manga desidratada. Quatro diferentes tratamentos osmóticos foram aplicados em pedaços de manga seguidos de secagem. A secagem sem tratamento osmótico foi considerada como controle. Amostras secas pré-tratadas com cálcio apresentaram menor teor de açúcares e maior retenção de ácidos na fruta. O incremento da sacarose e da glicose durante o tratamento osmótico contribuiu para a manutenção da qualidade nutricional e da cor do produto desidratado, quando comparado ao controle. Os produtos desidratados com pré-tratamento osmótico foram mais preferidos e apresentaram maior intenção de compra. A combinação do pré-tratamento osmótico com a secagem convectiva proporcionou maior aceitação da manga desidratada, uma vez que oferece melhor qualidade.

Termos para Indexação: Secagem, osmodesidratação, qualidade, *Mangifera indica* L. cv Palmer**.**

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Introduction

Brazil is the seventh largest mango producer in the world (FAOSTAT, 2013), with expressive production of the American varieties Tommy Atkins, Haden, Kent, Keitt and Palmer. In the last years, the latter has stood out because it is a late cultivar with flavor, aroma and quality characteristics attractive for consumers (TEIXEIRA; DURIGAN, 2011).

The Brazilian production exceeds 1 million tons of mangoes a year (TREICHEL et al., 2016); however, about 28% is wasted due to inadequate post-harvest practices (REETZ et al., 2015) and to the high perishability, which favors rapid deterioration (SOARES JUNIOR et al., 2003).

According to the Food and Agriculture Organization of the United Nations (FAO), Brazil is among the ten countries in the world that most wastes food, with fruits accounting for, on average, 30%. This high percentage of losses occurs mainly during the harvest season and is a worldwide concern (AGÊNCIA BRASIL, 2015).

The full utilization of food, including those considered out of consumption standard, is an alternative to minimize losses and waste in Brazil, which could be processed and used in the form of co-products, providing added value to food production (EMBRAPA, 2015). Thus, one of the ways to reduce losses and increase the added value of mango is drying or dehydration.

Dehydration favors the use of fruits that are not commercially available in the fresh form, whether by deformation, mechanical or insect damage, since during processing, damaged parts can be excluded without compromising the final quality of the product. In addition, dehydration allows obtaining a product with longer shelf life and with easy transportation and storage, as well as the practicality in the consumption and availability in the off-season. Therefore, dehydrated mango becomes a food option with flavor and color sensory characteristics of fresh fruit, which meets the consumer's needs, who seeks practical and healthy foods.

Osmotic dehydration as pre-treatment to drying has favored retention of color, flavor and aroma, in addition to reducing the processing time. Osmotic treatment consists of the immersion of the fruit in hypertonic solutions where the cell wall acts as a semi-permeable selective membrane, favoring the partial removal of water (LENART; PIOTROWSKI, 2001).

The addition of calcium chloride in the osmotic solution may promote greater firmness in fruit texture (MIGUEL et al., 2007). In addition, calcium is the mineral most common in the human body, being essential for bones and teeth (LEÃO; SANTOS, 2012), and for the performance of several metabolic functions (SANTOS et al., 2003). However, osmotically dehydrated fruits, with or without added calcium, still require further treatment for their preservation. In this context, the convective drying of osmotically pre-treated products completes the reduction of the water content in order to prevent the growth of microorganisms and maintain the product at room temperature.

Thus, this study aimed to evaluate the influence of osmotic pre-treatment with and without addition of calcium chloride on the nutritional and sensory characteristics of dehydrated mango.

Material and methods

Mangoes (*Mangifera indica* L.) cultivar Palmer were purchased in the local market at ripe maturity stage. Fruits were washed in potable water and immersed in sodium hypochlorite solution (1%) for 15 min. They were then peeled, cut into 1.5 x 2.5 x 1.5 cm pieces and submitted to the bleaching process in water at 80 ° C for 30 s, followed by immersion in ice water.

For the osmotic treatment, mango pieces were placed in sugar solutions, according to Table 1, in the fruit:solution ratio of 1: 4, at 40 ° C for 2h and at 111 rpm in shaker (TECNAL TE-420). Mango pieces were then drained and rinsed with distilled water to remove excess solution and dried on absorbent paper.

For convective drying, mango pieces were dehydrated in an air circulation dryer (1.6 m/s) at 50 ° C for 24 hours. The dehydrated product was packed in low density polyethylene packages and maintained at -18 ° C until analysis.

Moisture, protein and fixed mineral residue contents were determined (AOAC, 1990). Total lipids were determined by the method Bligh and Dyer (1959), reducing sugars (RS) and total reducing sugars (TRS) by titration (LANE; EYNON, 1934), and fibers according to AOAC (1995). The energy value was calculated using Atwater conversion factors (4 kcal / g for proteins and carbohydrates and 9 kcal / g for lipids) for components values in g / 100 g of wet mass (MERRIL; WATT, 1973). The moisture content was calculated on wet basis and the other components on dry basis.

Titratable acidity (TA) was determined by volumetric method (AOAC, 1997) and soluble solids (SS) by direct reading in bench refractometer (TECNAL, RMT model). pH was determined by digital potentiometer (INSTRUTHERM PH-2000) and water activity (Aw) by direct reading on Aqualab digital hygrometer (model CX-2T Decagon Devices Inc., USA) at 25ºC previously calibrated with distilled water.

Color was determined in colorimeter (Minolta, model CR 400). and L* (brightness), a* (green-red) and b* (blue-yellow) parameters were read in CIELab system, with six replicates. Color saturation (C*) was calculated by Equation 1 according to Santos et al. (2016).

$$C^* = \sqrt{(a^*) + (b^*)} \qquad \text{(Equation 1)}$$

Color, texture, sweetness, flavor attributes and overall evaluation were evaluated by 50 judges, among students and employees of the Federal University of Grande Dourados (UFGD), using the combined acceptance-preference test using a 9-point hedonic scale anchored on extremes 1 (I disliked very much) and 9 (I liked very much). An intent-to-buy test was also applied with a 5-point scale (1 = I certainly would not buy, and 5 = I certainly would buy). Tests were performed in individual cabins, with white lighting. They were performed according to recommendations of environment and distribution of samples described by Meilgaard et al. (2007). Each judge received the samples packed in coded cups distributed in a balanced and randomized manner in complete blocks, accompanied by a glass of water.

The Acceptability Index (AI) was calculated according to Equation 2, where A is the average score of the attribute and B is the highest score observed in the assessed attribute (TEIXEIRA et al., 1987).

$$IA(\%)= \frac{(Ax100)}{B} \qquad \text{(Equation 2)}$$

The results obtained in the physical, chemical and sensory analyses were evaluated by analysis of variance (ANOVA) and Tukey's mean comparison test ($P < 0.05$) using STATISTICA® 8.0 software (STATSOFT, 2007).

Results and discussion

The nutritional composition of fresh, dehydrated mango samples with previous osmotic treatment with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3), sucrose + glucose + $CaCl_2$ (T4) and dehydrated without osmotic pretreatment (T5) are presented in Table 2. Lower moisture contents were observed in samples pretreated with sucrose and glucose solutions (Treatments T3: sucrose + glucose and T4: sucrose + glucose + $CaCl_2$) in relation to samples pretreated with solutions containing only sucrose (Treatments T1: sucrose and T2: sucrose + $CaCl_2$). According to Riva et al. (2005), glucose has lower molecular weight compared to sucrose and behaves similarly to sorbitol, which has greater capacity to penetrate the vegetal tissue, forming a thin layer on the surface with less possibility of crystallization, which allows higher migration of water vapor from the sample during drying. The influence of calcium can be verified in the treatment of sucrose + $CaCl_2$ (T2) due to the formation of calcium pectate, which favors cell stiffness, impairing the diffusion of water vapor from the fruit to the medium during drying (SILVA et al., 2014).

In sucrose + $CaCl_2$ (T2) and sucrose + glucose + $CaCl_2$ (T4) treatments, TRS contents were statistically equal to treatment without osmotic dehydration (T5) (control), demonstrating that calcium was efficient in reducing the incorporation of sugars during osmotic treatment. According to Udomkun et al. (2014), calcium strengthens the cell wall structure by interacting with pectic acid to form calcium pectate. Calcium pectate, in turn, reduces the cell wall porosity by limiting the transport of larger molecules, restricting sugar gain (MAURO et al., 2016). On the other hand, treatments in which only sucrose (T1) and sucrose + glucose (T3) were used, presented higher TRS levels, mainly in the treatment with sucrose, indicating that there was greater sucrose impregnation.

Regarding the RS contents, osmotically pretreated samples presented lower RS values compared to fresh fruit. During the osmotic process, three simultaneous mass transfer flows occur: migration of water from inside of the fruit to the medium, increase of solutes from the solution to the fruit and migration of some constituents from the fruit to the medium, such as lower molecular weight sugars, vitamins, organic salts and others. The migration of hexoses from inside the fruit to the medium justifies the lower RS content. The highest RS values were obtained for samples treated with partial replacement of sucrose by glucose in the osmotic solution (Treatments T3: sucrose + glucose and T4: sucrose + glucose + $CaCl_2$). Samples osmotically dehydrated with sucrose + $CaCl_2$ (T2) presented lower RS content, but there was no significant difference among treatments in relation to the presence or absence of calcium chloride.

In osmotically pretreated samples, protein and lipid contents were lower in relation to treatment without osmotic dehydration (T5). This may have occurred due to the destruction of the plasma lipoproteic membrane of some of the vegetal tissue cells due to the high osmotic pressure in which they were submitted (60% osmotic solution). Similar behavior was reported by Rodrigues (2003) in the osmotic dehydration of apple cv. Fuji in sucrose solution (60%) for 210 min. The author verified that much of the vegetal tissue cells were damaged during the osmotic process. However, there was no statistical difference between treatments with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3) and sucrose + glucose + $CaCl_2$ (T4), which shows that the type of sugar and the addition of $CaCl_2$ did not influence the loss of these nutrients.

Regarding the mineral content, there was no significant difference among treatments with osmotic dehydration. However, difference between these and treatment without osmotic dehydration (T5) was verified. The concentration of minerals was lower in osmotically pre-dehydrated samples, regardless of the type of treatment, probably due to loss during the osmotic process by the solubilization of salts (QUEIROZ, 2006).

In treatment without osmotic dehydration (T5), the content of fibers was higher (3.79 ± 0.07 g / 100g), statistically differing from the other treatments. The lowest contents were verified for treatments submitted to osmotic dehydration in 60% sucrose solution with and without the addition of calcium chloride (T1 and T2). In the extraction of fibers carried out by heat treatment with acid and alkaline solution, insoluble fibers were mostly obtained. However, soluble fibers can remain in the fruit, which were not completely removed by chemical treatment, allowing inferring that, during osmotic dehydration, these fibers can migrate to the medium, as well as salts and organic acids, which justifies the lower value of fibers. When statistically evaluating Table 2, it is observed that the drying process without osmotic dehydration (T5) influenced the following components: moisture, RS, proteins and fibers.

The energy value of the dehydrated product was higher in samples osmotically dehydrated in sucrose (T1) and sucrose + glucose (T3) solutions, which was already expected due to the energy contribution of these sugars. In sucrose + $CaCl_2$ (T2) and sucrose + glucose + $CaCl_2$ (T4) treatments, the influence of calcium chloride was observed, significantly reducing the sucrose increment in the fruit. According to Araújo (2010), calcium reduces the sugar gain, consequently stiffening the fruit. The calcium-forming effect on the cell structure of processed fruits can be explained by the interaction between calcium ions and pectin of the cell wall (MARTÍN-DIANA et al., 2007; UDOMKUN et al., 2014), creating a barrier that hinders the ingress of sugars into the fruit. Shigematsu et al. (2005), on the osmotic dehydration of star fruit slices observed that the osmotic process with calcium chloride significantly reduced the impregnation of sucrose into the fruit.

Table 3 presents the levels of acidity, soluble solids, pH, Aw and color of fresh samples and samples dehydrated with and without previous osmotic treatment. Samples submitted to calcium chloride (T2: sucrose + $CaCl_2$ and T4: sucrose + glucose + $CaCl_2$) showed higher acidity compared to sucrose (T1) and sucrose + glucose (T3) treatments, which behavior can be justified by the formation of pectate calcium. According to Mauro et al. (2016), calcium pectate reduces the cell wall porosity, limiting the migration of organic acids, which explains the higher acidity observed in samples submitted to calcium chloride (sucrose + $CaCl_2$ and sucrose + glucose + $CaCl_2$). There was no statistical difference between the fresh fruit and sample dried without osmotic dehydration, suggesting the possible degradation of acids by the drying temperature (QUEIROZ, 2006; MENDES et al., 2013). The pH values corroborate with the acidity results.

Soluble solids content was higher in samples osmotically pretreated with sucrose + glucose + $CaCl_2$ (T4). There was no significant difference between values obtained for treatments with and without addition of calcium chloride (sucrose, sucrose + $CaCl_2$, sucrose + glucose and sucrose + glucose + $CaCl_2$).

The water activity differed significantly among all treatments, being lower in sucrose + glucose + $CaCl_2$ (T4) treatments and without osmotic dehydration (T5) and higher in sucrose + $CaCl_2$ (T2) treatment. The addition of $CaCl_2$ did not influence water activity, but the partial replacement of sucrose by glucose (T4: sucrose + glucose + $CaCl_2$), where the osmotic solution was composed of 20% glucose syrup and 40% sucrose, suggests higher glucose impregnation, decreasing water activity. In the study by Borges and Menegalli (1994), water loss was also higher in mango drying with osmotic pretreatment. According to the authors, during osmotic dehydration, sugar remains in solution with higher concentration on the fruit surface, helping in the diffusion of water by osmotic flow and, consequently, accelerating the drying process, that is, the product submitted to osmotic dehydration enters the dryer with lower moisture content.

Regarding the color, the drying process caused an increase in a *, b * and C * parameters in respect to the fresh fruit, as the loss of water favored the concentration of pigments, consequently, brightness (L *) was reduced. Samples dried without osmotic dehydration (T5) presented lower L * value, probably due to the enzymatic and non-enzymatic browning of fruits. The results of osmotically pretreated samples, except for sucrose + $CaCl_2$ (T2) treatment, show that the osmotic pretreatment was efficient in preserving the characteristic color of the fruit (yellow), verified by the higher b * values and color saturation (C *) in relation to samples without osmotic dehydration (T5). The a * values of samples submitted to osmotic dehydration were higher than those of fresh fruit, which suggests a higher concentration of pigments.

Figure 1 shows the sensory evaluation of mango samples dehydrated with previous osmotic treatment in sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3), sucrose + glucose + $CaCl_2$ (T4) solutions and dehydrated without osmotic treatment (T5). Samples dehydrated with osmotic pretreatment were better accepted than untreated samples. Among the evaluated attributes, sweetness was influenced by the addition of $CaCl_2$ during the osmotic pretreatment with sucrose + glucose + $CaCl_2$ (T4) reflected by the lowest score assigned (5.88 ± 1.92). In addition, glucose has lower sweetness compared to sucrose, allowing the production of less sweet products, and calcium reduces the impregnation of sugars in the product (MAURO et al., 2016), contributing to lower sweetness. The higher preference of the judges was for the sample of treatment with sucrose solution and, therefore, more sweet. For the other attributes, the results did not present significant difference among osmotic dehydration treatments.

According to Teixeira et al. (1987), for a product to be considered sensorially accepted, the acceptability index (AI) must be at least 70%. Figure 2 shows the AI values of the different treatments for the sensory attributes evaluated. Samples of sucrose (T1), sucrose + $CaCl_2$ (T2) and sucrose + glucose (T3) treatments obtained acceptability index higher than that recommended by literature for all evaluated attributes, which suggests the possibility of commercial insertion of the product. The lowest AI was checked for samples without osmotic pre-treatment.

Regarding the intent-to-buy test, (Figure 3), samples dehydrated with previous osmotic treatment in sucrose (T1) and sucrose + glucose (T3) solution presented higher purchase intention scores, corroborating the preference of judges.

The frequency distributions of “surely buy” and “probably buy” responses were 58.33% (sucrose), 54.17% (sucrose + $CaCl_2$), 54.17% (sucrose + glucose), 41.56% (sucrose + glucose + $CaCl_2$) and 8.33% (without osmotic dehydration). For product dehydrated without osmotic treatment, no judge chose the concept “certainly would buy”, confirming the preference for osmotically dehydrated products.

Table 1. Concentration of sugars and calcium chloride according to treatment to be used in the osmotic dehydration of mango cv. Palmer (*Mangifera indica* L.)

Treatments	Osmotic solution		
	Sucrose (%)	Glucose (%)	$CaCl_2$ (%)
T1. Sucrose	60	–	–
T2. Sucrose + $CaCl_2$	60	–	0.12
T3. Sucrose + glucose	40	20	–
T4. Sucrose + glucose + $CaCl_2$	40	20	0.12
T5. Without osmotic dehydration	–	–	–

Table 2. Nutritional composition and energy value of fresh mango, dehydrated with previous osmotic treatment with sucrose (T1), sucrose + CaCl2 (T2), sucrose + glucose (T3) and sucrose + glucose + CaCl2 (T4) and dehydrated without osmotic treatment (T5).

Components	*Fresh*	Treatment				
		T1 Sucrose	T2 Sucrose + $CaCl_2$	T3 Sucrose + glucose	T4 Sucrose + glucose + $CaCl_2$	T5 WOD
Moisture (g/100g)	83.55±0.17[a]	13.12±0.17[cd]	14.18±0.53[b]	12.27±0.29[c]	11.12±0.14[e]	13.46±0.15[bd]
TRS (g/100g)	57.85±0.94[d]	89.99±3.00[a]	66.70±1.70[c]	75.56±1.06[b]	62.25±2.71[cd]	63.36±2.76[cd]
RS (g/100g)	20.15±0.27[a]	13.39±0.34[d]	11.40±0.20[e]	14.96±0.67[bc]	15.91±0.71[b]	13.91±0.31[cd]
Protein (g/100g)	11.60±1.57[a]	3.87±0.00[bc]	2.96±0.03[c]	3.04±0.19[c]	3.89±0.07[bc]	5.94±0.11[b]
Lipids (g/100g)	1.48±0.93[a]	0.74±0.20[a]	0.72±0.09[a]	0.84±0.14[a]	0.67±0.16[a]	1.71±0.16[a]
Minerals (g/100g)	2.65±0.15[a]	1.77±0.16[b]	1.52±0.06[b]	1.69±0.06[b]	1.53±0.11[b]	2.71±0.08[a]
Fibers (g/100g)	1.03±0.14[d]	1.35±0.11[c]	1.53±0.11[c]	1.92±0.07[b]	1.95±0.18[b]	3.79±0.07[a]
Energy value (kcal/100g)	47.88	331.96	244.7	282.5	240.43	253.2

*WOD: dehydrated without osmotic treatment. TRS: total reducing sugars. RS: reducing sugars. Moisture expressed on wet basis (g / 100g) and energy value in kcal / 100g wet sample. The other components were expressed as g / 100 g dry matter. Means followed by equal letters in the same row do not differ from each other ($P \geq 0.05$) by the Tukey test.

Table 3. Physical and chemical characteristics of fresh mango, dehydrated with previous osmotic treatment with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3) and sucrose + glucose + $CaCl_2$ (T4) and dehydrated without osmotic treatment (T5).

Analysis		*Fresh*	Treatment				
			T1 Sucrose	T2 Sucrose + $CaCl_2$	T3 Sucrose + glucose	T4 Sucrose + glucose + $CaCl_2$	T5 WOD
TA (g $_{citric\ acid}$/100g)		0.71±0.06[b]	0.84±0.12[b]	2.30±0.39[a]	1.13±0.15[b]	2.20±0.59[a]	1.58±0.48[ab]
pH		4.26±0.03[b]	4.94±0.16[a]	4.12±0.10[b]	4.77±0.03[a]	4.22±0.25[b]	4.87±0.17[a]
SS (°Brix)		15.00±0.00[c]	67.70±1.60[ad]	63.60±2.21[bd]	68.50±0.70[ab]	72.20±3.20[a]	66.80±1.50[bd]
Water activity		0.983±0.0005[a]	0.689±0.001[c]	0.719±0.004[b]	0.687±0.001[c]	0.647±0.002[f]	0.663±0.001[e]
Color:	L*	52.23±2.40[a]	48.01±4.90[ab]	39.63±9.39[bc]	50.05±6.66[ab]	43.22±6.67[ab]	31.17±2.40[c]
	a*	2.71±2.79[b]	11.51±5.11[a]	11.17±2.40[a]	11.58±1.99[a]	9.74±2.43[a]	11.55±2.24[a]
	b*	46.17±6.04[a]	47.64±3.47[a]	32.58±4.92[b]	49.86±6.27[a]	44.11±11.49[a]	34.29±4.88[b]
	C*	46.32±6.09[ab]	49.22±3.69[a]	34.48±5.16[b]	51.19±6.53[a]	45.22±11.55[ab]	36.22±5.01[b]

WOD: dehydrated without osmotic treatment. TA: titratable acidity; SS: soluble solids. L: brightness, a*: green-red chromaticity, b*: yellow-blue chromaticity, C*: chromaticity variation. Means followed by equal letters in the same row do not differ from each other (P≥0.05) by the Tukey test.

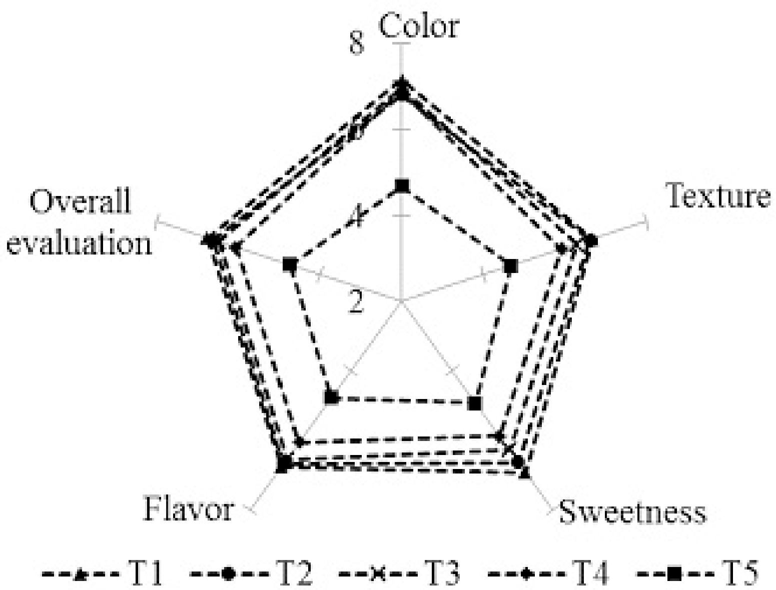

Figure 1. Averages of values assigned by judges for each attribute of mango dehydrated with previous osmotic treatment with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3) and sucrose + glucose + $CaCl_2$ (T4) and dehydrated without osmotic treatment (T5).

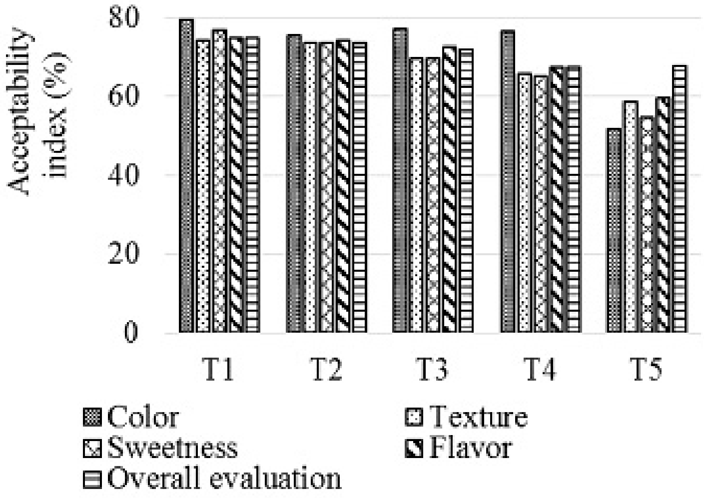

Figure 2. Acceptability index of mango dehydrated with previous osmotic treatment with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3), sucrose + glucose + $CaCl_2$ (T4) and dehydrated without osmotic treatment (T5).

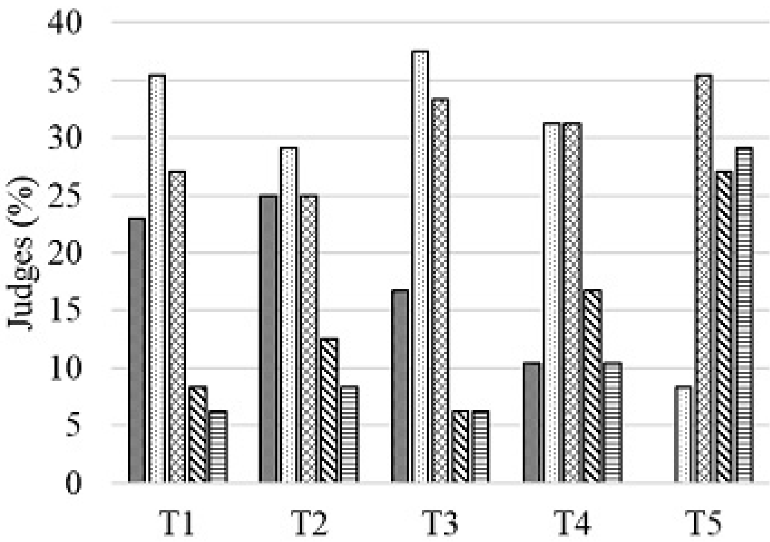

Figure 3. Purchase intention of mango dehydrated with previous osmotic treatment with sucrose (T1), sucrose + $CaCl_2$ (T2), sucrose + glucose (T3), sucrose + glucose + $CaCl_2$ (T4) and dehydrated without osmotic treatment (T5).

Conclusion

The addition of calcium chloride in osmotic solutions promoted lower sugar incorporation and higher acid retention in osmotically dehydrated fruits. The increase of sucrose and glucose during osmotic pre-treatment contributed to the maintenance of the nutritional quality and color of the dehydrated product when compared to product without osmotic dehydration. Products dehydrated with previous osmotic treatment were more preferred and showed greater purchase intention. The combination of osmotic treatment with convective drying provided greater acceptance of dehydrated mango since it offers better quality.

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