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Physical and chemical changes in guava raisin (*Psidium guajava* l.) produced by osmotic dehydration and drying convective

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Abstract

The osmotic dehydration pre-treatment is used to partially reduce the fruit initial water content, before convective drying. Purpose of the present work is to investigate the influence of osmotic treatment followed by convective drying on the physicochemical parameters of guava slices. The Paluma guava was cut into slices of 3.0 × 2.0 × 0.9 cm, dehydrated and dipped in sucrose syrup at concentrations of 40, 50 and 60 °Brix, at temperatures of 30, 40 and 50 °C. The process was again supplemented by convective drying at temperatures of 50, 60 and 70 °C. Guava-raisins with and without pre-osmotic treatments were subjected to the following physico-chemical analyzes: soluble solids, pH, total acidity, ash, reducing and total sugars, water activity (A_w). The color was considerably changed into a darker and the total sugar reduced as a result of the syrup concentration and osmotic dehydration temperatures. Also, the pH and A_w decreased through application of treatments. From the results it is recommended that the production of guava passes under dehydrating conditions of 60 °Brix at 50 °C and further drying temperature of 60 ° C is efficient.

Keywords: chemical parameters; dehydrated food; osmotic dehydration; physico-, tropical fruit; *psidium guajava* L.
Abbreviations: A_w_water activity, TA_titratable acidity.

Introduction

Guava (*Psidium guajava* L.) stands out for its higher vitamin C content; six times as much as that found in most citrus fruit such as the acerola, camu-camu and cashews. The fruit exhibits higher amounts of sugar, vitamin A, vitamin B, phosphorus, iron and calcium (Silva et al., 2014).

According to Sahoo et al. (2015), the guava is highly perishable, and undergoes rapid, post-harvest deterioration along the course of a few days of storage under ambient conditions. This is due to the fruit's extremely natural breathing rate. The main changes that occur after a few days of storage include weight loss due to moisture loss, decreased turgor, degradation of chlorophyll, which causes loss of color, change in texture, loss of nutritional value, and the consequent reduction of its market value.

Among the processes to preserve and prolong the availability of guavas for consumption, drying methods are used with the sole purpose of decreasing perishability, preserving, at the same time, the fruit's natural qualities (Castro et al., 2014).

Osmotic dehydration has been reported as a relevant, partial drying method capable of reducing the fruit water content by dipping it into a concentrated solution which contains one or more solutes, resulting in a significant water transfer from the product onto the surrounding medium (Souraki et al., 2013; Cataldo et al., 2011). It is an economical method capable of reducing the operation costs brought about by conventional drying processes; however, this method does not reduce the water content to levels that would significantly minimize deterioration by microbiological or biochemical action. Thus, osmotic dehydration is used as a pretreatment for subsequent conventional drying (Al-Harahsheh et al., 2009; Correa et al., 2010).

The combination of various drying methods for fruit drying has been applied after the use of pre-treatments, whose purpose is to reduce energy consumption during the removal of water along the process; or else for modifying the structure of the fruit tissue to accelerate the drying process (Zou et al., 2013; Alam et al., 2014; Oliveira et al., 2014).

The importance of drying processes in agriculture is based on the quality of the food supplied, following adequate storage. After harvest, the fruit will be available for a few days for fresh consumption, so the osmotic dehydration and drying resources will be responsible for the product's prolonged preservation. In specific cases, the drying mechanism produces raisins, adding special value to the product for worldwide consumption.

The production of guava raisins through osmotic dehydration followed by hot air drying is considered as an alternative to use the agro-industrial fruits in their advanced maturation stages and yield production. As a result, prolonged shelf life, preservation and better market value are expected. The present study aimed to verify the influence of osmotic treatment followed by convective drying considering the guava physicochemical parameters.

Results and Discussion

physicochemical parameters of guava in natura

Table 1 shows the mean values with their corresponding variation coefficients of fresh guava physico-chemical parameters. The mean value of average soluble solids ranged from 7.40 to 11.40 °Brix as reported by Coser et al. (2014).

The pH and acidity values detected in guava *in natura* were lower than those found by Bialves et al. (2012) and Grigio et al. (2011). On the other hand, the percentage of total sugars was higher than the value reported by Lima et al. (2002). The authors detected 4.61% of total sugars in the Paluma guava variety when fully ripe. It should be observed that the difference between the physico-chemical composition of fruits of the same species and at the same stage of maturity can be attributed to edaphic-climatic factors most common in the species' cultivation region.

The value of A_w found for fresh guava confirms Fellows' classification (2006) which points out that foods with water activity higher than 0.95 should be classified as fresh and highly perishable; similar to fresh guavas which are most perishable and susceptible to rapid deterioration.

Physicochemical parameters of raisins guava

The corresponding mean values for different osmotic treatments following convective drying of sliced guava, for the parameters of soluble solids, pH, acidity and ash are presented in Table 2, where all treatments were significantly different from each other (p> 0. 05).

The highest soluble solids (48 °Brix) were obtained by dehydration at 50 °C and 60 °Brix, plus further drying at 70 °C. The lowest amount of soluble solids has been found after drying treatment *in nature* at a temperature of 60 ° C. Souza et al. (2011) reported that an increase in soluble solids during the production of dried solids can be attributed to both the solid gaining during dehydration and the concentration (evaporation of water) during drying.

Despite variations in pH values, the guava slices, when subjected to treatment, presented a range of values varying from 3.24 to 3.68. By comparing these results with those shown in Table 2 for the fresh fruit, a small decrease in pH was observed, which according to Derossi et al. (2015), can be attributed to a concentration of hydrogen ions caused by the elimination of water.

It has been observed that the ash content did not exhibit a well-defined behavior between treatments (Table 2). However, by comparing the means of treatments with the percentage of ash found in fresh guava (Table 1), it has become apparent that the osmotic treatment followed by drying does cause a considerable increase in ash percentage. The solid gains via osmotic treatment followed by their own concentration during the drying process did cause an increase in the product's mineral content, causing a consequent increase in the percentage of ash in the guava slices. Elias et al. (2008), after osmotically evaluating the ash content in dehydrated khaki followed by convective drying, reported a 94% increase in ash content.

Elias et al. (2008) after evaluating the osmotically dehydrated ash content following convective drying, observed a 94% increase in the ash content of the samples after the process. Higher levels of acidity have been observed in dehydrated guava slices at 30 °C and 60 °Brix for all drying temperatures. According to Manica et al. (2000), acidity takes on evaluation criteria and flavor classification where acidity values *in nature* guava vary from 0.24 to 1.79% of citric acid, which permits classification of fruit in moderate flavor and consequently well-accepted for fresh consumption.

By comparing the ATT contents of guava raisin with those found in fresh guava, a well-defined behavior has not been observed, because the sugar uptake can promote a reduction in acidity, while drying causes the higher concentration of the acids in the fruits. As a result, the percentage of acidity in sliced guava subjected to dehydration will depend on the amount of sugar assimilated by the fruit tissue and the amount of water removed through drying. Different result was reported by Udomkun et al. (2015). The authors observed decreased acidity in papaya subjected to osmotic dehydration followed by convective drying.

Table 3 presents the results of the comparative values of means between the different osmotic treatments followed by convective drying on slices of guava which includes: reducing sugars, total sugars and water activity, which were statistically different. Although the sucrose applied to the osmotic process (treatment) was found to be non-reducing sugar, an increase of reducing sugars was detected in all treatments. Previous work has pointed towards reducing sugar content as a function of hydrolytic activity (Marques et al., 2007) caused by an increase in temperature during dehydration, which caused an inversion of sucrose. The most reduction in sugars has been observed in treatments using the combination of high temperature and high concentration of sucrose (50 ° to 60 ° Brix). These had the highest sugar uptake during the process.

The osmotic treatment followed by drying caused an increase in the total percentage of sugars following the incorporation of sucrose and concentrations of solids present in the fruit. Germer et al. (2011), on osmotic dehydration of peaches in sucrose solution, have also found an increased in total content of sugars after osmotic dehydration.

The osmotic pre-treated samples showed higher A_w values due to the caramelized sugar surface layer set during drying, forming a surface layer of sugar, which somehow hindered water release. The samples that did not go through osmotic dehydration exhibited smaller A_w values, as they did not have additional barrier to prevent water release, facilitating mass transfer.

Table 4 shows the chromaticity coordinates (L*, H*, C*) obtained for the different treatments of guava-raisin. It can be observed that the samples subjected to convective drying presented the highest L* values when compared to pre-osmotically treated samples, revealing; therefore, a darker dehydration color under conditions of 50 °C and 60 °Brix. This fact may be attributed to the amount of sugar attached to the product surface, which, upon contact with heat, causes the darkening as a result of caramelization.

The dry treatment at 50 °C, caused the highest value of brightness on samples pre-treated under the experimental condition 1 (30 ° C and 40 ° Brix), whereas not possessing a greater amount of sugar, it has a larger amount of water, forming a far more intense molasses. The molasse renders the surface considerably dark upon contact with the heat for longer periods of time.

Table 1. Mean and standard deviation of the physio-chemical characteristics of paluma guava *in natura*.

Guava *in natura*	
Soluble solids	9.30 ± 0.01
pH	3.72 ± 0.14
Acidity	0.46 ± 0.02
Ash	0.42 ± 0.08
Reducing sugars	5.82 ± 0.32
Total sugars	7.01 ± 0.01
Water activity, Aw	0.98 ± 0.01

Fig 1. Peeled fruits (A), seeded, (B) and sliced (C)

Table 2. Mean values of soluble solids, ph, ash and acidity in guava under different osmotic treatments following complementary drying.

Drying temperature	Osmosis temperature	Sucrose concentration	Soluble solids	pH	Ash	Acidity
50 °C	30	40	25.50 de	3.60 b	1.15 cd	0.42 abcd
	50	40	25.00 e	3.24 l	1.14 cd	0.27 def
	30	60	37.00 c	3.27 jl	1.09 cd	0.48 ab
	50	60	41.50 c	3.68 a	1.38 b	0.26 ef
	40	50	26.00 de	3.46 f	1.12 cd	0.36 bcdf
	In natura		13.50 f	3.61 b	1.01 d	0.36 bcdf
60 °C	30	40	26.5 0de	3.54 d	1.23 bc	0.39 abcde
	50	40	28.00 d	3.51 e	1.00 d	0.22 f
	30	60	37.50 c	3.34 i	1.00 d	0.43 abc
	50	60	47.50 a	3.54 d	1.37 b	0.25 ef
	40	50	27.00 de	3.37 gh	1.18 cd	0.32 cdef
	In natura		15.50 f	3.39 g	1.11 cd	0.38 bcde
70 °C	30	40	25.00 e	3.57 c	1.24 bc	0.42 abc
	50	40	27.50 de	3.33 i	1.12 cd	0.29 cdef
	30	60	38.50 c	3.36 hi	1.64 a	0.52 a
	50	60	48.00 a	3.61 b	1.21 bc	0.31 cdef
	40	50	27.00 de	3.60b	1.11 cd	0.38 abcde
	In natura		15.50 f	3.29 j	1.18 cd	0.41 abcd
DMS			2.55	0.03	0.20	0.14
CV%			2.82	0.28	5.23	13.07

All mean values introduced by the same letter are not statistically different from each other, according to Tukey's test, at a 5% probability level.

Table 3. Mean values of reducing sugars, total sugars and water activity.

Drying temperature	Osmosis temperature	Sucrose concentration	Reducing sugars	total sugar	A_w
	30	40	17.34 e	21.26 i	0.62 g
	50	40	29.03 bc	37.98 c	064 f
50 °C	30	60	19.97 de	25.30 h	0.69 a
	50	60	34.83 a	37.58 c	0.69 a
	40	50	26.29 bc	30.82 ef	0.67 b
	In natura		8.27 g	11.49 l	0.59 h
	30	40	18.83 de	20.09 i	0.62 g
	50	40	26. 09 c	31.80 de	0.64 f
60 °C	30	60	18.45 de	22.47 i	0.67 b
	50	60	34.18 a	48.17 b	0.68 a
	40	50	26.5 c	28.80 fg	0.65 de
	In natura		12.54 f	17.14 j	0.59 h
	30	40	21.20 d	25.14 h	0.60 h
	50	40	29.96 b	33.78 d	0.62 g
70 °C	30	60	17.17 e	20.60 i	0.66 cd
	50	60	34.83 a	51.70 a	0.67 bc
	40	50	25.79 c	28.31 g	0.65 e
	In natura		11.93 fg	15.30 j	0.59 h
DMS			3.79	2.40	0.009
CV%			5.40	2.79	0.47

All mean values introduced by the same letter are not statistically different from each other, according to Tukey's test, at a 5% level of probability.

Table 4. Mean color parameters of guava subjected to different osmotic treatments and complementary drying.

Drying Temperature	Osmosis Temperature	Sucrose Concentration	L*	H*	C*
	30	40	36.85 ab	18.78 fgh	33.25 ghi
	50	40	33.60 ef	19.99 de	32.09 hi
50 °C	30	60	35.27 d	18.08 hi	35.92 bcd
	50	60	36.29 bc	25.12 b	36.14 bc
	40	50	34.49 de	19.35 defg	36.21 bc
	In natura		37.74 a	18.46 ghi	35.26 cdf
	30	40	34.75 d	18.74 fgh	34.33 defg
	50	40	34.91 d	19.55 def	32.19 hj
60 °C	30	60	36.77 d	19.17 efg	35.00 cdefg
	50	60	35.01 d	24.97 bc	38.38 a
	40	50	32.34 gh	18.61 fgh	33.72 efgh
	In natura		35.37 cd	19.13 efg	35.42 cde
	30	40	32.75 fg	19.93 de	31.68 i
	50	40	31.68 hi	24.13 c	39.04 a
70 °C	30	60	31.22 i	27.52 a	37.67 ab
	50	60	34.87 d	25.74 b	38.16 a
	40	50	33.34 f	17.62 i	33.50 fgh
	In natura		36.37 b	20.27 d	35.21 cdef
DMS			0.93	0.98	1.80
CV%			0.88	1.54	1.67

All mean values introduced by the same letter are not statistically different from each other, according to Tukey's test, at a 5% level of probability.

Table 5. Experimental matrix for osmotic dehydration of guava slices.

Experiments	Osmosis temperature (°C)	Sucrose concentration (°Brix)
1	30	40
2	50	40
3	30	60
4	50	60
5	40	50

Mancilla-Nuñez et al. (2013) have observed brightness values on osmotically pretreated strawberries lower than those found in fresh fruit, indicating darker coloring when compared to fresh strawberry subjected to osmotic dehydration.

The value of the H* hue presented significant difference among treatments (Table 4). A range from 18.08 to 20.27 can be seen in almost all treatments, except for the experimental condition four (50 °C and 60 °Brix) which ranged from 24.97 to 25.74 for all three drying temperatures.

Using the scale for H*, a 0 proximity for all treatments can be observed, showing a clear tendency towards a reddish color pattern. In fact the experimental condition 4 shows a close value to pure red, when compared to the other treatments, revealing a higher percentage of sugar, which, subjected to heating, causes caramelization, altering the natural coloring of the fruit. Consequently, it can be stated that the presence of sugar in large quantities brings about color alterations in guava raisins.

The average chroma C* values ranged from 31.68 to 39.04 in all treatments. Comparing the values obtained after osmotic treatment and drying with the results of guava *in natura* (Table 1), an increase in C* values, indicating stronger colors for the guava raisins was verified. According to Mendes et al. (2013), an increase in solids concentration accounts for the stronger color of the product which explains the higher values of C*.

Atares et al. (2011) studied the effect of osmotic dehydration on the banana quality and noticed changes in the color of fresh bananas after osmotic treatment, reporting that L* and H* significantly reduced ($p \leq 0.05$) after a four-hour osmotic dehydration treatment.

Materials and Methods

Fruits of processing

Guavas of the *Paluma* variety were purchased at the local market in Campina Grande. The guavas were acquired at their full stage of maturity and selected by skin color. They were free from physical damage or any other imperfections, such as those caused by microorganisms. The guavas were washed under running tap water and then immersed for 10 minutes in a 50 ppm chloride solution for complete cleansing. Following this process, the fruit was evenly peeled, the seeds were removed and the pulp was cut into slices of 3.0 × 2.0 cm, considering the natural average thickness of the fruit, which is 0.9 cm, as shown in Fig 1.

Osmotic dehydration and drying

The osmotic solution was obtained by the complete dissolution of commercial sucrose in distilled water at concentrations of 40, 50 and 60 ° Brix, at temperatures of 30, 40 and 50 °C combined as shown in Table 5. The dehydration process was initiated by dipping the slices in guava syrup at a ratio of 1:15 (g/g) fruit/syrup, at a total time of 1440 min. The drying process was carried out on *in natura* pretreated guava slices, heated in an air drier at temperatures of 50, 60 and 70 °C.

Parameters assessed

Physico-chemical determinations were carried out on fresh guava slices after having dried them with hot air. To characterize the product, regardless of treatment, fruits were dried until they reached an average moisture content of 0.18 + 0.20 b.u. Analyzes were performed in triplicate in order to minimize the errors.

The soluble solids content was determined by utilizing a refractometer, and the reading was expressed in °Brix. The pH was determined by the potentiometric method, previously calibrated with buffer solutions of 7.0 and 4.0 at a temperature of 20 ° C.

The titratable acidity (TA) values, expressed in percentage, were determined by immersing the sample into a sodium hydroxide solution at 0.1N using phenolphthalein as an indicator. A fixed amount of minerals (ash) was obtained through incineration, determining; therefore, the weight loss of the material subjected to heating in a muffle at a temperature of 550 °C until constant weight is obtained.

The sugar content present in the sample was determined by the volume of sugar solution required to reduce Fehling's solution to a volume. The results were expressed as percentages. The water sample activity was determined as result of the Aqualab CX-2T Decagon at 25 ° C.

The color analysis was determined and measured instrumentally by using a HunterLab MiniScan XE Plus spectrophotometer under a CIELAB color system, which generated the readings of L* (lightness), a* (-a* transition from green to red + a *), and b * (-b* transition from blue to yellow + b*). Based on the parameters (L*, a* and b*). The hue (H* = arctan b* / a*) and chroma (C* = (a* 2+b*2) ½) were obtained in accordance with Lawless and Heymann's methodology (1998).

Statistical analysis

Statistical analysis of the data was performed by a completely randomized design, and the average subjected to analysis of variance (ANOVA) compared by Tukey test at 5% probability, using the computer program Sisvar version 5.3 (Ferreira, 2010).

Conclusion

The osmotic dehydration process and the drying of guava slices cause an increase in ash percentage, reducing sugars and total sugars. Both the pH and the water activity decrease as a result of osmotic dehydration and drying. The highest osmotic dehydration temperature of 50 °C, followed by a concentration of 60 °Brix gave the raisins the highest concentration of soluble solids and reducing sugars. The fruit color was preserved after osmotic treatment, but the samples with higher concentrations of sugar suffered superficial darkening as a result of increasing drying temperatures.

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