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Effect of reconditioning and reuse of sucrose syrup in quality properties and retention of nutrients in osmotic dehydration of guava

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Abstract

The aim of this study was to assess the effect of the reconditioning and reuse (RR) of sucrose syrup in quality properties and retention of nutrients in guava during osmotic dehydration (OD).Two trials of 15 OD cycles were conducted with RR of osmotic solution. The parameters water loss (*WL*) and solid incorporation (*SI*), as well as microbial load and physical chemical properties of syrup and fruit were evaluated. The results showed that the RR did not modify the parameters *WL* and *SI*, and the microbial load remained low. The RR did not influence the color of osmodehydrated fruit, as well as the nutrients retentions, but probably it influenced the citric acid and reducing sugar retentions. At the end, the syrup was enriched of vitamin C, polyphenols, potassium, with traces of lycopene, β-carotene and other minerals (Fe, Mg, Mn, Zn), and could be employed to formulate new products.

KEYWORDS: vitamin C; polyphenols; lycopene; minerals; recycling

INTRODUCTION

Guava (*Psydium guajava* L.) is a very tasty fruit, and its exceptional nutritional content is drawing attention all over the world, being known as "superfruit".[1] The red guava is a source of vitamin C (up to 200 mg/ 100g), being rich in phenolic compounds (up to 150 mg GAE/ 100 g), lycopene (6 mg/ 100 g) and minerals.[2, 3]

Owing to the increasing interest and the fact that the fruit is produced mainly in tropical countries, drying is an option targeting the global market, and the osmotic dehydration (OD) is an alternative of pre-process. In OD, the partial removal of water occurs due to the difference in chemical potential established during the contact of fruit and a hypertonic solution. Besides the water in OD, fruit also loses natural soluble compounds and gains solutes from the solution. In osmotic dehydration process of fruits, usually sugars are applied as osmotic agents, and the temperature and time process vary from 30 to 60 °C and 1 to 4 hours respectively. [4,5,6,7,8] The process is a pre-treatment, and does not ensure microbiological stability, requiring complementary process for conservation.[9, 10] In this way, studies report promising results concerning the application of OD to different fruits like papaya[11], mango[12], cashew[13], apple[14], cantaloupe[15], mulberry[16], and in this specific case, guava[4,5,6] .

However, the main difficulty in OD is managing the solution.[17] In an osmotic cycle, the solution is diluted with the water gain and with the solute losses to fruit, causing a decrease in osmotic potential and changes in physicochemical properties.[18] Putting away the solution at each use could make the process economically infeasible and environmentally unfriendly.[19] Moreover, discarding the spent solution is throwing away nutrients and natural compounds received in the process.[20] In general, the solution can be directly reused in OD, without any reconditioning, or after a reconditioning process by water evaporation or by adding solute to recover the original concentration.[21]

Good nutrients retention and quality maintenance of raw materials are usually attributed to osmotic dehydration due to the mild process conditions.[22] However, the losses of the natural solutes to solution are not negligible in the process.[23] In this way, some works report losses around 30-60% of vitamin C, phenolic compounds and minerals in OD.[24,25] Therefore, with the reuse, solution could be enriched with nutrients and employed as ingredient in the development of new products.[26] Furthermore, concentration gradients decrease with the solution reuse in OD, and in thesis may minimize the losses from fruit. Grabowski et al.[27] observed a decrease in anthocyanin loss in blueberry OD with the solution reuse. Moraga et al.[28] reported a decrease of citric acid loss with the reuse of sucrose syrup in grapefruit OD. In both studies the reuse of solution was carried out without reconditioning.

In this context, the purpose of this study was to evaluate, in the osmotic dehydration of guava, the effect of reconditioning and reuse of sucrose syrup in dehydration parameters, fruit and syrup physicochemical properties, and nutrient retentions.

MATERIAL AND METHODS

Guavas, Paluma variety, were acquired from a Campinas producer (São Paulo, Brazil). Fruits (7-8 cm of diamenter) were harvested at same maturity stage and stored at room temperature (~25 °C) up to 5 days for ripening and conduction of experimental tests. At each osmotic cycle, fruits were selected at same maturity stage by skin color. Syrup was prepared with refined sucrose (União, Coperçucar, Brazil) and distilled water.

Experimental Methods

Two trials of 15 OD cycles were carried out concomitantly at same process conditions. At each cycle, fruits were washed, sanitized (150 mg sodium hypochlorite/ L), manually peeled and deseeded, and cut into 4 pieces. The OD process conditions were: sucrose syrup concentration of 65 °Brix; syrup mass: fruit ratio of 4:1; process temperature and time of 45 °C and 4 h. The choice of process conditions was based on preliminary tests and studies reported in literature. [4,5,6,8] Regarding the process temperature, Sagar and Kumar [6] reported 60°C as optimal condition in guava OD, considering the best water removal rate and quality aspects. However, Chandra and Kumari [29] stated that process temperatures above 50ºC may result in browning reaction, flavor deterioration, and tissue modification. The authors defined process temperatures below 50°C as mild conditions in OD, with higher color and flavor retentions, resulting in products with superior sensory characteristics.

In the trials, two identical baths (Model 7306, PolyScience, Niles, EUA), each with 10 L/ min circulation pump and a capacity of 30 L were employed. The first cycle was carried out with fresh syrup, and the subsequent cycle reconditioned syrup was used. At the end of each cycle, osmodehydrated fruit was drained, rinsed in water, and carefully dried with absorbent paper. The syrup reconditioning process was carried out according to Germer et al.[30]: sieving through a steel sieve (1 mm mesh) for removing suspended particles; concentrating in a vacuum vat (Model C055, Mecamau, Espírito Santo Pinhal, Brasil) at 0.5 kgf/ cm^2 (~70°C) for recovering the initial concentration; adding new syrup in order to return to the original mass, since part of the syrup was lost due to adherence to fruits and equipments. Reconditioned syrup was stored at room temperature (~25 °C) for the subsequent cycle.

Mass Transfer Parameters

The parameters of water loss (*WL*) and solids incorporation (*SI*) of the fruits in OD were calculated using the following functions:

$$WL = (U_i M_i - U_f M_f)/M_i \times 100 \quad \text{(g of water/ 100 g of initial mass)} \qquad (1)$$

$$SI = (ST_f M_f - ST_i M_i)/M_i \times 100 \quad \text{(g of solute/ 100 g of initial mass)} \qquad (2)$$

Analyses

Analyses were carried out in different cycles with fresh fruit (FF), osmodehydrated fruit (OF) and initial syrups. The following properties were analyzed: soluble solids content; moisture and total solids content; water activity; instrumental color; pH; titratable acidity; reducing sugar content; vitamin C content; total polyphenol content; minerals content (P, Ca, Cu, K, Na, Mg, Mn, Fe, Zn); β-carotene and lycopene contents; and microbial load.

The soluble solid content was determined using an optical bench refractometer (Model

10450, Abbe Refratometer, Buffalo, EUA), and pH with a potentiometer (Model DM 20, Digimed, Santo Amaro, Brasil). Total acidity (TA) was determined by an acidimetric method using citric acid as the base for calculation (AOAC, 2006). The moisture content was determined in a vacuum oven at 70ºC to constant weight, and the sugar content by Munson & Walker method.[31] Water activity was determined using a hygrometer (Decagon Devices, Aqualab-3TE, USA) at 25°C. The total polyphenol content was determined by Folin Ciocalteau spectroscopic method.[32] A Chromameter colorimeter (CR300, Minolta, Osaka, Japan) was used for the color analyses using the CIELAB system (d=0/ D65 illuminant). Chroma parameter was calculated from the chromaticity parameters *a** (green/red) and *b** (blue/yellow) using the following function:

$$Chroma = \sqrt{a^{*2} + b^{*2}} \tag{3}$$

The vitamin C content was determined by titration according to Oliveira et al.[33]. The microbial load was determined by yeast and mold counts, according to Downes & Ito[34]. The analyses of minerals were carried out by inductively coupled plasma optical emission spectrometry (ICP OES) (Model Vista MPX,Varian, Mulgrave, Australia) after sample preparation according to Queiroz et al.[35]. The content of carotenes was evaluated according to Carvalho et al.[36], from the acetone extraction and transfer to petroleum ether, with quantification of β-carotene and lycopene by high performance liquid chromatography (HPLC). The nutrient retentions were calculated according to Murphy et al.[37].

Statistical Analyses

The experiments were carried out in duplicate and analyses were done at least in triplicate, with the exception of mineral contents, done in duplicate. Different mean values were statistically evaluated by analysis of variance (ANOVA) and by Tukey's test at $p \leq 0.05$ employing Statistica 8.0 (StatSoft Inc., Tulsa, USA).

RESULTS

Process Conditions

Syrup concentration in terms of soluble solids content (SS) had a slight variation throughout the RR cycles according to Figure 1a. Values presented significant differences ($p \leq 0.05$) between some cycles, with overall average of 65.14 ± 0.42 °Brix. Variation was considered acceptable for a pilot trial. SS contents of fresh fruit also showed some significant differences ($p \leq 0.05$) between cycles, although without any defined tendency, and with overall average of 7.7 ± 0.7 °Brix (Figure 1b). The overall average of mass syrup: mass fruit ratio was 4.17(± 0.17): 1 (kg of syrup: kg of fruit) at the OD cycles. Table 1 shows that microbial load of syrup, fresh fruit and osmodehydrated fruit remained low throughout the trials, and certainly washing and sanitizing, as well as the adopted good practices, contributed to this result. However, the vacuum concentration during the reconditioning process (~70°C / ~10 min) might have had pasteurization effect, as reported by Germer et al.[30]] in RR of sucrose syrup in OD of peach. Based on these results, it is possible to affirm that the reconditioning operations were very efficient, and the 15 OD cycles were carried out in very similar conditions.

Osmotic Dehydration Parameters

Figure 1c shows there were no significant differences (p>0.05) between *WL* and *SI* parameters throughout the cycles, whose means were respectively 42.34 ± 2.16 g/ 100 g and 4.77 ± 0.82 g/ 100 g. The values are higher than those reported by Vieira et al.[4] in OD of guavas, respectively 29 g/ 100 g and 3 g/ 100 g for *WL* and *SI*. Therefore, despite small differences in syrup concentration and soluble solids contents of fresh fruit, the RR process did not influence the OD parameters. Similar results were reported by Germer et al.[30] in OD of peach with RR of sucrose syrup.

Physicochemical Properties

Table 2 presents mean values of physicochemical properties of fresh and osmodehydrated fruit throughout the study. Titratable acidity (TA), pH and water activity (a_w) of fresh fruit presented significant differences (p≤0.05) throughout the cycles, but they did not follow a clear trend. Figure 2a, on the other hand, shows that TA of syrup continuously increased during RR, and the reason is probably the leaching of acids from fruit to solution, as reported by Valdez-Fragoso et al.[38]. Retention values (RT) obtained for citric acid (CA) confirm there were losses of this compound by fruit (Table 2). Nevertheless, it is possible to see that the losses were higher at the first three cycles. Moraga et al.[28] also observed the decrease of citric acid losses in the reuse of syrup in OD of grapefruit, and attributed the fact to the decrease of concentration gradient with the accumulation of acids in solution. On the other hand, there was a reduction of the pH of syrup at the initial cycles, stabilizing around the value 4.0 (Figure 2b), very close to the fresh fruit pH (3.88 ± 0.08). Valdez-Fragoso et al.[39] reported the same behavior in a RR trial of apple OD. According to the authors, the lowering of pH is interesting for syrup conservation, avoiding spoilage, and as CA is a weak acid, the continuous gain throughout the cycles does not change the pH after the equilibrium.

With respect to reducing sugar (RS), Table 2 shows there were no significant differences ($p>0.05$) between the fresh fruit contents at the different cycles. This result together with the observation of slight variations in other fresh fruit physicochemical properties revealed that there was no significant change in the maturity stage of the raw material, and the differences are more related to the inherent variability of the same. As expected, fruit RS content increased in OD at each cycle, due to the water removal in dehydration process (Table 2). However, the RS contents of osmodehydrated fruit presented significant differences ($p\leq0.05$) between the cycles, with higher values at the final ones. On the other hand, Figure 2c illustrates the continuous increase of RS syrup content with the RR. According to Dalla Rosa & Giroux[18], the growth of RS syrup content during OD happens due to acid hydrolysis of the non-reducing sugar and RS gain by leaching from fruit. Probably both mechanisms occurred in the present study. There might have been a flow of RS from fruit to solution, according to the losses showed in Table 2 (retention values). Although at the final cycles, due to acid hydrolysis of solution sugar, the RS net flow might have reversed, causing gains by fruit. However, it has to be considered that this result could be due to the action of the enzyme invertase, which is responsible for the inversion of sucrose into glucose and fructose. In guava, the invertase content grows with ripening[40,41], and the fruits of the final cycles would have a higher content of this enzyme. Yet, there was not an important maturation of raw material throughout the cycles, weakening this hypothesis. Moreover, it is noteworthy that high reducing sugar content may influence the obtained product stability during storage since it can start Maillard reaction, and further investigation is necessary. The increase of RS contents in syrup may also be related to the slight reduction of the syrup water activity throughout the cycles (Figure 2d). Valdez-Fragoso at al.[38] correlated the increase of RS content in syrup during the RR in apple OD with the decrease in water activity. According to the authors this behavior is due to the a_w lowering capacity of the sugars, and the combined low a_w (~0.90) and low pH (~4) of syrup would reduce the chances of syrup spoilage by bacteria.

Color

Color of fresh fruit showed slight variation throughout the study according to the measured parameters L^*, a^* and b^*, shown at Table 3. The values presented significant differences ($p \leq 0.05$) between cycles, but did not follow defined trends. Table 3 has the dimensionless values of the fruit color parameters. An increase of chromatic parameters is observed in OD at almost all cycles (a_{adim} and $b_{adim}>1$), as expected with the removal of water and pigments concentration. On the other hand, there was a slight whitening of fruit in OD ($L_{adim}>1$), probably due to sugar up take in the cellular tissue, also reported by Pereira et al.[5]. Table 3 also shows there were practically no significant differences ($p> 0.05$) between the dimensionless parameters throughout the cycles. Therefore, the RR must have no influence on color of osmodehydrated fruits. Regarding syrup, Figure 3a shows L^* parameter decreases throughout the cycles, indicating a darkening, as reported by Fragoso-Valdez et al.[38] in apple OD with RR. Authors attributed the observed browning to Maillard reaction initiated between amino acids and reducing sugars. As shown in Figures 3b and 3c, there was an expressive variation of syrup chromatic parameters throughout the RR. Solution was initially greenish ($a^* < 0$), and became reddish ($a^* > 0$) (Figure 3b). The increase of b^* parameter was greater, indicating a substantial enhancement of the yellow color in syrup (Figure 3c), resulting in an important increase of Chroma parameter (Figure 3d). Such behavior can be explained by the fruit pigment accumulation in the solution. Similar results were reported by García-Martinez et al.[42] in a RR trial in apple OD.

Minerals

Fresh guavas were rich in potassium, with intermediate contents of iron, phosphorus, calcium and manganese, and had traces of sodium, copper and zinc (Table 4). The determined levels are close to the composition reported by Queiroz et al.[35] for Paluma variety. There was almost no variation in main mineral contents in fresh fruit throughout the study. The retention values show that there was loss of all minerals in OD process (64-97%). However, the retention variations of each mineral do not follow trends through the cycles, suggesting no influence of RR on the flows. Overall averages of retention were, in descending order by mineral: iron (86 ± 23%), calcium (84 ± 9%), zinc (78 ± 14%), phosphorous (77 ± 12%), potassium (77 ± 8%), manganese (74 ± 8%), and magnesium (70 ± 8%). Copper variation is not being considered due to the high oscillations, and sodium due to the possible influence of sodium hypochlorite used in sanitizing operation. The obtained retention values are higher than those reported by Queiroz et al.[35] in OD of guava with sucrose syrup, which stayed in the range of 36-80%. Peiró et al.[43], in a trial of 8 OD cycles of grapefruit with reuse of sucrose solution, reported losses between 28-59% per cycle. In a later study, regarding the reuse of sucrose syrup in pineapple OD, Peiro-Mena et al.[44] reported losses of minerals between 40-60%. In both studies, performed without syrup reconditioning, authors concluded that mineral losses were not influenced by reuse. It can be seen from Figure 4a that mineral contents of syrup increased with RR (with the exception of sodium) due to leaching from fruit and accumulation in solution. In the case of sodium, the use of sodium hypochlorite in sanitizing could also have influenced the results. Also, it is possible to see there might have been some calcium in new syrup. Figure 4b shows the flow of potassium was the highest one, followed by phosphorus and magnesium. Some traces of iron, manganese and zinc were also detected (<1 mg/ 100 g) in syrup. On the 15thcycle, syrup had the following average concentrations of minerals: potassium (113 ± 4 mg/ 100 g); calcium (5.40 ± 0.14 mg/ 100 g); phosphorous (4.8 ± 0.1 mg/ 100g); magnesium (3.00 ± 0.14 mg/ 100g).

Vitamin C

Fresh fruit vitamin C content showed significant differences (p≤0.05) between the cycles (Table 5), while the overall average of 36.47 ± 5.66 mg/ 100 g was lower than the values reported by Queiroz et al.[35] and Morgado[45] for the Paluma variety, respectively 49.1 and 95 mg/ 100 g. The low levels are due to the less advanced fruit ripening stages employed, since the vitamin C content of guava increases with maturation [45]. There was loss of vitamin in OD (Table 5), but the average values of retentions were close throughout the cycles, with overall average of 54 ± 6%, discarding the hypothesis of the RR influence. Queiroz et al.[35] and Erler & Schubert[46] reported vitamin C retentions close to 80% in guava OD (50 °C/ 2h) and strawberry OD (20°C/ 5h) respectively. On the other hand, Zao et al.[47] reported vitamin C retention of 15% in mango OD (30°C/ 2h), and Araya-Farias et al. [48] determined a rate of 22% in seabuckthorn fruit OD (40°C/ 6h). According to Santos & Silva [49], the loss of vitamin C in fruit OD happens due to oxidation and leaching to solution due to high water solubility of the molecule. Indeed, Figure 5a shows there was a significant increase in vitamin C content in syrup, reaching 95 mg/ 100g in 15 cycles. Peiró et al.[43] reported a content of vitamin C in syrup of 4 mg/ 100 g after 8 cycles of reuse in grapefruit OD. However, vacuum pulse was employed in the beginning of the trial, favoring the solute impregnation and retention in fruit.

Polyphenols

Table 5 shows that the levels of total polyphenols in fresh fruit had significant differences ($p \leq 0.05$) throughout the cycles, with overall average of 118 ± 21 mg GAE/ 100 g, which is between the values reported by Morgado [45] and Oliveira et al.[50] for Paluma variety, respectively 77 and 148 mg GAE/ 100 g. It can be seen in Table 5 that polyphenol retentions in OD were high, with values greater than 87%. These percentages are in accordance with the value of 80% reported by Blanda et al.[24] in apple OD, and 74% observed by Sette et al.[51] in a dry infusion of raspberry (sugar and fruit). Devic et al.[52], on the other hand, reported a loss of polyphenols around 40% in apple OD. The authors observed that leaching was higher for low molecular weight compounds, such as hydroxycinnamic acids, and lower for high weight molecules, such as cyanidins. According to Chiari et al.[53] Paluma guava variety contains mainly flavonoids and tannins, higher molecular weight polyphenol compounds. That would explain in part the high retentions observed in the present study. On the other hand, Nagai et al.[54] found that the addition of ascorbic acid in solution minimized the loss of polyphenols in mango OD. In this regard, the previously mentioned accumulation of vitamin C in syrup may also have contributed to the result. Furthermore, polyphenol retentions varied in the cycles without any trend, showing no influence of RR in the flows. According to Figure 5b, there was a continuous increase in polyphenol content in syrup, leading to a content of 37 mg/ 100 g at 15 °C. Kucner et al.[55] also reported gains for polyphenols by sucrose syrup in blueberry OD, reaching in a single cycle the content of 7 mg GAE/ 100g.

Carotenes

Concerning β-carotene content of fresh fruit, the overall average was approximately 85 μg/ 100g, lower than the value reported by Siqueira et al.[56] for Paluma guava, around 180 ug/ 100g. The low level in the present study, due to the fruit ripening stage employed, resulted in high deviations and hindered the retention calculation. Table 5 shows that fresh guava had a high level of lycopene, and the contents varied slightly throughout the study. The overall average of 5.97 ± 0.81 mg/ 100 g are close to the value reported by Rodriguez-Amaya et al.[57] for Paluma variety, which is 6.6 mg/ 100 g. The lycopene retention values were high, in the range of 65-97%, without showing a clear variation tendency throughout the cycles (Table 5), pointing to no influence of RR in the flows. Shi et al.[58] reported that OD process retained more total lycopene in tomato than other dehydration methods. Authors stated that sugar enters the tomato matrix and strengthens the binding forces on lycopene. In the present study, losses might have occurred due to oxidation or thermal degradation, and some leaching to solution, since the compound is a lipid-soluble molecule. Indeed, Figure 5c shows that there was some transfer of lycopene to syrup, reaching the content of 0.62 ± 0.18 mg/ 100 g in the 15th cycle. The same happened with β-carotene, whose traces were observed in syrup as of the 12th cycle (Figure 5d). The gain of these pigments partly explains the color changes of syrup, which became yellower throughout the cycles (item 3.4), in accordance to Xianquan et al.[59] that states lycopene produces a yellow color when dissolved in solutions. Germer et al.[30] and Heng et al.[60] have already related the solution color with the gain of carotenes in peach and papaya OD respectively. In this context, Pan et al. [61] reported that the carotene losses of carrot and pumpkin in OD is related to the compound contents in final solutions. However none of these studies presented the quantification of carotene in syrup.

CONCLUSION

The study revealed that there is technical feasibility in reconditioning and reuse of sucrose syrup in osmotic dehydration of guava throughout 15 cycles. Process conditions were maintained almost constant throughout the cycles, as well as osmotic parameters. Microbial load remained low in the system. However, physicochemical properties of syrup have changed in the process. There was lowering of pH, increase of acidity and reducing sugars contents. There was also darkening, probably due to non enzymatic browning, and syrup became reddish and yellowish due to gains of pigments. Some changes are beneficial, such as the lowering of pH, which might contribute to the syrup conservation. However, the increase of reducing sugars can decrease the stability of syrup and products. At the end of reuse, syrup resulted relatively rich in vitamin C (~95 mg/ 100 g), polyphenols (~37 mg GAE/ 100 g) and potassium (~113 mg/ 100 g), presenting traces of lycopene, β-carotene and other minerals (Fe, Mg, Mn and Zn). There was no influence of the reconditioning and reuse of syrup on the retention of fruit nutrients, which varied in the range of 54-98%, nor in color of osmodehydrated fruit. However, process has probably minimized citric acid leaching from fruit and caused gain of reducing sugars by fruit due to acid hydrolysis of sugar syrup. In this context, storing the syrup under refrigeration between each use might contribute to quality maintenance, but the costs should be considered. The spent syrup at the end of various reuse cycles has great potential and can still be used as an ingredient in the formulation of new products.

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NOMENCLATURE

WL	water loss
SI	solids incorporation
U_i	initial moisture content
M_i	initial mass
U_f	moisture content at the end of the process
M_f	mass at the end of the process
ST_f	total solids content at the end of the process

ST_i initial solids content

L^* lightness ($L^* = 0$ for black and $L^* = 100$ for white)

a^* chromaticity parameters (green [-] to red [+])

b^* chromaticity parameters (blue [-] to yellow [+])

L^*_{dim} dimensionless parameter L^* (L^* of osmodehydrated fruit/L^* of fresh fruit)

a^*_{dim} dimensionless parameter a^* (a^* of osmodehydrated fruit/ a^* of fresh fruit)

b^*_{dim} dimensionless parameter b^* (b^* of osmodehydrated fruit/b^* of fresh fruit)

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Table 1. Yeast and mold count in initial syrup, fresh fruit (FF) and osmodehydrated fruit (OD) for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup[a].

Cycle		**Initial Syrup**		**FF**		**OD**	
		Trial 1	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
1	**Mold**	$< 10^2$	$< 10^2$	$< 10^2$	2×10^2 [a]	$< 10^2$	$< 10^2$
	Yeast	$< 10^2$	$< 10^2$	$2{,}6 \times 10^3$	4×10^2 [a]	$< 10^2$	$< 10^2$
4	**Mold**	$< 10^2$	$< 10^2$	$< 10^2$	1×10^2 [a]	$< 10^2$	2×10^2 [a]
	Yeast	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$
8	**Mold**	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	1×10^2 [a]	1×10^2 [a]
	Yeast	1×10^2 [a]	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$
12	**Mold**	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$	2×10^2 [a]
	Yeast	$< 10^2$	$< 10^2$	$< 10^2$	1×10^2 [a]	$< 10^2$	$< 10^2$
15	**Mold**	1×10^2 [a]	2×10^2 [a]	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$
	Yeast	$< 10^2$	$< 10^2$	$< 10^2$	1×10^2 [a]	$< 10^2$	$< 10^2$

[a]Estimated count quantification limit of the method.

Table 2. pH, titratable acidity (TA), water activity (Aw) and reducing sugar content (RS) of fresh fruit (FF) and osmodehydrated fruit (OF) for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup[a].

Cycle	pH (FF)	pH (OF)	TA (FF) (g ca/100g)	TA (OF) (g ca/100g)	RT cítric acid (%)	Aw (FF)	Aw (OF)	RS (FF) (g/100g)	RS (OF) (g/100g)	RT reducing sugar (%)
1	3.89±0.02[a]	4.06±0.10[a]	0.340±0.010[a]	0.387±0.012[a]	75.1±1.0	0.992±0.002[a]	0.983±0.003[a]	5.50±0.66[a]	7.23±0.37[a]	87.9±12.7
3	3.83±0.07[b]	3.85±0.05[b]	0.414±0.018[b]	0.498±0.021[b]	74.1±0.3	0.997±0.004[ab]	0.983±0.005[a]	5.03±0.83[a]	7.83±0.47[a]	97.2±13.5
6	4.03±0.07[c]	4.00±0.07[ad]	0.344±0.026[a]	0.462±0.025[c]	87.7±0.8	1.001±0.004[b]	0.987±0.005[a]	5.63±0.33[a]	8.07±0.76[a]	93.8±6.6
9	3.84±0.09[a]	3.82±0.04[bc]	0.374±0.020[a]	0.502±0.008[b]	84.2±5.9	0.997±0.003[b]	0.985±0.003[a]	5.65±0.70[a]	11.93±0.91[b]	138.8±14.7
12	3.90±0.10[ac]	3.97±0.07[d]	0.371±0.011[a]	0.483±0.023[bc]	84.5±5.0	0.998±0.001[b]	0.985±0.001[a]	5.46±0.33[a]	10.55±0.53[b]	124.6±0.1
15	3.80±0.09[a]	3.85±0.04[be]	0.415±0.030[b]	0.542±0.025[d]	81.8±11.2	0.997±0.002[ab]	0.986±0.004[a]	5.90±0.86[a]	11.49±1.02[b]	124.9±33.6

[a]Means in the same column followed by different letters indicate significant difference at $p \leq 0.05$.

Table 3. Color parameters of fresh fruit (FF) and dimensionless color parameters for osmodehydrated fruit (OF) for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup[a,b].

Cycle	FF			OF		
	L*	***a****	***b****	$\boldsymbol{L_{adim}}$	$\boldsymbol{a_{adim}}$	$\boldsymbol{b_{adim}}$
1	47.28±5.38[ab]	25.08±4.43[a]	20.27±2.11[ac]	1.09±0.00[a]	1.11±0.01[a]	1.19±0.00[a]
3	49.48±4.58[a]	25.43±4.51[ae]	20.12±2.17[a]	1.02±0.04[a]	1.12±0.17[a]	1.20±0.02[a]
5	49.09±5.98[ab]	19.96±5.29[b]	23.08±2.48[be]	0.98±0.01[a]	1.36±0.03[a]	1.03±0.08[a]
7	48.81±2.95[ab]	29.25±2.58[cd]	21.78±1.60[bcde]	1.04±0.01[a]	1.00±0.06[a]	1.06±0.01[a]
9	45.75±5.06[bc]	26.67±5.47[acde]	21.13±2.94[acdf]	1.13±0.04[a]	0.94±0.18[a]	1.16±0.04[a]
11	43.60±2.85[c]	30.02±2.68[d]	20.59±1.72[acdf]	1.09±0.02[a]	0.95±0.04[a]	1.06±0.01[a]
13	49.92±3.62[a]	26.00±5.42[ace]	22.06±2.39[ef]	0.94±0.07[a]	1.32±0.03[a]	1.29±0.06[a]
15	47.79±4.01[ab]	28.35±3.58[ed]	21.45±2.04[abde]	1.05±0.12[a]	1.06±0.06[a]	1.07±0.11[a]

[a] Means in the same column followed by different letters indicate significant difference at $p \leq 0.05$.

[b] $Parameter_{adim}$ = Color parameter (*L**, *a**, *b**) of osmodehydrated fruit / color parameter (*L**, *a**, *b**) of fresh fruit.

Table 4. Retentions of minerals (RT) and minerals content of fresh fruit (FF) and osmodehydrated fruit (OF) for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup^{a,A}.

Cycle		Calcium (mg/100g)	Copper (mg/100g)	Iron (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)	Magnesium (mg/100g)	Manganese (mg/100g)	Zinc (mg/100g)	Phosphorus (mg/100g)
1	FF	9.22 ± 2.74^{a}	0.13 ± 0.05^{a}	0.15 ± 0.05^{a}	213.75 ± 24.05^{ab}	2.15 ± 0.59^{a}	6.16 ± 0.36^{a}	0.07 ± 0.0^{a}	0.17 ± 0.03^{a}	16.82 ± 1.83^{a}
	OF	9.58 ± 2.51^{A}	0.13 ± 0.11^{A}	0.15 ± 0.05^{A}	227.25 ± 29.77^{A}	2.09 ± 0.56^{AB}	5.92 ± 0.84^{AC}	0.08 ± 0.01^{A}	0.19 ± 0.05^{A}	18.39 ± 3.14^{A}
	RT(%)	77.6±49.8	11.5±1.4	73.6±52.3	71.6±20.7	71.4±43.4	64.0±15.0	68.5±9.4	77.6±37.7	70.2±25.6
4	FF	9.03 ± 0.89^{a}	0.22 ± 0.13^{a}	0.11 ± 0.01^{a}	242.50 ± 5.92^{ab}	0.95 ± 0.11^{b}	5.86 ± 0.20^{a}	0.08 ± 0.01^{a}	0.17 ± 0.00^{a}	19.57 ± 4.50^{a}
	OF	13.50 ± 1.41^{B}	0.07 ± 0.06^{A}	0.18 ± 0.00^{A}	298.00 ± 2.00^{B}	2.50 ± 0.24^{B}	6.86 ± 0.08^{AB}	0.09 ± 0.00^{B}	0.20 ± 0.01^{A}	18.21 ± 2.33^{A}
	RT(%)	93.4±23.6	21.6±1.3	105.5±0.7	75.7±1.7	162.2±0.24	72.1±2.6	74.2±7.5	72.4±5.6	84.6±11.5
8	FF	8.37 ± 1.01^{a}	0.11 ± 0.08^{a}	0.12 ± 0.02^{a}	209.50 ± 8.70^{b}	1.30 ± 0.31^{ab}	5.54 ± 0.04^{a}	0.08 ± 0.01^{a}	0.17 ± 0.01^{a}	16.82 ± 1.45^{a}
	OF	11.86 ± 1.96^{AB}	0.18 ± 0.08^{A}	0.19 ± 0.05^{A}	273.25 ± 4.27^{B}	2.26 ± 0.23^{AB}	6.28 ± 0.23^{ABC}	0.09 ± 0.01^{B}	0.21 ± 0.02^{A}	17.93 ± 2.54^{A}
	RT(%)	86.3±3.6	38.2±5.6	82.5±13.8	79.8±5.1	112.5±45.1	69.3±2.7	71.5±4.8	75.6±3.9	75.5±2.7
12	FF	8.51 ± 0.24^{a}	0.11 ± 0.08^{a}	0.13 ± 0.01^{a}	228.50 ± 12.56^{ab}	1.95 ± 0.77^{ab}	5.71 ± 0.34^{a}	0.07 ± 0.00^{a}	0.16 ± 0.01^{a}	16.17 ± 0.63^{a}
	OF	9.6 ± 0.21^{A}	0.06 ± 0.02^{A}	0.15 ± 0.02^{A}	275.50 ± 12.45^{B}	2.14 ± 0.21^{AB}	5.75 ± 0.52^{C}	0.08 ± 0.01^{AB}	0.20 ± 0.03^{A}	17.36 ± 2.69^{A}

	RT(%)	71.8±3.7	12.9±2.1	73.3±10.4	76.8±0.3	76.6±30.3	64.4±9.9	74.9±7.6	79.8±12.5	71.6±14.3
15	FF	7.82±1.08[a]	0.05±0.02[a]	0.11±0.01[a]	246.75±21.25[a]	1.68±0.42[ab]	5.95±0.48[a]	0.07±0.00[a]	0.16±0.01[a]	18.66±3.59[a]
	OF	11.05±0.79[AB]	0.07±0.01[A]	0.17±0.02[A]	303.00±8.29[B]	1.82±0.12[A]	7.24±0.16[B]	0.09±0.09[B]	0.21±0.01[A]	20.64±2.50[A]
	RT(%)	90.6±3.7	82.4±0.0	97.0±8.2	78.6±7.2	70.3±13.6	77.7±2.5	82.0±3.6	83.8±7.3	83.6±4.1

[a] Means in the same column followed by different letters indicate significant difference at $p \leq 0.05$ for fresh fruit.

[A] Means in the same column followed by different letters indicate significant difference at $p \leq 0.05$ for osmodehydrated fruit.

Table 5. Vitamin C, total polyphenols and lycopene contents of fresh fruit (FF), osmodehydrated fruit (OF), and respective retentions (RT) for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup[a].

Cycle	**Vitamin C**			**Cycle**	**Total Polyphenols**			**Lycopene**		
	FF (mg/100g)	**OF (mg/100g)**	**RT (%)**		**FF (mg GAE/100g)**	**OF (mg GAE/100g)**	**RT (%)**	**FF (mg/100g)**	**OF (mg/100g)**	**RT (%)**
1	44.39±11.33[a]	36.87±7.68[a]	58.5±7.1	**1**	103.49±11.83[a]	138.57±7.96[a]	91.0±8.1	5.35±0.47[ab]	6.01±0.63[a]	74.5±9.7
3	31.80±5.31[b]	30.70±6.71[ab]	53.0±10.5	**4**	127.32±6.11[b]	203.10±7.43[b]	98.5±10.5	5.95±0.67[ab]	6.26±0.32[a]	64.9±7.6
6	31.85±3.12[bc]	27.85±2.49[ab]	56.5±3.9	**8**	147.61±5.48[c]	233.50±2.76[c]	96.9±7.4	5.21±0.48[a]	8.35±1.71[b]	97.4±18.4
9	32.87±4.32[b]	26.68±2.48[b]	50.7±4.4	**12**	121.25±5.83[b]	165.98±16.74[d]	87.5±15.1	7.25±1.45[b]	7.50±0.70[ab]	66.9±8.4
12	35.18±5.28[ab]	30.54±3.93[ab]	55.4±0.9	**15**	91.15±0.73[d]	169.73±27.21[d]	97.8±0.1	6.11±0.97[ab]	7.61±0.65[ab]	80.0±4.9
15	42.76±3.83[a]	32.92±5.30[a]	49.1±4.6							

[a] Means in the same column with different letters indicate significant differences ($p \leq 0.05$).

Figure 1. (a) Concentration of syrup (°Brix), (b) soluble solids content of fresh guava and (c) water loss (*WL*) (♦) and solid incorporation (*SI*) (■) parameters throughout 15 osmotic dehydration cycles of guava with reconditioning and reuse of sucrose syrup (means of the same parameter with different letters indicate significant difference at $p \leq 0.05$).

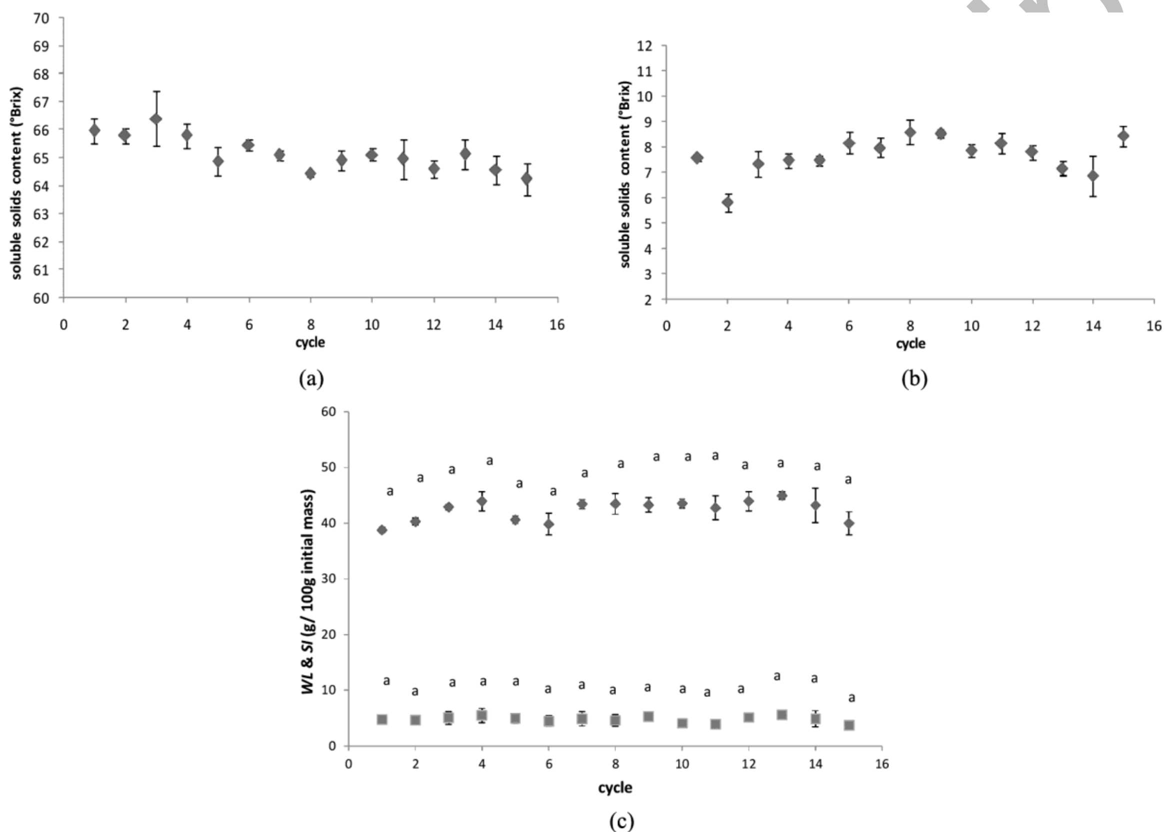

Figure 2. (a) Titratable acidity, (b) pH, (c) reducing sugar content and (b) water activity of syrup for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup.

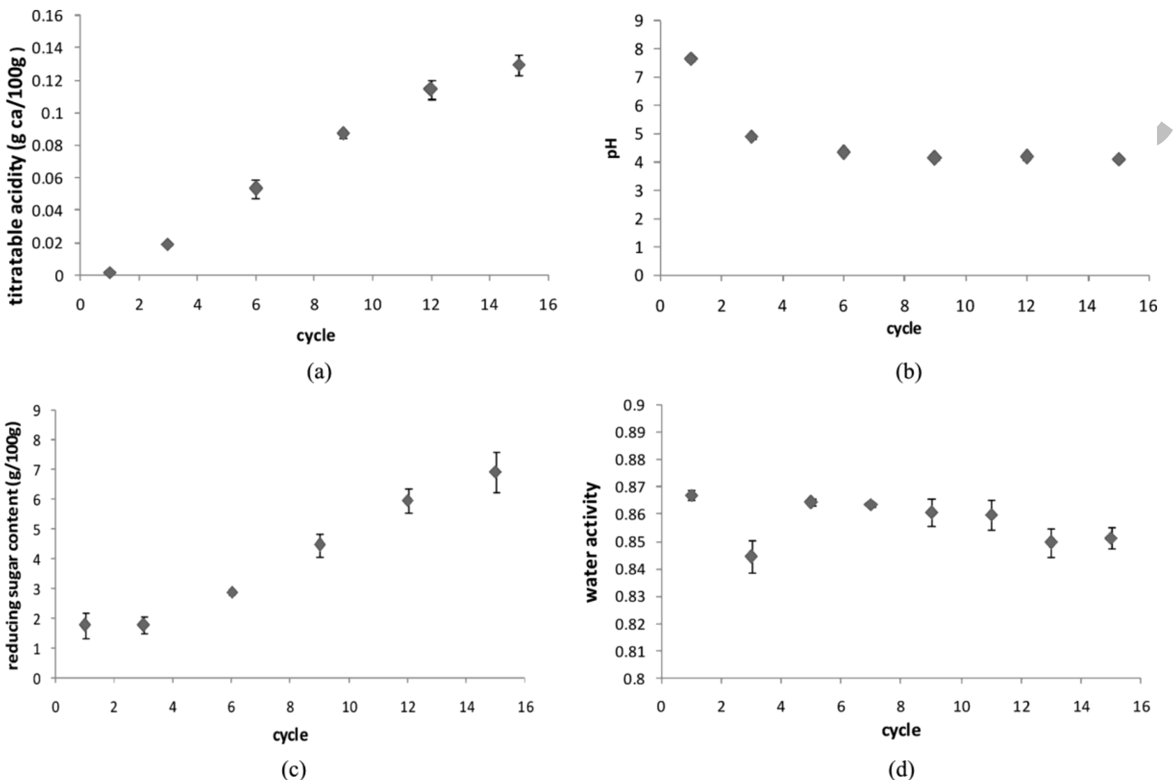

Figure 3. Color parameters of syrup in some cycles in OD of guavas with reconditioning and reuse of sucrose syrup: a) $L*$ (luminosity); b) $a*$ (green-red); $b*$ (blue-yellow); d) *Chroma*.

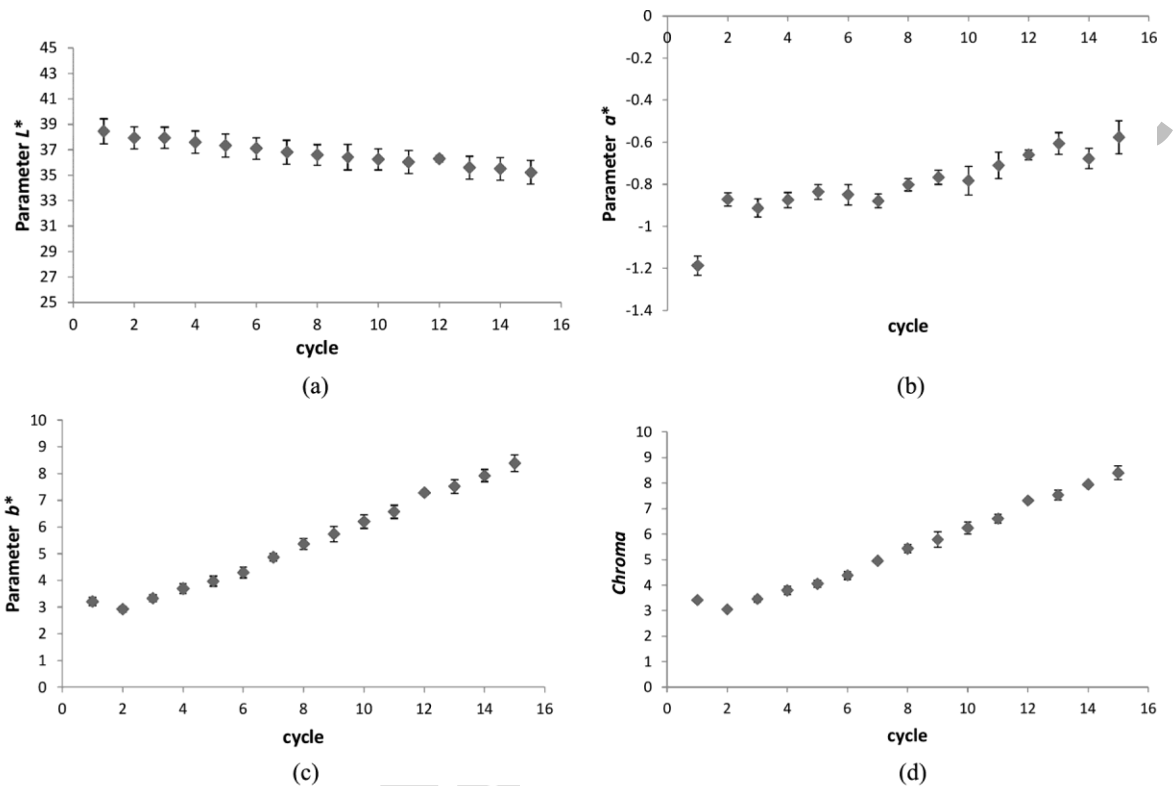

Figure 4. (a) Minerals content and (b) potassium content of syrup for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup (♦ calcium; ■ phosphorus; ▲. Sodium; X magnesium; • potassium)

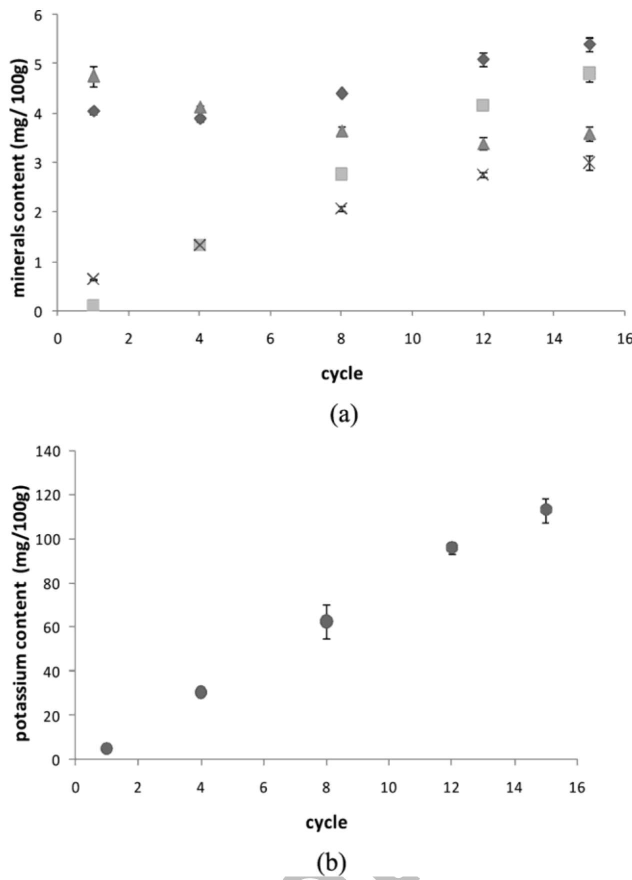

Figure 5. (a) Vitamin C content (b) total polyphenols content (c) lycopene content and (d) β-carotene content of syrup for some of the cycles in OD of guavas with reconditioning and reuse of sucrose syrup.