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ORIGINAL PAPER

# Development and Characterization of a Baked Snack from Rings of Green Apples

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**Abstract** Apple snacks were developed from green apple (Granny Smith) by baking. The effect of several pretreatments on properties such as color, texture, moisture, and water activity was studied. Blanching with steam, impregnation with calcium salts (calcium carbonate/calcium lactate), impregnation with sugars (fructose and maltodextrin), and addition of ascorbic acid were some of the pretreatments used. The addition of calcium proved to be favorable since it caused a reduction in the porous structure of the apple tissue associated with a greater firmness. The optimum selection of pretreatments on the rings of green apples gave as a result a snack with a higher acceptability in the evaluated attributes (color, sour taste, sweetness, and texture). Irrespective of the composition of the used solution of sugars, moisture, water activity, and lightness (*L*) of the baked apple rings did not differ significantly. The antioxidant activity of the obtained snack increased compared to that of fresh fruit due to the addition of ascorbic acid. The ascorbic acid content of apple snacks also turned out to be higher than that of fresh apples.

**Keywords** Baked apple rings · Calcium · Ascorbic acid

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## Introduction

A snack is a product easy to consume, accessible, small, solid, or liquid, which requires little or no preparation before consumption and whose purpose is to satisfy the hunger that occurs between meals. For decades, consumers have eaten fried products because of their combination of flavor and texture. However, the increasing consumers' concern about the relationship between food, nutrition, and health has emphasized the need to limit the intake of calories from fat and sugar with the incorporation of health beneficial elements such as dietary fibers. In the market, there are few crunchy snacks that can be considered healthy. An interesting alternative to currently popular snacks are baked apple rings, which, to the best of our knowledge, have received little attention.

Fruits and vegetables are low in calories and fat and contain valuable fibers and nutrients that can prevent the development of some diseases. From a nutritional standpoint, apple fruit is one of the most complete. Water represents 85 % of its composition; sugars, mostly fructose and to a lesser extent glucose and sucrose, rapidly assimilable in the body, are the most abundant constituents after water. The apple improves intestinal transit because of its high content in fiber, provides a small amount of vitamin C, and contains minerals among which potassium is the most abundant. The content and composition of the polyphenols present in apples are important as they contribute to the sensory quality of fresh fruit and processed apple products. These phytochemicals are also recognized for their antioxidant properties (Khanizadeh et al. 2008).

On the other hand, thermal processing causes changes in the microstructure and, hence, in the texture (Nisha et al. 2006). Texture is considered one of the most important criteria concerning consumer's acceptance of snack chips (Ramos et al. 2004; Deng and Zhao 2008; Setiady et al. 2009).

Calcium addition combined with heat treatment results in an increase in the firmness of vegetable tissue due to its ability to interact with pectins (Alzamora et al. 2000). Several works reported the influence of pretreatments with calcium salts in various plant systems, analyzing their influence from the point of view of mechanical properties (Sousa et al. 2007) and nutritional characteristics (Alzamora et al. 2005). Moreover, the addition of solutes in the process allows increasing product stability and reducing the drying time as well as provides ideal color and flavor. The addition of polysaccharides with high molecular weight such as maltodextrins being miscible with low molecular weight sugars increases the glass transition temperature (Roos 1995). This work focused on (a) developing a crispy snack from baked green apple rings using different pretreatments (blanching with steam, calcium salt impregnation, sugars, and ascorbic acid) and (b) analyzing the influence of these pretreatments on the quality and antioxidant properties of the apple rings.

## Materials and Methods

Granny Smith apples (*Malus domestica*), selected by size and appearance, were purchased from the local market. For the development of the experimental batches, standardized apples of approximately 85 % moisture and soluble solid content of 11±1 °Brix were selected and stored at 4–6 °C. For different pretreatments, fructose and maltodextrin (food grade, Parafarm, Argentina), calcium lactate gluconate (food and pharma grade, Jungbunzlauer, Germany), calcium carbonate (analytical grade, Mallinckrodt Chemical Works, USA), and ascorbic acid (food grade, Parafarm, Argentina) were used.

### Pretreatments of Apple Rings: Obtention of Snacks

Apples were washed, wiped with paper towel, and sliced to a thickness of 2±0.2 mm perpendicular to the core using a domestic processor (Yelmo, Argentina). Slices of 35 mm diameter were cut and the center of each slice was removed with a punch of 10 mm diameter. The apple rings were dried with paper towel. A group of 10 rings was simultaneously immersed in a solution of 2.5 % (*w*/*v*) calcium carbonate (CC) or 2.5 % (*w*/*v*) calcium lactate (CL) for 2, 15, and 60 min and then subjected to a blanching process with steam at 121 °C for 3 min by using a domestic steamer (Oster, Argentina). After that, the apple rings were cooled with crushed ice until reaching 30 °C and immersed in 200 ml of 30 % (*w*/*v*) aqueous solutions of maltodextrin (M) and fructose (F) at 30 °C. Solutions with different ratios of M/F (1:1, 2:1, and 1:2) were used. In all cases, 2 % (*w*/*v*) of ascorbic acid (AA) was added to the solutions of sugars, prior to the immersion of the samples.

Snacks were obtained by using a forced convection oven Multiequip HCE-3 at 100 °C for 1 h. From here onward, the apple samples obtained from impregnation with calcium lactate were immersed in the aforementioned solutions of maltodextrin/fructose with ratios of 1:1, 2:1, and 1:2 and baking will be named snacks $A_L$, $B_L$, and $C_L$, respectively. In addition, snacks obtained from the same pretreatments but adding calcium carbonate instead of calcium lactate will be named snacks $A_C$, $B_C$, and $C_C$. Snacks and baked apple rings will be considered as synonymous. Untreated baked apple rings were used as controls.

### Weight Loss as a Function of Time

In each experiment, the apple samples were taken at different times between 0 and 120 min, dried on filter paper, weighed, and returned to the solution to continue the process. The curves obtained for the weight loss (ML) as a function of time were fitted through an empirical model similar to that developed by Azuara et al. (1992). These equations require two adjustable parameters $ML_\infty$ and $A$.

$$ML = \frac{A\ t\ (ML_\infty)}{1 + A\ t} \tag{1}$$

where $t$ is the immersion time [min]; $ML_\infty$ is the weight loss in the equilibrium [g]; and $A$ is the other parameter [$min^{-1}$], which can be defined as the rate constant related to weight loss.

From $ML_\infty$ and $A$ values, the necessary time to achieve a reduction of 50 % of sample weight was obtained. This was selected as the time of immersion in solutions of sugars.

### Determination of Calcium Content

The sample was poured onto the porcelain crucibles, which were previously dried at 105 °C overnight to remove water. Ash was obtained in a muffle furnace at 550 °C according to the method described by Harbers (1998). Ash was dissolved in HCl 2 N and measured by atomic absorption spectrometry, with $LaCl_3$ (as interference suppressor), by using an atomic absorption spectrophotometer AA 6200 (Shimadzu, Japan), air-acetylene flame, 0.5 nm slit, and 422.7 nm wavelength. Triplicates were run with each set of apple samples. Mean values of calcium content (expressed as $g_{Ca}$ per 100 $g_{ash}$) were reported.

### Determination of Moisture Content

The moisture contents of fresh apples and snacks were determined by measuring their weight loss, upon drying in a vacuum oven at 70 °C until constant weight (AOAC 1980). Moisture results were expressed as grams of water per 100 g of dry sample (ds). Moisture was determined at least in triplicate.

Determination of Water Activity ($a_w$)

The water activity of the obtained snacks was evaluated by using AquaLab Water Activity Meter equipment (Decagon Devices, Inc., WA). Water activity was analyzed at least in triplicate.

Determination of Soluble Solid Content

The determination of soluble solids (°Brix) was performed by using a Hanna HI96801 refractometer (Hanna, Argentina) according to AOAC (1980). Solid soluble content was analyzed at least in triplicate.

Texture Analysis

Snack texture was evaluated at room temperature in a texturometer TA.XT2i—Stable Micro Systems (England) by using a semi-spherical probe of 5 mm diameter at a constant rate of 2 mm/s. Maximum force was determined at the point of rupture. For each batch (control; $A_L$, $B_L$, and $C_L$; and $A_C$, $B_C$, and $C_C$), 10 baked apple rings per treatment were analyzed.

Color Measurements

Snack color was determined by means of a Minolta colorimeter CR 400 Series (Japan). The CIELab scale was used, and lightness ($L$) and chromaticity parameters $a^*$ (red–green) and $b^*$ (yellow–blue) were measured. Samples were analyzed in triplicates, recording four measurements for each sample. Browning index (BI) which represents the purity of brown color was calculated as follows:

$$\mathrm{BI} = \frac{[100\,(x-0.31)]}{0.172} \tag{2}$$

$$x = \frac{(a*+1.75\,L)}{(5.645\,L + a*-3.012\,b*)} \tag{3}$$

Thermal Properties Evaluation

The thermal properties of apple snacks, untreated baked apple rings, and fresh fruit were determined by using a differential scanning calorimetry (DSC) model Q100 controlled by a TA 5000 module (TA Instruments, New Castle, USA) as described in a preliminary study (Tavera-Quiroz et al. 2012). The first scan was performed from −70 to 200 °C. After the first scan was completed, the sample was cooled until −70 °C and then a second scan was recorded between −70 and 250 °C.

From thermograms, the glass transition temperature ($T_g$) was obtained by using the Universal Analysis V1.7 F software (TA Instruments, New Castle, USA). Dynamic mechanical analysis (DMA) assays were conducted in dynamic-mechanical thermal equipment Q800 (TA Instruments, New Castle, USA) as described in a previous work (Rivero et al. 2012). Multifrequency sweeps from −100 to 200 °C at 5 °C min$^{-1}$ were carried out, with an isotherm of 10 min at −100 °C. Storage ($E'$) and loss ($E''$) modulus and tanδ ($E''/E'$) curves as a function of the temperature were recorded and analyzed by using the software Universal Analysis 2000.

Sensory Analysis

A sensory panel was performed to discriminate the difference between the three types of snacks A, B, and C and the control. The sensory tests were carried out in morning sessions. A 50 member panel, who like snacks or are regular consumers of snacks and who have experience in sensory evaluation, was selected after screening and briefed but not trained among the personnel of CIDCA, in La Plata, Argentina. They were between 25 and 55 years of age and the group was 70 % female and 30 % male. Samples were randomly coded and placed in trays. The analyzed attributes were overall acceptability, color, texture, sweetness, and sour taste using a nine-point hedonic scale for each. In addition, the panelists were asked to indicate the score of each sample on a scale of 1 (dislike extremely) to 9 (like extremely). For each one of these attributes, the average response of panelists was informed.

Analysis of Functional Properties of the Selected Snack

*Sugar and Ascorbic Acid Analysis*

The HPLC system used was a Waters equipment (Malaysia), model R-414. Solute elution was followed using a UV detector and RI detector. Sugar content (glucose, fructose, sucrose) of snacks previously selected by the panelists (the best snack formulated with calcium carbonate and the one with calcium lactate) was determined by using a modified HPLC method of Dolenc and Stampar (1997).

Slices of each sample were separately freeze-dried by milling with liquid nitrogen. Two grams of powder obtained from fresh fruit and the snacks were weighed and extracted by adding 10 ml of distilled water, vortexed, and homogenized under stirring (Vortex IKA, Argentina) for 45 min. The extracts were then centrifuged for 15 min at 15,000×$g$ (Rolco CM 2036, Argentina), and the supernatants were collected and then filtered through a 0.45-μm Millipore filter (Millipore Corporation, France). An aliquot (20 μl) of the resultant supernatant was used for HPLC analysis.

Sugar analysis was performed isocratically on a Microsorb R0086700, amino column (KNAUER, Germany) attached to a refractive index (RI) detector. The analysis was carried out at 35 °C at a flow rate of 1.2 ml min$^{-1}$ with acetonitrile (Merck, Germany)/water (70:30) as the mobile phase.

The liquid chromatographic method used for the determination of ascorbic acid (AA) consisted of an isocratic elution procedure with UV–visible detection at 245 nm. One gram of frozen sample was mixed with 5 ml of an aqueous solution containing 5 % (*w*/*v*) metaphosphoric acid (Sigma Aldrich, USA) for 15 min and centrifuged for 10 min at 2,000 rpm (Rolco CM 2036, Argentina). Separations were carried out on a 5-mm RP C18 column of 150–4.6 mm (WAT 045905, Ireland). The employed mobile phase was a mixture of metaphosphoric acid 0.5 %–acetonitrile (93:7) (Nojavan et al. 2008).

*Total Polyphenol Content and Antioxidant Capacity Analysis*

The analysis of total polyphenol content and antioxidant activity was carried out on fresh and baked samples without the addition of ascorbic acid, which interferes in the measurement and gives a false positive. Slices of each sample were separately freeze-dried by milling with liquid nitrogen. Two grams of powder obtained from the fresh fruits and snacks was weighed and extracted by adding 10 ml of ethanol 96 %, vortexed, and homogenized under stirring for 40 min. The extracts were then centrifuged for 10 min at 10,000×*g* and the supernatants were collected. The antioxidant capacity of ethanol extracts was analyzed in triplicate. The polyphenol content was measured by using the Folin–Ciocalteau method (Singleton et al. 1999). Chlorogenic acid (Fluka, USA) was used as standard. The results were expressed as $mg_{chlorogenic\ acid}/100\ g_{ds}$.

Antioxidant capacity was analyzed by 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) ($ABTS^{+}$) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) methods. In the ABTS method, the pre-formed radical monocation of $ABTS^{+}$ is generated by oxidation of ABTS (Sigma Aldrich, USA) with potassium persulfate (Sigma Aldrich, USA) and is reduced in the presence of such hydrogen-donating antioxidants (Re et al. 1999). An aliquot of each sample or Trolox standard (Sigma Aldrich, USA) was mixed with $ABTS^{+}$ radical cation solution and absorbance was read at 734 nm after 1 min. Aqueous solutions of different Trolox concentrations were used for calibration. Results were expressed as millimoles of Trolox equivalents (TEAC) per gram of dry weight ($mmol_{TEAC}/g_{ds}$).

The results obtained by the DPPH method (Sánchez-Moreno et al. 1998) were expressed as radical scavenging activity or inhibition of free radical percentage (I%) where the absorbance of the reaction mixture containing both the DPPH free radical and the antioxidant is related to the absorbance of the reaction mixture without any antioxidant after an incubation period of 60 min, using the equation

$$I\% = \frac{A_0 - A_1}{A_0} 100 \quad (4)$$

where $A_0$ is the absorbance of the reaction mixture without any antioxidant (blank) and $A_1$ is the absorbance of the reaction mixture with the addition of the antioxidant. For all assays, the absorbance was measured in a spectrophotometer Hitachi U-1900 (UK).

Statistical Analysis

Systat software (SYSTAT, Inc., Evanston, IL, USA) version 10.0 was used for statistical analysis. Analysis of variance (ANOVA) was conducted with the data to assess significant differences between the samples. Regressions and Fisher LSD mean comparison test were applied in case of finding significant differences, using a significance level of 0.05.

Principal component analysis (PCA) was carried out on mean values by using Infostat v2009 software (Córdoba, Argentina). PCA was applied to the correlation matrix of the average sensory and instrumental parameter values to illustrate the relationship among variables and samples.

## Results and Discussion

A 2-min calcium salt immersion was selected considering that for longer times, calcium content did not vary significantly ($P>0.05$) (Fig. 1). The obtained results for calcium content showed that the apple slices impregnated with CC contained more amount of calcium than those impregnated with CL for the selected treatment time. The results showed values of about 31 $g_{Ca}/100\ g_{ash}$ for the rings impregnated with calcium carbonate and values ranging between 19 and 26 $g_{Ca}/100\ g_{ash}$ for calcium lactate (Fig. 1). The Recommended Dietary Allowance (RDA) is between 1,000 and 1,300 mg of Ca per day. A serving of 20 g of snack treated with calcium lactate

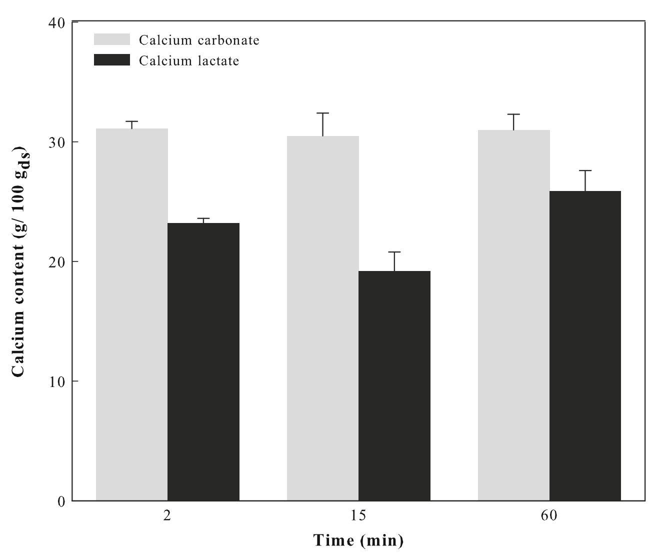


**Fig. 1** Calcium content of apple slices after 2, 15, and 60 min of impregnation with calcium carbonate (CC) and calcium lactate (CL)

provides the equivalent to 150 mg Ca, the same amount of half a cup of yogurt (Cabo Masip et al. 2008).

Considering that this mineral has a high heat resistance, it is expected not to be affected by the baking process, obtaining high levels of Ca in the support matrix (Fuertes and Navarro 2011). After immersion in maltodextrin and fructose solution (soluble solid content ranging from 24 to 26 °Brix), unbaked samples were weighted at different times up to 120 min. It was observed that the weight loss of raw apple rings increased as a function of the time. The obtained curves were modeled according to Eq. (1). Figure 2 exhibits a good agreement between experimental and predicted data for all studied formulations ($R^2$=0.990). The $ML_\infty$ and $A$ constant values were obtained from Eq. (1). Treatment time for immersion in sugar solutions was established as the time at which ML turned out to be 50 % of $ML_\infty$ value. This time ranged between 9 and 19 min. Azuara and Beristai (2002) found that the increase of ML over time is probably due to the fact that the solid gain is smaller than the water loss. The relatively large molecular size of the maltodextrins is an obstacle for its penetration into the apple tissue, suggesting that solutes of high molecular weight such as maltodextrins form a dense layer on the surface of the apple disk, which produces a concentration gradient and increases water migration from apple disks to the concentrated solution. In accordance with this explanation, the higher the maltodextrin concentration, the greater the $ML_\infty$. In this case, the order of maltodextrin increasing concentration turned out to be C, A, and B.

## Physicochemical Properties of Apple Crispy Snacks

Figure 3a. b depicts snacks $A_C$, $B_C$, and $C_C$ and $A_L$, $B_L$, and $C_L$. Properties, namely hardness, color parameters, moisture, and $a_w$ for snacks, are reported in Table 1. The water activity and $L$ values of baked apple rings showed no significant differences ($P$>0.05) regardless of the ratio of M/F and the calcium salt used. Snack $A_L$ showed the lowest $b$* value (yellow decreased compared to the other samples), and there were no significant differences ($P$>0.05) among $b$* parameters of snacks treated with calcium carbonate (Table 1). On the other hand, browning index is reported as an important parameter in processes where enzymatic or nonenzymatic browning takes place (Schebor et al. 1999; Guerrero et al. 1996; Jalaee et al. 2011). As can be observed in Table 1, BI would seem to reflect the differences visible to the naked eye better than color parameters. It is well known that the Maillard reaction is favored by the presence of carbonate owing to its alkalinity, which coincides with the higher values of BI found for snacks $A_C$, $B_C$, and $C_C$. López-Malo et al. (1998) found BI ranging between 50 and 57 for apples osmotically dehydrated.

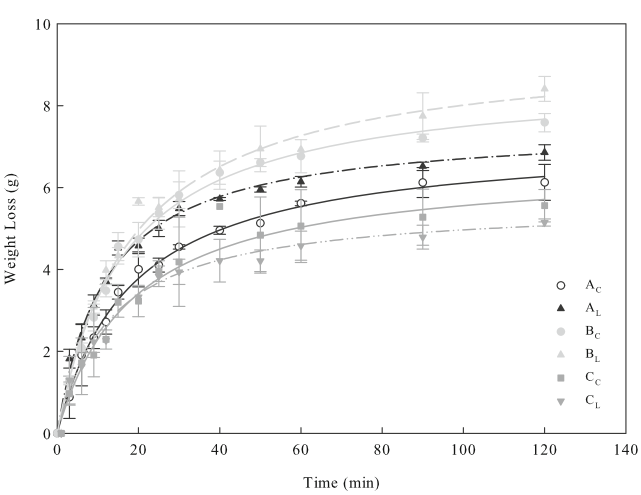


**Fig. 2** Weight loss (WL) curves for apple rings submitted to pretreatment with maltodextrin/fructose solutions and calcium salt. Experimental values for snacks prepared with CC and CL (*symbol*) and model (*line*)

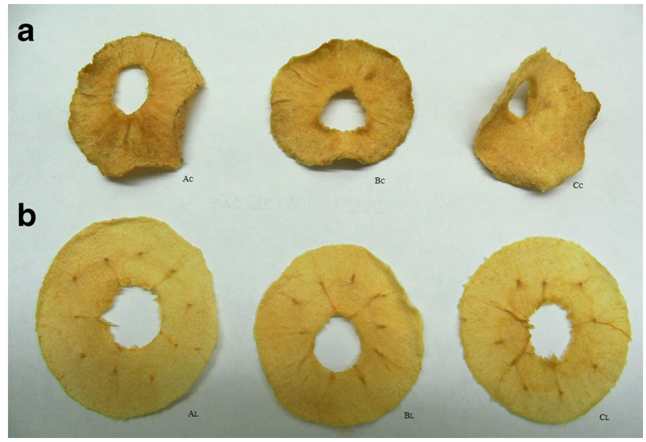


**Fig. 3** *a* Snacks $A_C$, $B_C$, and $C_C$ and *b* snacks $A_L$, $B_L$, and $C_L$ obtained by a baking process. Capital letters correspond to treatment with sugar solutions 1:1, 2:1, and 1:2 (M/F ratio) and subscripts correspond to impregnation with CC and CL, respectively

The moisture content of the group treated with CL did not show significant differences ($P$<0.05) in comparison with the group submitted to CC impregnation (Table 1). Moisture values varying between 3.45 and 5.45 % were informed by Joshi et al. (2010) working on dried apple snacks. Maximum forces at break were obtained for snacks $C_L$ and $C_C$ (Table 1).

As is known, the maximum force at break and the crispness are inversely related (Huang et al. 2011). In the penetration test, hardness is the maximum force required to break the sample (Choy et al. 2012), and crispness denotes if the fractures are abrupt under the application of a relatively small force (the first peak force) (Huang et al. 2011; Tavera-Quiroz et al. 2012). Figure 4 represents the force–displacement curves for the control and snacks $A_L$ and $A_C$. For snack $A_C$, small drops can be observed in force due to small cracks, whereas for snack $A_L$, the pattern was similar but quicker. Control exhibited a smooth curve without the occurrence of sharp drops.

If the material is brittle (i.e., has a low work to fracture), the fracture will travel quickly, resulting in sudden unloading of the muscles; this is seen as a sudden (vertical) drop in load on a force–deflection curve. The fracture is then somehow

**Table 1** Physical properties of apple snacks obtained by baking at 100 °C

| Snack | M/F ratio | Hardness (N) | $L$ | $a^*$ | $b^*$ | Browning index | Moisture ($g_{water}$/100 $g_{ds}$) | $a_w$ |
|---|---|---|---|---|---|---|---|---|
| Control | – | 0.9a (0.55) | 72.9b (3.54) | 1.8a (0.97) | 25.3c (2.03) | 42.9c (0.99) | 9.4b (1.98) | 0.45b (0.03) |
| $A_L$ | 1:2 | 2.2b (1.02) | 65.8a (3.01) | 3.5b (1.23) | 18.2a (0.94) | 33.0a (0.48) | 1.7a (0.05) | 0.31a (0.02) |
| $B_L$ | 1:1 | 2.5b (0.55) | 66.1a (2.41) | 3.4b (1.10) | 19.5b (1.24) | 38.7b (0.59) | 2.1a (0.37) | 0.32a (0.01) |
| $C_L$ | 2:1 | 4.7c (1.97) | 63.4a (2.88) | 4.1b (1.44) | 20.8b (1.38) | 39.2b (0.66) | 2.2a (0.05) | 0.35a (0.01) |
| $A_C$ | 1:2 | 2.5b (1.39) | 60.2a (5.83) | 3.3b (0.84) | 26.7c (2.10) | 80.4d (0.97) | 2.4a (0.42) | 0.34a (0.02) |
| $B_C$ | 1:1 | 5.0 c (2.56) | 59.9a (2.52) | 4.0b (0.99) | 27.5c (1.43) | 83.7d (0.71) | 2.1a (0.22) | 0.36a (0.02) |
| $C_C$ | 2:1 | 4.4c (2.12) | 59.0a (3.08) | 5.7c (0.59) | 29.1c (3.01) | 89.1e (1.36) | 2.3a (0.88) | 0.36a (0.01) |

Different letters indicate significant differences between snacks ($P<0.05$).
Values between parentheses are standard deviation

inhibited and stops, only to start again as the food is deformed further. In many materials (e.g., potato crisps), these drops result in a texture related to crispness (Vincent 1998).

## Analysis of Thermal Properties

The temperature of the relaxation process associated to the glass transition temperature ($T_g$) was determined through the DSC technique and the maximum peak of the loss modulus $E''$ curves by DMA. In fruits, glass transitions are detected due to the presence of sugars, including glucose, fructose, sucrose, and biopolymers (Vega-Gálvez et al. 2012). For fresh apple, a value of −40 °C was found in accordance with $T_g$ informed by Bai et al. (2001). From DSC thermograms, when apple rings with no pretreatments were submitted to baking (control), a value of 8.5 °C was obtained (Fig. 5a). Meanwhile, the $T_g$ of snacks ranged from 45 to 52 °C as shown in Fig. 5b. The treatments applied caused an increase of $T_g$, but the obtained values did not differ significantly among the samples. As explained, the higher moisture content of the control set the $T_g$ about 8.5 °C. As is well known, the lower the water content, the higher the glass transition temperature. The addition of polysaccharides with high molecular weight, such as maltodextrins, enhances the glass transition temperature, allowing passage to the glassy state (Bonazzi and Dumoulin 2011; Fabra et al. 2011). The increase of $T_g$ in snacks

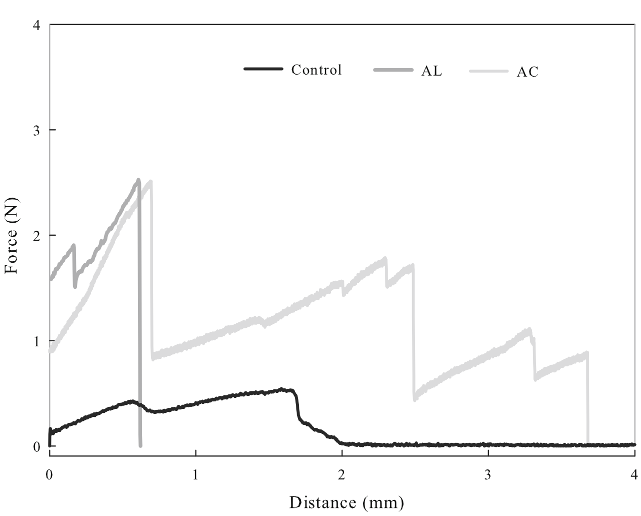


**Fig. 4** Force–displacement curves for the control and snacks $A_L$ and $A_C$

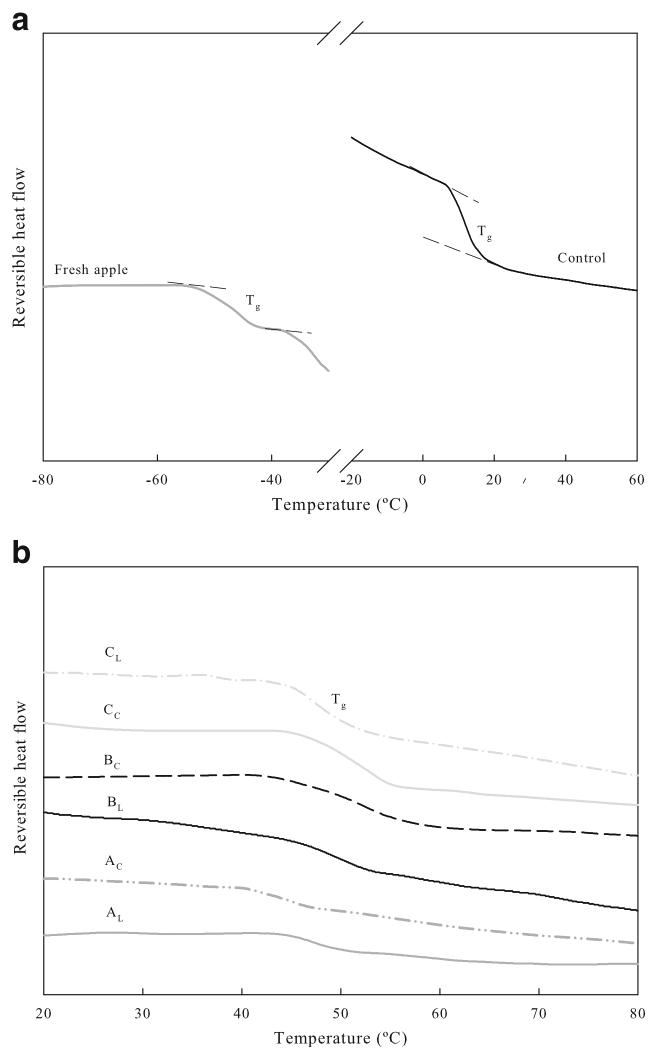


**Fig. 5** Thermograms obtained by DSC for **a** fresh apple and untreated baked apple rings (control); **b** all the developed snacks

turned the product more stable at room temperature, widening the range of relative humidity in which snacks maintained their texture. However, as the product is hygroscopic, it must be packaged, because after a certain time, it will get moisturized and the glass transition temperature will drop below the room temperature. The packaging provides an advantage for the conservation of the final product at room temperature, as long as the moisture content remains almost constant during the storage.

Contreras et al. (2005), working on air-dried apple cylinders, pretreated in apple juice, reported a $T_g$ value of about 40 °C. These results are also in agreement with those obtained by Sonthipermpoon et al. (2006), who found that the $T_g$ values of banana flake increased with the addition of maltodextrin. In the same way, the addition of maltodextrin to the apple puree caused an increase in $T_g$ by 10–30 °C, according to Jakubczyk et al. (2010).

Through the DMA technique, the same trend was observed, with $T_g$ values varying between 50 and 60 °C. The majority of polysaccharides comprising maltodextrin cannot penetrate cell membranes due to its high molecular weight. Consequently, maltodextrin contribution to the soluble solid content is due to the entry of mono- and disaccharides, which results in a rate suitable for acting as hydrocolloid stabilizers in obtaining low moisture products.

## Sensorial Analysis

The analyzed attributes such as acceptability, color, texture, sweetness, and sour taste of the snacks were improved by impregnation with sugar solutions and calcium salts in relation to the control attributes. Taking into account the obtained results of the sensory analysis of samples with the addition of calcium lactate, the scores given by the panelists to each tested snack were 7.5 for $A_L$, 6.8 for $B_L$, and 6.9 for $C_L$. In general, the snacks formulated with calcium lactate obtained higher scores than those formulated with calcium carbonate (Table 2). Considering the scores, snacks $A_L$ and $A_C$ were selected for further analyses. Color and sweetness scores turned out to be similar for snacks A, B, and C, irrespective of the calcium salt used.

## PCA of Sensory and Instrumental Data

Figure 6a, b shows PCA biplots used to visualize and summarize the relationships between the samples and the sensory and instrumental attributes. As can be observed in Fig. 6a, PC1 and PC2 explained 85 and 12 % of the variance, respectively. The PCA correlation plot shows the clustering of snacks into two main groups. Snacks formulated with calcium lactate were separated from snacks prepared with calcium carbonate, and the separation was achieved along PC1. Snacks prepared with the addition of CL had positive values of PC1 as well as snack $A_C$, whereas $B_C$ and $C_C$ had negative values. $A_L$ was placed to the right almost on the PC2 axis, indicating that this snack obtained the highest acceptability, texture, and color attribute values. Among the formulations prepared with CC, $A_C$ showed the highest values of all variables studied, whereas $B_C$ and $C_C$ presented the lowest values.

Inspecting the contributions, biplot shown in Fig. 6b revealed that the variability explained by the first component was 62 % and the second one 28 %. In this case, a similar behavior to the one discussed above was obtained. Snacks with CL were separated from snacks with CC and the break was observed principally along the PC2 axis. The control was better interpreted in terms of moisture and *L* values, whereas $B_C$ and $C_C$ were more associated with *b**, *a**, and hardness. $A_L$ and $B_L$ were located equidistant from all instrumental variables considered. Taking into account the calcium salt used in the formulation, the best snacks were selected for further analysis ($A_L$ and $A_C$).

## Analysis of Functional Properties of the Selected Snack

After the completion of the sensorial analysis, snacks $A_L$ and $A_C$ were selected as objects of additional studies. Ascorbic acid content, antioxidant activity, and polyphenol content were determined.

**Table 2** Results of the sensorial analysis obtained for the control and snacks A, B, and C submitted to calcium lactate and calcium carbonate treatments, formulated by immersion in solutions 1:1, 2:1, and 1:2 (M:F), respectively

| Snack | Acceptability | Texture | Color | Sweetness | Sour taste | Score |
|---|---|---|---|---|---|---|
| Control | 5.6a (1.45) | 4.5a (1.74) | 6.4a (1.77) | 6.0a (1.83) | 5.4a (2.01) | 5.4a (1.73) |
| $A_L$ | 7.2c (1.55) | 7.5d (1.72) | 7.7d (1.49) | 6.6a,b (1.87) | 6.6b,c (1.87) | 7.5c (1.32) |
| $B_L$ | 7.0c (1.71) | 6.9c (1.72) | 7.3b,c,d (1.59) | 6.1a (2.01) | 6.5b,c (2.00) | 6.8b (1.65) |
| $C_L$ | 7.1c (1.73) | 6.8c (2.06) | 7.4c,d (2.06) | 6.9b (1.83) | 6.9c (1.80) | 6.9b (1.42) |
| $A_C$ | 6.8b,c (1.73) | 6.2b,c (2.48) | 6.9a,b,c (1.78) | 6.5a,b (1.87) | 6.6b,c (1.99) | 7.1b,c (1.66) |
| $B_C$ | 6.1a,b (1.41) | 5.2b (2.19) | 6.6a,b (1.79) | 6.0a (1.62) | 6.0a,b (1.90) | 6.4b (1.49) |
| $C_C$ | 5.5a (1.92) | 4.0a (2.05) | 6.5a (1.75) | 6.3a,b (1.84) | 5.6a (1.62) | 5.5a (1.70) |

Different letters indicate significant differences between snacks ($P<0.05$).

Values between parentheses are standard deviation

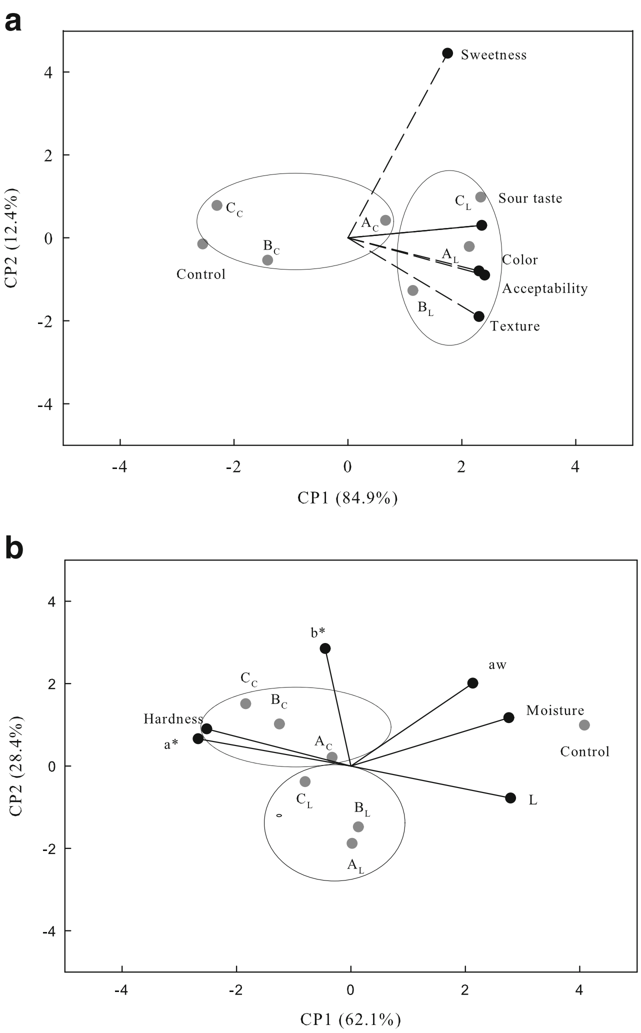


Fig. 6 Principal component analysis (PCA) biplot of **a** sensorial parameters and **b** instrumental parameters used to differentiate snacks treated with different maltodextrin/fructose ratios and two calcium salts

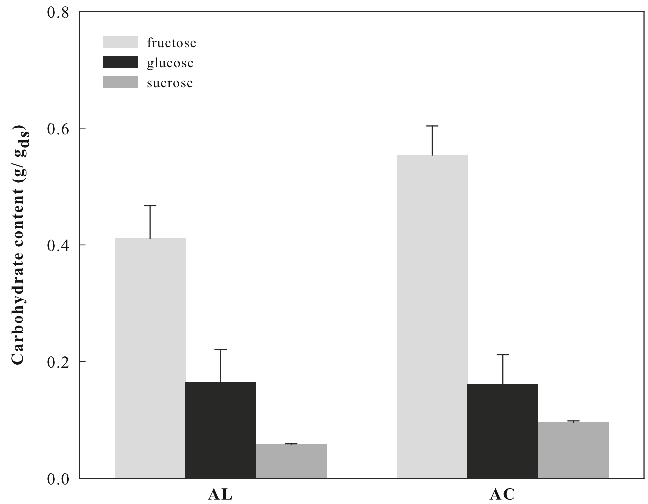


**Fig. 7** Soluble carbohydrate contents in snacks $A_L$ and $A_C$

### *Soluble Carbohydrates and Ascorbic Acid Contents*

Fructose, glucose, and sucrose contents of snacks $A_L$ and $A_C$ are shown in Fig. 7. Only fructose content between both snacks was significantly different, being the content of $A_C$ 37.5 % higher than that of $A_L$.

Ascorbic acid, an essential antioxidant in human diets, is widely used for supplementation (Pallauf et al. 2013). The addition of ascorbic acid during the impregnation of the apple rings promoted beneficial effects since the amount absorbed by snacks $A_L$ and $A_C$ was significantly higher than the content of fresh fruit ($P<0.05$). These snacks retained over two thirds of the amount of the ascorbic acid added, obtaining values of about 20 mg/$g_{ds}$ (Table 3). Consequently, there exists an increase of vitamin C into apple rings through the addition of ascorbic acid. Fuertes (2011) observed the protective effect of the pectin matrix on both calcium and vitamin C added. They reported that this fact may be due to the characteristics of the matrix, that being continuous allows the partial retention of the bioactive compound trapped in the network, either in the continuous phase or in the interstices.

### *Antioxidant Activity and Polyphenol Content*

The total polyphenol content (TPC) of the samples baked without the addition of ascorbic acid increased with respect to fresh fruit from 5.5±0.61 to 8.0±0.74 $mg_{acid\ chlorogenic}/g_{ds}$ on averaged. A similar result was found by Sun-Waterhouse et al. (2010). They observed that a prolonged exposure of snack bars to high temperature during baking might destroy some of the complexes formed between bound phenolics and other food components, causing an increase in snack phenols extracted.

Antioxidant activity expressed as TEAC ($mmol_{Trolox}/g_{ds}$) is reported in Table 4. TEAC value obtained from fresh fruit turned out to be similar to those found by Kunradi Vieira et al. (2009). Values found in baked apple rings were almost 20 and 40 times higher than that of fresh apple. The results obtained by DPPH demonstrated a high antioxidant activity for snacks $A_L$ and $A_C$ corresponding to a 100 % reduction of radical DPPH for a concentration of 200 mg/ml of the extract regardless of the used calcium salt (Eq. 4). In contrast, fresh apples showed reductions about 20 % for the same extract

**Table 3** Ascorbic acid content and Trolox equivalent capacity antioxidant (TEAC) of snacks $A_L$ and $A_C$ in relation to fresh apple

| Sample | Calcium salt | Ascorbic acid ($mg_{AA}/g_{ds}$) | TEAC values ($mmol_{Trolox}/g_{ds}$) |
|---|---|---|---|
| Fresh apple | – | 0.47a (0.02) | 0.04a (0.03) |
| Snack $A_L$ | Lactate | 20.06b (1.40) | 0.74b (0.10) |
| Snack $A_C$ | Carbonate | 19.62b (1.50) | 1.38c (0.02) |

Different letters indicate significant differences between apple samples ($P<0.05$).

Values between parentheses are standard deviation concentration. As was aforementioned, remaining AA in the snack was the main responsible for the increase in the antioxidant capacity. In accordance with Tan and Harris (1995), the antioxidant capacity depends on the complexes formed during the drying process, such as glucose–cysteine or fructose–cysteine. In treatments where strong browning took place, higher antioxidant capacity was also observed (Manzocco et al. 2001; Vega-Gálvez et al. 2012).

## Conclusions

The pretreatment of the apple rings with a solution containing calcium improved the quality of their texture. The use of calcium salt, sugar (maltodextrin and fructose), and ascorbic acid prior to the baking process brought as a result a product-type snack, with no fat or sodium added with good consumers' acceptance. The use of maltodextrins allowed enhancing the texture without greatly affecting the taste of fresh fruit. In addition, being a high molecular weight polysaccharide, maltodextrin produced a shift of the glass transition temperature to higher values in relation to those values obtained for apple rings submitted to baking without the addition of sugars. This increase in $T_g$ values brought with it an increase in the structure resistance to relative humidity changes. However, considering the hygroscopicity of fructose, the snacks obtained should be stored in a suitable container to maintain the crispness. Taking into account the obtained results by using principal component analysis, the snack with the best properties was $A_L$, prepared with the addition of calcium lactate and a 1:1 maltodextrin/fructose ratio. To sum up, due to the impact of snacks on people's food habits and the trend for consumers to re-evaluate the nutritional importance of food, baked apple snacks could be a healthier alternative to snacks prepared with the addition of sodium or obtained by a frying process.

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