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Baked snack from green apples formulated with the addition of isomalt

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ABSTRACT

The objectives of this study were: to develop a crispy snack with the addition of isomalt and maltodextrin, to assess physical, chemical and sensory properties and to evaluate the stability during storage and after being conditioned at different relative humidities. Isomalt, produced by reducing isomaltulose (6-O-α-D-glucopyranosyl-D-fructofuranose) is used in food products as a noncariogenic nutritive sweetener. Its use had a protective effect on the apple tissue submitted to high temperatures since the snack had good quality attributes and also preserved the added ascorbic acid during the baking process. Isotherms showed a resistant behavior pattern in regions of low a_w, but on exceeding 0.7 of a_w the moisture content increased dramatically. Similar trends were followed by snack texture and T_g.

1. Introduction

Sugar alcohols or polyols are typical sucrose replacers in baked foods (Olinger & Velasco, 1996) and their properties have been studied by many authors (Baeva, Terzieva, & Panchev, 2003; Ronda, Gómez, Blanco, & Caballero, 2005). Polyols present potential advantages over sucrose as food ingredients because they produce a lower glycemic response; hence they are suitable for diabetics (Martínez-Cervera, Salvador, & Sanz, 2014). In addition, polyols are non-cariogenic as they are not or only scarcely metabolized by oral micro-organisms (Ghosh & Sudha, 2012; Kroger, Meister, & Kava, 2006) and have slightly reduced sweetness and caloric values. Sorbitol has only 10.89 kJ/g, maltitol 8.79 kJ/g, isomalt 8.37 kJ/g and erythritol 0.84 kJ/g compared to sucrose, which provides 16.75 kJ/g Olinger and Velasco (1996) replaced sugar in baked products such as cake and biscuit with lactitol, maltitol, isomalt, sorbitol, and polydextrose. They described changes in the spread, crust color, and tacky surface.

Isomaltulose (6-O-α-D-glucopyranosyl-D-fructofuranose) called palatinose is used in various food products as a noncariogenic nutritive sweetener. It is digestible and the ratio of the digestibility is estimated to be about one-fifth the digestibility of sucrose. Isomalt, produced by reducing isomaltulose, is an equimolar mixture of O-D-glucopyranosyl-1, 6-D-sorbitol and O-D-glucopyranosyl-1, 6-D-manitol. A significant property of isomalt is its ability of to not absorb water until water activity reaching values higher than 0.85. Hence, it is used in hard candies and coatings since it contributes to extend the shelf life of stored products. According to manufacturer's specifications, when isomalt is dissolved in water, the crystals need very little energy to dissolve (−39.36 J/g) and from a chemical point of view it has no reducing end-groups and it remains stable under prolonged exposure to pHs in the range of 2–10.

Maltodextrin improves the quality of dehydrated products, decreasing their stickiness and increasing their stability (Roos & Karel, 1991). This fact has been associated to the ability of maltodextrin to absorb water forming a protective barrier on the surface

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of hygroscopic particles, and its capacity to increase the glass transition temperature (Valenzuela & Aguilera, 2015).

Fruit is a food group which is presently receiving more attention among the population due to its interesting and healthy properties such as high functional and nutritional value, being rich in fiber, minerals, vitamins and terpenes antioxidant compounds (Cavanah, Hipwell, & Wilkinson, 2003; Dhiraj, Reza, & Shetty, 2005; Peinado, Rosa, Heredia, Escriche, & Andrés, 2013).

To the best of our knowledge, there is hardly any study discussing the addition of isomalt to snacks and there is no data about snack's behavior during its storage. Therefore, the objectives of this study were: to develop a crispy snack with the addition of isomalt and maltodextrin, to assess physical, chemical, and sensory properties and to evaluate the stability during storage and after being conditioned at different relative humidities.

2. Materials and methods

Fig. 1 shows a flowchart of the key stages in the preparation of the snacks, and steps for different property determinations.

Granny Smith apples, selected by size and appearance, were purchased from the local market. For the development of the experimental batches, standardized apples with moisture of 85%, pH of 3.4 and soluble solid content of 11 ± 1°Brix were selected and stored at 4–6 °C.

For different pretreatments, ascorbic acid (Parafarm, Argentina), calcium lactate gluconate (food and pharma grade, Jungbunzlauer, Germany), isomalt (Palatinit, Germany) and maltodextrin (food grade, Parafarm, Argentina) were used. According to technical specifications provided by the manufacturer, the maltodextrin used had a dextrose equivalent (DE) of 15.4.

2.1. Snack preparation

Apples were processed following the procedure described in Tavera-Quiroz, Urriza, Pinotti, and Bertola (2014). In brief, apples were washed, wiped with paper towel and cut into slices 2 ± 0.2 mm thick, perpendicular to the core using a domestic processor (Yelmo, San Justo, Argentina).

The center of each slice was removed and the rings were dried with paper towel. A group of 10 rings was immersed in a solution of 2.5 g/100 ml calcium lactate (CL) for 2 min to increase the tissue consistency (Tavera-Quiroz et al., 2014) and then subjected to a blanching process with steam (121 °C) for 3 min by using a domestic steamer (Oster, Buenos Aires, Argentina). After that, the apple rings were cooled with crushed ice until reaching 30 °C and immersed in 30 g/100 ml aqueous solutions of isomalt (I) and maltodextrin (M) for osmotic dehydration for 15 min. Solutions with different ratios of I:M (1:1, 1:2 and 2:1) with the addition of 2 g/100 ml of ascorbic acid (AA), were used.

Snacks were obtained by using a forced convection oven Multiequip HCE-3 (Bahía Blanca, Argentina) at 140 °C for 30 min. Untreated apple rings baked at 140 °C for 30 min were used as a control.

From here onwards, the apple samples obtained by incorporation of calcium lactate, immersion in the solutions of different I:M ratios (1:1, 1:2 and 2:1) and baking will be called snacks Iso A, Iso B and Iso C, respectively.

2.2. Analysis of snacks prepared with different I:M ratios

2.2.1. Moisture content and water activity

Fresh apples and snack moisture contents 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).

Water activity of obtained snacks was evaluated by using AquaLab Water Activity Meter equipment (Decagon Devices, Inc., Washington, USA) at 20 °C. Water activity as well as moisture of the samples was analyzed in triplicate.

2.2.2. Texture and color analysis

Snack texture was evaluated in a texturometer TA.XT2i – Stable Micro Systems (Surrey, UK) by using a semi-spherical probe of 5 mm diameter at a constant rate of 1 mm/s. For each batch, 10

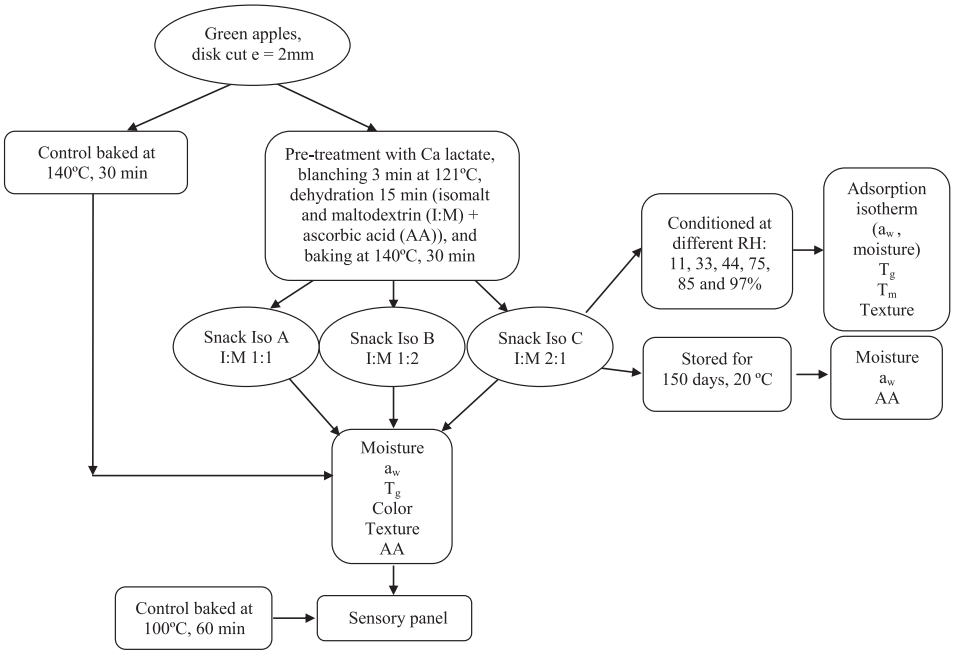

Fig. 1. Flowchart of the key stages in the preparation and the steps in the property determinations of snacks.

samples were analyzed separately, obtaining the corresponding force–deformation curves.

Snack color was determined by means of a Minolta colorimeter CR 400 Series (Osaka, Japan). The CIELab scale was used, and lightness (L) and chromaticity parameters a* and b* were measured. Samples were analyzed in triplicate, recording four measurements for each sample. Browning index (BI) represents the purity of brown color and it is reported as an important parameter in processes where enzymatic or nonenzymatic browning takes place (Buera, Lozano, & Petriella, 1986; Guerrero, Alzamora, & Gerschenson, 1996; Jalaee, Fazeli, Fatemian, & Tavakolipour, 2011). It was calculated as follows:

$$BI = \frac{\left[100\left(\frac{a^*+1.75L}{5.645L+a^*-3.012b^*} - 0.31\right)\right]}{0.172} \quad (1)$$

2.2.3. Thermal properties by DSC

Thermal properties of apple snacks and fresh fruit were determined by using a DSC model Q100 controlled by a TA 5000 module (TA Instruments, New Castle, USA) as described in a preliminary study (Tavera-Quiroz, Urriza, Pinotti, & Bertola, 2012). The first scan was performed from −70 °C 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.

2.2.4. Sensory analysis

A sensory panel was conducted to discriminate the difference between the three types of snacks Iso A, Iso B and Iso C obtained from sugar solutions of I:M ratios 1:1, 2:1 and 1:2 and the control. A 50 member panel was selected after screening among personnel of CIDCA, in La Plata, Argentina. The panelists, regular consumers of snacks with experience in sensory evaluation but without training, were between 25 and 55 years old. Samples were randomly coded and placed in trays. The analyzed attributes were overall acceptability, color, texture, sweetness and sour taste using a 9-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.

2.3. Analysis of functional properties of the selected snack

2.3.1. 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, 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 of the selected snack were tested. Mean values of calcium content (expressed as mg_{Ca} per 100 g_{ds}) were reported.

2.3.2. Carbohydrate content and ascorbic acid analysis by HPLC

The HPLC system used was a Waters equipment (Milford, USA), model R-414. Solute elution was followed using a UV detector and RI detector.

Carbohydrate content (glucose, fructose, sucrose, isomalt) determination was made using a modified HPLC method of Dolenc and Stampar (1997). 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/water CH_3CN/H_2O (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. Separations were carried out on a 5 mm RP C18 column of 150 mm-4.6 mm (WAT 045905, Ireland). The employed mobile phase was a mixture of HPO_3 0.5% –acetonitrile (93:7) (Nojavan et al., 2008).

2.3.3. Antioxidant capacity

The analysis of antioxidant activity was carried out as explained in a preliminary work (Tavera-Quiroz et al., 2014). Briefly, 2 g of each sample, previously frozen in liquid nitrogen, was mixed with ethanol under constant agitation and centrifuged. The supernatant was collected in order to analyze the antioxidant capacity by DPPH methods. The results obtained were expressed as radical scavenging activity or inhibition of free radical percentage (I %) as follows:

$$I\% = \frac{A_o - A_1}{A_o} \times 100 \quad (2)$$

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.

2.3.4. Sorption isotherms analysis

Sorption isotherms at 10, 20, 40 °C for selected snack were studied according to the methodology described by Demarchi, Quintero-Ruiz, De Michelis, and Giner (2013). In brief, 1 g of the snack was equilibrated at each temperature 10 ± 2, 20 ± 2 y 40 °C ± 1 °C in different atmospheres of saturated salts: LiCl, $MgCl_2$, K_2CO_3, NaCl, KCl and K_2SO_4 giving relative humidity (RH) values of 11, 33, 44, 75, 85 and 97%, respectively. All isotherms were determined in triplicate, using an individual flask for each sample. Conditioning was achieved for at least 2 weeks to ensure the equilibration of the water content in the snacks with that of the atmosphere. Samples were weighed at regular intervals until reaching constant weight. After that, water activity was determined by the static gravimetric method. Equilibrium was assumed as variations in moisture content became less than 0.003 g_{water}/g_{ds}.

In addition, the kinetics of water sorption by the snacks was also performed by the hygrometric method using the Aqualab hygrometer (Section 2.2.1).

For all samples in the equilibrium, moisture content, a_w, texture and thermal properties were measured. GAB (Guggenheim-Anderson-de Boer) model were used to fit sorption isotherm data. GAB isotherm model can be expressed as follows:

$$M_w = \frac{m_0 C K_{a_w}(1 - K_{a_w} + C K_{a_w})}{(1 - K_{a_w})} \quad (3)$$

where,

M_w is the equilibrium moisture at a given a_w, m_o is the monolayer moisture content (g_{water}/g_{ds}) and C and K_{aw} parameters of sorption dynamic equilibrium.

2.4. Statistical analysis

Systat-software (SYSTAT, Inc., Evanston, IL, USA) version 10.0 was used for all statistical analysis. The data were analyzed by using analysis of variance (ANOVA), regressions and Fisher LSD mean comparison test were applied. The significance level used was 0.05.

Table 1
Physical properties of apple snacks obtained by baking at 140 °C for 30 min.

Snack	Moisture (g_{water}/100 g_{ds})	a_w	Force at break (N)	L	a*	b*	Browning index
Control 140 °C	7.75b (0.46)	0.601b (0.02)	0.95a (0.15)	52.04b (5.8)	10.53c (0.85)	27.48c (0.79)	86.42d (0.71)
Iso A	2.21a (0.25)	0.432a (0.01)	1.25a (0.18)	66.01a (1.38)	2.31a (0.75)	20.83a (0.76)	42.52a (0.99)
Iso B	1.89a (0.80)	0.421a (0.01)	2.04b (0.21)	59.56a (1.55)	0.78b (0.37)	15.27b (0.42)	29.56b (0.48)
Iso C	1.78a (0.40)	0.455a (0.02)	1.04a (0.18)	64.91a (1.46)	3.03a (0.57)	21.60a (0.82)	39.19c (0.59)

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

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.

3. Results and discussion

Physicochemical properties of snacks subjected to treatments with different ratios of I:M are shown in Table 1.

As can be observed, control apple rings, baked at 140 °C for 30 min without any treatment, exhibited a moisture content close to 8 g_{water}/100 g_{ds}. After the pretreatments with I:M, moisture decreased on average 4 times (dry base) whereas water activity underwent a reduction from 0.6 to 0.45 ($p < 0.05$). Similar moisture values were found by Tavera-Quiroz et al. (2014) working on apple snacks treated with the addition of fructose and maltodextrin. Color parameters showed evident signals of lower development of the caramelization reaction in snacks treated with I:M compared to the control. It would be inferred from Table 1 that the pre-treatments had a protective effect on the apple tissue submitted to high temperatures since the BI values obtained for snacks from Eq. (1) were lower than that quantified in the control.

Force at maximum deformation increased as a consequence of the application of the pre-treatments. In the penetration test, hardness is the maximum force required to break the sample (Choy, May, & Small, 2012), and crispness denotes if the fractures are abrupt under the application of a relatively small force (the first peak force) (Huang, Min, Mujumdar, & Lim, 2011; Tavera-Quiroz et al., 2014). Since crispness is associated with rapid drops in force and a rapid propagation of the fracture, requires of a brittle material, which results in sudden unloading of the jaw muscles involved in mastication (Vincent, 1998). This behavior can be observed in Fig. 2 for the snack Iso C, showing an abrupt slope and small drops in force due to small cracks.

In the other hand, control depicted a similar pattern but with a smooth curve extended for longer time without the occurrence of sharp drops.

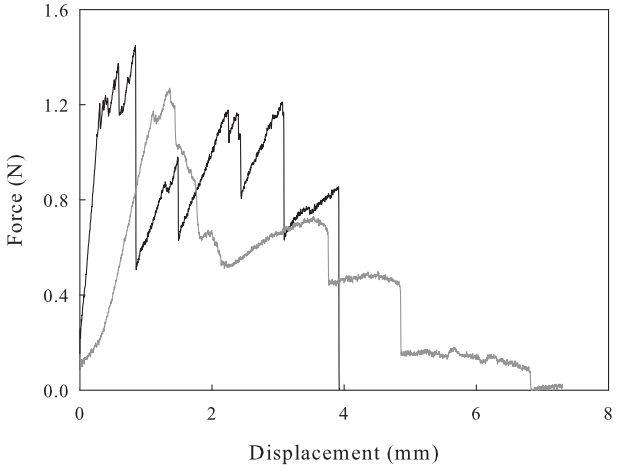

Fig. 2. Force – displacement curves for the control (gray line) and snack Iso C (black line) as prepared.

3.1. Analysis of thermal properties

The glass transition temperature (T_g) was determined by using the DSC technique. From DSC thermograms T_g values of isomalt and maltodextrin turned out to be 61 and 132 °C, respectively, whereas for fresh apple a T_g value of −40 °C was found in accordance with T_g informed by Bai, Rahman, Perera, Smith, and Melton (2001). A value of 11 °C was obtained for the control whereas the snacks' T_g were 75, 102 and 68 °C for Iso A, B and C. Although these results are in accordance with moisture content because the control presented the highest value (7.75 g_{water}/100 g_{ds}), the influence of maltodextrin content was also noteworthy since snack Iso B was prepared with the highest amount of maltodextrin. Several authors informed that the addition of increasing amounts of maltodextrin of high molecular weight increased the glass transition temperature (Bonazzi & Dumoulin, 2011; Fabra, Márquez, Castro, & Chiralt, 2011). The use of isomalt in combination with maltodextrin turned the product more stable at room temperature, shifting the snack T_g to higher values and widening the range of relative humidity in which snacks maintained their texture in comparison with snacks formulated with fructose and maltodextrin (Tavera-Quiroz et al., 2014).

3.2. Ascorbic acid content

Table 2 shows the effect of the baking process on the retained amount of ascorbic acid (AA) for both, control and snacks. The addition of ascorbic acid during the immersion of the apple rings promoted beneficial effects since the percentage of retained AA was lower in the fruit submitted to baking than in the snacks, which was almost 50% on average. The Recommended Dietary Allowance (RDA) of vitamin C covers an expanded range of values, from 40 mg/day to 3 g/day. Hence, a serving of 20 g of the snacks formulated with isomalt would nearly cover a demanding daily requirement of vitamin C.

Table 2
Percentage of ascorbic acid retained after the baking process at 140 °C for the control and snacks prepared with different I:M ratios.

Sample	mg_{AA}/g_{ds} (before baking)	mg_{AA}/g_{ds} (after baking)	AA retained (%)
Control	1.07a (0.11)	0.16a (0.07)	14.9a
Iso A	54.50b (1.87)	25.16b (0.04)	42.5b
Iso B	55.49b (1.12)	31.02c (1.46)	55.9c
Iso C	50.46b (1.42)	25.67b (1.60)	50.8b

Different letters indicate significant differences between snacks ($p < 0.05$). Values between parentheses correspond to standard deviation.

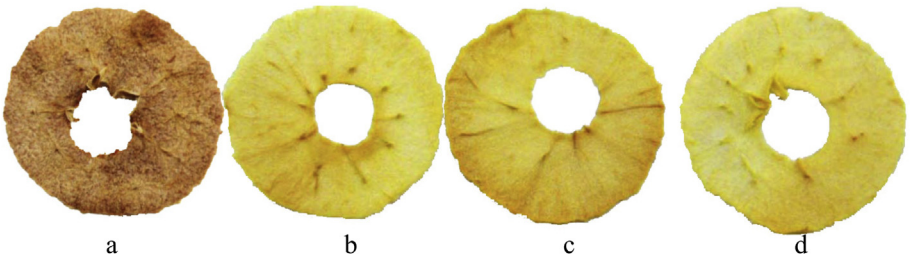

Fig. 3. Photographs of the control (a) as well as snacks Iso A (b), Iso B (c) and Iso C (d) obtained by pre-treatments with calcium lactate, isomalt and maltodextrin prior to the baking process.

Table 3
Results of the sensorial analysis obtained for the control and snacks submitted to baking at 140 °C for 30 min.

Snack	Acceptability	Sour taste	Sweetness	Color	Texture	Score
Control 140 °C	2.4c (0.32)	2.3c (0.28)	2.1c (0.26)	1.2b (0.08)	6.8a (1.38)	1.4c (0.09)
Iso A	6.2a (1.67)	5.9a (2.14)	5.5a (1.83)	6.6a (2.07)	7.1a (1.61)	6.8a (1.46)
Iso B	6.5a (1.68)	6.5a (1.71)	5.9a (1.83)	6.5a (1.93)	7.0a (1.88)	7.0a (1.39)
Iso C	6.8a (1.54)	6.3a (1.97)	6.3a (1.75)	6.8a (1.87)	7.0a (1.87)	7.1a (1.51)
Control 100 °C	5.8b (1.42)	5.4b (1.45)	6.4a (1.65)	6.4a (1.74)	4.7b (1.55)	5.7b (1.35)

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

3.3. Sensory analysis

The analyzed attributes such as acceptability, color, texture, sweetness and sour taste of the snacks were improved by the mass transfer from isomalt and maltodextrin solution and calcium salts in relation to the attributes of control baked at 140 °C. As expected, panelists gave very low scores to this control in every attribute owing to the great development of the caramelization reaction with a high BI value (Fig. 3 and Table 1). For this reason, the comparison was also carried out with rings baked at 100 °C as a secondary control for this trial. In this latter case, scores also turned out to be lower than those obtained by snacks.

The scores of the snacks did not presented significant differences ($p > 0.05$) giving values of 6.8, 7.0 and 7.1 on average, for Iso A, B and C, respectively (Table 3). Taking into account that all evaluated attributes did not differ significantly ($p > 0.05$) and a higher content of isomalt in the formulation improves the hygroscopic properties, the snack called Iso C was selected for further analyses.

3.4. PCA of sensory and instrumental data

Fig. 4a shows PCA bi-plot that allows visualizing the relationships between the samples and the sensory attributes. As can be observed, PC1 and PC2 explain 78 and 22% of the variance, respectively. In addition, PC1 represents 99% of appearance, color and sweetness and 98% of sour taste, whereas PC2 corresponds to 99% of texture. Snack Iso C obtained the most positive values of PC1 whereas Iso A the least positive values. Iso C was placed to the right, indicating that this snack obtained the highest scores for the attributes. Given that the control baked at 140 °C received poor scores in all the attributes except in texture, its location in PCA bi-plot was opposite to snack clusters far from the origin along the x-axis but close to the origin along the y-axis.

Bi-plot showed in Fig. 4b was used to summarize the relationship between snacks and instrumental data. Inspecting the contributions, the variability explained by the first component was 81% and the second one 18%. In this case, a similar behavior to the one discussed above was obtained. The control was better interpreted in terms of moisture, a* and a_w values whereas all the snacks were located opposite to these attributes. Iso B was more associated with the hardness whereas Iso A and Iso C were located close to L parameter (Table 1).

3.5. Analysis of functional properties of the snack Iso C

After the completion of the sensory analysis, the snack Iso C was selected for additional studies namely calcium and carbohydrate content. In addition, adsorption isotherms, texture analysis and

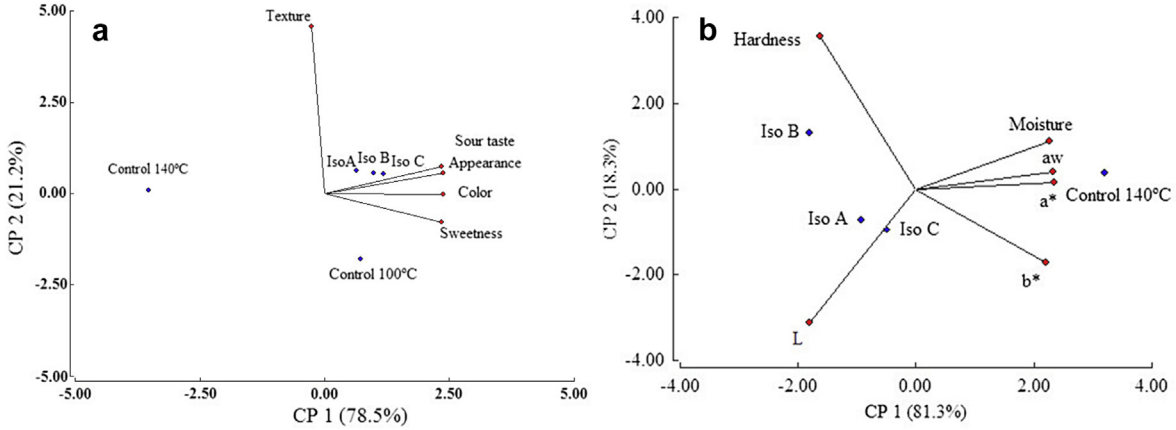

Fig. 4. Principal component analysis (PCA) biplot of: a) sensory parameters and b) instrumental parameters used to differentiate snacks treated with different isomalt:maltodextrin ratios.

thermal properties were evaluated after being conditioned at different RH whereas moisture and AA were evaluated during storage for 150 days.

3.5.1. Calcium, carbohydrate contents. Antioxidant capacity

In previous work, Tavera-Quiroz et al. (2014) found that the optimum time of immersion in calcium lactate was of 2 min. With higher times there were no significant changes in the amount of Ca incorporated in the apple tissue, hence 2 min was the time used in the present work. Calcium content turned out to be of 216.5 ± 5 $mg_{Ca}/100\ g_{ds}$ for the snack Iso C.

In reference to isomalt and sugar contents, obtained values for the selected snack were 0.20 ± 0.01 $g_{isomalt}/g_{ds}$, 0.17 ± 0.02 $g_{fructose}/g_{ds}$, 0.06 ± 0.01 $g_{glucose}/g_{ds}$ and 0.02 ± 0.01 $g_{sucrose}/g_{ds}$.

The results obtained by DPPH demonstrated a high antioxidant activity for the snack Iso C corresponding to a 95% reduction of radical DPPH for a concentration of 80.5 mg/ml of the extract (Eq. (1)). In contrast, fresh apples showed reductions about 10% for the same extract.

3.5.2. Storage of snack Iso C

Snack Iso C was stored for 150 days, in which moisture and AA were monitored.

As can be seen in Table 4, moisture content continuously increased presenting significant difference ($p < 0.05$) during the reporting period. On the contrary AA stayed constant until 120 days, later when underwent an abrupt change and decreased 57% with respect to the average initial value.

3.5.3. Snack conditioning at different RH prior to evaluation

3.5.3.1. Adsorption isotherm. As is well known, the structure and therefore the properties of snacks are strongly related to the water content. As can be seen in Fig. 5, the obtained isotherms of adsorption are typical of matrices with a high content of soluble solid and correspond to type III (J-type) in BET'S classification, characteristic of materials with high sugar content (Falade, Olukini, & Adegoke, 2004; Valenzuela & Aguilera, 2015).

Isotherms showed a resistant behavior pattern in regions of low a_w, but on exceeding 0.7 of a_w the moisture content increased dramatically (Romano et al., 2014). In the curve obtained by the hygrometric method (data not shown), the experimental value of a_w was higher than 0.36 in all the range of RH between 0.11 and 0.4, irrespective of the RH value. Demarchi et al. (2013) informed similar results. The sorption curves did not show significant differences for 10, 20 and 40 °C. Parameter values obtained from de GAB model fit (Eq. (3)) are detailed in Table insert in Fig. 5, for gravimetric data.

3.5.3.2. Texture analysis. Once the snack Iso C reached the equilibrium at each RH, the texture was evaluated through the results obtained of the curves force − deformation.

Table 4
Evolution of moisture content and ascorbic acid for stored snack Iso C for 150 days at 20 °C.

Storage time (days)	Moisture ($g_{water}/100\ g_{ds}$)	Ascorbic acid (mg_{AA}/g_{ds})
30	1.37a (0.10)	25.09a (0.32)
60	3.27b (0.55)	28.57a (2.13)
90	3.81c (0.64)	25.37a (2.97)
120	4.32c (0.13)	22.24a (0.36)
150	6.02d (0.25)	10.73b (0.24)

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

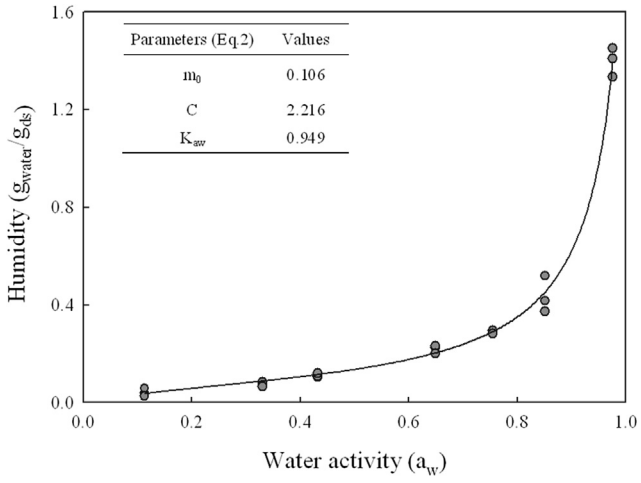

Fig. 5. Sorption isotherm at 20 °C for the snack Iso C conditioned at different RH, obtained from the experimental values (●) and predicted ones (——) by the GAB model. Experimental data were obtained determining a_w by the gravimetric method. Table insert shows the values of: the monolayer moisture content m_o, and C and K_{aw} parameters of GAB model.

As can be seen in Fig. 6, when RH reached 44%, the snack Iso C lost its quality in terms of texture. Up to this RH value, an increase in the stickiness was observed in the stabilized samples, represented by a major deformation and a lower slope.

3.5.3.3. DSC analysis. With increasing RH values, melting peaks shifted towards higher temperatures and greater enthalpy values were observed in Table insert in Fig. 7a. In addition, a slight decrease of the glass transition temperature was found up to RH of 43% (Fig. 7b).

These results are in accordance with the texture curves, indicating that a collapse of the structure was produced as a consequence of the water uptake by the snacks during storage without a suitable packaging.

4. Conclusions

A snack with good properties in terms of texture, color and taste was developed with the addition of calcium, maltodextrin and

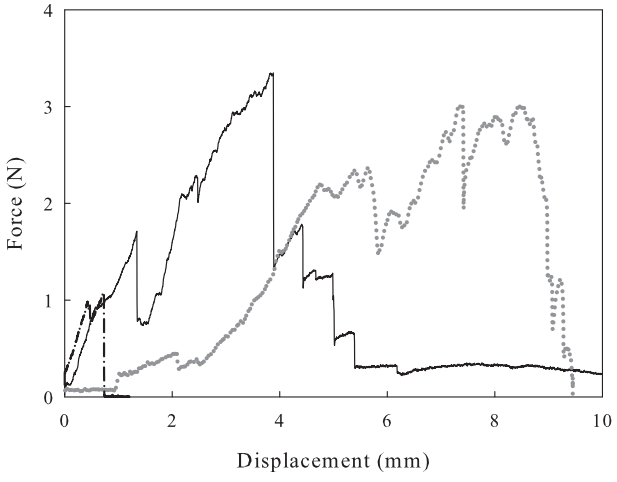

Fig. 6. Force − displacement curves for the snack Iso C conditioned at different RH; dash-dot line 11%, solid line 33% and dotted line 44%.

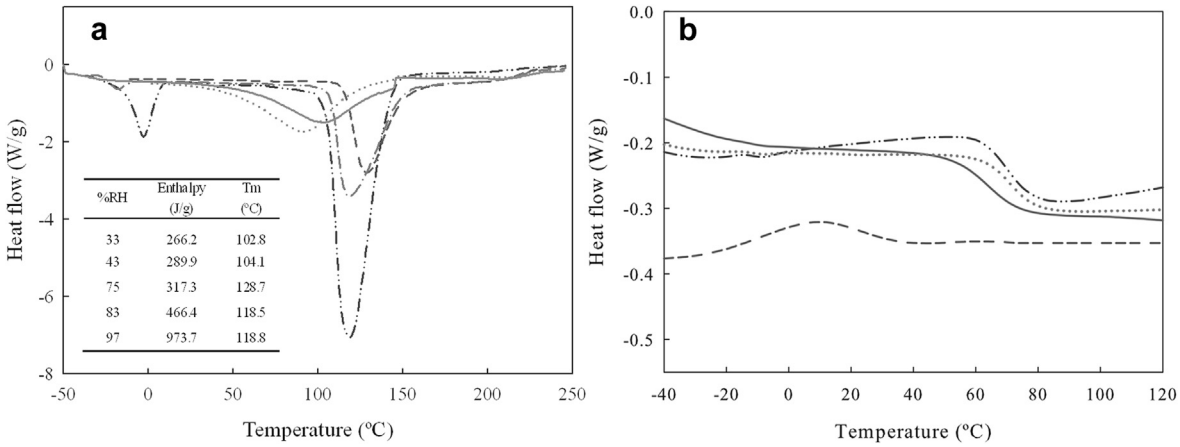

Fig. 7. DSC thermograms of snack Iso C conditioned at different RH showing: a) melting point from 1st scan; dotted line 33%, solid line 44%, dash line 75%, dash-dot line 85% and dash-dot-dot line 97%, and b) glass transition temperature from 2nd scan; dash-dot-dot 11%, dotted line 33%, solid line 44% and dash line 75%. Table insert shows the enthalpy values and melting temperatures.

isomalt to apple rings, with no fat or sodium added as well as with good consumers' acceptance. The presence of isomalt allowed baking at 140 °C for a short time without detriment to the quality's attributes. This is an innovative food product since isomalt has hardly been used to formulate snacks.

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