LWT - Food Science and Technology 93 (2018) 24–31

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Physicochemical and nutritional characterization of sweet snacks formulated with *Prosopis alba* flour

Leonardo Sciammaro[a], Cristina Ferrero[a], Cecilia Puppo[a,b,*]

[a] CIDCA – Facultad de Ciencias Exactas (UNLP – CONICET), Calle 47 y 116, 1900 La Plata, Argentina
[b] Facultad de Ciencias Agrarias y Forestales (FCAyF - UNLP), 60 y 119, 1900 La Plata, Argentina

ARTICLE INFO

Keywords:
Prosopis alba flour
Sweet snack
Texture
Sensorial quality
Nutritional composition

ABSTRACT

Prosopis alba flour (PAF) is an adequate ingredient for preparing gluten-free sweet snacks of high nutritional value. Therefore, the objective of this work was to use this flour, together with sugar and honey, as agglutinant agent in the elaboration and functional characterization of sweet snacks. Snacks were formulated with ancestral American seeds (22% amaranth, 22% quinoa, 7.8% quinoa) and variable amounts of each of the three agglutinants (48.2% total) according to an experimental design for mixtures with the restriction of non using only PAF as agglutinant. Five formulations were obtained and characterized by color, moisture, water activity and texture parameters. Sensorial attributes of the two best snacks selected by a test of preference (A and E), were determined using a 9 points hedonic scale. Snacks with sugar or sugar from PAF presented after heating the major variation of color. Snacks with PAF presented intermediate values of moisture and higher values of consistency, resilience and elasticity. The snack containing equal amounts of each agglutinant (A) presented equivalent sensory attributes as that elaborated only with sugar (E). Concluding, PAF resulted a suitable ingredient along with sugar and honey for sweet snacks destined to celiac people that also resulted well accepted by consumers.

1. Introduction

Cereal snacks (bars, flakes, bite-size snacks) are ready to eat products of good taste and high shelf-life. The popularity of these products is based on their easy availability at any time of the day, allowing their consumption either in-between main foods or as part of them. The highest consumers of these snacks is the age group within 18–24 years old. Besides their convenience, this type of foods can present high nutritional quality when they are fortified with minerals and vitamins and they can be also a source of dietary fiber. These products were introduced in the middle of the 1990's as a healthy alternative to candies and comfitures, at the same time that consumer begun to be aware about the importance of a healthy diet (Bower & Whitten, 2000). Different reasons led to the higher consumption of cereal snacks, including the decrease of the frequency of lunch at home, the consciousness of a healthy diet, and the idle time conducting to a higher consumption of comfits. The market target of cereal snacks is large as can be inferred from their claims: healthy, without preservatives, low in sodium, without added sugar, for athletes, among others. Although these products are commonly associated to healthy foods, Boustani and Mitchell (1990) demonstrated that in many cases bars are less healthy than any comfit. Cereal snacks often contain sucrose as main ingredient, which not only sweetens, but also has an agglutinant function. Usually, these bars are composed by a base of oatmeal, honey, soybean oil, whole wheat, barley, laminated whole rice, delactosed whey, and in some cases fruits and nuts. Natural sweeteners and fats are generally used as ligand agents (Cook, Keyser, Swanson, Zielke, & Zielinski, 1984). Dordoni et al. (2015) elaborated an eco-innovative sorghum snack, an organic and gluten-free product formulated with white sorghum, powdered grape seeds, honey, and dark chocolate with the aim of increasing healthy properties through the presence of polyphenols, high fiber content, low level of sodium, and a low caloric intake. Nevertheless, these bars contribute to high energy level (402 kCal/100 g).

In this work, traditional ingredients as cereals have been changed by seeds of different American species, widely used in different gastronomy purposes, like chia (*Salvia hispánica*), quinoa (*Chenopodium quinoa*) and amaranth (*Amaranthus caudatus*). These species are known as “pseudocereals” since they do not belong to the gramineous family but they are used in a similar way than cereal grains but with increased benefits for health. The chia is well known as a source of α-linolenic, an omega-3 fatty that is about 65% of the oil content. Chia seed is also rich in antioxidants (chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol). It is also a good source of dietary fibre. The multiple therapeutic effects of chia include the control of diabetes,

* Corresponding author. CIDCA – Facultad de Ciencias Exactas (UNLP – CONICET), Calle 47 y 116, 1900 La Plata, Argentina.
E-mail address: mcpuppo@quimica.unlp.edu.ar (C. Puppo).

https://doi.org/10.1016/j.lwt.2018.03.019
Received 30 October 2017; Received in revised form 19 February 2018; Accepted 8 March 2018
Available online 09 March 2018

dyslipidaemia, hypertension, as anti-inflammatory, antioxidant, anti-blood clotting, laxative, antidepressant, antianxiety, analgesic, vision and immune improver (Ullah et al., 2016). Quinoa is an Andean crop already used by the Incas as a valuable food; it is a source of high-quality proteins with a balanced aminoacid composition similar to that of casein. Besides, this seed is a good source of linoleic acid (an Omega 6) that represents 50.2% of the total fatty acids (Repo-Carrasco, Espinoza, & Jakobsen, 2003). Amaranth is also an Andean crop that contains a high quality protein and is a source of minerals, dietary fiber and antioxidants (Caselato-Sousa & Amaya-Farfán, 2012).

In many cereal snacks, sucrose, and even honey, are used as ligand agents. In the present work blends with different proportions of algarroba (*Prosopis alba*) flour (PAF), sucrose and honey were used.

Algarroba flour is the product obtained after grinding roasted whole pods of white algarrobo (*Prosopis alba*). This flour is usually used as a cacao and coffee substitute since it has no excitant substances as caffeine and theobromine. It contains 63% of soluble sugars (41% sucrose, 10% glucose, 12% fructose), 25% of total dietary fiber, 6% of proteins, low content of lipids (1.5%), high amount of soluble polyphenols (2.7 g/kg) and high antioxidant capacity (1.2 μmol TROLOX/kg) (Sciammaro, Ferrero, & Puppo, 2015). These substances could be beneficial for decreasing the risk of chronic diseases as cancer, diabetes or cardiovascular disorders (Xiao, Muzashvili, & Georgiev, 2014).

Due to its high nutritional properties and sugar content, good flavor and taste, this flour constitutes an ideal ingredient for preparation of sweet products like pastries, muffins and biscuits. The combination of algarroba flour with whole seeds, all of them gluten-free, in sweet snacks formulations would permit to obtain a high nutritional food, versatile, thus adding value to this underused crop. These snacks would contribute with dietary fiber, minerals, vitamins, w-3 and w-9 fatty acids, among other healthy components.

Therefore, the objectives of this work were to study physicochemical, sensory and nutritional quality of healthy sweet bite-size snacks elaborated with Andean seeds (chia, quinoa, amaranth), using *Prosopis alba* flour (PAF) as agglutinant in partial replacement of sugar and honey.

2. Materials and methods

2.1. Preparation of flours from Prosopis alba pods

Prosopis alba pods were collected in Santiago del Estero (Argentina). Pods were washed with drinking water and dried in a forced convection oven (Sanjor SL60SF, Buenos Aires, Argentina) at 80 °C up to constant weight. Samples were grinded (970 W of power, Moulinex, Alençon, France) and sieved with a 1000 μm (#18) sieve (ALEIN, Munro, Argentina) according to ASTM (ASTM, 2013) specifications. The fine fraction obtained (83% yield) was the flour (PAF) used for the sweet snack formulation.

2.2. Formulation of sweet snacks

The snack formulation was based on the typical composition of commercial cereal bars but a more balanced, natural formulation without additives and preservatives was attempted to achieve. Sweet snacks were formulated with a mix of three kinds of seeds: 7.8% chia, 22% quinoa, 22% amaranth (51.8% of the total snack weight). No extra fat was added because it was totally replaced by the lipids present in chia seeds. Granola formed by oat, nut and honey, and popped rice usually present in commercial samples were replaced by amaranth and quinoa seeds. Agglutinants of commercial snacks (sugar and honey) were replaced by a mixture including *Prosopis alba* flour. These ingredients also acted as sweeteners.

The formulation of the agglutinant agent (48.2% of the total snack weight) was obtained according to a mixture design of three components using the Design Expert 7.0 program. A design restriction was imposed: PAF was not used alone, since sugar and honey are also necessary ingredients for agglutination. The different formulations of the agglutinant are shown in Table 1. The model yielded five points, belonging to the vertices and the central point of a trapeze; the central point was evaluated by duplicate for the estimation of the pure error.

Table 1
Experimental design for the agglutinant of the sweet snacks.

Sample	Codified variables			Decodified variables (g/48.2 g)		
	Honey	Sugar	PA flour	Honey	Sugar	PA flour
A	0.333	0.333	0.333	16.07	16.07	16.07
B	0	0.333	0.666	0	16.08	32.12
C	1	0	0	48.2	0	0
D	0.333	0	0.666	16.08	0	32.12
E	0	1	0	0	48.2	0

Seeds were previously treated. Chia and amaranth seeds were heated in a recipient each 10 g-portions: chia was toasted at intermediate, while amaranth was popped at low heating rate. With the aim of eliminating saponins, substances that confer bitter taste, quinoa seeds were submerged in drinking water (1:8), agitated and rinsed out up to eliminate all the foam. Thereafter, seeds were heated in three times their volume of water until water started boiling, leading to rest 3 min. Moisture of quinoa seeds was determined by weight difference. The mass of moisturized seeds equivalent to 22 g of dry seed necessary for the snack formulation, was calculated. Honey, sugar and PAF were not previously processed.

Snacks were prepared introducing in a stainless steel recipient the wet quinoa, honey, sugar and finally PAF. Ingredients were mixed. After that treated chia and amaranth seeds were incorporated up to obtaining a homogeneous product. The mix was equilibrated 24 h at 4 °C and between 6 and 8 g was introduced in circular moulds (diameter: 30 mm, height: 15 mm). Samples were placed in preheated trays and heated at 160 °C during 25 or 30 min, depending on the formulation. Cooking time was previously determined in order to achieve a water activity of 0.7, enough low to prevent microbial spoilage.

After cooling, snacks were unmolded, cover with plastic film, and stored 24 h at 20 °C for ulterior analysis.

2.3. Color measurement

Color measurements were performed on 40 snacks for each formulation using a tristimulus color analyzer (Chroma Meter CR 400, Konica Minolta, Osaka, Japan). Parameters L*, a* and b* of the CIELAB color space were determined. Variation of color after cooking (ΔE_{2000}) (CIEDE 2000) was calculated transforming L*, a* and b* in C* and h* parameters and applying several equations according to Luo, Cui, and Rigg (2001) and Sharma, Wu, and Dalal (2005).

2.4. Water activity

Water activity (a_w) was measured using the hygrometric method at 20 °C in an AQUALAB Serie 3TE water activity meter (Decagon Devices Inc., Pullmann, WA, USA) according to AOAC 978.18 method (AOAC, 1998). In this equipment, the sample was led to be equilibrated with the air present in a sealed chamber. The technique is based on bringing the headspace air relative humidity to equilibrium with the product a_w, being this equilibrium attained without modifications in the a_w of the sample due to the large ratio of sample mass to headspace air mass. Therefore, by measuring the air equilibrium relative humidity (h_{re}) with an accurate chilled-mirror dew point sensor and a noncontact infrared thermometer, the water activity of the product was determined as $a_w = h_{re}$. Assays were performed by triplicate.

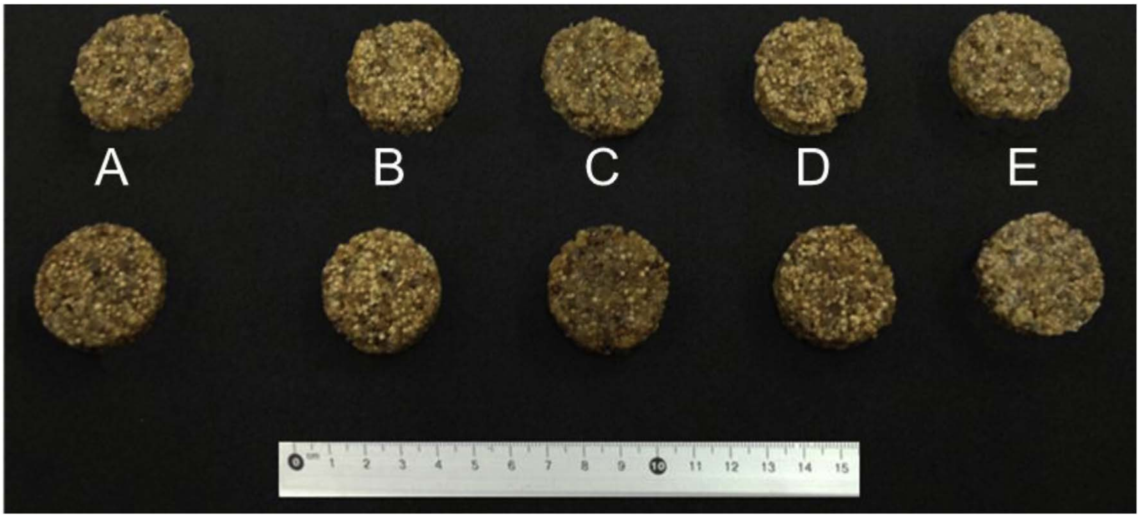

Fig. 1. Sweet snacks before and after baking. Identification of formulations: refer to Table 1.

2.5. Texture profile analysis (TPA)

Texture Profile Analysis was performed on snacks using a TA.XT2i Texture Analyzer (STABLE MICRO SYSTEMS, Surrey, U.K.) with a load cell of 25 kg. Ten pieces (10 p) of snacks were assayed for each formulation. Snacks underwent a cycle of double compression that reproduces in an empiric form a two-bite texture profile. Compression was performed up to 40% of deformation, according to the original height of the snack with a cylindrical probe of 75 mm diameter (SMS/75) at a crosshead speed of 0.5 mm seg^{-1}. A curve of compression force vs time was obtained. As in the case of breads (Bigne, Puppo, & Ferrero, 2016), consistency, cohesiveness, resilience and elasticity were calculated as textural parameters. Consistency was the sum of the areas under the force vs. time curve corresponding to the first and second compression cycles. Cohesiveness was calculated as the ratio between the positive area of the second cycle and the positive area of the first cycle. Resilience was calculated as the ratio between the portion of area between the maximum force and the end of the first peak and the portion of area between the beginning of the first peak and the maximum point. Elasticity was calculated as the d_2/d_1 ratio, being d_2 and d_1 the distances between the initial and the maximum forces of second and first compression peaks, respectively.

2.6. Microstructure

Snack samples were analyzed by Environmental Scanning Electron Microscopy-ESEM. Images were taken with a FEI ESEM Quanta 200 equipment (Hillsboro, OR, USA) with energy dispersive system (EDS) with filament of tungsten as source of electrons. Snacks were cut in 12 mm^3 sections and mounted on a metal support dish, to be scanned at 25 °C and 5–6 Torr, at 20 kV acceleration voltage (Quintero Ruiz, Demarchi, & Giner, 2014). Surface Photographs were taken at magnifications of 500X and 2000X.

2.7. Sensory analysis of sweet snacks

In a previous work, a sensory analysis of snack samples in which evaluators ordered the fifth snacks of this work by preference assay (Sciammaro et al., 2015), was performed. The most accepted was E formulation that not contains PAF and significantly differed from the other ones. In the second place, sample A was selected which contains equal quantities of the three agglutinants. In the base of these previous results of acceptability, the two snacks of best preference (A and E) were selected for a sensory acceptability assay with Hedonic scale of nine points. A non trained panel of 55 persons was used. Attributes of overall acceptability, appearance, cohesiveness, flavor, sweetness and astringency were evaluated.

2.8. Proximal composition

Proximal composition was performed according to AOAC methods (AOAC, 1998), on the sweet snack formulation selected by sensory evaluators that contains *Prosopis alba* flour (formulation A). Moisture of samples was determined by triplicate after drying under vacuum at 50 mBar and 70 °C up to constant weight. Protein content was determined according to Kjeldahl method; the factor utilized for conversion nitrogen to protein was 6.25. Lipid content was determined using Soxhlet method; samples were dried 2 h at 100 °C and extracted during 2 h with petroleum ether (35-60 °C fraction). Total dietary fiber was determined by enzymatic hydrolysis (Megazyme kit, K-TDRF, Megazyme, Wicklow, Ireland) according to the AOAC method. Total soluble polyphenols were determined according to Sciammaro, Ferrero, and Puppo (2016). Carbohydrate content different from fiber was determined by difference. Assays were performed by duplicate.

2.9. Statistical analysis

Statistical analysis was performed with Origin 9 Pro software (Origin Lab Corporation, Northampton, USA). Parameters were analyzed according to the general linear model. Significant differences between means (LSD) were analyzed by Fisher test ($p < 0.05$).

3. Results and discussion

3.1. Color and hydration properties of sweet snacks

Fig. 1 shows the appearance of the different snacks after baking. An important characteristic appreciated by the consumers is the color of the product. In baked foods, this parameter indicates the magnitude of caloric energy applied to the product during baking. The parameter ΔE can be used as a measure of the global color variation after baking process, and can be related with interactions between different components during heating that influence physical and sensory characteristics. In this work, it was established for ΔE a minimum value of 3.7 (Sun-Waterhouse, Teoh, Massarotto, Wibisono, & Wadhwa, 2010) to state that there are differences in color between samples before and after baking. Fig. 2 shows the variation of ΔE values as a function of baking time. Except for formulation A (33% of each agglutinant agent),

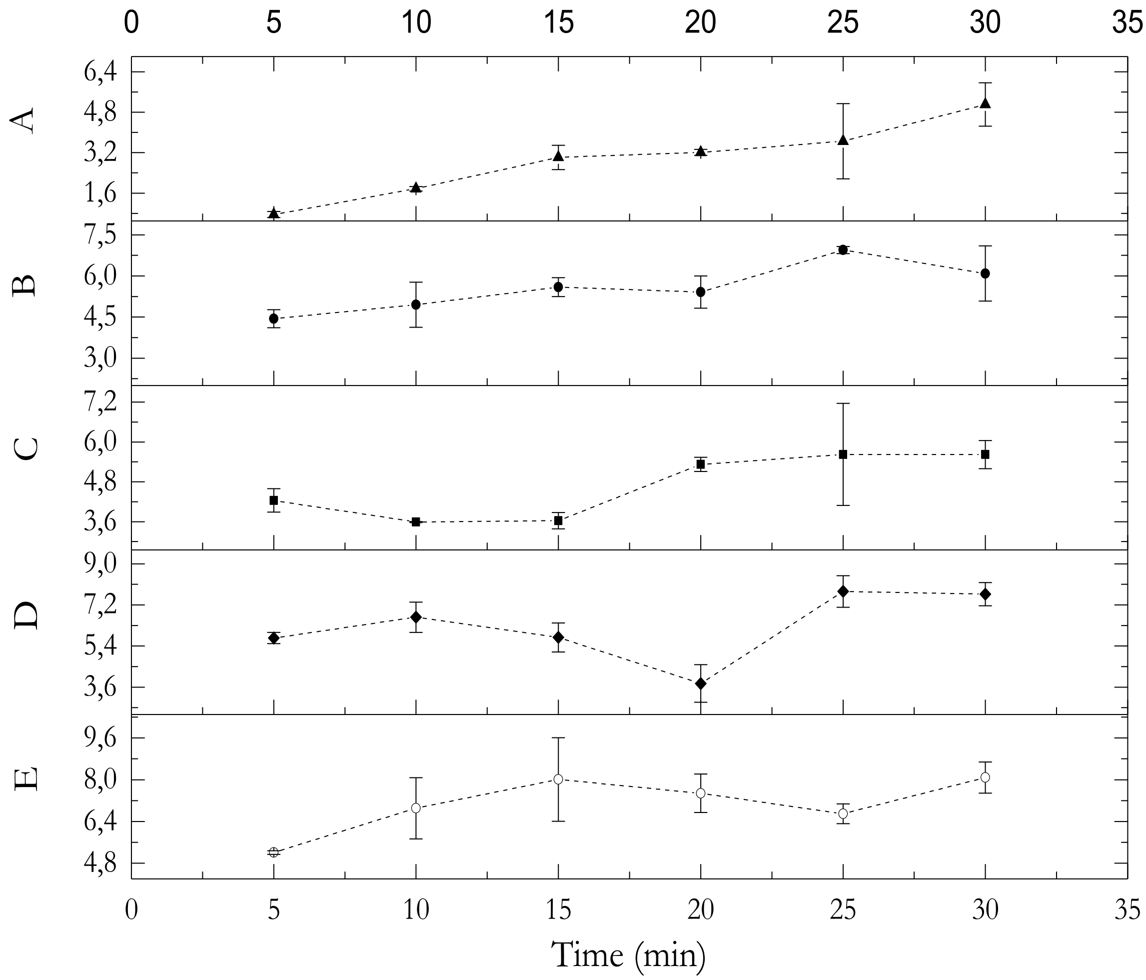

Fig. 2. Color variations, ΔE_{2000}, of sweet snacks with baking time.

Table 2
Cooking times and values of moisture and a_w for different formulations of sweet snacks.

Sample	Time (min)	Moisture (%)	a_w (-)
A	25	17.83 ± 2.50 ^{AB}	0.695 ± 0.042 ^{A}
B	25	17.30 ± 3.86 ^{B}	0.710 ± 0.077 ^{A}
C	30	21.73 ± 1.70 ^{A}	0.716 ± 0.051 ^{A}
D	30	15.75 ± 1.01 ^{BC}	0.645 ± 0.053 ^{A}
E	30	12.70 ± 1.96 ^{C}	0.670 ± 0.037 ^{A}

Different letters in the same column indicate significant differences between values ($p < 0.05$).

values of ΔE higher than 3.7 were observed, thus indicating, that baking influenced color properties of snacks. For the same content of honey (33%), the snack D that contains PAF but do not contain added sugar, presented a ΔE higher than that observed for the snack A, suggesting

Table 4
Coefficient values of models of different texture parameters.*

Consistency	Consistency = +33.91 * Honey + 38.33 * Sugar +371.09 * PA flour $r^2 = 0.97$ p model = 0.024 p lack of fit = 0.051
Cohesiveness	Cohesiviness = +0.33 * Honey +0.38 * Sugar +0.46 * PA flour $r^2 = 0.96$ p model = 0.034 p lack of fit = 0.90
Resilience	Resilience = +0.12 * Honey +0.14 * Sugar +0.30 * PA flour $r^2 = 0.99$ p model = 0.0051 p lack of fit = 0.4684
Elasticity	Elasticity = +0.46 * Honey +0.43 * Sugar +0.78 * PA flour $r^2 = 0.950$ p model = 0.0495 p lack of fit = 0.508

*All parameters presented a linear fit model.

Table 3
Texture parameters of sweet snacks.

Sample	Consistency	Cohesiveness	Resilience	Elasticity
A	148.7 ± 29.6 ^{C}	0.402 ± 0.016 ^{B}	0.182 ± 0.005 ^{B}	0.582 ± 0.018 ^{C}
A′	144.7 ± 25.4 ^{C}	0.382 ± 0.019 ^{C}	0.190 ± 0.011 ^{B}	0.531 ± 0.035 ^{D}
B	237.4 ± 95.9 ^{B}	0.433 ± 0.033 ^{A}	0.243 ± 0.016 ^{A}	0.639 ± 0.090 ^{B}
C	27.0 ± 5.2 ^{D}	0.334 ± 0.014 ^{D}	0.121 ± 0.004 ^{D}	0.457 ± 0.039 ^{E}
D	283.4 ± 23.2 ^{A}	0.419 ± 0.012 ^{AB}	0.244 ± 0.008 ^{A}	0.698 ± 0.033 ^{A}
E	47.3 ± 5.0 ^{D}	0.385 ± 0.010 ^{C}	0.144 ± 0.006 ^{C}	0.439 ± 0.017 ^{E}

Different letters in the same column indicate significant differences between values ($p < 0.05$). A': duplicate of central point.

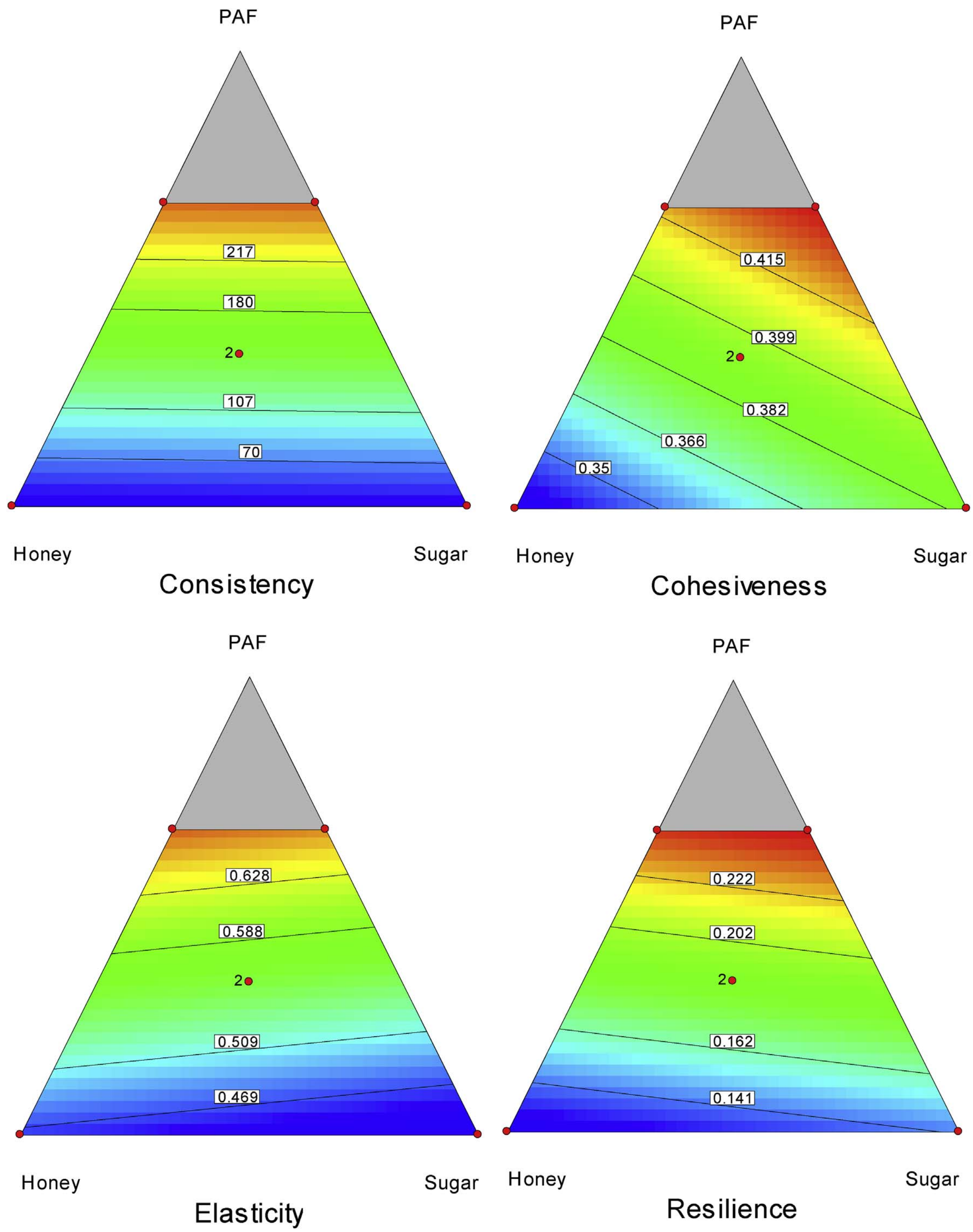

Fig. 3. Surface contour graphs for sweet snacks texture parameters: consistency, cohesiveness, resilience, elasticity.

that carbohydrates, that are able for reacting with proteins for rendering Maillard reactions are not equally available in each formulation. In the case of formulations with PAF, a proportion of the soluble sugar content is contributed by this flour, which contains an amount of 52.1 ± 1.79 (Sciammaro et al., 2016).

Table 2 shows the values of total baking time, moisture and water activity. Snacks with PAF presented intermediate values of moisture that were significantly different to those observed for the other samples. The sample with the lowest content of moisture was that containing only sugar (E), while the highest moisture was observed for the snack that contain only honey (C). No significant differences in a_w values of different snacks were observed. On the other hand, for approximately the same a_w, sample with honey (C) and with sugar (E) presented the highest and lowest moisture contents, respectively.

3.2. Texture of sweet snacks

Values of texture parameters of snacks are shown in Table 3. Formulations of highest consistency were those that contained the highest amount of PAF (B and D), while the softer sample was the snack that contains only honey (C); the last one did not present significant difference with the formulation with only sucrose as agglutinant (E).

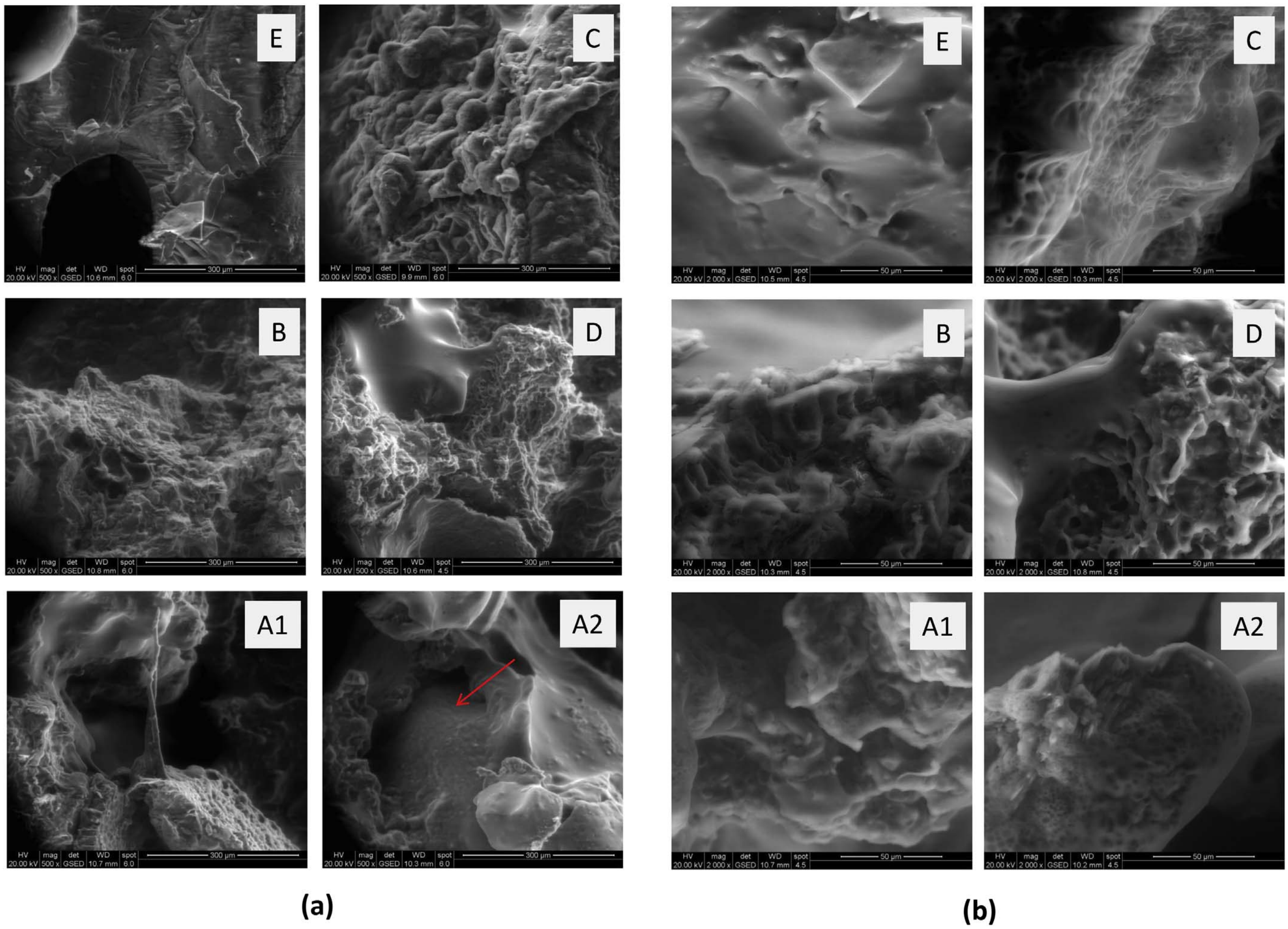

Fig. 4. ESEM micrographs of sweet snacks. Identification of formulations: refer to Table 1 a) 500X, b) 2000X.

Table 5
Values of sensory attributes of sweet snacks.

	Overall Acceptability	Appearance	Cohesiveness	Flavor	Sweetness	Astringency
A	6.20 ± 1.82^{A}	7.00 ± 1,48^{A}	5.45 ± 2.17^{A}	5.75 ± 1.94^{A}	6.07 ± 2.12^{A}	6.18 ± 1.98^{A}
E	6.68 ± 1.57^{A}	5.75 ± 1,90^{B}	5.55 ± 1.97^{A}	6.23 ± 1.53^{A}	6.70 ± 1.89^{A}	6.57 ± 1.93^{A}

Different letters in the same column indicate significant differences between values ($p < 0.05$).

Snacks with the highest level of PAF presented higher cohesiveness, resilience and elasticity. In a previous work values of chewiness were informed (Sciammaro et al., 2015), they were slightly different from those of consistency. Sample with the highest chewiness was the one with high content of PAF along with honey (D), while samples with the lowest values of this parameter were those containing only honey (C) or sugar (E). Formulation A was the snack with an intermediate behavior, because it was composed by the same quantity of the three agglutinants. All texture parameters fitted a linear model ($p < 0.05$, $r^2 > 0.9$) (Table 4).

Fig. 3 shows contour surface for the different texture parameters. An increase in consistency with the increase of PAF content (displacement to red) was observed. For cohesiveness, it can be observed that sugar with PAF (B) generates a more cohesive product; although it has no significant difference with formulation D (honey + PAF), it can be detected a tendency to higher cohesiveness for snacks that were formulated with PAF and sugar. This tendency could be attributed to the water retention due to the fibre provided by PAF in B and D formulations, leading to more compact and structured snacks. On the contrary, formulations C and E presented significant differences, being C less cohesive.

Resilience is the capacity of the product to return to its original form after the first compression. It can be observed that values of resilience resulted very low for all formulations (< 0.25), although samples with the highest values were those with the high amount of PAF. Elasticity was defined as the height that reached the snack between the first and the second compression cycle. PAF conferred high elasticity to formulations.

In summary, sucrose tends to soften, while honey and mainly PAF tends to toughen snacks, increasing consistency, suggesting that more crispy products will be obtained with this flour when it is used as a binder component.

3.3. Microstructure of sweet snacks

Microstructure of the snacks was analyzed by ESEM assay and photographs are shown in Fig. 4. Fig. 4a shows micrographs of samples at a magnification of 500X. In all of them, it can be observed that the

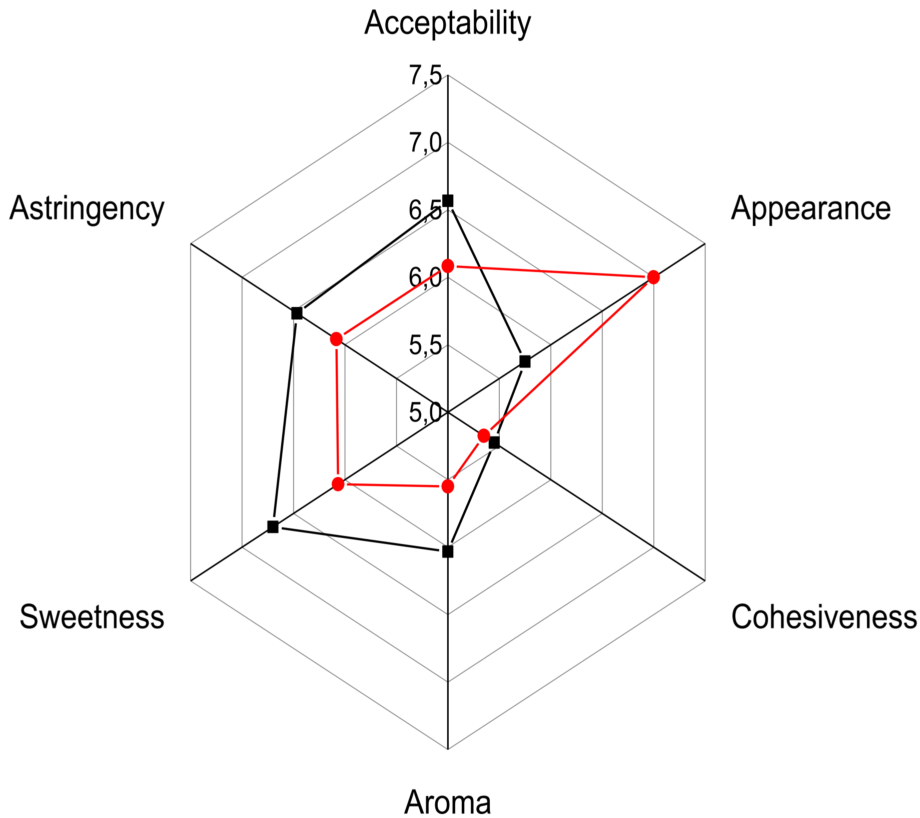

Fig. 5. Sensory attributes of snack A (red circle) and snack E (black square). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 6
Proximal composition of *Prosopis alba* flour and sweet snack.

g/100 g (d.b.)	PA flour	Snack A
Moisture	4.76 ± 0.09	17.83 ± 2.49
Ash	3.09 ± 0.14	2.28 ± 0.076
Protein (N_T x6.25)	7.73 ± 0.12	10.78 ± 0.059
Lipids	0.67 ± 0.03	5.24 ± 0.01
Total polyphenols	0.621 ± 0.005	0.102 ± 0.008
Total dietary fiber	23.3 ± 0.27	20.84 ± 0.16
Carbohydrates[a]	60.45	43.03

[a] Carbohydrates different from dietary fiber were determined by difference.

film of agglutinant covers the seeds. When sucrose is the only agglutinant used (sample E), laminar sheets with crystalline appearance were observed. Sample with only honey (C) in the formulation presented a smooth surface with rounded structures; the latter could be produced by bubbles covered by solidified honey components, probably non-crystallized one. These microstructure differences between formulations C and E could explain the less cohesive character of snack C. One of the main honey components is fructose, a sugar that difficultly crystallize from an aqueous solution (Hanover & White, 1993); in addition honeys with a high fructose/glucose ratio (more than 1.4) generally crystallize more slowly (Grégrová, Kružík, Vrácovská, Rajchl, & Čížková, 2015). Due to this phenomenon, honey would have a less effective behavior as binding agent, rendering a less cohesive snack. As it can be observed in the micrograph, sucrose of formulation E forms crystals that would difficult the disintegration of the snack.

Samples that contain high amounts of PAF (B and D) exhibited a film structure with several strands, with inhomogeneous and rough aspect. However in sample D some smooth zones, probably formed by honey, can be appreciated. For formulation A (honey + sucrose + PAF) it can be observed a strand of agglutinant that connect a piece of fibre, that could belong to PAF, with other part of the sample (Fig. 4 a A1). In Fig. 4 a A2 a binder layer covering a seed (red arrow) can be observed. Also in that sample, soft (right) and rough (left) regions corresponding to the different components described above, can be observed. Fig. 4 b shows photographs corresponding to a more expanded field of different structures observed in Fig. 4 a.

3.4. Acceptability of sweet snacks

As it was previously described, the two samples selected by panelists with a preference assay (Sciammaro et al., 2015), snack A and E, were then characterized according to different attributes. Table 5 shows mean values for each attribute that were compared in a spider web graph in Fig. 5. Significant differences between samples A and E were observed only for the attribute "appearance", with higher values for A formulation. No significant differences were detected for the other attributes, despite snack E presented a tendency to higher values. These results suggest that sugar acting as binder agent can be partially replaced by PAF. However, this flour should be preferably incorporated at levels < 35%. Moreover, snacks containing only honey were not totally accepted by consumers, perhaps because of the excessive sweetness conferred by fructose.

3.5. Proximal composition of the preferred sweet snack

Table 6 shows chemical composition of snack A in comparison with PAF. Only this snack was analyzed, because it was the formulation with algarrobo flour preferred by panelists. A snack with *Prosopis alba* flour would contribute with several substances that would exert healthy effects on consumers. Nutritional and bioactive components of the flour and seeds of *Prosopis alba*, like polyphenols with antioxidant capacity, were previously studied by several authors (Cardozo et al., 2010; Cattaneo et al., 2016; Cattaneo et al., 2014; Picariello et al., 2017;

Sciammaro et al., 2016). Respect to protein, the flour presented a relative low content (7.73%), but this value was increased in the snack, due to the protein contribution of the seeds. Sciammaro et al. (2015) proved the absence in PAF of prolamins that induce celiac disease using a competitive enzymatic-immunoassays with polyclonal antibodies (limit value: 0.1 mg/100 g flour); therefore this flour could be an adequate ingredient for gluten-free foods.

It was observed in PAF a high content of total soluble sugars (52.1 ± 1.79%), constituted by glucose, fructose and mainly sucrose (Sciammaro et al., 2016). In snack A, as in PAF, dietary fiber content was higher than 20%; two snacks would contribute with almost 10% of the recommended daily fiber intake for adults of 30 g (Institute of Medicine, 2005). From total fiber content in the snack A (20.84%), 3.71% was provided by PAF while 17.13% were supplied by seeds. In addition, one snack A would contribute with 262 Kcal/100 g. Other snacks with seeds like the formulation reported by Dordoni et al. (2015) exhibited a caloric contribution of 402 Kcal/100 g.

On the other hand, a parameter that indicates stability during storage of food products is water activity (aw); therefore a_w measured for snack A was 0.651 ± 0.036, a value that is below the limit security value (a_w = 0.7) selected as safe. No antecedents of research on this kind of product formulated with *Prosopis alba* flour was found, although Escobar, Estévez, and Guiñez (2000) prepared cereal bars with roasted cotyledons of *Prosopis chilensis* and different amounts of nut and peanut that presented lower values of moisture (7.2–11.2%) and aw (0.59–0.65). Sun-Waterhouse et al. (2010) formulated filled bars with popped rice, glucose syrup, honey, vegetable oil, rolled oat, glycerol, whey serum, maltodextrin and pectin for the cover; while for the filling paste they utilized pectin, sugar, citric acid, glucose syrup, honey, margarine, glycerol and apple puree. These authors could achieve a protein content between 1.07 and 3.66%. Their bars also presented higher contents of lipids (8.48–9.97%) and lower amounts of water (5.6–10.7%) and a_w (0.460–0.483).

Estévez et al. (1995) found for their bars values of 1.5–2.1% ash, 29–30% lipids, 10–15% protein and 49–57% of carbohydrates; and values of a_w between 0.6 and 0.75 (similar to those obtained in the present work). The National Institute of Industrial Technology of Argentina (INTI, 2011) published an inform with a qualitative analysis of the 10 main commercial cereal bars of trade-mark. Results obtained confirmed ranges of 4.4–9.4% for proteins, 7.7–27% for lipids, 57–82% for carbohydrates; evidencing a widely range for each component, depending on the type of product. A result to highlight is that none of all cereal bars commercialized in our country overcame the protein content of the snacks formulated in this work; behavior that could be attributed not only to PAF, also to protein provided by seeds, mainly by quinoa (ranging from 9.1 to 15.7%) (Nowak, Du, & Charrondière, 2016) and amaranth (ranging 13.2–18.4% according to the species) (Orona-Tamayo & Paredes-López, 2017). In addition, the snack with PAF presented a lipid content lower than that observed for commercial products.

4. Conclusions

Prosopis alba flour presents high contents of soluble sugars, dietary fiber and polyphenols with antioxidant capacity. In addition, this flour does not contain prolamins. All these properties make of this flour a high quality nutritional ingredient for baked products and especially for gluten-free ones. Using this flour as agglutinant jointly with sugar and honey, and incorporating it at levels lower than 35% in the mix, allowed obtaining sweet snacks with high consistency and cohesiveness, a desired texture property. The snack was well accepted by consumers and by its content of proteins and lipids and more than 20% of fiber can be a good option both for celiac and non-celiac people.

Acknowledgements

The authors want to acknowledge Mrs. Nancy Campos from Santiago del Estero for providing us the algarrobo pods and the University of La Plata (UNLP) (UNLP-A230 2012-2015) and Consejo Nacional de Investigaciones Científicas y Técnicas de la Argentina (CONICET) (CONICET, PIP 0289 2013-2015) for the granted funds.

References

AOAC (1998). *Official methods of analysis of AOAC international.* Gaithersburg, Md.: AOAC International.

ASTM (2013). *Standard specification for woven wire test sieve cloth and test sieves.* West Conshohocken, PA.: ASTM International.

Bigne, F., Puppo, M. C., & Ferrero, C. (2016). Fibre enrichment of wheat flour with mesquite (Prosopis spp.): Effect on breadmaking performance and staling. *LWT-Food Science and Technology, 65*, 1008–1016.

Boustani, P., & Mitchell, V.-W. (1990). Cereal bars: A perceptual, chemical and sensory analysis. *British Food Journal, 92*, 17–22.

Bower, J. A., & Whitten, R. (2000). Sensory characteristics and consumer liking for cereal bar snack foods. *Journal of Sensory Studies, 15*, 327–345.

Cardozo, M. L., Ordoñez, R. M., Zampini, I. C., Cuello, A. S., Dibenedetto, G., & Isla, M. I. (2010). Evaluation of antioxidant capacity, genotoxicity and polyphenol content of non conventional foods: Prosopis flour. *Food Research International, 43*(5), 1505–1510.

Caselato-Sousa, V. M., & Amaya-Farfán, J. (2012). State of knowledge on amaranth grain: A comprehensive review. *Journal of Food Science, 77*, R93–R104.

Cattaneo, F., Costamagna, M. S., Zampini, I. C., Sayago, J., Alberto, M. R., Chamorro, V., et al. (2016). Flour from Prosopis alba cotyledons: A natural source of nutrient and bioactive phytochemicals. *Food Chemistry, 208*, 89–96.

Cattaneo, F., Sayago, J. E., Alberto, M. R., Zampini, I. C., Ordoñez, R. M., Chamorro, V., et al. (2014). Anti-inflammatory and antioxidant activities, functional properties and mutagenicity studies of protein and protein hydrolysate obtained from Prosopis alba seed flour. *Food Chemistry, 161*(0), 391–399.

Cook, M. L., Keyser, W. L., Swanson, P., Zielke, M. W., & Zielinski, W. J. (1984). *Food bar.* Google Patents.

Dordoni, R., De Cesare, S., Dioni, M., Mastrofilippo, T., Quadrelli, D., Rizzi, R., et al. (2015). Design and development of an eco-innovative sorghum snack. *Chemical Engineering Transactions, 43*, 187–192.

Escobar, B., Estévez, A., & Guiñez, M. (2000). Almacenamiento de barras de cereales elaboradas con cotiledones de algarrobo (Prosopis chilensis (Mol) Stuntz). *Archivos Latinoamericanos de Nutricion, 50*, 152–156.

Estévez, A., Escobar, B., Vasquez, M., Castillo, E., Araya, E., & Zacarías, I. (1995). Cereal and nut bars, nutritional quality and storage stability. *Plant Foods for Human Nutrition, 47*, 309–317.

Grégrová, A., Kružík, V., Vrácovská, E., Rajchl, A., & Čížková, H. (2015). Evaluation of factors affecting crystallization of disparate set of multi-flower honey samples. *Agronomy Research, 13*(5), 1215–1226.

Hanover, L. M., & White, J. S. (1993). Manufacturing, composition, and applications of fructose. *American Journal of Clinical Nutrition, 58*(5), 724S–732S.

Institute of Medicine (2005). *Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids.* National Academy Press. Food and Nutrition Board, Institute of Medicine, National Academieswww.nap.edu.

INTI (2011). *Argentinean program of behavior of products like cereal bars*.

Luo, M. R., Cui, G., & Rigg, B. (2001). The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Research & Application, 26*, 340–350.

Nowak, V., Du, J., & Charrondière, U. R. (2016). Assessment of the nutritional composition of quinoa (Chenopodium quinoa Willd.). *Food Chemistry, 193*, 47–54.

Orona-Tamayo, D., & Paredes-López, O. (2017). Amaranth Part 1—sustainable crop for the 21st century: Food properties and nutraceuticals for improving human health. *Sustainable protein sources* (pp. 239–256). Academic Press.

Picariello, G., Sciammaro, L., Siano, F., Volpe, M. G., Puppo, M. C., & Mamone, G. (2017). Comparative analysis of C-glycosidic flavonoids from Prosopis spp. and Ceratonia siliqua seed germ flour. *Food Research International, 99*, 730–738.

Quintero Ruiz, N. A., Demarchi, S. M., & Giner, S. A. (2014). Effect of hot air, vacuum and infrared drying methods on quality of rose hip *(Rosa rubiginosa)* leathers. *International Journal of Food Science and Technology, 49*, 1799–1804.

Repo-Carrasco, R., Espinoza, C., & Jacobsen, S.-E. (2003). Nutritional value and use of the andean crops Quinoa (Chenopodium quinoa) and Kañiwa (Chenopodium pallidicaule). *Food Reviews International, 19*, 179–189.

Sciammaro, L., Ferrero, C., & Puppo, M. C. (2015). Adding value to algarrobo fruit. Study of chemical and nutritional composition for its application in sweets snacks. *Revista de la Facultad de Agronomía-La Plata, 114*(1), 115–123.

Sciammaro, L. P., Ferrero, C., & Puppo, M. C. (2016). Chemical and nutritional properties of different fractions of Prosopis alba pods and seeds. *Journal of Food Measurement and Characterization, 10*(1), 103–112.

Sharma, G., Wu, W., & Dalal, E. N. (2005). The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research and Application, 30*, 21–30.

Sun-Waterhouse, D., Teoh, A., Massarotto, C., Wibisono, R., & Wadhwa, S. (2010). Comparative analysis of fruit-based functional snack bars. *Food Chemistry, 119*, 1369–1379.

Ullah, R., Nadeem, M., Khalique, A., Imran, M., Mehmood, S., Javid, A., et al. (2016). Nutritional and therapeutic perspectives of chia (*Salvia hispanica* L.): A review. *Journal of Food Science & Technology, 53*, 1750–1758.

Xiao, J., Muzashvili, T. S., & Georgiev, M. I. (2014). Advances in the biotechnological glycosylation of valuable flavonoids. *Biotechnology Advances, 32*, 1145–1156.