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Original article

Astringent and non-astringent persimmon cremogenates made with different thickeners

Damián Taboada,[1] Jorge García-Hernández,[2] María Dolores Ortolá[1] & María Luisa Castelló[1]*

1 University Institute of Food Engineering – FoodUPV, Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022, Spain
2 Centro Avanzado de Microbiología de Alimentos (CAMA), Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022, Spain

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Summary Due to the surplus in the production of 'Rojo Brillante' persimmon in Spain, there is great interest in developing products made from this fruit that can take full advantage of production peaks. However, heat treatment can reverse the astringency, limiting the diversity of products derived from persimmon. The aim of this study was to characterise physicochemically astringent and non-astringent persimmon cremogenates subjected to pasteurisation and elaborated with different thickeners (guar gum, sodium alginate and pectin). Several aspects were specifically analysed: the evolution during the storage of the soluble solid content, water, total phenols, antioxidant capacity, optical and mechanical properties, as well as the microbiological stability. The sensory acceptability of the selected cremogenates was also evaluated. The results showed that the final colour of the samples depended on the initial level of astringency of the raw material; the non-astringent persimmons were much darker ($L^* \approx 40$–50) than astringent persimmons ($L^* \approx 65$–70), and the type of thickener used had no effect and led to no difference. Furthermore, the cremogenate was harder (F ≈ 20–120 N) when astringent persimmons were used. In astringent cremogenates the thickeners evaluated help in reducing the total phenol content after 3 months of storage in 40% when compared to the control. The heat treatment applied (70 °C, 30 min) did not reverse the astringency, so this type of cremogenate could be a commercial outlet for the waste or surplus of this fruit. In this regard, non-astringent persimmons with pectin would be recommended for the preparation of cremogenates from this fruit since they were also those that the scored best in the sensory analysis.

Keywords Astringency, cremogenate, persimmon, storage, thickeners.

Introduction

Persimmon (*Diospyros kaki* Thunb.) is a crop originating in China, typical of subtropical and tropical areas, which has spread widely in Europe since the seventeenth century (Giordani, 2003). On this continent, it is mainly cultivated in the Mediterranean basin, where it has traditionally been a minor fruit; in recent decades, however, it has become very popular, particularly in Spain, due to the success of the 'Rojo Brillante' variety. In its physiological maturation, the fruit is very soft, which hinders its commercialisation, but before this, when the fruit is still firm, it is astringent due to the high content of soluble tannins in persimmon. In response to this, different post-harvest techniques have been developed to eliminate the astringency of fruits when they are immature (Perucho *et al.*, 2015). Currently, the most widely used treatment is the exposure of the fruit to high concentrations of CO_2, developed by the Valencian Institute of Agricultural Research (IVIA) in order to eliminate the astringency of fruits when they are immature (Arnal & Del Río, 2003; Perucho *et al.*, 2015). Thanks to the development of these techniques, the fruit does not lose firmness, which translates into a substantial improvement in the processes of marketing and transport over long distances (Llácer & Badenes, 2003). This technique is based on the fact that, in the presence of acetaldehyde, a volatile compound produced by the fruit under certain conditions, the tannins change into their insoluble form, in which they are not detectable at the sensory level since they do not produce the sensation of dryness in the mouth associated with astringency. This acetaldehyde can be generated in the fruit through the oxidation of endogenous or exogenous ethanol and also through the decarboxylation of pyruvic acid. Therefore, acetaldehyde accumulation in the

*Correspondent: E-mail: mcasgo@upv.es

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fruit can be induced by subjecting it to anaerobic conditions or *via* the exogenous applications of ethanol. The acetaldehyde accumulated in the fruit acts as a bridge connecting two proanthocyanidins, which causes their insolubilisation and the consequent loss of astringency (Perucho *et al*., 2015).

Persimmon harvesting is seasonal in Spain, taking place in autumn and early winter and thus limiting its availability on the market to the months of October–January in this area, months in which there is a high production (Martínez-Las Heras *et al*., 2016). Due to this high production in such a short period of time, it is necessary to look for alternatives to fresh persimmon consumption so as to deal with the surplus of persimmon and permit its consumption throughout the year. Some alternatives have been the elaboration of persimmon jam (Rodríguez *et al*., 2022), spreadable products (Castelló *et al*., 2011), purees, pastes, juices and jams (Carbonell *et al*., 2012; Suntudprom, 2014; Tsurunaga *et al*., 2022), and snacks (Alberca *et al*., 2018), among others. Cremogenates could also be a possible alternative means of prolonging the commercialisation of persimmon surpluses. However, some studies point out that the incorporation of persimmon into new food matrices could be hindered by astringency problems associated with tannin solubilisation after thermal processing and/or storage. Therefore, the use of thickeners that can not only improve the texture of the product but also maintain the insolubility of the tannins, may be a viable strategy for the development of new products (Tsurunaga *et al*., 2022). Thus, from a chemical point of view, pectin forms complexes with tannins and with some catechins, depending on the hydrogen bonds and hydrophobic interactions that occur between the carboxylic groups of pectins and the hydroxyl phenolic groups of tannins (Mamet *et al*., 2017). Alginates are structural polysaccharides extracted from brown algae. Most applications of alginate are based on its gel-forming ability through cations binding; the transition from water-soluble sodium alginate to water insoluble calcium alginate, for example (Galus & Lenart, 2013). Guar gum is an agrochemical processed from endosperm of cluster bean with the ability to form hydrogen bonding with water molecule offering good properties as thickener and stabiliser (Mudgil *et al*., 2014).

For all the above-mentioned reasons, the main objective of this study was to evaluate the physicochemical, microbiology and sensory parameters of cremogenates made with different thickeners (pectin, guar gum and sodium alginate) and with astringent and non-astringent persimmon. The antioxidant capacity and level of astringency was also determined in order to know the influence of these thickeners in stopping the reversion of astringency by the heat treatment.

Materials and methods

Raw and chemical materials

'Rojo Brillante' persimmons were supplied by the Cooperativa Agrícola de Catadau S. COOP. LTDA (Catadau, Valencia). All the fruit came from the same batch, but some had undergone CO_2 treatment to remove astringency (non-astringent) and some had not (astringent). The persimmons were stored at 10 °C until processing.

Citric acid (E330) was incorporated in every case. Pectin (E440), sodium alginate (E401) and guar gum (E412) supplied by GUINAMA, S.L.U. were used as thickening agents.

Preparation of cremogenates

Eight formulations of cremogenates were prepared with astringent (A) and non-astringent (B) persimmon and different thickeners (without thickener: C, pectin: P, sodium alginate: S, guar gum: G). Thus, an example of the notation for the formulation with astringent persimmon and sodium alginate is SA.

Persimmons were peeled and the stalks removed. They were then blended in a food processor (Vorwerk, Thermomix TM31, Wuppertal, Germany) at 290 g for 20 s. Then, 0.5% (w/w) of citric acid and 1% (w/w) thickener, if necessary, were added and the same speed was used until 2 min was reached.

After that, for each formulation, nine glass jars of 90 g capacity (previously sterilised in a thermoregulated bath at 100 °C for 30 min) were filled. Next, the jars were placed in a thermal bath at 70 °C for 30 min under water to pasteurise the content. Subsequently, the jars were placed in a cold bath until they reached room temperature in order to achieve a vacuum. Finally, they were stored in a refrigerator at 4 °C for 3 months.

Determination of pH, moisture, total soluble solids (TSS) and water activity

The pH of the persimmon cremogenates was analysed using a pH meter (METTLER TOLEDO, model SevenEasy) at 0, 1 and 3 months. The water content was obtained *via* the gravimetric method in an oven (J.P SELECTA, model conterm type poupinel 2000201, Barcelona, Spain) at 60 °C until a constant weight was reached for the first and third months. The TSS were quantified with a refractometer (ATAGO, model 3T) at 20 °C at 0 and 3 months and expressed as °Brix. For this, 1 mL of sample was centrifuged at 6991 g for 30 min and the supernatant was recovered. The water activity (a_w) was analysed using a dew point hygrometer (AquaLab Decagon Devices, Inc., model

4TE, Pullman, Washington, USA) at a temperature of 25 °C at time one and after the third month. All of these determinations were performed for each formulation in triplicate.

Optical and mechanical properties

The optical properties of the cremogenates were analysed using a spectrocolorimeter (Konica Minolta, Inc., model CM – 3600d, Tokyo, Japan) in sextuplicate for each formulation at 0, 1 and 3 months. For that purpose, the CIE $L^*a^*b^*$ reference system was used with the D65 illuminant and a 10° observer. The luminosity L^* and the coordinates a^* (+ red and − green) and b^* (+ yellow and − blue) were recorded.

A back extrusion test with a universal press (TA.XT.plus Texture Analyser, Microsystems Stable, Godalming, UK) was performed to register the mechanical properties of the persimmon cremogenates. To do so, a cylindrical container (70 mm internal height and 48 mm internal diameter) was filled with 30 g of product and a cylindrical probe (45 mm diameter) pressed that content. The test conditions were as follows: penetration at a speed of 100 mm/min followed by the subsequent raising of the probe. The texture study was carried out on six samples for each formulation after the first and third month of storage.

Antioxidant capacity and total phenols

An adaptation of the DPPH method reported by Martínez-Las Heras *et al.* (2016), DPPH (2,2-diphenyl-1-pyrhydrylhydrazyl) was applied. Basically, it consists of the reaction of the free radical with the antioxidants in the sample. The activity is quantified by the colour change in the solution based on the measurement of the variation of the absorbance at a wavelength of 515 nm using a spectrophotometer (Thermo Fisher Scientific, Inc. Helios Zeta UV–VIS, Waltham, MA, USA). The measurements were compared with a standard line of Trolox (6-hydroxy-2 2-carboxylic acid, 5,7,8-tetramethylchroman) and expressed as mg Trolox per 100 g sample.

The Folin–Ciocalteu colorimetric method (Martínez-Las Heras *et al.*, 2016) was analysed and the total phenol content of the samples was obtained. The principle of this method is the reduction of the Folin–Ciocalteu reagent by the total phenols, resulting in a blue colouring which was analysed at 765 nm with a

Table 1 Values of water activity (a_w), total soluble solids (TSS) (expressed in °Brix) and moisture of cremogenates prepared with astringent (A) and non-astringent (B) persimmon and different thickeners (without thickener: C, pectin: P, sodium alginate: S, guar gum: G) after 0, 1 and 3 months of storage

Formulation	Time (months)	a_w	pH	TSS (°Brix)	Moisture (g water/100 g total product)
CA	0	–	3.69 ± 0.01^{FG}	18.87 ± 0.12^{F}	79.9 ± 0.6^{BC}
	1	0.976 ± 0.002^{ABC}	3.72 ± 0.01^{G}	–	–
	3	0.972 ± 0.001^{ABC}	3.64 ± 0.01^{DE}	18.13 ± 0.06^{DE}	79.8 ± 0.2^{BC}
CB	0	–	3.55 ± 0.01^{B}	17.07 ± 0.12^{B}	81.35 ± 0.06^{EF}
	1	0.972 ± 0.001^{ABC}	3.54 ± 0.01^{AB}	–	–
	3	0.976 ± 0.002^{ABC}	3.52 ± 0.01^{A}	16.4 ± 0.0^{A}	81.5 ± 0.1^{F}
GA	0	–	3.65 ± 0.01^{DE}	17.3 ± 0.2^{B}	79.9 ± 0.4^{BC}
	1	0.985 ± 0.002^{C}	3.67 ± 0.01^{EF}	–	–
	3	0.973 ± 0.001^{BC}	3.62 ± 0.01^{CD}	17 ± 0^{B}	79.73 ± 0.03^{BC}
GB	0	–	3.62 ± 0.02^{CD}	17.13 ± 0.3^{B}	81.3 ± 0.2^{EF}
	1	0.976 ± 0.001^{C}	3.60 ± 0.01^{C}	–	–
	3	0.977 ± 0.003^{BC}	3.56 ± 0.01^{B}	17.37 ± 0.06^{BC}	81.04 ± 0.14^{EF}
PA	0	–	3.40 ± 0.01^{FG}	18.7 ± 0.3^{F}	80.30 ± 0.13^{CD}
	1	0.973 ± 0.002^{AB}	3.72 ± 0.01^{G}	–	–
	3	0.964 ± 0.001^{A}	3.63 ± 0.01^{CD}	17.13 ± 0.06^{B}	79.65 ± 0.12^{BC}
PB	0	–	3.70 ± 0.01^{G}	18.8 ± 0.2^{F}	78.88 ± 0.07^{A}
	1	0.974 ± 0.001^{AB}	3.65 ± 0.01^{DE}	–	–
	3	0.972 ± 0.001^{A}	3.63 ± 0.01^{CD}	18.6 ± 0.1^{EF}	79.9 ± 0.2^{BC}
SA	0	–	3.83 ± 0.03^{I}	19.53 ± 0.12^{G}	78.9 ± 0.3^{A}
	1	0.977 ± 0.000^{BC}	3.85 ± 0.01^{IJ}	–	–
	3	0.970 ± 0.000^{AB}	3.76 ± 0.02^{H}	18.9 ± 0.3^{F}	78.934 ± 0.103^{A}
SB	0	–	3.87 ± 0.01^{K}	17.867 ± 0.115^{D}	79.5 ± 0.4^{AB}
	1	0.977 ± 0.002^{BC}	3.72 ± 0.01^{IJ}	–	–
	3	0.974 ± 0.000^{AB}	3.76 ± 0.01^{H}	17.83 ± 0.06^{CD}	80.80 ± 0.06^{DE}

Values (mean of three replications) ± standard deviation followed by the same letter, within the same column, are not significantly different ($P \le 0.05$; Tukey's test).

spectrophotometer (Thermo Fisher Scientific, Inc. Helios Zeta UV–VIS, Waltham, MA, USA). The measurements were compared with a standard line of gallic acid at different concentrations and the concentration of total phenols was expressed as mg gallic acid per 100 g sample.

Both analyses were performed in triplicate for each formulation after the first and the third months of storage.

Microbiology analysis

Microbiological analyses were carried out according to Spanish R.D. regulations. 3484/2000, of December 29, which establishes hygiene standards for the production, distribution and trade of prepared foods and in accordance with European regulations [Regulation (EC) No 2073/2005] relating to the microbiological criteria applicable to products food.

Total mesophilic aerobes, moulds and yeasts, *E. coli*, Enterobacteriaceae and *Staphylococcus aureus* were counted in triplicate for each formulation stored for 3 months. In addition, a detection analysis for *Listeria monocytogenes* and *Salmonella* spp. was carried out. The samples of the different persimmon cremogenates were aseptically collected for microbiological analysis as described below. One gram of each sample was diluted in 9 mL of buffered peptone water (Scharlab), and serial decimal dilutions were performed. 0.1 mL of each serial dilution was seeded on Plate-count agar (PCA agar, Scharlab), Dichloran-rose bengal chloramphenicol agar (DRBC agar, Scharlab), Violet Red Bile Glucose Agar (VRBG agar, Scharlab), Tryptone Bile X-Glucuronide Agar (TBX chromogenic Selective Medium, Merck) and Baird Parker agar (Scharlab) for the counts of total mesophilic aerobes, moulds and yeasts, Enterobacteriaceae, beta-glucuronidase-positive *Escherichia coli* and coagulase-positive *Staphylococcus aureus*, according to ISO 4833-1:2013, ISO 21527-2:2008, ISO 21528-2:2017, ISO 16649-1:2018 and ISO 6888-1 standards, respectively. Plates were incubated at the temperatures and for the times required for each assay: 72 ± 3 h at 30 °C ± 1 °C for total mesophilic aerobes, 5–7 days at 25 °C ± 1 °C for moulds and yeasts, 24 ± 2 h at 37 °C for Enterobacteriaceae, 18–24 h at 44 °C for beta-glucuronidase-positive *Escherichia coli* and 24 ± 2 h at 37 °C for coagulase-positive *Staphylococcus aureus*. The detection analysis of *Listeria monocytogenes* and *Salmonella* spp. was carried out according

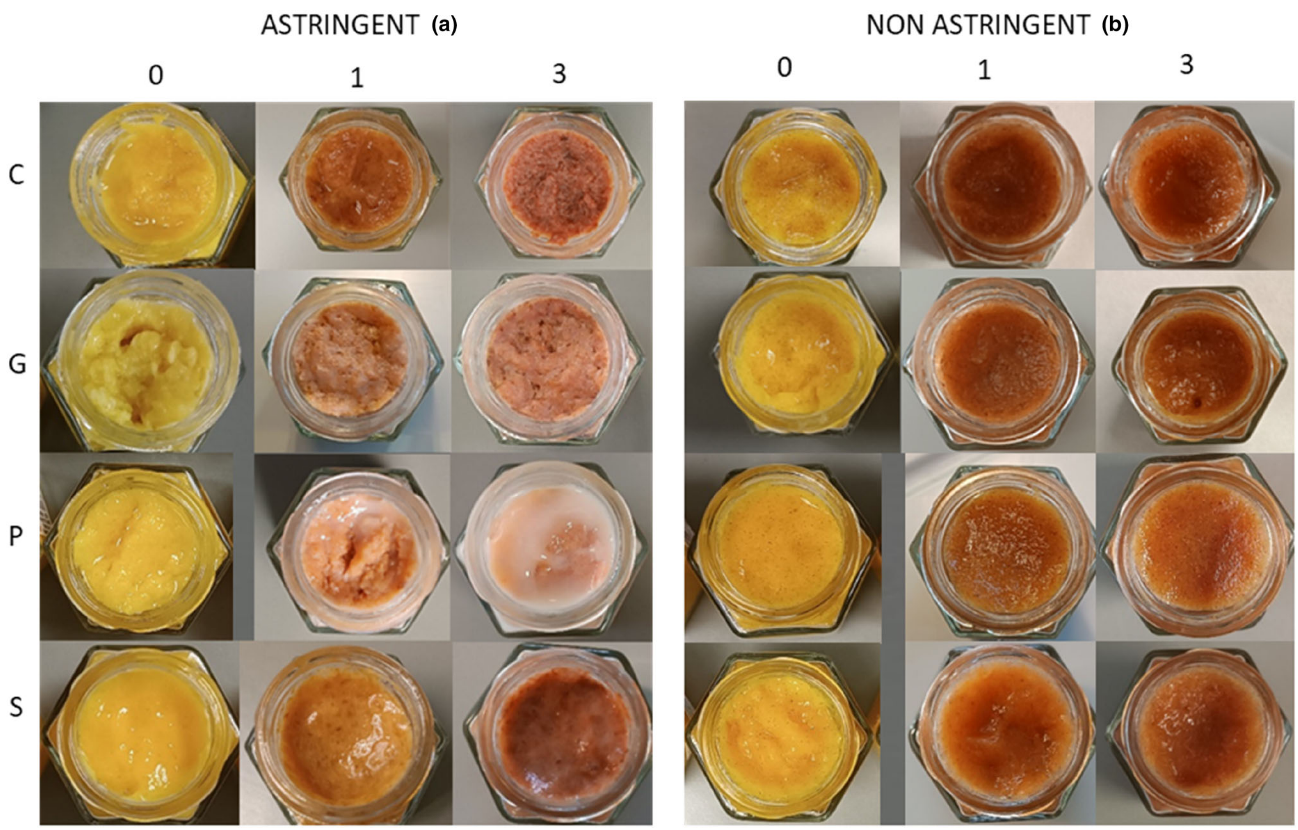


Figure 1 Evolution of the surface colour of cremogenates over time: (a) with astringent persimmons and (b) with non astringent persimmons.

to ISO 6579-1:2017, ISO 11290-1:2017 standards, respectively. The counts were expressed in colony forming units per gram of product analysed (CFU/g).

Sensorial evaluation

At the end of the storage period, the degree of acceptance of four of the studied formulations (those made with non-astringent persimmon: CB, GB, PB, SB) was analysed, as they were considered the most suitable due to their texture, colour, astringency and to the results obtained in the microbiological analysis. The panel of trained tasters consisted of 20 people aged between 18 and 60 years old who liked persimmon keeping a balance between women and men.

All the samples were presented at the same time and numbered with random three-digit codes. Prior to tasting the sample, the appearance, colour, aroma and consistency were rated and after the tasting, the sweetness, acidity, astringency and taste of each of the formulations were scored on a nine-point hedonic scale (ISO 4121:2003 and UNE-87025:1996), with 1 being 'I dislike it very much', and 9 being 'I like it very much'. Purchase intention was assessed on a 5-level Likert scale, with 1 being 'I would definitely not buy it' and 5 'I would definitely buy it'. In addition, some of the attributes (colour, aroma, sweetness and acidity) were evaluated by the Just About Right (JAR) scale to see if they were well optimised or if, on the contrary, they needed to go up or down in intensity (Riedel *et al.*, 2015). The questionnaire was prepared using the Office 365 'Forms' tool.

Statistical analysis

To evaluate the effect of the factors studied (formulation, astringency level and storage time) on the a_w, pH, TSS, moisture, antioxidant capacity and total phenols, a multifactorial ANOVA was carried out using SPSS.16.0 software considering a significance level of 95% and comparing the means with Tukey's test.

Optical and mechanical properties were evaluated by a multifactor analysis of variance (MANOVA) and Tukey *post hoc* test at a significance level of 95%.

Previously, the homogeneity of variances were evaluated by the Levene tests.

Results and discussion

Composition (TSS and % water), a_w and pH

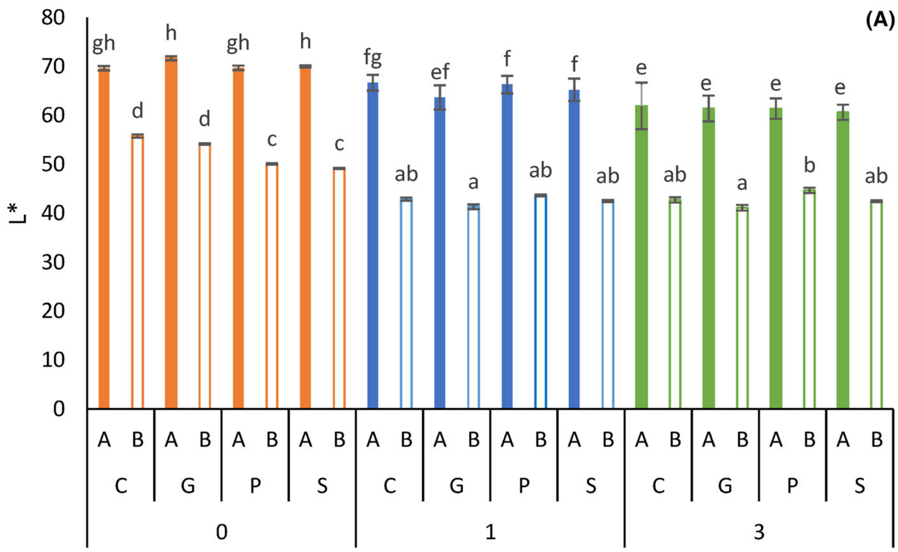
Table 1 shows the results of the composition, a_w and pH of the cremogenates. The pH of the formulations always remained between 3.5 and 3.9, with slight variations over time, which would guarantee the microbiological stability of the product. According to ANSES (2011), a pH between 4 and 4.3 is established as the limit at which pathogens, such as *Listeria monocytogenes*, can grow. Furthermore, safety is guaranteed against botulism, since the bacteria needs media with a pH higher than 4.5 for its development, and against *E. coli*, which grows at pH ranges of 6–8 (AESAN, 2003). In all the formulations made with astringent persimmon, there was a slight rise in pH after the first month of storage, but then a drop to below the initial level in the third month of storage. As a general rule, in cremogenates made with non-astringent persimmon, there was a slight progressive decrease in pH throughout storage. These results were similar to those obtained in previous studies into guava jam (Mesquita *et al.*, 2013) and rose petal jam (Shoaei *et al.*, 2022). Although the same amount of citric acid was added to all the formulations, only in the cremogenates with sodium alginate there was an interaction of this thickener with the acid, leading to a smaller reduction in the pH of the mixture.

The a_w did not vary by using astringent or non-astringent persimmons. However, the ANOVA reflects a significant influence of the main factors, thickener used ($F = 7.73$, $P < 0.001$) and storage time ($F = 15.79$, $P < 0.001$), with no interactions between them. The cremogenates with pectin lower the a_w compared to the control (without thickener), especially at

Table 2 Statistical analysis of the effects of formulation, time, astringency and their interactions on optical properties (L^*, a^* and b^*)

Factors	Parameters	F	P
Formulation (A)	L^*	7.138	$1.88{\cdot}10^{-4}$***
	a^*	316.498	$8.30\ 10^{-57}$***
	b^*	127.905	$3.21{\cdot}10^{-37}$***
Time (B)	L^*	490.791	$1.70{\cdot}10^{-58}$***
	a^*	7.910	$5.93{\cdot}10^{-4}$***
	b^*	758.823	$7.90{\cdot}10^{-69}$***
Astringency (C)	L^*	6133.712	$7.05{\cdot}10^{-105}$***
	a^*	1038.114	$6.47{\cdot}10^{-61}$***
	b^*	1282.714	$6.51{\cdot}10^{-66}$***
A * B	L^*	9.6674	$1.14{\cdot}10^{-8}$***
	a^*	12.795	$3.93{\cdot}10^{-11}$***
	b^*	1.847	$9.56{\cdot}10^{-2}$ns
A * C	L^*	1.875	$1.37{\cdot}10^{-1}$ns
	a^*	123.954	$1.33{\cdot}10^{-36}$***
	b^*	85.7214	$1.05{\cdot}10^{-29}$***
B * C	L^*	37.659	$2.03{\cdot}10^{-13}$***
	a^*	48.670	$3.33{\cdot}10^{-16}$***
	b^*	23.872	$1.87{\cdot}10^{-9}$***
A * B * C	L^*	6.973	$2.23{\cdot}10^{-6}$***
	a^*	32.863	$3.51{\cdot}10^{-23}$***
	b^*	9.780	$9.22{\cdot}10^{-9}$***

ns, not significative.
***$P < 0.001$.



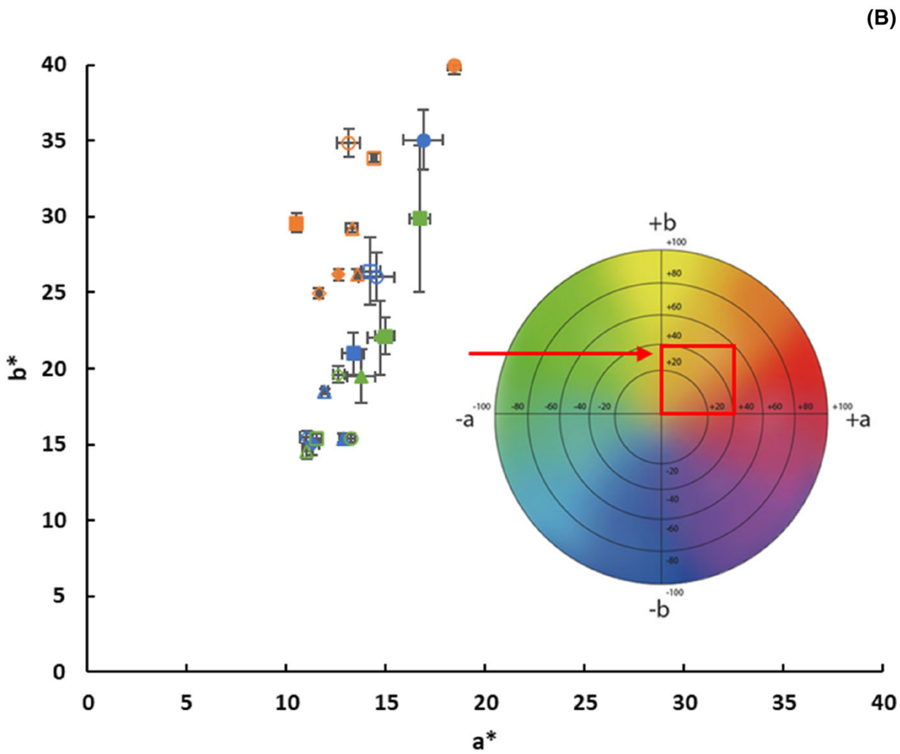


Figure 2 Lightness (L^*) (A) of cremogenates and location in the chromatic diagram (b^* vs. a^*) (B) at different storage time (0: orange, 1 month: blue and 3 months: green symbols) with different formulations (Control: C or circle; Guar gum: G or triangle; pectin: P or rhombus and sodium alginate: S or square). Filled bars or symbols indicate formulations made with astringent persimmon (A), empty bars or symbols indicate formulations made with non-astringent persimmon (B). Identical letters indicate homogeneous groups obtained in the MANOVA and the Tukey *post hoc* test (n.s = 95%).

the end of storage. With the addition of sodium alginate or guar gum, the a_w of the product increases, which would be related to the lower capacity of these hydrocolloids to retain water in the structure. With storage, the a_w of all the samples decreased.

The soluble solids (TSS) presented values of between 17 and 19 °Brix. Although the type of thickener, time or fruit type (astringency or non-astringency) had a significant statistical influence on the soluble solid content, these variations were very small.

The moisture remained constant at values of between 79 and 81%, with small variations depending on the type of fruit used. Thus, cremogenates made with astringent persimmons have a lower water content than those made with non-astringent persimmons.

Optical and mechanical properties

Figure 1 shows the evolution of the surface colour in the jars of all the formulations. The initial appearance (T0) of the samples was more uniform and orange with respect to the appearance reported by Tsurunaga *et al.* (2022) in persimmon cremogenates formulated with different polysaccharides as thickeners and subjected to different sterilisation treatments (100 °C-40 min or 121 °C-4 min). In the present study, it should be noted that as the storage time progressed the colour of all the formulations changed with respect to the initial value. The samples prepared with astringent persimmon acquired a more intense pinkish tone on their surface. In the case of the formulations elaborated with the non-astringent persimmon, after 1 month of storage they acquired a uniform brownish colour that was maintained until the third month of storage. It can be appreciated that the formulations elaborated with non-astringent persimmon were similar in colour, unlike those elaborated with astringent persimmon, in which case a greater difference can be appreciated at first sight.

The optical properties were analysed jointly by means of a MANOVA statistical analysis with three parameters (L^*, a^* and b^*) and three factors (type of thickener (formulation), storage time (time) and type of persimmon used (astringency)). Table 2 shows the results of the multivariate linear model obtained using Pillai's trace as a test statistic. It can be seen that, in addition to the significance of the main factors, these are correlated with each other.

Figure 2a shows the results obtained from the lightness (L^*) study. In the astringent cremogenates, the L^* was higher than in the non-astringent cremogenates and decreased over time. In the non-astringent cremogenates, L^* also decreased over time but stabilised after the first month for non-astringency samples. These results are consistent with the pictures shown in the previous figure, since lightness is one of the attributes of perceived colour (along with hue and chroma), which gives a sensation of brightness or darkness depending on its value (varying from 0 for a black, to 100 for a white).

Figure 2b shows the chromatic diagram, in which all samples were below 20 in the a^* coordinate and below 40 in the b^* coordinate. Over time, the a^* coordinate remained more stable while the b^* coordinate showed a significant reduction, the yellow losing in intensity.

The mechanical properties were also analysed jointly by means of a MANOVA statistical analysis with two parameters (F and A) and three factors (type of thickener (formulation), storage time (time) and type of persimmon used (astringency)). Table 3 shows the results of the multivariate linear model obtained using Pillai's trace as a test statistic. As can be observed, in addition to the significance of the main factors, these are correlated with each other.

Figure 3 shows the results of the maximum force (A) and the area (B) under the curve obtained in the back extrusion test performed on the cremogenates after 1 and 3 months of storage. It can be seen that the cremogenates made with astringent persimmon had significantly greater maximum force than the non-astringent cremogenates, except in the case of those made with sodium alginate. As with the maximum force, the area under the curve, which represents the compression work, was greater in the astringent cremogenates than in the non-astringent; the exception was the astringent made with sodium alginate, which has lower values than non-astringent. The storage time led to an increase in both the peak force and area under the curve in the case of the astringent

Table 3 Statistical analysis of the effects of formulation, time, astringency and their interactions on mechanical properties (maximum force (F) and area under the curve (A))

Factors	Parameters	F	*P*
Formulation (a)	F	154.947	$2.36{\cdot}10^{-21}$***
	A	8.320	$2.23{\cdot}10^{-4}$***
Time (b)	F	6.887	$1.24{\cdot}10^{-2}$***
	A	28.425	$4.69{\cdot}10^{-6}$***
Astringency (c)	F	718.970	$2.71{\cdot}10^{-26}$***
	A	100.317	$3.27{\cdot}10^{-12}$***
a * b	F	6.245	$1.49{\cdot}10^{-3}$***
	A	10.032	$5.28{\cdot}10^{-5}$***
a * c	F	219.400	$4.93{\cdot}10^{-24}$***
	A	25.999	$2.57{\cdot}10^{-9}$***
b * c	F	9.276	$4.20{\cdot}10^{-3}$***
	A	29.400	$3.53{\cdot}10^{-6}$***
a * b * c	F	8.069	$2.78{\cdot}10^{-4}$***
	A	11.363	$1.84{\cdot}10^{-5}$***

***$P < 0.001$.

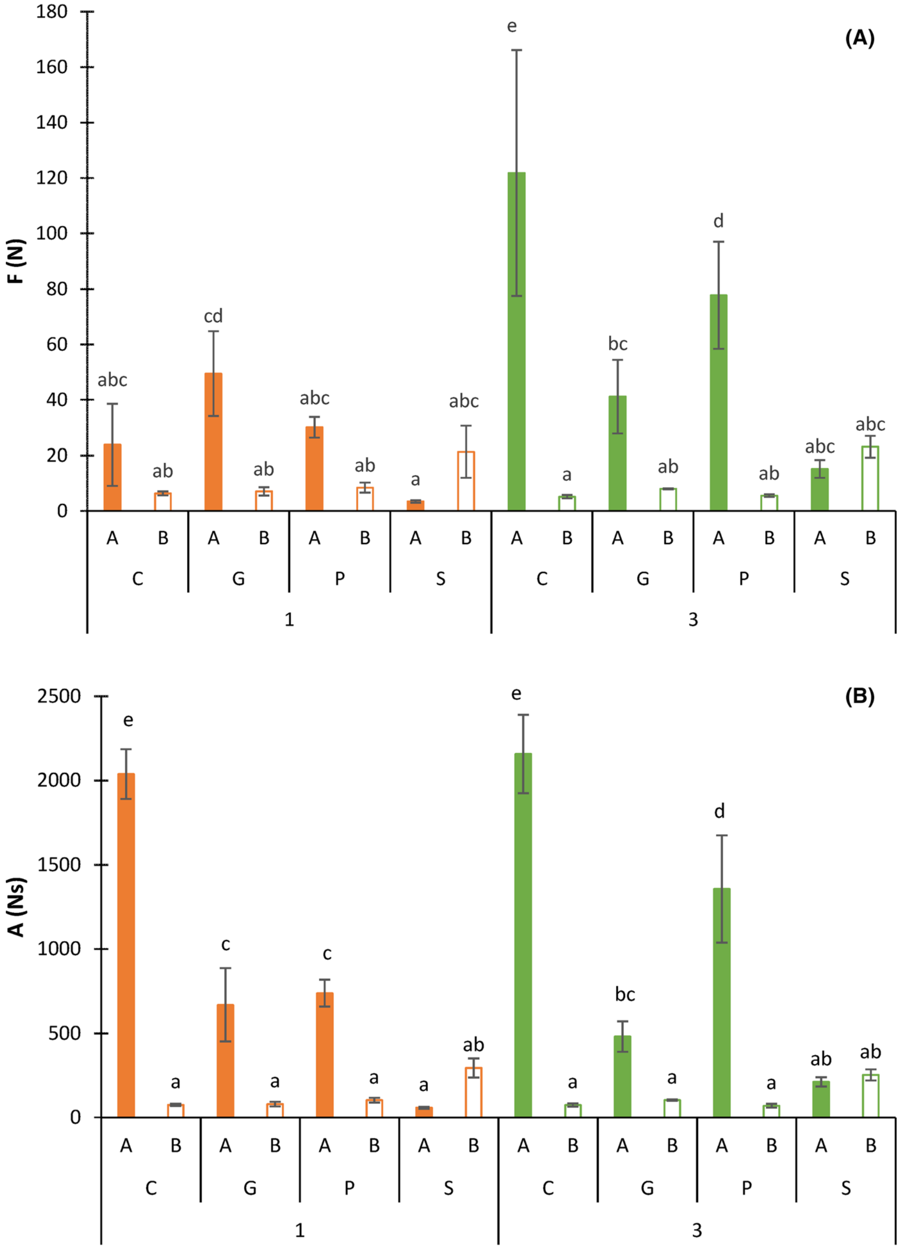


Figure 3 Back extrusion results (A: maximum force (F), B: area under the curve (A)) of cremogenates after 1 month (blue bars) and after 3 months (green bars). Filled bars indicate formulations made with astringent persimmon (A), empty bars indicate formulations made with non-astringent persimmon (B). Identical letters indicate homogeneous groups obtained in MANOVA (n.s = 95%).

cremogenates, while no significant differences were observed for the non-astringent cremogenates.

These results would be coherent with the sensation perceived when stirring the cremogenates: all of the non-astringents and the SA have a creamy texture, while the texture of the rest of the astringents was much harder. This would be a determining factor when choosing the cremogenate, since both texture and mouthfeel are determining factors in consumer acceptance and preference (Guinard & Mazzucchelli, 1996).

Antioxidant capacity and total phenols

Figure 4 shows the results obtained for antioxidant capacity (A) and total phenols (B) after 1 and

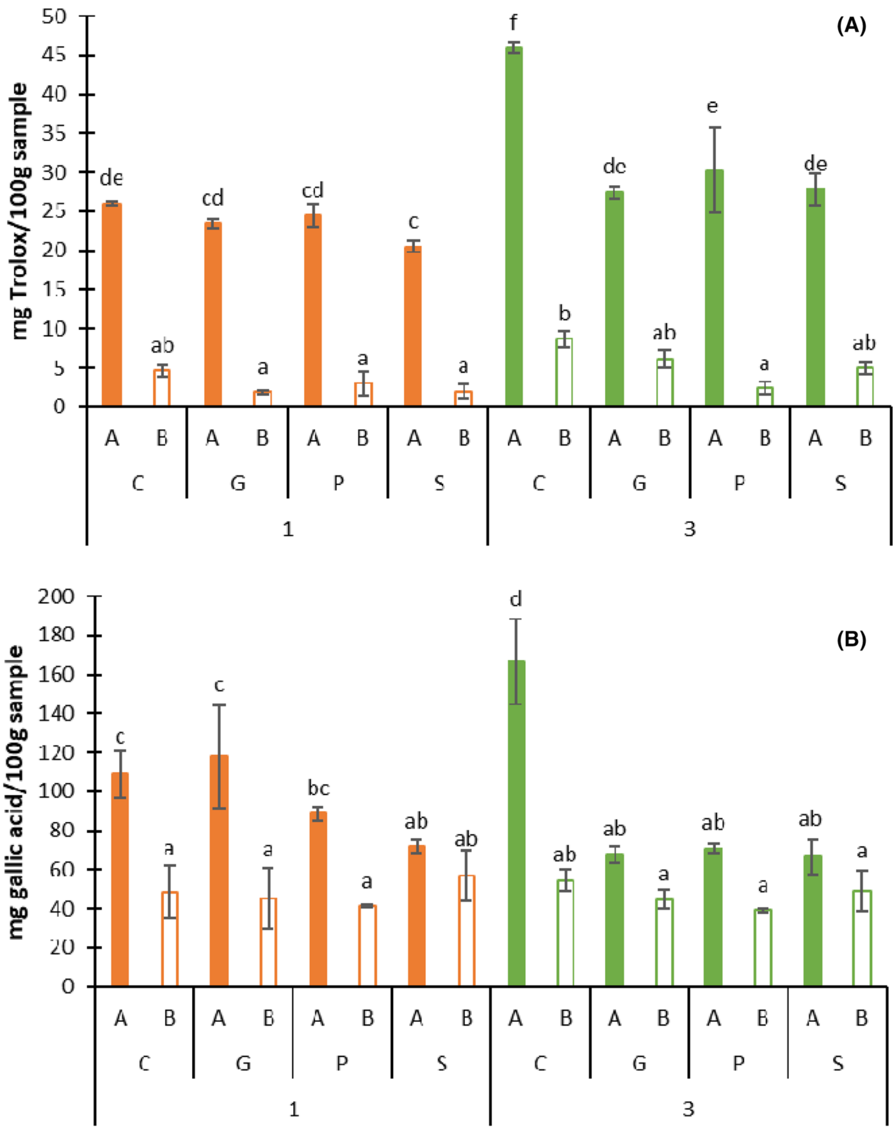


Figure 4 Antioxidant capacity (A) expressed as mg Trolox/100 g sample and total phenols (B) expressed as mg gallic acid/100 g sample of persimmon cremogenates after 1 month (orange bars) and after 3 months (green bars). Filled bars indicate formulations made with astringent persimmon (A), and empty bars indicate formulations made with non-astringent persimmon (B). Identical letters indicate homogeneous groups obtained in ANOVA (n.s. = 95%).

3 months of storage. Cremogenates made from astringent persimmons had significantly higher values than those made from non-astringent persimmons, probably due to the more limited availability of soluble tannins or the loss of other antioxidant components during CO_2 treatment. In most of the cremogenates, moreover, these values increased as the time passed, which could be related to the colour changes observed above, as a consequence of the appearance of pigments that contribute to an increase in their antioxidant capacity.

In general, the measurement of total phenols is related to the content of soluble tannins (Taira *et al*., 1997; Poiana *et al*., 2012; Oksuz *et al*., 2015) and, thus, to the astringency level of the sample. On the one hand, the results obtained indicate that without the addition of thickeners, insoluble tannins solubilise during storage time, especially in the case of astringent cremogenates (A). However, the addition of thickeners blocks this solubilisation and, therefore, the cremogenates maintain a low level of astringency over time. Cremogenates made with non-astringent raw

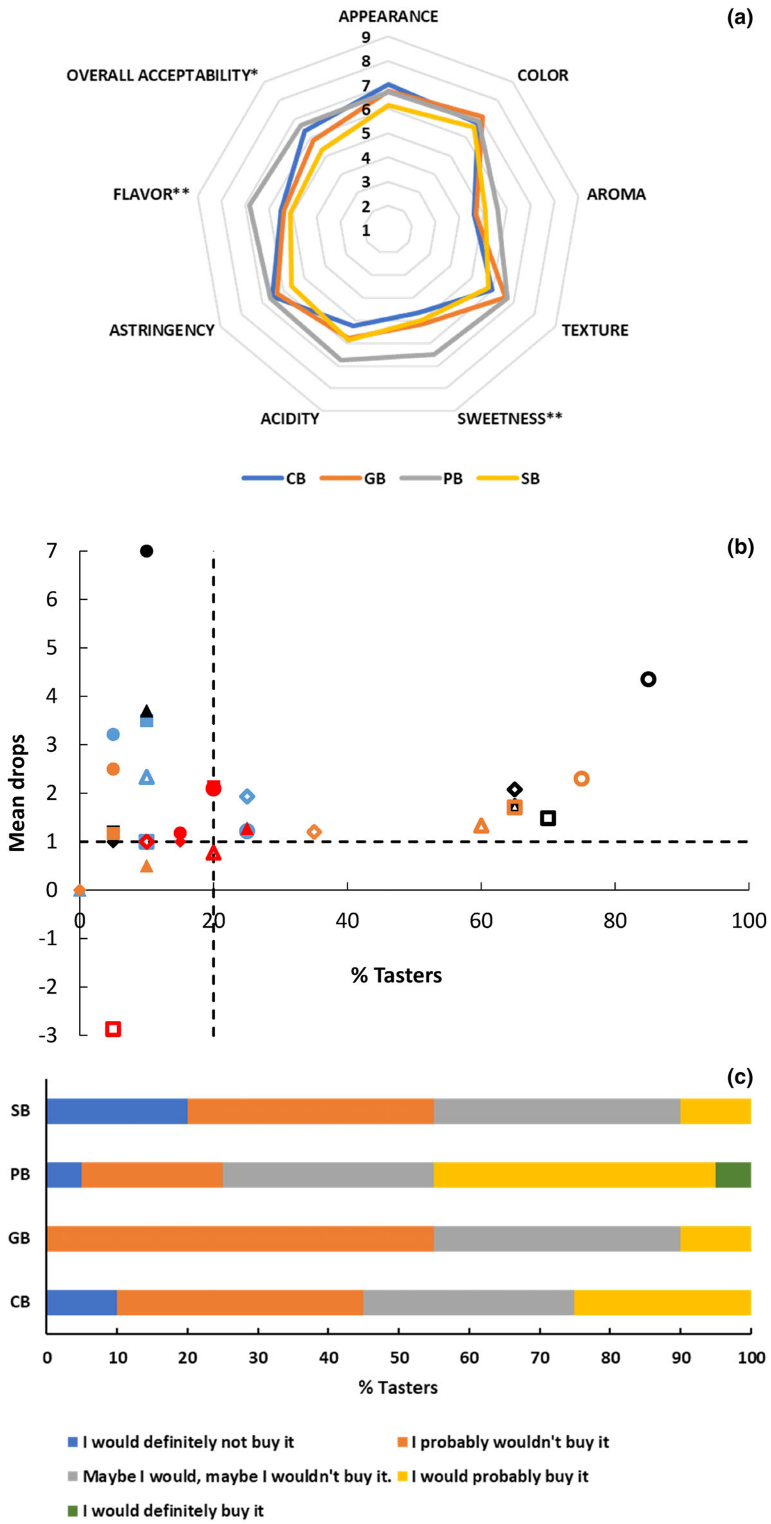


Figure 5 (a) Sensory evaluation results measured by a hedonic scale. *95% significance level. **99% significance level. (b) Penalty analysis plot. Symbols: CB (●), GB (▲), PB (♦), SB (■). Colours: Colour (blue), aroma (black), sweetness (orange), acidity (red). Too much (filled symbol), too little (empty symbol). (c) Purchase intention.

material always have a low level of total phenols, regardless of the time and type of thickener added. Therefore, in relation to the final astringency level of the product, it seems interesting to add a thickener, especially if the raw material used is astringent. In this case, sodium alginate could be the most recommendable of those studied here. These results are similar to those obtained by Tsurunaga *et al*. (2022) in which case high and low methoxyl pectins, carrageenan, xanthan gum and sodium alginate reduced the astringency in the untreated product. In addition, high and low methoxyl pectins and sodium alginate prevented astringency reversion after a 40-min heat treatment at 100 °C.

Microbiological analyses

The CFU/g of all the persimmon cremogenates after 3 months of storage at 4 °C were lower than 10^2 aerobic mesophiles, moulds and yeast, enterobacteries, *E. coli* and *Staphylococcus aureus* and there was no presence of *Listeria monocytogenes* and *Salmolella* spp. Therefore, these products can be considered safe.

Sensory analyses

Based on the above results, the sensory analysis was only carried out on the samples prepared with non-astringent persimmon (CB, GB, PB, SB) after 3 months of storage, since the astringent formulations did not possess the appropriate properties, mainly due to their texture, colour and greater astringency.

Figure 5a shows the results of the sensory evaluation of the different attributes (using a hedonic scale of 1–9) of these samples and Fig. 5b shows the penalty chart. As can be seen, the cremogenate made with pectin (PB) was better evaluated than the rest in terms of appearance, highlighting its flavour and sweetness. However, in general, the tasters found no significant differences between the control and the rest of the cremogenates. As a whole, the tasters penalised all the samples (Fig. 5b), considering that the attributes were too limited, especially the colour, aroma and sweetness. This could be a consequence of the tasters' expectations of this product, perhaps comparing it to a jam, which contains sugar. Thus, more than 50% of the tasters would not buy the cremogenates prepared with guar gum and sodium alginate, while they would buy the control cremogenates (more than 25%) and those containing pectin (more than 45%) (Fig. 5c).

Conclusions

The addition of thickeners reduced the astringency level of persimmon cremogenates made from astringent persimmons very little and would therefore not be accepted by the consumer. Besides, in general, the astringent cremogenates showed a paler colour and their texture was much harder. The preparation of persimmon cremogenates, previously subjected to the elimination of astringency, by means of a 30-min heat treatment at 70 °C, adding pectin, guar gum or sodium alginate at 1% as thickening agents and 0.5% citric acid as pH regulator, does not reverse the astringency of the product. However, the physicochemical and sensory properties differ depending on the thickener used. In this sense, the use of pectin would be recommended because of the better characteristics of the final product. This product, with no added sugar, may represent an alternative means of taking advantage of the surplus of this fruit and could be included in food matrices, such as dairy desserts or cakes, enriching them with antioxidants. Further studies should be conducted in order to stablish the shelf life of these type of products including other thickeners specially focusing on improving their colour.

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Author contributions

María Luisa Castelló: Investigation; funding acquisition; methodology; validation; writing – review and editing; formal analysis; resources; supervision; conceptualization. **Damián Taboada:** Methodology; investigation; formal analysis; writing – original draft. **Jorge Garcia-Hernandez:** Resources; methodology; investigation; formal analysis; conceptualization. **María Dolores Ortolá:** Investigation; funding acquisition; validation; methodology; formal analysis; resources; writing – review and editing; supervision.

Conflict of interest

The authors declare that they do not have any conflict of interest.

Ethical approval

A sensory test was conducted with human subjects. The data obtained were treated in accordance with the Regulation (EU) 2016/679 of the European Parliament and of the Council of April 27, 2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation).

Informed consent

Informed consent was obtained from all study participants.

Peer review

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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