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ORIGINAL ARTICLE

Sensory quality, volatile compounds and color of pear juice treated with β-cyclodextrin

Antonio J. Andreu-Sevilla · Ángel A. Carbonell-Barrachina · José M. López-Nicolás · Francisco García-Carmona

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Abstract The effect of the addition of β-cyclodextrin (β-CD), the most used of natural CDs, on the pear juice quality was studied. Several properties of this fruit juice, such as color, odor and aroma have been evaluated in both the absence and presence of β-CD for the first time. A study of the aroma profile of pear juice showed that esters, aldehydes, alcohols and terpenes are the most important chemical families of volatile compounds present in this fruit juice. Furthermore, a trained sensory panel was used to quantify odor/aroma attributes of pear juices in both the presence and absence of increasing β-CD concentrations. The addition of β-CD at a concentration of 15 mM to pear juice significantly increased its global quality, color intensity and reduced its browning but without any significant decrease in aroma. For this reason, a concentration of 15 mM of this type of natural CD is recommended to be used in pear juice manufacturing.

Keywords Cyclodextrin · Flavor · Sensorial quality · Color · Volatiles · Pear juice

Introduction

Color and aroma are probably the most important sensory attributes influencing consumers' preferences [1–3]. The maximum preservation of these organoleptic properties in fruit juices during processing and storage is one of the main objectives of fruit processors. To limit color and/or aroma degradation or loss during manufacturing and commercial distribution, several studies have reported the advantages of encapsulating key ingredients prior to their use in foods and beverages [4].

Many treatments have been proposed and studied in detail to improve the organoleptic quality of foods, including presence/absence of oxygen, pH, temperature, activation/inactivation of different oxidizing enzymes or the use of commercial encapsulation practices such as spray-drying, freeze-drying, extrusion, co-acervation and co-crystallization [5]. But not all of them have been successful in improving the final quality of foods especially because they negatively change the sensory profile of foods [7]. Thermal treatments, for examples, can produce negative effects in foods, such as nonenzymatic browning, nutrient loss and the formation of undesirable products (off-flavors) such as 5-hydroxymethylfurfural [6]. Moreover, some chemical treatments have been associated with severe allergy-like reactions in certain populations, for which reason the FDA has restricted their use to only a few applications [7].

The food industry it is looking for natural additives that can be used to improve the color and flavor of foods; cyclodextrins (CDs) are among the most promising natural additives because they are able to simultaneously improve color and aroma. CDs are naturally occurring cyclic oligosaccharides derived from starch with six, seven, or eight glucose residues linked by α(1 → 4) glycosidic bonds in a cylindrically shaped cavity with a hydrophobic internal surface and a hydrophilic outer surface, designated α-, β-, and γ-CDs, respectively [8, 9]. The hydrophobic cavity is able to form inclusion complexes with a wide range of

A. J. Andreu-Sevilla · Á. A. Carbonell-Barrachina
Department of AgroFood Technology, Food Safety and Quality Group, Miguel Hernández University, Carretera de Beniel, km 3.2, 03312 Orihuela, Alicante, Spain

J. M. López-Nicolás (✉) · F. García-Carmona
Department of Biochemistry and Molecular Biology-A Faculty of Biology, University of Murcia, Campus de Espinardo, 30100 Murcia, Spain
e-mail: josemln@um.es

organic guest molecules related with the sensory properties of food products which are encapsulated by CDs [8, 9].

Several studies have studied thoroughly the effects of different CDs on the color of juices of different fruits, such as banana, pear or grape [10–14]. These studies showed that the fruit juice enzymatic browning could be slowed down but also activated when increasing concentrations of different CDs are added. But unfortunately, consumer preference is not only based on color but also on flavor (combination of odor, taste and aroma). Consequently, there is an urgent need to study the effects of the CD addition on more complex sensory properties such as odor and aroma and not only on color; perhaps the first and most obviously affected sensory attribute but not the only one. In this way and although many investigations have focused on preparing various encapsulated flavors by CDs [15], only one paper has previously reported the effect of the addition of one CDs, α, on the flavor profile of pear juice [16]. This is the first experiment evaluating the effects of the addition of β-CD (perhaps the most popular type of CD to complex different guest molecules in foods) on both odor and aroma (components of flavor) of pear juice, using both sensory and instrumental protocols. β-CD is a cyclic oligosaccharide composed of α-(1-4) linkages of seven glucose units. It has a cavity at the center of its molecular arrangements, which forms an inclusion complex with various compounds [8]. β-CD is nontoxic, edible nonhygroscopic, and chemically stable. Moreover, this type of natural CD, with GRAS status, has been approved recently for use as additive in the European Union. The corresponding E-numbers assigned is E-459.

Pear juice was the model juice selected for this study because it is one of the most popular juices in Spain and probably worldwide. Indeed, *Pyrus communis* L. cv. Conference is one of the most important cultivars in Europe with a yearly production of more than 500,000 t, much of which is processed to produce pear juice [17].

Bearing in mind all the above, this work has two main objectives: i) to analyze instrumentally the effect of the addition of β-CD on the color and volatile compounds of pear juice; and ii) to study the intensities of odor, aroma and global quality parameters of the pear juice in the presence of different concentrations of β-CD by a trained sensory panel.

Materials and methods

Materials

The chemicals were purchased from Fluka (Madrid, Spain). β-CD was purchased from Sigma-Aldrich (Madrid, Spain) and used as received.

Juice preparation

Pears *(Pyrus communis* cv. Conference*)* were purchased from local supermarkets and stored at 4 °C until needed. They were peeled, cored and sliced prior to juicing in a Moulinex Y36 blender. The pear juice obtained was immediately collected and mixed in a beaker containing 25 mL of distilled water alone or plus β-CD (7.5 and 15 mM). All pear juices (control, 7.5 and 15 mM β-CD) were placed on a magnetic stirrer for 20 min to be oxidized.

Color changes assessment

To measure the color parameters, a ColorFlex version 1.72 colorimeter (Hunterlab, Reston, U.S.A.) certified by ISO 9001 with a D75 light source and the observer at 10° was used at 25 °C.

The color parameters corresponding to the uniform color space, CIE$L^*a^*b^*$ [18], were obtained directly from the apparatus. Within the uniform space, two color coordinates, a^* and b^*, as well as a psychometric index of lightness, L^*, are defined. In this system, a^* takes positive values for reddish colors and negative values for greenish ones, whereas b^* takes positive values for yellowish colors and negative values for bluish ones. L^* is an approximate measurement of luminosity, which is the property according to which each color can be considered as equivalent to a member of the gray scale, between black and white, with values ranging from 0 to 100. The total color difference (ΔE^*), a single value which takes into account the differences between L^*, a^* and b^*, of the sample and standard was also studied.

For all experiments, the previously described mixtures containing pear juice were used in the color evolution assays, using the measurements at time 0 as standard. This 0 time corresponded to the first measurement, which was made 1 min after the pears had been juiced and the materials dissolved in the juice. All the measurements were made at different times during the first 40 min after the materials had been dissolved in the pear juice, i.e., just when the enzymatic browning was beginning.

Three readings were obtained for each replicate to obtain uniform color measurements.

Extraction of volatile compounds

Liquid–liquid direct extraction method was adopted to extract volatile compounds from the pear juice. The juice sample (200 mL) with an internal standard of β-ionone (final concentration 0.50 mg L^{-1}) was placed into a 500 mL-Erlenmeyer flask. The volatile compounds were extracted with a mixture of diethyl ether and pentane (1:1), total volume 100 mL. The juice sample with solvents was continuously and gently shaken in a rotary shaker (Certomat®R, B. Braun Biotech International) at very low revolutions, 70 rpm, for 2 h at room temperature. The solvent fraction was then separated from the juice sample using a separating funnel. The solvent extract was dried over 5 g anhydrous Na_2SO_4 (Panreac Química S.A., Barcelona, Spain) and concentrated to about 0.25 mL in a Vigreaux column. The volatile compounds in the concentrate were determined by GC-MS.

GC-MS analytical conditions

The isolation, identification and quantification of the volatile compounds were performed on a gas chromatograph, Shimadzu GC-17A (Shimadzu Corporation, Kyoto, Japan), coupled with a Shimadzu mass spectrometer detector GC-MS QP-5050A. The GC-MS system was equipped with a TRACSIL Meta X5 column (Teknokroma S. Coop. C. Ltda, Barcelona, Spain; 30 m × 0.25 mm × 0.25 µm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 mL min^{-1} in a split ratio of 1:10 in the following program: (a) 40 °C for 5 min; (b) rate of 3.0 °C min^{-1} from 40 to 200 °C and hold for 1 min; (c) rate of 15 °C min^{-1} from 200 to 280°C and hold for 10 min. Injector and detector were held at 250 and 300 °C, respectively. 2 µL of the extracts were always injected.

Mass spectra were obtained by electron ionization (EI) at 70 eV, and a spectrum range of 45 to 450 m/z was used. Typical chromatograms are depicted in Fig. 1.

Table 1 shows the authentic chemicals used as standards, the system of identification of each compound and experimental and literature Kovats indices (KI). Most of the compounds were identified by simultaneously using three different analytical methods: (1) KI, (2) GC-MS retention indices (authentic chemicals), and (3) mass spectra (authentic chemicals and Wiley spectral library collection). Identification was considered tentative when based only on mass spectral data. For the quantification of the volatile compounds, β-ionone was added as internal standard (50 µL of 1 g L^{-1}) at the beginning of the extraction process (data included in this study should be considered as semi-quantitative because no standard curves were carried out for individual quantified volatile compounds). All the aroma standards used for identification and quantification purposes were food grade (Sigma-Aldrich, Flavours and Fragrances, Milwaukee, WI, USA).

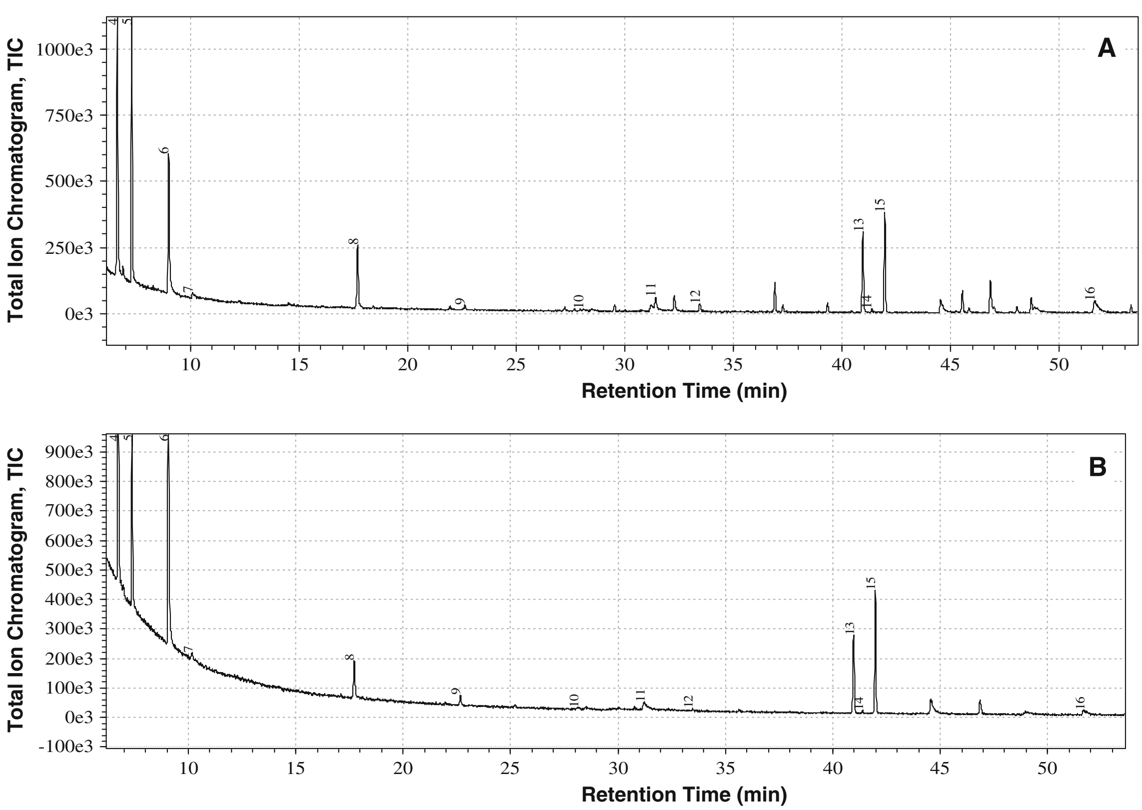

Fig. 1 Gas chromatograms of control pear juice (**a**) and pear juice treated with 15 mM β-cyclodextrin (**b**)

Table 1 Volatile compounds studied with their identification method, Kovats indices for the present study and literature values and odour thresholds

Volatile compound	Peak	Identification[a]	Kovats Index (KI)	
			Experimental	Literature[b]
1-Butanol	1	Std, KI, W	673	669
Propyl acetate	2	Std, KI, W	736	728
2-Methyl-1-butanol	3	Std, KI, W	764	755
Hexanal	4	Std, KI, W	803	801
Butyl acetate	5	Std, KI, W	817	813
trans-2-Hexenal	6	Std, KI, W	851	856
1-Hexanol	7	Std, KI, W	873	864
Hexyl acetate	8	Std, KI, W	1012	1010
Nonanal	9	Std, KI, W	1102	1103
Hexyl 2-methylbutanoate	10	KI, W	1208	1220
1-Decanol	11	Std, KI, W	1271	1274
2,4-Decadienal	12	Std, KI, W	1317	1316
β-Ionone	13	Internal standard	1483	1484
trans-α-Bergamotene	14	KI, W	1492	1480
α-Farnesene	15	KI, W	1506	1500
Coniferol	16	KI, W	1739	1729

[a] "Std, KI, W" means that retention times and Kovats indexes of authentic standards were used for identification besides the general comparison of experimental mass spectra to spectra of authentic standards and Wiley library (W). "KI, W" means that identification was based on Kovats indexes and comparison with Wiley library. "W" compounds tentatively identified (only Wiley library was used for identification)

[b] NIST database [28]

Sensory evaluation with trained panel

A panel of seven panelists, aged 20–42 years (4 female and 3 male) was trained in descriptive evaluation of fruits and juices. Details about panel selection and training can be found in a work published by our group [19].

Descriptive Sensory Analysis (DSA) has been successfully used for comparing odor and taste attributes in foods and their products [20, 21]. Pear juices were assessed using a flavor profile method [22].

Prior to DSA, panelists discussed the odor and aroma attributes of pear juice during two preliminary orientation sessions, each lasting 90 min, until they had agreed on their use of odor and aroma attributes. During these orientation experiments, panelists evaluated five different coded samples of pear juice from different manufacturers. A total of 20 attributes/properties (8 referred to odor, 8 to aroma and 3 to global properties: color, odor and aroma and 1 referred to global quality) were identified and standards were made available for panelists; further details can be found in López-Nicolás et al. [16].

Measurements were performed in individual booths with controlled illumination (70–90 fc) and temperature (23 ± 2 °C) [22, 23].

Individual pear juices were scored for the intensity of the studied attributes using a 100 mm-long line with line anchors of 0 = no intensity and 100 = very intense.

Panelists relied on their training experience to score products. Samples (coded with a three-digit random number) were presented randomly to each panelist to evaluate (samples were evaluated in triplicate).

Statistical analysis

For each of the above-mentioned analyses at least three replications were carried out. The ± values represent the standard errors of the measurements.

Data from the DSA experiments were subjected to analysis of variance (ANOVA) and the Tukey's least significant difference multi-comparison test to determine significant differences among samples.

Statistical analyses were carried out using Statgraphics Plus 5.1 software (Manugistics, Inc., Rockville, MD, U.S.A.) and graphics using Sigma Plot 9.0 (SPSS Science, Chicago, U.S.A).

Results and discussion

Effect of the β-cyclodextrin addition on the CIEL*a*b* color coordinates of pear juice

The main sensory and nutritional properties of pear juice may be strongly altered due to enzymatic browning [24]. For this reason, this adverse biochemical reaction needs to be controlled. To define the color of pear juice completely in the absence and presence of increasing concentrations of β-CD (0–15 mM), several scalar parameters (L^*, a^*, b^*) were measured (Table 2).

In Table 2 we can observe a rapid decrease in lightness (L^*) of pear juice in the absence of CD. However, in the presence of increasing concentrations of β-CD (0–15 mM)

Table 2 Changes with time of L^*, a^* *and* b^* coordinates of pear juice in the absence and in the presence of different β-CD concentrations

Reaction time (min)	Hunter values		
	L^*	a^*	b^*
Without β-CD			
0	73.42 ± 0.71	0.66 ± 0.02	24.12 ± 0.32
10	48.13 ± 0.56	9.15 ± 0.42	26.41 ± 0.33
20	41.72 ± 0.45	11.51 ± 1.05	26.80 ± 0.34
40	39.15 ± .0.43	11.82 ± 1.08	26.91 ± 0.34
β-CD 7.5 mM			
0	73.42 ± 0.71	0.66 ± 0.02	24.12 ± 0.32
10	50.32 ± 0.53	8.09 ± 0.24	26.00 ± 0.45
20	43.45 ± 0.39	9.51 ± 0.34	26.21 ± 0.45
40	41.25 ± 0.38	10.43 ± 0.71	26.31 ± 0.46
β-CD 15 mM			
0	73.42 ± 0.71	0.66 ± 0.02	24.12 ± 0.32
10	54.67 ± 0.73	7.21 ± 0.26	25.53 ± 0.41
20	47.70 ± 0.32	8.73 ± 0.39	25.90 ± 0.42
40	44.29 ± 0.34	9.41 ± 0.45	26.01 ± 0.44

this decrease was delayed due, probably, to the complexation of some polyphenolic substrates of polyphenoloxidase, the enzyme responsible of enzymatic browning, present in the pear juice. Moreover, a^* increased sharply during the first 10 min in the absence of β-CD; therefore, the pear juice became redder during the reaction time. However, when increasing concentrations of β-CD were present in the pear juice, the a^* was reduced (Table 2). Furthermore, in the presence of β-CD, the increase in b^* towards yellow colors observed in the absence of any agent, was significantly slowed.

Effect of the β-cyclodextrin addition on the total concentration of volatile compounds of pear juice

Volatile compounds will influence both odor and aroma of pear juices. Odor and aroma can be defined as the perception of volatile compounds while smelling and tasting the pear juice, respectively. The volatile compounds that contribute to fruit aroma are produced through metabolic pathways during ripening, harvest, postharvest, storage, and processing and are influenced by many factors, including fruit variety and technological treatments, among others [3].

Up to date, no experiments have been published reporting the effects of different concentrations of β-CD on the volatile compounds of juices; only a manuscript published recently by our research group [16] studied the effect of the addition of α-CD on this same property. Thus, the next step was to analyze the changes of the total concentrations of volatile compounds in the presence of increasing concentrations of β-CD. In Table 3, it can be observed that the addition of β-CD to the pear juice at a concentration of 7.5 mM led to a slight, but not statistically significant, decrease in the total concentrations of the main volatile compounds (15.1 ± 0.27) compared to the control juice (17.4 ± 2.7 mg L^{-1}). On the other hand, the addition of this same CD at 15 mM resulted in statistically ($p < 0.05$) lower concentration of total volatiles, 12.7 ± 0.2 mg L^{-1} compared to the control juice.

The fact that the addition of high concentrations of β-CD (15 mM) resulted in marked improvement of juice

Table 3 Volatile compounds (mg L^{-1}) quantified in control and β-cyclodextrin treated (7.5 and 15 mM) pear juices

Volatile compound	HSD-value	Control	7.5 mM β-CD	15 mM β-CD
		Concentration (mg L^{-1})		
1-Butanol	0.18	0.80[†] a[‡]	0.60 b	0.43 b
Propyl acetate	0.10	0.82 a	0.57 b	0.35 c
2-Methyl-1-butanol	0.03	0.22 a	0.22 a	0.22 a
Hexanal	0.24	3.20 a	3.11 a	2.24 b
Butyl acetate	0.26	5.03 a	5.18 a	5.15 a
trans-2-Hexenal	0.33	2.54 a	1.73 b	1.60 b
1-Hexanol	0.07	0.29 a	0.25 a	0.23 a
Hexyl acetate	0.15	1.80 a	1.25 c	1.05 b
Nonanal	0.04	0.11 a	0.10 a	0.08 a
Hexyl 2-methylbutanoate	0.05	0.10 a	0.08 a	0.06 a
1-Decanol	0.11	0.91 a	0.72 b	0.35 c
2,4-Decadienal	0.03	0.04 a	0.04 a	0.03 a
trans-α-Bergamotene	0.03	0.03 a	0.03 a	0.04 a
α-Farnesene	0.33	1.36 a	0.97 b	0.65 b
Coniferol	0.07	0.20 a	0.24 a	0.19 a
TOTAL	2.5	17.4 a	15.1 ab	12.7 b

[†] Values are the mean of 3 replicates. [‡] Values followed by the same letter, in the same row, were not significant different ($p < 0.05$), Tukey's multiple-range test

color without a dramatic reduction of the concentration of the total volatile compounds meant that an in depth study into influence of these results on the sensory quality of the juices as perceived by a trained sensory panel is necessary.

Effect of the *β*-cyclodextrin addition on the concentrations of the main chemical families of pear juice

The total concentration of each one of the chemical families in pear juice (e.g., aldehydes, alcohols, ketones, esters, lactones, terpenes, etc.) is generally low (μg L^{-1}) and can be affected by a number of technological and agronomic factors [3]. Moreover, different studies show that there is a clear relationship between concentrations of the above-mentioned chemical families and the final quality of the pear juices. For this reason, the fist step of this section was to evaluate the concentration of the main volatile compounds included in the chemical families of pear juice. Moreover, no study about the complexation of the main volatile compounds of pear juice by *β*-CD has been reported to date. Therefore, in this section we have also studied the effects of the addition of *β*-CD pear juice on the total concentrations of each one of the chemical families under study to evaluate which concentration of *β*-CD provides the best results.

The identified volatiles (all these compounds have previously been isolated and identified in fresh pears and pear juices [25–27]) present in the pear juice were identified and quantified by GC-MS and they could be grouped into four chemical families: (i) esters (propyl acetate, butyl acetate, hexyl acetate, and hexyl-2-methylbutanoate); (ii) aldehydes (hexanal, *trans*-2-hexenal, nonanal, and 2,4-decadienal); (iii) alcohols (1-butanol, 2-methyl-1-butanol, 1-hexanol, 1-decanol, and coniferol), and (iv) terpenes (*trans*-α-bergamotene and α-farnesene).

Our result showed the following distribution of the volatile compounds in control pear juice: esters (44.0%), aldehydes (33.8%), alcohols (13.8%) and terpenes (8.0%). To evaluate the effect of the presence of *β*-CD in the pear juice on these volatile compounds and the aroma profile of the different chemical families, increased *β*-CD concentrations were added to the reaction medium. In general, the addition of *β*-CD, at both concentrations under study, resulted in increases of esters and decreases of all other families (aldehydes, alcohols and terpenes) (Fig. 2). Esters are associated with fruity descriptors while aldehydes are mainly related to green and grass descriptors; this experimental observation will justify the highest quality of juices treated with 15 mM. These instrumental data will affect the green and fruity notes (odor and aroma) detected by the trained panel (Table 4), as indicated by the sensory descriptors of these chemical groups, represented by hexanal (aldehydes) and butyl acetate (esters) (Table 1).

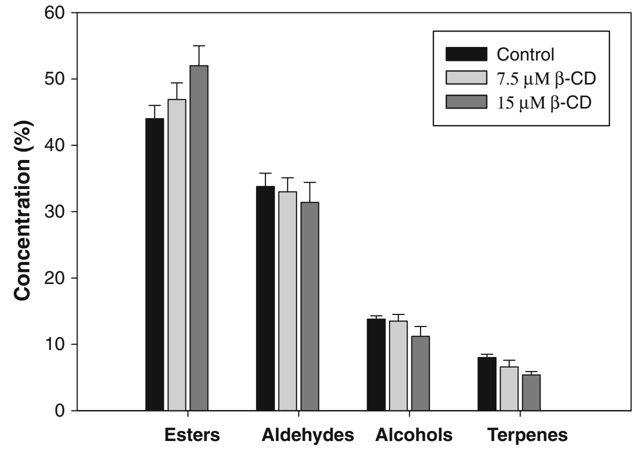

Fig. 2 Grouping of volatile compounds according to their chemical nature in control and *β*-cyclodextrin treated (7.5 and 15 mM) pear juices

Table 4 Descriptive sensory analyses of control and *β*-cyclodextrin treated (7.5 and 15 mM) pear juices

Attribute	ANOVA test		Treatments		
	Assessor	Treatment (HSD-value)	Control	Concentration *β*-CD (mM)	
				7.5	15
Odor					
Green	NS[†]	1.4**	5.6[‡] a[¥]	3.4 b	4.3 ab
Acid	NS	0.5*	4.6 a	1.9 b	2.3 b
Fresh	NS	0.7**	4.9 a	2.1 b	2.6 b
Floral	NS	0.5*	3.0 b	2.3 c	4.0 a
Fruity	NS	0.4**	4.7 a	4.0 b	4.7 a
Cooked/Caramel	NS	0.6*	1.7 b	2.1b	3.4 a
Pear	NS	0.8**	6.3 a	4.0 c	4.9 b
Unnatural	NS	0.3*	0.9 b	1.1 ab	1.3 a
Aroma					
Green	NS	0.9*	3.9 a	2.7 b	3.1 ab
Acid	NS	0.5*	3.6 a	2.1 c	2.7 b
Fresh	NS	0.8*	4.4 a	2.5 b	3.0 b
Floral	NS	0.5 NS	3.3 a	3.0 a	3.4 a
Fruity	NS	0.8**	6.1 a	4.0 c	5.1 b
Cooked/Caramel	NS	0.7*	3.6 b	4.0 ab	4.6 a
Pear	NS	0.8**	6.6 a	5.0 b	5.0 b
Unnatural	NS	0.3 NS	1.6 a	1.6 a	1.6 a
Global					
Color	NS	0.7**	8.6 a	7.2 b	5.6 c
Odor	NS	0.9**	6.1 a	4.2 b	4.9 b
Aroma	NS	0.8**	6.3 a	5.0 b	5.6 ab
Quality	NS	0.5**	5.9 b	5.1 c	6.6 a

[†] N.S. = not significant F ratio ($p > 0.05$), *, **, and ***, significant at $p < 0.05$, 0.01, and 0.001, respectively. [‡] Values are the mean of 9 samples (3 replicates × 3 sessions). [¥] Values followed by the same letter, within the same variation source, were not significant different ($p < 0.05$), Tukey's multiple-range test

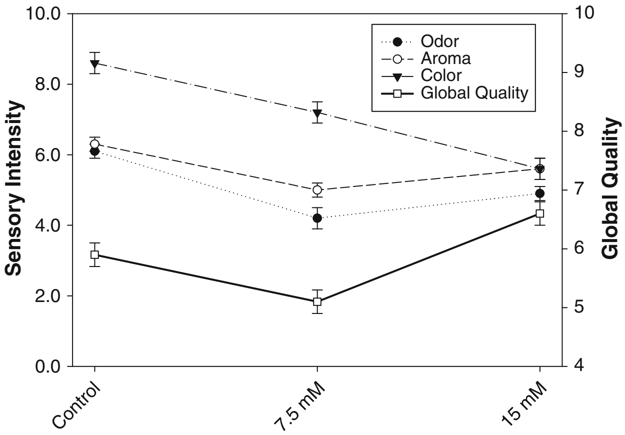

Fig. 3 Intensities of the main sensory properties (color, odor and aroma) describing the quality of control and β-cyclodextrin treated (7.5 and 15 mM) pear juices

The final conclusion of this section is that the addition of β-CD to the pear juice caused only slight and minor changes in the chemical families of the volatile compounds.

Effect of the β-cyclodextrin addition on the main sensory properties of pear juice

As is demonstrated previously, two important instrumental parameters related with the quality of pear juice, the CIE$L^*a^*b^*$ color coordinates and both the type and concentration of volatile compounds, are affected by the presence of β-CD in the reaction medium. To evaluate if these changes have influence on the main sensory quality properties, the next step in this investigation was to study the effects of the β-CD addition on the sensory parameters of pear juice.

To reach this objective, a trained panel was used for the sensory evaluation of pear juice. The result show that the improvement in color (reduction of the color intensity from dark to clear) observed previously was not always related with an improvement in global odor, global aroma and global quality (Fig. 3). In this way, the addition of 7.5 mM β-CD resulted in a better color but not in a better odor/aroma of pear juice. A higher concentration of β-CD, 15 mM, was required to get similar concentrations of total volatile compounds and better color and aroma (higher percentage of esters than aldehydes) than in control juice. The addition of 15 mM β-CD to the pear juice only had a slightly negative effect, a decrease in the intensity of odor from 6.1 ± 0.2 to 4.9 ± 0.2 (Table 4). However, several positive effects were found, for instance, in the color intensity (decrease from 8.6 ± 0.5 down to 5.6 ± 0.3) and global quality (increase from 5.9 ± 0.3 up to 6.6 ± 0.3). Finally, no statistically significant effect was observed for the juice aroma. According with these results, a concentration of 15 mM of β-CD is recommended to be used in the food industry.

Conclusion

Although color preservation is one of the main objectives of fruit processors, the quality of pear juice is also affected by other properties, such as odor, aroma and taste, which finally influence consumer preference. In this study we have demonstrated that the addition of increasing β-CD concentrations resulted in improved color (prevention of enzymatic browning). Moreover, the presence of different β-CD concentrations had different effects on the concentrations of individual volatile compounds, their grouping in chemical families and the total concentration volatile compounds of pear juice. The addition of α-CD at 7.5 mM led to the pear juice with good color (acceptable CIE-L*a*b* parameters) but with the lowest aromatic quality: low intensities of the pleasant notes and high intensity of the unnatural notes. However, the addition of β-CD at a concentration of 15 mM to pear juice significantly increased its global quality, color intensity and reduces its browning but without any significant decrease in aroma. For this reason, a concentration of 15 mM of this type of natural CD is recommended to be used in the food industry.

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