EFFECT OF HYPERBARIC STORAGE AT ROOM TEMPERATURE ON THE VOLATILE PROFILE OF STRAWBERRY JUICE

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ABSTRACT

The effect of hyperbaric storage at room temperature on the volatile profile of raw strawberry juice was evaluated. To do so, volatile profiles of strawberry juices maintained at 20 °C and different pressure levels (0.1, 50, and 200 MPa) for 15 days were analyzed by gas chromatography-mass spectroscopy and compared to those of control samples at day 0. Data corresponding to juices stored under traditional refrigeration (0.1 MPa/5 °C) for the same period are also presented for comparison. Hierarchical Cluster Analysis (HCA) and Partial Least Squares Discriminant Analysis (PLS-DA) were applied to discriminate the samples according to the storage conditions. The results clearly showed that samples stored under pressure were the most similar to the control juices at day 0. Moreover, hyperbaric storage, unlike refrigeration at atmospheric pressure, was efficient to avoid changes in all the key aroma compounds detected in the strawberry juice.

Keywords: hyperbaric storage; strawberry juice; volatile profile; high pressure; food preservation

INTRODUCTION

About 50% of total energy in the food industry is consumed by refrigeration-related facilities. The generation of this energy contributes to CO_2 production, global warming, and

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26 climatic change, which nowadays are considered major threats to our planet. For all these
27 reasons, in recent decades many efforts have been made in the food-agro industry to improve
28 the performance of conventional refrigeration systems, to find new environmentally friendly
29 refrigeration technologies, and also to look for new energy-saving opportunities in food
30 preservation (James & James, 2010; Tassou, Lewis, Ge, Hadawey, & Chaer, 2010).

31 Hyperbaric storage of food at room temperature could be one of these opportunities
32 because it only involves energy costs during compression, and no additional energy is required
33 to maintain the product under pressure for long times. Consequently, hyperbaric storage has
34 attracted the attention of many researchers during the last few years, and some studies have
35 been made recently to assess the feasibility of this technology to extend the shelf life of either
36 fresh fruits and vegetables or processed products. In fresh fruits and vegetables, hyperbaric
37 storage is used as a postharvest technique and it consists in subjecting the product to a
38 pressure environment in which the proportion of air components is maintained. In this case,
39 pressure is maintained at a relatively low level (0.1–1.0 MPa) to avoid damage to the cell
40 structure of living tissues, and it is expected to influence the postharvest physiology and quality
41 of the stored fruit and vegetables (Baba & Ikeda, 2003; Liplap, Boutin, LeBlanc, Vigneault, &
42 Raghavan, 2014; Liplap, Vigneault, Toivonen, Charles, & Raghavan, 2013). In processed food
43 (non-living tissues), pressure is transmitted by a liquid medium and it can be increased
44 considerably (25–220 MPa), especially in homogenized products. Recently, several authors
45 have shown that hyperbaric storage at room temperature could be an interesting technology for
46 short-term preservation of juices from various products, such as strawberry, melon, or water
47 melon (Segovia-Bravo, Guignon, Bermejo-Prada, Sanz, & Otero, 2012; Fidalgo et al., 2013;
48 Queirós et al., 2014). In strawberry juice, Segovia-Bravo et al. (2012) found that hyperbaric
49 storage for 15 days, at pressures of 25 MPa and higher, was able to reduce the initial microbial
50 load of the juice by more than 2 log units to levels below the limit of detection. Moreover,
51 pressure was effective to attenuate viscosity and color losses. However, the effect of hyperbaric
52 storage on the volatile profile of the strawberry juice was not evaluated.

53 It is widely assumed that high pressure does not substantially alter the fresh odor of
54 fruits and vegetables because small molecular flavor compounds are not directly affected by
55 pressure. Thus, different authors have reported that pressure (200–600 MPa) applied for short

56 times (1–20 min) at room temperature has no significant effect on the volatile profile of various
57 homogenized fruit products, such as strawberry coulis (Lambert, Demazeau, Largeteau, &
58 Bouvier, 1999) and guava (Yen & Lin, 1999) or orange (Baxter, Easton, Schneebeli, & Whitfield,
59 2005; Vervoort et al., 2012) juices, among others. However, there are hardly any data about the
60 effect of longer-term pressure exposures. Pressure storage could indirectly alter the content of
61 some odor compounds by enhancing or retarding enzymatic and chemical reactions, and
62 subsequently result in undesired changes in the overall odor (Viljanen, Lille, Heiniö, & Buchert,
63 2011).

64 The aim of this work was to study the effect of hyperbaric storage at room temperature
65 on the volatile fraction of strawberry juice. To do so, the volatile profiles of strawberry juices
66 stored at different pressure levels (0.1, 50, and 200 MPa) and 20 °C for 15 days were analyzed
67 by gas chromatography-mass spectroscopy (GC-MS) and compared with those of control
68 samples at day 0. Data corresponding to samples stored under traditional refrigeration (0.1
69 MPa/5 °C) for the same period are also presented for comparison. The results obtained in this
70 paper provide important data to evaluate the viability of hyperbaric storage at room temperature
71 for food preservation.

72

73 **2. MATERIALS AND METHODS**

74 **2.1. Sample**

75 Strawberries (*Fragaria x ananassa* Duch., cv. Chandler) were purchased at commercial
76 maturity from a local supplier. The fruits were washed with tap water and processed with a juicer
77 (Moulinex Frutti Pro, Moulinex, France). The liquid obtained was then centrifuged at 3500 *g* and
78 7 °C for 10 min (Sorvall Evolution RC Superspeed centrifuge, Thermo Scientific, Madrid, Spain).
79 The supernatant was subsequently collected, filtered through a 0.1 mm pore diameter sieve,
80 and stored at –80 °C until utilization. Before each storage experiment, a frozen batch of
81 strawberry juice was thawed overnight at 5 °C and transferred to 50 mL polypropylene tubes.
82 The tubes were completely filled with strawberry juice and closed with screw caps sealed by a
83 nitrile rubber O-ring.

84 Control juice at day 0 (C samples) was then characterized by measuring some of its
85 physicochemical properties (see Table 1). Soluble solids concentration (°Brix) was
86 approximated by using a digital refractometer (Leica AR200, Leica Microsystems Inc., New
87 York, USA) with automatic temperature compensation, pH was measured with a pH-meter (pH-
88 Burette 24 1S equipped with a pH 50 21 electrode and a C.A.T. 55 31 temperature sensor,
89 Crison Instruments, Barcelona, Spain), and color was determined, as L* (lightness), a*
90 (redness), and b* (yellowness), with a CM-3500d spectrophotometer (Konica Minolta, Japan).

91

92 **2.2. Storage experiments in strawberry juice**

93 Storage experiments under pressure were carried out in a pilot-plant high-pressure
94 storage system (model SV1, Institute of High Pressure Physics, Unipress Equipment Division,
95 Poland). It was composed of two high-pressure stainless steel vessels with independent
96 pressure control, two control terminals, and a high-pressure pump (model BP3, Institute of High
97 Pressure Physics, Unipress Equipment Division, Poland). Both vessels had 100 mm internal
98 diameter, 130 mm height and a working volume of 1 L and they were located in individual
99 thermostatic chambers.

100 Strawberry juices were stored for 15 days at 20 ± 2 °C and two different pressure levels
101 (50 and 200 MPa) to obtain samples labeled as T20_50MPa (20 °C/50 MPa) and T20_200MPa
102 (20 °C/200 MPa). Temperature and pressure were recorded every 30 s by a data acquisition
103 system (MW100 Data Acquisition Unit, Yokogawa Electric Corporation, Tokyo, Japan). Storage
104 experiments at atmospheric pressure for 15 days were performed in two thermostatic chambers
105 tempered either at 20 ± 2 °C or at 5 ± 2 °C to obtain T20_Patm (20 °C/0.1 MPa) and T5_Patm
106 (5 °C/0.1 MPa) samples, respectively. All the storage experiments were performed in triplicate.

107

108 **2.3. Headspace analysis in strawberry juice**

Immediately after storage, three grams of each strawberry juice sample was transferred into 22 mL glass vials. Then the vials were sealed with polytetrafluoroethylene (PTFE)/Butyl septa and crimp caps, and frozen at –80 °C till use.

Volatile analyses were performed using an Agilent 6890N Series gas chromatograph coupled to an Agilent 5973 Series mass selective detector (Agilent Technologies, Heilbronn, Germany) and equipped with a TurboMatrix 40 Trap Headspace sampler (Perkin Elmer, Shelton, CT, USA). Before the analysis, all the sample vials were completely thawed at room temperature and an aliquot of 10 µL of 2-octanone (32.72 mg/L in water) was added as internal standard to each vial. Samples were maintained at 80 °C for 25 min to drive the volatile compounds from the strawberry juice into the headspace. Volatile compounds were then sent to the TurboMatrix trap to be concentrated. Four trap load cycles of 5 min were carried out for each vial. The trap was subsequently dried by passing helium (99.995%) through it for 7 min to remove moisture. Finally, the analytes were thermally desorbed, through a transfer line heated at 110 °C, for 3 min and transported into the injection port of the GC column, at 240 °C and in splitless mode, for separation. Chromatographic separation was achieved on an HP-5MS capillary column (30 m x 0.25 mm i. d.; 0.25 µm film thickness, 5% Phenyl Methyl Siloxane, Agilent Technologies, Palo Alto, CA, USA), using helium as carrier gas at a constant flow rate of 1.2 mL/min. The initial oven temperature was held at 40 °C for 4 min, then increased at 4 °C/min to 110 °C and at 6 °C/min to 180 °C, maintained at 180 °C for 5 min, then again increased at 8 °C/min to 230 °C, and finally held at this temperature for 2 min.

The outlet of the column was coupled to the Agilent 5973 mass selective detector. It operated in electron impact ionization mode at 70 eV, using full-scan acquisition mode from m/z 30 to 550. MS ion source and quadrupole temperatures were 230 °C and 150 °C, respectively.

2.4. Data analysis

The GC-MS chromatograms obtained were evaluated and integrated using the ChemStation program (Agilent Technologies, Palo Alto, CA, USA). Identification of peaks in the chromatograms was performed by injection of commercial standards, by spectra comparison with the Wiley Registry 7th Edition Mass Spectral Library (Wiley and Sons Inc., Germany) and the National Institute of Standards and Technology (NIST) 2005 Mass Spectral Library, and by

138 calculation of linear retention indices (LRI) using retention time data from a series of alkane
139 standards (C_6 – C_{20}) run under the same chromatographic conditions. The normalized peak
140 area of each compound was then calculated as the ratio of its peak area to the area of the
141 internal standard.

142 In a first step, Hierarchical Cluster Analysis (HCA), an unsupervised pattern recognition
143 method, was applied to calculate similarities among the samples and establish whether a
144 discriminant classification method could be developed subsequently. A hierarchical clustering
145 procedure with complete linkage, using the Pearson correlation distance, was used to generate
146 clusters.

147 After this exploratory analysis, data were subjected to Partial Least Squares
148 Discriminant Analysis (PLS-DA) to look for potential differences in the volatile profiles of the
149 juices in order to classify the samples according to storage conditions. In this analysis,
150 compound abundances were considered as explanatory X-variables and the different classes of
151 samples as categorical Y-variables or responses. All data were mean-centered and the
152 variables were weighted by their standard deviation to give them equal variance. A PLS-DA
153 calibration model was generated using all the samples to find the latent variables (LV) or factors
154 in X that will best predict the latent variables in Y. Full cross-validation (leave-one-out) was then
155 used to select the optimum number of latent variables or PLS-DA factors.

156 To evaluate the importance of each volatile compound in discriminating a specific
157 sample, Variable Identification (VID) coefficients were estimated for each compound and
158 response. VID coefficients were calculated as the correlation coefficient between each original
159 X-variable and the Y-variables predicted by the PLS-DA model. In this paper, X-variables with
160 an absolute value of the VID coefficient higher than 0.80 were considered of interest for the
161 response examined. Moreover, to have a global view of these discriminant variables, they were
162 plotted individually as a function of the class of juice.

163 All the multivariate analyses (HCA and PLS-DA) were performed with The
164 Unscrambler® X, v. 10.2 (CAMO Software AS, Oslo, Norway).

165

166 **3. RESULTS AND DISCUSSION**

167 Thirty-one volatile compounds, including esters, aldehydes, alcohols, terpenoids,
168 aromatic compounds, a furanone, and a ketone, were identified in the strawberry juices
169 analyzed (Table 2). Resolution between hexanal and ethyl butanoate was too low for a proper
170 quantitative measurement, and therefore data for the two compounds are presented together in
171 Table 2. All the compounds detected in the samples had previously been described in the
172 volatile profile of strawberry and strawberry products by many authors (Aubert, Baumann, &
173 Arguel, 2005; Golaszewski, Sims, O'Keefe, Braddock, & Littell, 1998; Jetti, Yang, Kurnianta,
174 Finn, & Qian, 2007; Kafkas et al., 2005; Pérez & Sanz, 2010).

175 In control juices, trans-2-hexenal, methyl acetate, methyl butanoate, and hexanal +
176 ethyl butanoate peaks exhibited the largest abundances (data not shown). Moreover, according
177 to other authors (Kafkas et al., 2005; Pérez & Sanz, 2010), esters were the qualitatively and
178 quantitatively most important class of volatiles in C samples. However, from a flavor point of
179 view, it is well recognized that the most abundant volatile compounds are not necessarily the
180 most important sensory compounds. Some volatile compounds, usually known as key flavor
181 compounds, are determinant in the aroma perceived, even at very low concentrations. Among
182 the major compounds detected in control juices, methyl and ethyl butanoates, methyl
183 hexanoate, trans-2-hexenyl acetate, and linalool have previously been identified as key flavor
184 compounds in the typical strawberry-like odor by sensory evaluation methods (Aubert et al.,
185 2005; Jetti et al., 2007; Larsen, Poll, & Olsen, 1992; Schieberle & Hofmann, 1997; Siegmund,
186 Derler, & Pfannhauser, 2001). Other compounds, found in C samples at much lower
187 concentrations, such as 3-methylbutyl acetate, 2-heptanone, hexyl acetate, and 2,5-dimethyl-4-
188 methoxy-3(2H)-furanone, also known as mesifurane, have also been described as important for
189 strawberry aroma (Forney, Kalt, & Jordan, 2000; Larsen & Poll, 1992; Larsen et al., 1992;
190 Siegmund et al., 2001).

191 After 15 days of storage, samples maintained at atmospheric pressure and 20 ºC were
192 clearly spoiled and stale and musty notes were detected in their aroma due to considerable
193 microbial spoilage. Volatile compounds identified in these samples were those typical for
194 fermented fruit products (data not shown). In contrast, samples maintained at 20 ºC under

195 pressure did not show any evidence of deterioration. These results could be related with a
196 limited microbial activity during hyperbaric storage, because previous experiments in strawberry
197 juices maintained for 15 days under pressure and at room temperature showed that pressure
198 inhibited microbial growth (Segovia-Bravo et al., 2012).

199 At this point, T20_Patm samples were excluded from further testing and only C,
200 T5_Patm, T20_50MPa and T20_200MPa samples were included in the following analyses to
201 focus differentiation in non-spoiled samples.

202 **3.1. Exploratory analysis**

203 A Hierarchical Cluster Analysis of the data was first performed, as an exploratory
204 technique, to detect groups in the samples, based on similarity or closeness measures. As
205 shown in Figure 1, all the replicated samples were correctly grouped together. HCA allowed
206 subdivision of the juice samples into clusters that exhibited a high degree of both intracluster
207 similarity and intercluster dissimilarity. At the maximum distance (relative distance = 10), that is,
208 at the highest level of differentiation, T5_Patm juices are separated from the rest and therefore
209 they are classified as completely different from the other ones. At a relative distance of about
210 4.1, three clusters were established: cluster “a” consists of T5_Patm samples; cluster “b”
211 comprises juices stored under high pressure (T20_50MPa and T20_200MPa samples) and
212 cluster “c” corresponds to C samples. These results certainly reveal that juices preserved under
213 pressure for 15 days are the most similar to control samples at day 0. This is a clear indicator
214 that hyperbaric storage at 20 °C makes it possible to preserve the volatile fraction of strawberry
215 juices for at least 15 days, better than traditional cold storage does.

216 **3.2. Discriminant analysis**

217 A Partial Least Squares Discriminant Analysis of the compounds detected in the aroma
218 profile of the strawberry juices gave some interesting information about the differences between
219 them. The PLS-DA model performed consisted of seven latent variables or factors which
220 explained 99.4% of the Y-variance. Figure 2a presents the correlation loadings plot for the first
221 two latent variables, which together explained 63% of the Y-variance. It shows how the effect of
222 storage temperature (20 ºC or 5 ºC) is mainly explained on the basis of the first latent variable,

while the effect of pressure (atmospheric or high pressure) is mainly included in the second factor.

The correlation loadings plot indicates the correlation between the original variables and the PLS-DA factors of the model, and it is very useful to determine volatiles characterizing classes of samples. As an example, the coordinates of a given type of juice on the first and second latent variables show how well this juice is correlated with these latent variables. The inner and outer ellipses in the plot represent correlation coefficients r = 70% and r = 100% (or R^2 values of 50% and 100%), respectively. Thus, for a variable located between the two ellipses, more than 70% of its variability is explained by the first two latent variables. Figure 2a clearly shows how C and T5_Patm samples can be relatively well characterized by these two factors. Volatile compounds located between the ellipses and close to C samples, such as furan-2-methyl acetate, 2,4-hexadienal, or trans-2-hexenal should be characteristic of C samples, while those located in the opposite extreme of the plot, such as linalool or α-terpineol should present low abundances in control samples as compared to all the other juices. Obviously, both highly negatively and highly positively correlated compounds could act as potential discriminants of C samples. In the same way, volatile compounds located close to T5_Patm juices, such as 1-hexanol, present a high positive correlation with these samples while those located in the opposite extreme, such as hexanal + ethyl butanoate, trans-2-hexenyl acetate, or benzyl acetate present a high negative correlation with T5_Patm juices.

Figure 2a also reveals that two latent variables are not enough to discriminate T20_50MPa and T20_200MPa samples, which are grouped close together. Therefore, more factors are needed in the model to differentiate these samples effectively. Thus, Figure 2b presents a correlation loadings plot accounting for the third and fourth latent variables of the PLS-DA model. It illustrates how discrimination between T20_50MPa and T20_200MPa samples is mainly managed through the third latent variable of the PLS-DA model. Thus, T20_200MPa juices present a large positive loading on LV3 while T20_50MPa samples exhibit negative values just like butyl acetate.

3.3. Effect of storage conditions on the volatile profile of strawberry juice

The results obtained clearly show that the different storage conditions assayed in this paper distinctly affect the volatile profile of strawberry juice, and therefore sample discrimination by PLS-DA is possible. To evaluate the importance of each volatile compound in discriminating a specific sample, VID coefficients were calculated for each volatile and response. VID coefficients identify those compounds that are highly correlated, either positively or negatively, with a given class of juice. Thus, volatiles with a high absolute value of the VID coefficient for a class of juice present a particularly high or low abundance in that specific class as compared to all the other classes, and therefore they could act as class discriminants.

Table 3 reveals that, in control juices, furan-2-methyl acetate, trans-2-hexenal and 2,4-hexadienal have VID coefficients higher than 0.80. This means, as Figure 3 clearly shows, that the abundance of these volatiles was significantly higher in C samples than in all the stored juices. This high content in C_6 aldehydes is probably due to the tissue disruption involved in the juice extraction. These compounds are formed enzymatically through the action of lipoxygenase, oxygen, and linoleic and linolenic acids, and it is widely known that tissue disruption and homogenization enhance their formation (Forney et al., 2000; Sumitani, Suekane, Nakatani, & Tatsuka, 1994). Then, during storage, these aldehydes are progressively degraded if enzymatic activities are not completely inhibited. Thus, significant decreases in C_6 aldehyde concentration during cold storage of strawberry juices have been described previously in the literature (Aguiló-Aguayo, Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2009).

The VID coefficients in Table 3 also reveal that linalool is less abundant in C samples than in the other juices. Therefore, during storage, linalool could be released from its glycosidic precursor by enzymatic hydrolysis carried out by β-glucosidase.

3.3.1. Storage at 5 °C: Traditional refrigeration

After 15 days of storage at 5 °C, some changes occurred in the volatile profile of the juice, as expected. The VID coefficients in Table 3 reveal that T5_Patm samples differed substantially from all the other samples in a number of volatile compounds (Figure 4a). Thus, 1-hexanol presented a large positive correlation with T5_Patm juices, while hexanal + ethyl

279 butanoate, trans-2-hexenyl acetate, benzyl acetate, nerolidol, and methyl hexanoate presented
280 a large negative correlation.

281 Significant increases in 1-hexanol concentration were reported by Navarro, Verret,
282 Pardon, & El Moueffak (2002) in untreated strawberry puree stored at 4 °C. In this paper, after
283 15 days of storage at 5 °C and 0.1 MPa, 1-hexanol concentration increased by more than 600
284 times. This increase in 1-hexanol content could be related to the activity of alcohol
285 dehydrogenase because a decrease was also observed in the relative abundance of hexanal +
286 ethyl butanoate (Figure 4a). With regard to key aroma compounds, Figure 4a shows that
287 refrigeration produces substantial drops in trans-2-hexenyl acetate and nerolidol abundances.
288 The peak corresponding to hexanal + ethyl butanoate also decreased substantially, but
289 degradation of ethyl butanoate cannot be justified from these data because, as commented
290 above, individual contributions of hexanal and ethyl butanoate could not be differentiated.
291 However, Aguiló-Aguayo et al. (2009) found that ethyl butanoate concentration decreased
292 during refrigerated storage of strawberry juices. This probable ethyl butanoate degradation
293 together with the proved decay of trans-2-hexenyl acetate and nerolidol could significantly affect
294 the aroma perceived in T5_Patm juices.

295

296 **3.3.2. Hyperbaric storage at 20 ºC**

297 Detailed comparison of the volatile profiles of the strawberry juices showed that storage
298 under pressure at 20 °C avoided most of the changes experienced in T5_Patm samples (Figure
299 4a), although a decrease in the abundance of furan-2-methyl acetate, trans-2-hexenal, and 2,4-
300 hexadienal, potential discriminators of C samples, was still observed (Figure 3). Nevertheless,
301 the drop in these aldehydes content was substantially lower than that observed in T5_Patm
302 samples, especially in the samples stored at 50 MPa. Various authors have proved that
303 pressure between 200 and 400 MPa, applied for 20 min at room temperature, significantly
304 increases hexanal and trans-2-hexenal contents in strawberry products such as coulis or purees
305 (Lambert et al., 1999; Navarro et al., 2002). Increases in C_6 aldehydes after pressure
306 processing are widely reported in fruit and vegetable products in the literature, especially in non-
307 homogenized products (Sumitani et al., 1994; Viljanen et al., 2011). However, it is important to

note that these increases should be attributed to an enhanced enzymatic oxidation of linoleic and linolenic acids induced by pressure, which produces tissue disruptions and favors contact between enzymes and substrates. In this paper, the content of C_6 aldehydes in T20_50MPa and T20_200MPa juices after storage was considerably higher than in T5_Patm samples. This could be due either to an increased formation of C_6 aldehydes induced by pressure or to a limited alcohol dehydrogenase (ADH) activity during hyperbaric storage. ADH, which can convert C_6 aldehydes to their derived alcohols, could present a low activity under pressure. Thus, unlike in T5_Patm samples, no increases in 1-hexanol content were detected in T20_50MPa and T20_200MPa juices (Figure 4a).

Table 3 also reveals that, after hyperbaric storage, only butyl acetate exhibited a positive VID coefficient slightly higher than 0.80 for T20_50MPa juices, and thus this compound is more abundant in T20_50MPa samples than in the other juices (Figure 4b). No more volatiles with high VID coefficients appeared in T20_50MPa samples, and T20_200MPa juices did not present any potential characteristic compound. Discrimination of samples stored under pressure is, therefore, more difficult, as previously mentioned, but this means that no substantial changes occurred in any compound in these samples as compared to all the other juices.

However, the most remarkable fact was that none of the degradations observed in key flavor compounds in T5_Patm samples occurred when the storage took place under pressure. Thus, Figure 4a shows that decreases in trans-2-hexenyl acetate, methyl hexanoate and nerolidol were not detected in T20_50MPa and T20_200MPa samples. Moreover, a significant increase in linalool concentration can be observed in samples preserved under pressure. This increase is especially noteworthy because it could be associated with relatively high levels of β-glucosidase activity during storage. β-Glucosidase is involved in the release of flavor volatiles in fruits, and various authors have previously shown that its activity in strawberry is not only not affected but even increased after pressure treatments between 200 and 400 MPa for 15 min at room temperature (García-Palazon, Suthanthangjai, Kajda, & Zabetakis, 2004; Zabetakis, Koulentianos, Orruño, & Boyes, 2000).

The evolution of methyl butanoate, 3-methyl butyl acetate, 2-heptanone, hexyl acetate, and mesifurane was also studied during the hyperbaric storage (data not shown), although

these volatiles were not classified as potential discriminants for any class of juice by the VID procedure. Nevertheless, they are considered of interest because they have been reported in the literature as key flavor compounds in strawberry (Jetti et al., 2007; Larsen & Poll, 1992; Larsen et al., 1992; Schieberle & Hofmann, 1997). The results revealed that the abundance of these compounds remained unaltered after 15 days of storage in juices preserved under pressure.

4. CONCLUSIONS

This paper offers the first data in the literature about the effect of hyperbaric storage at room temperature on the volatile profile of a homogenized fruit product. The results obtained clearly showed that pressure avoided the spoilage of samples stored at 20 ºC for 15 days. Moreover, hyperbaric storage was more efficient than refrigeration to maintain the volatile profile of strawberry juices unaltered for 15 days, and thus samples stored under pressure were the most similar to control juices at day 0. In fact, no changes in any key aroma compound were detected after hyperbaric storage. Nevertheless, sensory analyses are needed to test whether the differences observed would be detectable by human perception.

The results obtained in this paper offer encouraging new data for the characterization of hyperbaric storage of food at room temperature. This new environmentally friendly technology could provide an interesting opportunity to reduce energy costs in food preservation. However, much more research is needed (microbial behavior and enzymatic activities under pressure, stability of bioactive compounds, capital and operating costs, among other things) to establish its real potential.

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