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Effect of hyperbaric storage at room temperature on color degradation of strawberry juice

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ABSTRACT

Recent studies show that hyperbaric storage at room temperature (HS-RT) could be an interesting method for food preservation. In this paper, the effect of HS-RT on color degradation was evaluated in strawberry juice. To do so, strawberry juices were stored for 1, 2, 5, 7, 10, and 15 days at three pressure levels (0.1, 50, and 200 MPa) and 20 °C. The evolution of the instrumental color parameters L*, h°, C*, and ΔE*, total phenolic and anthocyanin contents, polyphenoloxidase and peroxidase activities, and percent polymeric color (PPC) during storage was compared in samples maintained at different pressures. Color differences due to the storage pressure were slight to the naked eye, but instrumentally perceptible on some of the storage days. The results showed that the storage pressure affected some mechanisms of color degradation. Thus, significant peroxidase inactivation (on storage days 5, 7, and 15) and lower PPC (on storage days 5, 7, and 10) were found in the samples stored at 200 MPa when compared with those maintained at atmospheric pressure.

1. Introduction

Hyperbaric storage at room temperature (HS-RT) has attracted the attention of many researches due to its potential advantages for food preservation (Fidalgo et al., 2014; Ko and Hsu, 2001; Queirós et al., 2014; Segovia-Bravo et al., 2012). In HS-RT, food is preserved under pressure with no temperature control for storage times between some days to some weeks or months. The only energy consumption is produced at the beginning of storage, during compression, and no additional energy is required to maintain the product under pressure for long times. This can involve a considerable reduction in energy costs during food storage in comparison with other preservation methods such as freezing or refrigeration. Recent studies show that, depending on the pressure level applied, HS-RT can, not only inhibit microbial growth as refrigeration does, but also produce some microbial inactivation (Fidalgo et al., 2014; Queirós et al., 2014; Segovia-Bravo et al., 2012). However, much more research is still needed to elucidate the effect of pressure on other mechanisms implied in food quality degradation.

Color is one of the most important sensory attributes in food because this visual property is the first evaluated by consumers. In strawberry products, their attractive bright red color is mainly due to the presence of phenolic compounds, more specifically anthocyanins. However, these compounds are unstable and easily susceptible to degradation during storage, even in those products that have been previously pasteurized (Garzón and Wrolstad, 2002; Holzwarth et al., 2012b). Apart from microbial spoilage, color losses can be produced by enzymatic oxidation and non-enzymatic browning reactions. Enzymatic oxidations are catalyzed by oxidoreductases, such as polyphenoloxidase (PPO) or peroxidase (POD), among others, that degrade phenolic compounds to undesirable yellow, brown, or black pigments, responsible for color decay. Moreover, monomeric anthocyanins are also involved in complex associations, including copigmentation, self-association, and polymerization reactions that produce derived pigments and color changes during storage.

The effect of pressure on these degradation reactions is not clear. Most of data in the literature refer to high-pressure processing, a well-studied technology and already implemented in the food industry. In this case, relatively high pressure (200–600 MPa) is applied for only some minutes (5–25 min), but data about the effect of lower pressure applied for longer time are still very scarce (Fidalgo et al., 2014; Queirós et al., 2014; Segovia-Bravo et al., 2012).

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In a previous work, Segovia-Bravo et al. (2012) reported that color losses in strawberry juices stored under pressure (25–220 MPa) for 15 days at 20 °C were close similar to those observed in conventionally refrigerated samples. In contrast, color of samples stored at 20 °C and atmospheric pressure was dramatically altered. In these samples, microbial load increased exponentially during storage and pigment production by microorganisms could impart color to the contaminated juice. Moreover, products of microbial metabolism could also produce the oxidation of natural color compounds and/or changes in juice pH that strongly alter the color stability of anthocyanins. In juices stored at 25–220 MPa, pressure inhibited microbial growth and, in this way, it indirectly reduced color degradation. But, from these results, it is not clear if other mechanisms of color degradation, apart from microbial spoilage, are also affected by pressure or not.

Therefore, the purpose of this study was to evaluate the effect of pressure on color degradation of strawberry juice during storage at room temperature, without microbial interference. To achieve this goal, strawberry juices, with an added antimicrobial agent, were stored for 1, 2, 5, 7, 10, and 15 days at three pressure levels (0.1, 50, and 200 MPa) and 20 °C. Total color changes (ΔE*) and lightness (L*), hue (h°), and chroma (C*) evolution during storage were then compared in samples maintained at different pressures. Moreover, the concentration of total phenols and anthocyanins, the main compounds responsible for color of strawberry juice, was measured during storage. Finally, PPO and POD activities and percent polymeric color (PPC) were also studied to give an insight into the effect of pressure on some mechanisms involved in color changes and degradation of phenolic compounds during storage.

2. Materials and methods

2.1. Samples

Strawberries (*Fragaria x ananassa* Duch., cv. Sabrina) were purchased at commercial maturity from a local supplier. The fruits were washed with tap water and processed with a blender (Royal Blender Turbo 10-Speed, Type 212004, Princess, Netherlands). The liquid obtained was then centrifuged at 3500 g and 4 °C for 10 min. The supernatant was subsequently collected, filtered through a 0.1 mm pore diameter sieve, divided into enough aliquot parts to perform replicated experiments, and stored at −20 ± 2 °C until utilization.

2.2. Physicochemical analysis in strawberry juice at day 0

Before each storage experiment, a frozen aliquot part of strawberry juice was thawed overnight at 5 °C. Then, an antibiotic solution (Antibiotic antimycotin solution, Sigma, Ref. A5955) was added (1%, v/v) to avoid microbial interference in color changes. Juice was subsequently transferred into 150 mL plastic bags to be stored. Bags were thermo-sealed, avoiding headspace.

Juice at day 0 was characterized by measuring some of its physicochemical properties (see Table 1) to ensure that they did not change during the frozen storage. Total soluble solids concentration (TSS) was approximated by using a digital refractometer (Leica AR200, Leica Microsystems Inc, New York, USA). pH was measured with a pH glass electrode (6.0280.300 iEcotrode Plus, Metrohm, Herisau, Switzerland). Total titratable acidity (TA) was determined using an automatic titrator (Titrando 907, Metrohm, Herisau, Switzerland) according to the method described by Friedrich (2001). Color, total phenolic (TP) and monomeric anthocyanin (TMA) contents, PPO and POD activities, and percent polymeric color were estimated as described in the next sections.

All measurements were performed in triplicate for each thawed juice employed in each experiment. Data in Table 1 are mean and standard error values calculated from the results obtained in replicated experiments.

Table 1
Main characteristics of the strawberry juice employed in replicated experiments at day 0.

Parameter	Mean ± standard error
TSS (°Brix)	8.89 ± 0.08
pH	3.74 ± 0.00
TA (g citric acid·ml^{-1} of juice)	0.69 ± 0.00
L*	33.87 ± 0.10
H°	15.75 ± 0.09
C*	13.98 ± 0.07
TP (mg GAE·L^{-1} of juice)	781.3 ± 28.06
TMA (mg Pg-3-glu·L^{-1} of juice)	195.07 ± 7.30
PPO (OD·min^{-1}·mL^{-1} of juice)	1.78 ± 0.09
POD (OD·min^{-1}·mL^{-1} of juice)	0.27 ± 0.00
PPC (%)	6.8 ± 0.4

2.3. Storage experiments

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

Strawberry juices were stored for 1, 2, 5, 7, 10, and 15 days at 20 ± 2 °C and two different pressure levels (50 and 200 MPa) to obtain samples labeled as T20_50 MPa and T20_200 MPa, respectively. Temperature and pressure were recorded every 30 s by a data acquisition system (MW100 Data Acquisition Unit, Yokogawa Electric Corporation, Tokyo, Japan). T20_Patm samples were stored for the same periods at atmospheric pressure (0.1 MPa) in a thermostatic chamber tempered at 20 ± 2 °C. Immediately after storage, all juice samples were frozen at −30 ± 1 °C until analysis.

2.4. Color measurements

L*, a*, and b* color parameters were determined with a CM-3500d spectrophotometer managed by the color data software CM-S100w SpectraMagic™ (Konica Minolta, Japan). The spectrophotometer operated in the reflectance specular included mode with an aperture size of 8 mm in diameter. Measurements were made with the D65 standard illuminant and the ultraviolet component of the illumination was included. Illuminating and viewing configurations complied with the CIE diffuse/8° geometry. To make the measurements, a glass Petri-dish (42 mm internal diameter) was filled with 10 mL of juice, closed with its cap, and covered with a black cylinder. In each Petri-dish, five measurements were performed: one at its center and four at radial positions distributed 90° apart. The obtained L*, a*, and b* values were averaged.

From these mean values, the total color change ΔE*, hue angle h°, and chroma C* were also calculated according to the following equations:

$$\Delta E^* = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2} \quad (1)$$

$$h^\circ = \arctan\frac{b^*}{a^*} \quad (2)$$