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Changes in nutritional value of a multi-vitamins fortified juice packed in glass and standard PET bottles

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ABSTRACT

The evolution of ascorbic acid, β-carotene and α-tocopherol contents was assessed during the storage of a fortified juice packed in PET or glass bottles. During the course of storage, oxygen transfer rates and partial oxygen pressures were evaluated as well as the vitamins.

During the first month, a decrease of dissolved oxygen was observed for both PET and glass bottles. A strong degradation of ascorbic acid was noted after 3 months of storage (up to 54 at 72% in glass and PET bottles respectively) and the β-carotene content was virtually nil after 80 days. The ascorbic acid degradation was clearly stronger in PET comparing to glass bottles while no difference was observed for β-carotene between both packaging. However, β-carotene isomers (13-*cis*-β-carotene and 9-*cis*-β-carotene) were identified and their total concentrations were higher in glass bottles. The degradation reaction scheme of β-carotene seems to be mainly oxidation in PET bottles and isomerisation and then oxidation in glass bottles. Concerning tocopherol, its limited oxidation may be explained by regenerative action of ascorbic acid.

From a nutritional point of view, the juice packed in glass bottles is more interesting since β-carotene isomers still have pro-vitamin activity.

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1. Introduction

Diets with high contents of fruits and vegetables are recognized to be protective against several human diseases due to their richness in vitamins and antioxidant capacity. Vitamins are organic compounds that are required for various biological functions since their deficiency may lead to certain diseases. Juices obtained from fruits are a way to propose products rich in vitamins. However, concentrations of vitamins in juice vary in relation to origin, preparation and/or storage.

Acid ascorbic (vitamin C) is hydro-soluble and is present in high concentration in citrus fruit (Kennedy, Rivera, Lloyd, Warner, & Jumel, 1992; Zerdin, Rooney, & Vermue, 2003). Its major biological activity is related to the maintenance of the oxidation–reduction potential, inducing free radical inactivation (Kitts, 1997). This vitamin is partially degraded after thermal treatments like pasteurization during juice preparation but also during storage by oxidation (Berlinet, Brat, Brillouet, & Ducret, 2006; Bacigalupi et al., 2013).

Carotenoids are among the most common natural pigments, with β-carotene as the most prominent (Olson & Krinsky, 1995). In plants, carotenoids are responsible for many of the red, orange, and yellow hues of plant leaves, fruits and flowers and depending on their structure they have a provitamin A activity such as β-carotene, α-carotene. A diet rich in carotenoids is correlated with a diminished risk for several degenerative disorders, including various types of cancer, cardiovascular or ophthalmological diseases (Mayne, 1996). The preventive effects have been associated with their antioxidant activity, protecting cells and tissues from oxidative damage. Carotenoids are unsaturated molecules and can be degraded by isomerization (a change of configuration from its natural *trans* form to various *cis* isomer species) and oxidation through a radicalar mechanism with free radical attacks. Depending on temperature during processing, carotenoid losses are more

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less important: losses are greater at higher temperature than 100 °C (Amoussa-Hounkpatin, Mouquet-Rivier, Kayode, Hounhouigan, & Avallone, 2013).

The liposoluble vitamin E is found in foods such as oil, milk in four main forms, α, β, γ and δ-tocopherols. Tocopherols are natural lipophilic antioxidants which specifically protect polyunsaturated fatty acids against oxidation (Barba, Esteve, & Frigola, 2011). In human, high concentrations of α-tocopherol reduce the risk of disorders connected to free radicals (atherosclerosis, cancer, cataract, cell damage).

Due to the increasing demand for products with high nutritional value, food industry develops juices fortified with vitamins to counterbalance the losses during processing and storage. Indeed, thermal treatments induce undesirable changes such as micronutrient losses by chemical reactions.

For a good preservation of nutritional properties during storage, glass bottles are usually used to pack the juices. However, PET (polyethylene terephthalate) is increasingly used in beverage packaging due to its excellent mechanical properties, UV resistance, low weight bottle and recycled solutions being more eco-friendly. However, the use of PET-based bottles increases the risk of oxidation of juice components due to the non null permeability of this material. It was clearly evidenced by comparing ascorbic acid evolution in glass bottles compared to PET bottles (Berlinet, Brat, & Ducruet, 2008; Ros-Chumilla, Belissario, Iguaz, & Lopez, 2007).

The objective of this study was to assess the evolution of several vitamins with antioxidant activity (ascorbic acid, carotenoids and tocopherols) in a fortified juice according to the type of packaging (PET or glass bottles).

2. Materials and methods

2.1. Reagents

Metaphosphoric acid analytical (33.5–36.5%), 2,6-dichlorophenolindophenol sodium salt hydrate (purity ≥ 97%, based on dry substance), sodium bicarbonate (purity ≥ 99.7%), ferric chloride hexahydrate (98–102%) and ascorbic acid (purity ≥ 99.0%) were supplied by Fluka.

Glacial acetic acid (99–100%), absolute ethanol (analytic grade), orthophenanthroline (99%) and ammonium acetate (purity ≥ 98%) were purchased from Sigma–Aldrich.

2.2. Packaging material

A standard monolayer PET was used. Preforms were kindly puffed by Sidel, a provider of PET solutions for liquid packaging (Le Havre, France) to obtain bottles with 25 cl capacity and weighting 14 g. The thickness of bottle (measured at level body) was 150 ± 1.5 microns. PET bottles were closed by caps in polyethylene and polypropylene without any internal joint and supplied by Bericap (France). Glass bottles were closed by metallic caps.

2.3. Preparation of multi-vitamin juice from concentrate and conditioning

Concentrated multi-fruit and multi-vitamin juice (65°Brix) was supplied by LSDH (Laiterie de Saint Denis de l'Hôtel, France). The juice is composed of apple, pineapple, orange, grape, pear, peach, mango, apricot, banana, guava, kiwi and lemon. The preparation of juice and the filling were realised with the pilots of Sidel (Le Havre, France).

The concentrated juice was diluted in a tank by adding under agitation (600 rpm) water up to obtain a Brix of 10.5, i.e. 22.8 kg of concentrate, 12.8 kg of crystallized sugar and 175.1 L of water. Citric acid (240 g) and a mix of vitamin (100 g) containing vitamin C (95.8%), A (0.76%), B1 (1.34%), B6 (1.92%), B9 (0.19%) were added. The juice was intentionally fortified by vitamin E (α-tocopherol, 30 g) to observe interactions between vitamin C and E. The juice was degassed at 65 °C under vacuum (−0.65 mbar) and then flash pasteurized during 20 s at 95 °C in the pasteurization pilot (Sidel). The juice was cooled to 20 °C and maintained in a sterile tank before filling. The tank was maintained at 5 °C and under 130 mbar of pressure to avoid microbial contamination. Then, the juice was packed in PET or glass bottles using semi-automatic filler (Sidel). Bottles were previously sterilized by injection of peracetic acid solution (1800 ppm) during 10 min, under a pressure of 2 bars at 54 °C and caps were treated by ionization. Before filling, the bottles were washed with sterilized water previously filtered on 0.45 μm membrane. After filling, the headspace was inerted under N_2 flux at 1 bar and the bottle were manually closed with the caps. To verify the efficiency of pasteurization and filling, microbial analysis were carried out by enumeration of total flora on PCA (Plate Count Agar) and evaluation of fungi contamination on PDA (Potato Dextrose Agar). To check the microbial stability of juices during storage, microbial analyses were also carried out at selected times. No contamination was found both packaging.

The average pH of the packed juice was 3.75 and the final Brix 11.6.

The juices packed both in standard PET or glass bottles were stored at 20 ± 2 °C in total darkness during 3 months. The selected temperature imposed in the oven was regularly controlled using an external probe.

2.4. Methods

Analyses were carried out just after packing for dissolved oxygen (t = 0), at time 7 days for vitamins and then after different times of storage: 22, 37, 77 and 97 days. Analyses were performed in triplicate with 3 different bottles.

2.4.1. Oxygen transfer rate (OTR)

Oxygen transfer rate was measured on a MOCON-OXTRAN instrument according to the ASTDM-D3985 standard using a coulometric sensor. The test specimen was held so that the two sides of a test chamber were separated: one side was exposed to nitrogen and the other to air (i.e. O_2 at 21%). The temperature was maintained at 23 °C and the relative humidity at 50%. The OTR of the PET bottle was obtained from 5 replicates and was equal to 0.0291 cc/bottle/day.

2.4.2. Measurement of local O_2 content

Local oxygen partial pressure was determined using a Fibox 3 fibre optic oxygen meter purchased from PreSens Precision Sensing GmbH (Neuburg, Germany).

The O_2 sensitive optical sensors (spots of 4 mm diameter) selected for this study were the PSt3 sensors (PreSens Precision Sensing GmbH) that can be used for a range of oxygen pressures ranging from 0 to 100% O_2 (with a limit of detection at 0.03% and an accuracy of ±0.4% O_2 at 20.9% O_2 and ±0.05% O_2 at 0.2% O_2). A conventional two-point calibration in oxygen-free environment (nitrogen or sodium sulfite), and air saturated environment (i.e. 21% of O_2) has been performed before used. A PSt3 sensor had been glued inside each bottle using silicone glue prior to closure. The optical fibre, which is connected to transmitter, e.g. Fibox 3, is placed on the outer surface of the bottle, right opposite the sensor spot. Data acquisition was performed using PST3 software (PreSens). For each measurement, temperature was fixed at 20 °C, and oxygen measurements were compensated accordingly. Readings were performed by applying the optical fibre in front of the dot and

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