Postharvest Biology and Technology 136 (2018) 145–151

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Influence of modified atmosphere packaging (MAP) on aroma quality of figs (*Ficus carica* L.)

M.C. Villalobos[a,b], M.J. Serradilla[c], A. Martín[a,b,*], E. Aranda[a,b], M. López-Corrales[d], M.G. Córdoba[a,b]

[a] Nutrición y Bromatología, Escuela de Ingenierías Agrarias, Universidad de Extremadura, Avda. Adolfo Suárez s/n, 06071 Badajoz, Spain
[b] Instituto Universitario de Investigación en Recursos Agrarios (INURA), Avda, de la Investigación s/n, Campus Universitario, 06006 Badajoz, Spain
[c] Instituto Tecnológico Agroalimentario de Extremadura (INTAEX-CICYTEX), Área de Vegetales, Junta de Extremadura, Avda, Adolfo Suárez s/n, 06007 Badajoz, Spain
[d] Centro de Investigación Finca La Orden-Valdesequera (CICYTEX), Área de Hortofruticultura, Junta de Extremadura, Autovía Madrid-Lisboa s/n, 06187, Badajoz, Spain

ARTICLE INFO

Keywords:
Figs
Modified atmosphere packaging (MAP)
Sensory quality
Volatile compounds

ABSTRACT

The effect of passive modified atmosphere packaging (MAP) on the volatile compound profile of fig cultivars 'Cuello Dama Negro' (CDN) and 'San Antonio' (SA) during post-harvest storage was evaluated, to determine its impact on flavour and overall acceptability. Fruit was packaged using three types of microperforated films (ø = 100 μm): M10 (16 holes), M30 (five holes) and M50 (three holes); and a control macroperforated film (ø = 9 mm; five holes). The fruit were stored at 0 °C for 14 d. Fruit were also analysed after a period of shelf life at 20 °C for 2 d after cold storage. The volatile profile and its evolution during cold storage depended strongly on the fig cultivar. CDN displayed only moderate changes in the overall volatile profile for both, control and microperforated batches, during storage at 0 °C. In contrast, the volatile compound profile of SA was largely influenced by the duration of the cold storage and the shelf-life. Under refrigeration conditions, the microperforated M50 films allowed to delay changes in the volatile profile of SA, without negative influence on the fig flavour.

1. Introduction

Fruit quality is determined by several parameters, such as flavour, texture and appearance. Flavour, in particular, plays a major role in both the selection and enjoyment of fruit, being perceived simultaneously through two human senses: taste and smell (aroma) (Durán and Costell, 1999; Jiang and Zhang, 2010; Qiao et al., 2010). Aroma present in fresh and processed fruit, is affected by a complex group of chemical substances, such as aldehydes, alcohols, ketones, esters, lactones, and terpenes, which play an important role in the sensory quality (Ong et al., 2008; Riu-Aumatell et al., 2004).

The aroma of fresh figs (*Ficus carica* L.) has been attributed primarily to ethyl acetate, hexanal, β-caryophyllene, limonene, (*E*)-2-hexenal and octanal, (Buttery et al., 1986; Gibernau et al., 1997; Grison et al., 1999; Grison-Pigé et al., 2002). Other compounds associated with fig aroma include 2-furancarboxaldehyde, 5-hydroxymethyl-2-furancarboxylic acid, benzaldehyde, furfural and phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl phenol (Gozlekci et al., 2011). However, the variability in aroma compounds has been reported to depend on climatic conditions, genotype, maturity and technological factors such as harvest, postharvest treatments, processing and storage conditions (Botondi et al., 2003; Douillard and Guichard, 1990; Rizzolo et al., 1992; Winterhalter and Rouseff, 2002).

Although methods, as modified atmosphere packaging (MAP), can delay aroma deterioration, the biochemical changes that occur under these conditions can affect the flavour quality (Maul et al., 2000; Ratanachinakorn et al., 1997), inducing off-flavours and imbalances in the aroma profile (Mattheis and Fellman, 2000). Thus, despite the benefits of packaging under low oxygen gas composition on parameters, such as respiration rate, colour and firmness changes (Aguayo et al., 2003), when the package contains less than 3% O_2 and greater than 15% CO_2, the aroma volatiles may be profoundly affected (Kader et al., 1989). Moreover, a lack of flavour has been associated with modified atmosphere storage procedures (Ho, 1996; Hobson, 1988; Kader et al., 1978; Maul et al., 2000), due to the direct effect of both, temperature and atmospheric conditions, on the fruit metabolism, which lead to changes in the formation of flavour compounds.

Nevertheless, to the best of the authors' knowledge, the volatile profile has not been studied in figs, throughout storage under modified atmospheres. Thus, this work intended to study the evolution of the

* Corresponding author at: Nutrición y Bromatología, Escuela de Ingenierías Agrarias, Universidad de Extremadura, Avda. Adolfo Suárez s/n, 06071 Badajoz, Spain.
E-mail address: amartin@unex.es (A. Martín).

https://doi.org/10.1016/j.postharvbio.2017.11.001
Received 7 August 2017; Received in revised form 16 October 2017; Accepted 2 November 2017

volatile profile during storage life under different passive modified atmospheres of two fig cultivars: 'San Antonio' (SA) and 'Cuello Dama Negro' (CDN) and to assess the impact of these changes on the sensory quality of the fruit.

2. Materials and methods

2.1. Plant material

The fig (*F. carica* L.) cultivars selected (CDN; dark-coloured skin fig, also known as 'Black Mission'; and SA: dark-coloured skin fig), were harvested from experimental orchards at the Finca La Orden-Valdesequera Research Institute (38°85′19″N; 6°68′28″W, Guadajira, Badajoz, Spain). Fruit were manually collected when the figs reached their optimal ripening stage, depending on each cultivar, as previously described (Pereira et al., 2015; Villalobos et al., 2016) and were immediately transferred to the laboratory and stored cold, until packaging.

2.2. Packaging of fig fruit

Figs without defects, and homogeneous in colour and size, were visually selected for packaging. Approximately 400 g of fruit per polyethylene punnet (26 × 16 cm, 416 cm^2), were sealed with three types of microperforated biaxially oriented polypropylene (BOPP) film (40 μm thick), obtained from ACSA Films (Valencia, Spain). Thus, packaging batches for each cultivar were as follows: Control batches (C) for each cultivar: macroperforated film with five holes (ø = 9 mm); M10 batches: microperforated BOPP film with one hole per 10 mm (a total of 16 holes, ø = 100 μm); M30 batches: microperforated BOPP film with one hole per 30 mm (a total of five holes, ø = 100 μm), and M50 batches: microperforated BOPP film with one hole per 50 mm (a total of three holes, ø = 100 μm).

All batches from both cultivars were stored in darkness at 0 °C and 90–95% RH. After 14 d cold storage, six punnets from every batch and cultivar were randomly selected and analysed. Additionally, six punnets were stored at ambient temperature (20 °C) for 2 d, considering this period as the shelf-life, for an additional sampling. Three analytical samples by sampling were prepared and analysed for the determination of volatile compounds.

2.3. Determination of volatile compounds

Four peeled figs were randomly selected from each batch. The figs were homogenised and 1 g was weighed into a 10-mL headspace (HS) vial (Agilent Technologies, Santa Clara, CA), which was sealed with a PTFE-butyl septum (Perkin–Elmer, Waltham, MA) and an aluminium cap.

In order to extract the volatile compounds from the samples, a solid-phase microextraction (SPME) fibre (10 mm length, 75-μm thickness), coated with Carboxen–polydimethylsiloxane (Supelco, Bellefonte, PA) was used. The fibre was pre-conditioned at 280 °C for 1 h, in the GC injection port. Then, the fibre was inserted into the HS of the vial, heated at 40 °C, in a water bath, for 30 min, for the extraction of the volatile compounds. As described by Serradilla et al. (2010), the volatile compounds were separated by gas chromatography/mass spectrometry (GC/MS) (Agilent 6890 GC/5973 MS system; Agilent Technologies), using a 5% phenyl/95% polydimethylsiloxane column (30 m × 0.32 mm inner diameter, 1.05 μm film thickness; Agilent). A blank run was conducted, to discard possible volatile contamination during the analysis.

The identification of the volatile compounds was performed using the Kovats retention index, together with the NIST/EPA/NIH mass spectrum library (comparison quality > 90%) (Kondjoyan and Berdagué, 1996). The Kovats retention index of the compounds was calculated by analysing *n*-alkanes (R-8769, Sigma Chemical Co., St. Louis, MO), under the same conditions as the samples. Additionally, a laboratory-built MS spectral database, constructed from the analysis of pure compounds chromatographed using the same equipment and under the same conditions was also utilised, to confirm the identity of certain compounds, by a comparison of the retention time and mass spectra. Quantitative data were obtained from the total ion current chromatograms, by integration of the GC peak areas.

2.4. Sensorial analysis

A hedonistic test was performed, with an untrained panel of 15 judges that evaluated the descriptive attribute of fruit flavour, as well as the overall acceptability of the fruit before and after shelf-life. During each session, two fig fruit, randomly selected from each batch and cultivar, were evaluated by the judges, using a 0–10-point scale.

2.5. Statistical analysis

Data were statistically analysed using SPSS 15.0 for Windows (SPSS Inc Chicago, IL, USA). Sensory characteristics and the area of the volatile compounds were studied by one-way and two-way analysis of variance (ANOVA) and separated by Tukey's honestly significant differences test ($p \leq 0.05$). The main volatile compounds of each fig cultivar, were evaluated after cold storage, by principal component analysis (PCA), using films and shelf-life, as classification variables. The associations among the sensorial parameters studied, were also evaluated by Pearson correlation coefficients.

3. Results and discussion

3.1. Volatile compounds in fig cultivars at the time of harvest

The analysis of the volatile compounds using HS/SPME and GC/MS, allowed the identification of a total of 48 compounds (Table 1). The chemical classes that contributed to the aroma profile of these cultivars, were aldehydes (14), esters (6), hydrocarbons (5), furans (5), alcohols (5), ketones (4), pyranone derivates (3), terpene compounds (2), acids (2), pyrazines (1) and ethers (1). Most of these compounds have been previously described in fresh fig fruit (Grison-Pigé et al., 2002; Li et al., 2012; Oliveira et al., 2010a,b).

The hydrocarbons showed a high variability for both cultivars (2.10–17.92% of the total area). Hexane was the most abundant hydrocarbon, with maximum levels in SA, involving 12.16% of the total area for this cultivar (Table 1). Low amounts of short-chain alkanes, have been previously reported in fig fruit (Grison-Pigé et al., 2002) and their origin has been associated with lipidic oxidation (Sanz et al., 1997). Regardless of their origin, aliphatic and branched hydrocarbons are not among the most odour-active compounds described for fruit and have been considered as non-contributors to food flavour (Voilley and Etiévant, 2006).

The alcohols detected (3.90–4.76% of the total area) included linear and branched compounds (Table 1). The linear alcohol detected was 3-heptanol (OL3), which is linked to green notes and fresh green odours that are characteristically associated with yellow passionfruit (Werkhoff et al., 1998), for example. They are also considered to be relevant flavour volatiles in fig, although the light and yellow green cultivars contain higher levels of alcohols than the dark genotypes (Oliveira et al., 2010b). Significant differences in the levels of 2-methyl 1-butanol (OL2) and an unknown branched alcohol (OL4), were found between the cultivars (Table 1). SA cultivar contained the highest relative content of this latter compound (4.21% of the total area), while 2-methyl 1-butanol was more abundant in CDN cultivar (0.61% of the total area).

Aldehydes are among the most important aroma components in the flesh of figs (Oliveira et al., 2010b). These compounds included linear, branched, and aromatic aldehydes (12.15–17.88% of the total area;