



## EFFECTS OF FIRE FUMES ON ALMOND SAFETY AND QUALITY

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### ABSTRACT

A fire originated and burnt two cold chambers; the present study focused on almonds stored in adjacent chambers (4, 5, 6 and 13) and evaluated both their food safety and quality. Testing for polycyclic aromatic hydrocarbons, polychlorinated dibenzo-*p*-dioxins and dibenzofurans was carried out in affected facilities, packaging and almonds. Experimental results proved that fire fumes did not reach chambers 4-6, but traces were found in bin packaging of chamber 13; thus, packaging from this chamber were changed. Concentrations of benzo(a)pyrene were low enough to prove that fire fumes did not get in contact with the stored almonds. Later, only volatile compounds typical of nuts were identified in both raw and toasted almonds. Finally, a trained panel concluded that no sensory signal of fumes reaching almonds was found. This manuscript could be taken as a model protocol to establish whether fire fumes have reached and affected the safety and/or quality of foods. This information will be especially useful for insurance companies.

**Keywords:** Dioxins; PAHs; PCBs; sensory analysis; volatile compounds.

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## INTRODUCTION

A fire of electrical origin at a food company was reported in January 2007. The affected company is mainly dedicated to cold storage of foods, including bakery products (pizzas, bread baguettes, etc.), fruits and vegetables (palm dates, almonds, etc.), and concentrated juices (orange and lemon). The actual fire damage was limited to chambers 10 and 11 of the food company (**Fig 1**), although smoke and soot were carried throughout some of the cold chambers, especially those in direct contact with chamber 11 (chambers 7 and 8). About 100.000 kg of almonds were burnt in the fire, together with some electrical cables and isolation material.

The stored foods were confiscated by the Spanish Public Health Authorities until an appropriate laboratory was able to prove that the stored food was not affected by fumes from the fire and that foods were safe to consume. Testing for polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDDs/Fs) was done one week after the fire was extinguished. After discarding all safety issues, studies on food quality were carried out to prove that the quality of the food was still as good as it was before the fire.

The PAHs, PCDDs and PCDFs are toxic low volatile organic pollutants, partly known being carcinogenic and mutagenic for humans (Wobst *et al.*, 1999). Among other pollutants, these substances are formed and released during frequently occurring fire accidents in buildings where the fire loads usually do not contain hazardous materials.

PAHs, a class of several hundred compounds made of two or more fused benzene rings, are typical products of the pyrolysis and gasification processes (Ledesma *et al.*, 2000). These compounds are produced from the pyrosynthesis of small hydrocarbons or from the decomposition of aromatic macromolecules. PAHs are formed in almost all high temperatures processes, even in the presence of oxygen (Fialkov and Homann, 2001). Once these compounds are formed, they are very difficult to destroy because of their high thermal stability due to the presence of aromatic rings. The US EPA has specified 16 PAH compounds as priority pollutants, including for instance naphthalene, acenaphthylene, etc. Of these, eleven have been classified as animal carcinogens (US EPA, 1998; Fullana and Sidhu, 2005).

Dioxins are short for PCDDs and furans are short for PCDFs. This group comprises 75 chlorinated dioxins and 134 chlorinated dibenzofurans. The 2,3,7,8-tetrachlorodibenzodioxin has been the most studied and is the most toxic. Toxicity of dioxins and furans depends upon the number of chlorine atoms and their position on the ring structures and each has been

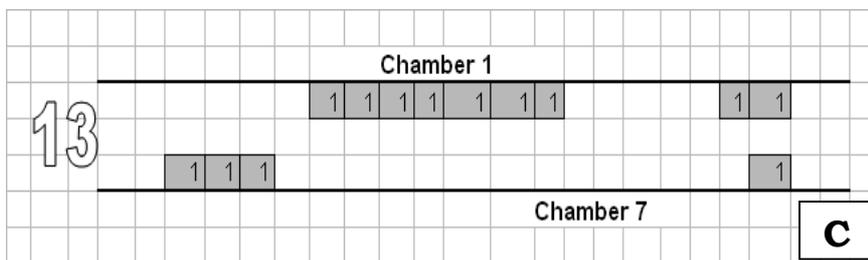
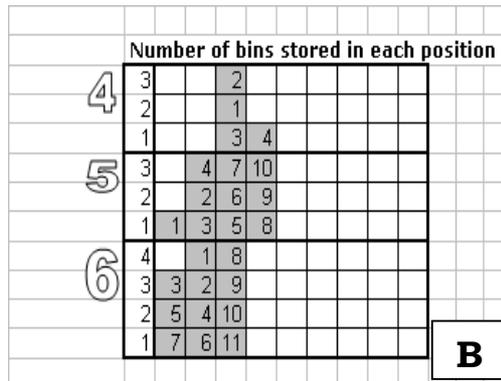
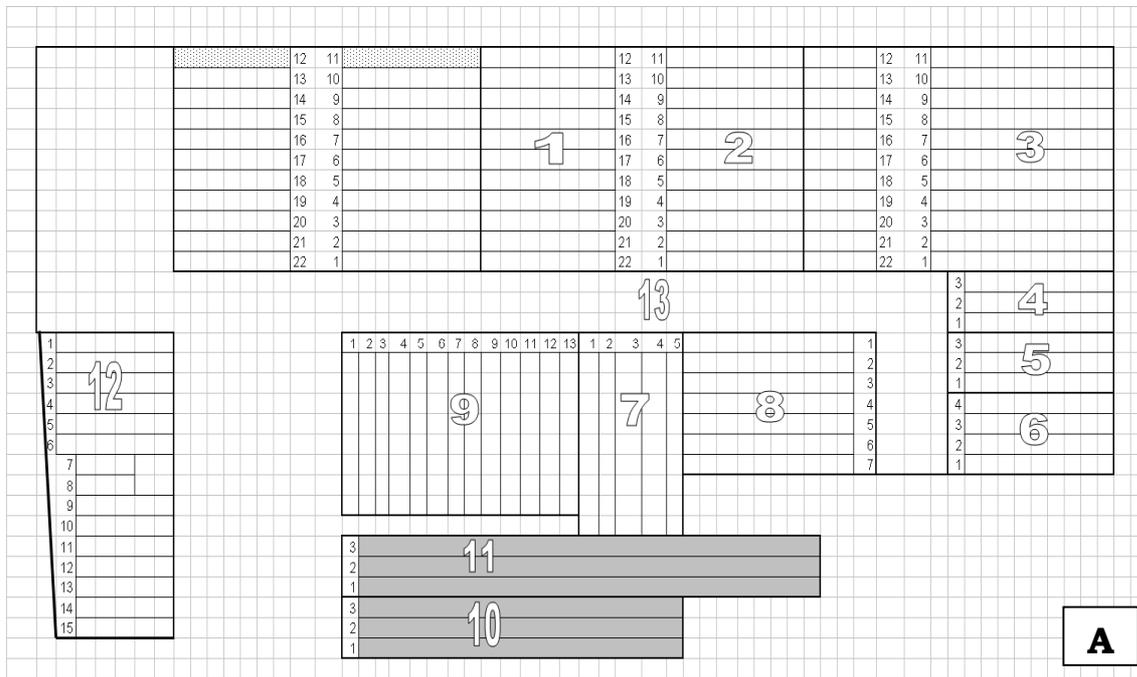
assigned a Toxicological Equivalent factor (TEF) to 2,3,7,8-tetrachloro-dioxin only 17 congeners are considered toxic. Burning chlorine containing material will emit dioxins into the air. The main sources of dioxins are fires (accidental and natural e.g. bonfires); clinical waste incineration; cremation; electric arc furnaces; sinter plant; combustion in industry; power stations. Dioxins are now known to be a human carcinogen and are involved in the promotion of soft tissue sarcomas (STS = cancer of fat and muscle tissue) and other cancers. Dioxins are associated with adverse reproductive and developmental effects, birth defects, immune system abnormalities, endometriosis and heart related conditions. Dioxin poisoning is long term due to gradual body accumulation (IARC, 1997).

It is extremely difficult to perform polyaromatic hydrocarbon (PAH) and/or chlorocompound (PCDD/F) sampling during real, uncontrolled accidental fires because of heat and toxic combustion gases, consequently soot samples collected after fires have largely been used to describe the amounts of PCDD/Fs generated during these events. It is, however, very difficult on the basis of such an analysis to estimate the concentrations of these substances in actual combustion gases (Ruokojärvi *et al.*, 2000).

Regarding quality, aroma of foods was studied using two different approaches: a) instrumental using the simultaneous distillation-extraction (SDE) technique and b) sensory using a trained panel. These aroma studies were mainly focused in the identification of any compound with a sensory descriptor close to smoke, fire, burnt, and similar, not previously reported in the scientific literature related to nuts, especially almonds.

The main objectives of this study were to measure the concentrations of PAHs, dioxins and furans in: a) the walls of the burnt chambers, b) the food packagings, and c) the stored products. These concentrations will make possible to estimate whether fire fumes have reached specific chambers and foods. The quality of stored food was finally studied only in those foods completely free from any potentially toxic compound originated during the fire of the burnt chambers.

MATERIAL AND METHODS



**Fig 1** Distribution of cold chambers in the storage facility affected by fire (A) and exact location of almonds within the affected cold chambers (4, 5, 6 and 13: B and C). The number in each cell indicates how many bins were piled in each location (B and C).

## **Material**

Fire occurred in chambers 10 and 11 of a food company located in Alicante (Eastern Spain) (**Fig 1**), causing a damage of about 3.000.000 €. The share of plastics in the fire load was small and the degree of destruction of the inventory was medium to high in chambers 10 and 11, and low in the other facilities of the company. Sampling (burnt materials and potentially affected foods) was carried out one week after the incident.

Chambers 1 and 12 contained mainly concentrated orange and lemon juices, while the chambers containing almonds were 4, 5, 6, and 13.

## **Sample Collection and Preparation**

Surface samples were collected in the affected chambers (10 and 11) and in their surrounding areas. Samples were extracted from the walls using cotton impregnated with toluene. Besides, small pieces of the cartoon protecting the almonds were cut and stored in sealed plastic bags at -18°C until analyses.

Almonds were collected one week after the fire incident and were stored in sealed plastic bags at 4°C until analyses. Almonds were under cold storage in chambers 4, 5, 6 and 13; the exact location of almonds within these chambers is depicted in **Fig 1**. Sampling was carried out with the supervision of the Spanish Public Health Authorities and following the Spanish legislation [REAL DECRETO 1089/2005; REAL DECRETO 604/2003; REGLAMENTO (CE) N° 1881/2006]. Samples of about 2 kg were collected from each one of the 1000 kg bins on the top of each pile. Information about batch numbers, type of packaging, etc. was provided by the food company and was fully available for researchers.

Peeled almonds were toasted at 165°C for 25 min with air velocity of 1 m s<sup>-1</sup> in the facilities of the Miguel Hernández University approximately 7 days after collection of samples. Samples were analyzed for volatile analyses and sensory analysis within 1 week after roasting.

## **Polycyclic Aromatic Hydrocarbons(PAHs)**

Cottons from wall sampling were extracted during 16 h with 80 mL of dichloromethane in a Soxhlet extractor. Before extraction the samples were spiked with 1 µL of a deuterated mixture (1,4-dichlorobenzene-d4, naphthalene-d8, acenaphthene-d10, phenanthrene-d10, chrysene-d12 and perylene-d12). The extracts were concentrated in a rotary evaporator Büchi R-210/R-215 (Büchi, Barcelona, Spain) until nearly dryness (3–5 mL). In order to remove the

fatty acid present in samples, extracts were clean up using a GPC (gel permeability column) according the EPA method 3640A.

The chromatographic analyses were performed using a Varian GC-MS-MS system comprising a CP-3900 gas chromatograph (Walnut Creek, CA, USA) with a 1077 injector, a CP-8410 autosampler and an ion-trap mass spectrometer (Varian Saturn 2100). Separations were carried out using a DB-5MS fused-silica capillary column (30 m × 0.25 mm i.d., 0.25 µm film thickness). Helium was used as carrier gas at a constant flow of 1.0 mL min<sup>-1</sup> and a pressure pulse of 25 psi with a duration of 0.50 min. The injected volume was 2 µL in splitless mode. Oven temperature was programmed as follows: 1 min at 50 °C, heated at 5 °C min<sup>-1</sup> to 310 °C and held for 5 min. The manifold, GC-MS interface and the ion trap temperatures were set at 60, 280 and 150 °C, respectively.

For the analysis of PAHs from the walls no ion preparation was use. The isolation, identification and quantification of the PAHs were performed on a gas chromatograph according US EPA method 8270 (1996). However, for the analysis of benzo(a)pyrene in almonds and in order to increase the detection limit, MS/MS ion preparation was use; parent and daughter ions were set at 252, waveform type was resonant and excitation amplitude 1.30.

### **Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans (PCDD/Fs)**

Approximately 5-10 g of each sample were weighed and mixed with anhydrous sodium sulphate to remove any trace of water. The sample was spiked with 20 µL of a mixture of 15 congeners <sup>13</sup>C<sub>12</sub>-labelled 2,3,7,8-substituted PCDD/Fs, as an internal standard. The samples were extracted for 16 h with 80 mL of dichloromethane in a Soxhlet extractor. The extracts were concentrated in a rotary evaporator (Büchi) until nearly dryness (3–5 mL). Later, concentrated extracts were subjected to an automated clean-up system using the Power Prep™ System (FMS Inc., MA, USA) with three different columns: silica, basic alumina and AX-21 active carbon. Finally, a fraction of extract was collected with 75 mL of toluene. Afterwards, this extract was concentrated with a rotary evaporator and later taken with a nitrogen stream down to the final volume. 10 µL of a mixture of <sup>13</sup>C<sub>12</sub>-1,2,3,4-TCDD and <sup>13</sup>C<sub>12</sub>-1,2,3,7,8,9-HxCDD recovery standards were added as well.

The PCDD/Fs analysis was carried out using high-resolution gas chromatography coupled to a high-resolution mass spectrometer (HRGC/HRMS). For HRGC, an Agilent HP5890 gas chromatograph equipped with a programmed temperature vaporizer (PTV) inlet with a septumless head was used. For HRMS, a Micromass Autospec Ultima NT mass

spectrometer (Micromass, Waters, UK) with a positive electron impact (EI+) source was employed. A DB-5 60 m fused silica capillary column was used for the separation of the isomer specific analysis.

The identification and quantification of each PCDD/Fs congener were performed by the isotope dilution method. The PCDD/Fs analyses were based on the US EPA Method for PCDD/Fs determinations (US EPA, 1994).

### **Volatile Organic Compounds in Food Packagings**

Desorption of the analytes was performed using an automatic thermal desorption device (Gerstel TDS2/TDSA, Mülheim an der Ruhr, Germany) coupled by a transfer line (152 mm length  $\times$  0.70 mm outside diameter  $\times$  0.53 mm internal diameter, i.d.) to a cryogenically cooled programmable temperature injection system (Gerstel CIS4). The desorption device was directly interfaced to an Agilent 6890N GC/5973N MS system, with helium as carrier gas and a DB-624 capillary column (30 m length  $\times$  0.25 mm i.d., 1.4  $\mu$ m film thickness).

A 1 cm<sup>2</sup> of carton from the food packagings were desorbed at 150 °C during 8 min, using He as carrier gas. Injector was kept at -200 °C during desorption and heated at 10°C s<sup>-1</sup> to 250°C during the injection. The program temperature was a) 50°C for 2.5 min b) rate of 10.0°C min<sup>-1</sup> from 40 to 250°C and hold for 7.5 min.

### **Simultaneous Steam-Distillation Extraction (SDE)**

Suspension of 30 g of ground almonds in 50 mL of ultrapure water (Milli-Q, Millipore Corp. Bedford, MA, USA) (resistance 18 m $\Omega$  cm<sup>-2</sup>) was placed in flask A of the Likens-Nickerson distillator (Afora, Barcelona, Spain) with 10 g NaCl (Merck, Darmstadt, Germany). In flask B, 50 mL of dichloromethane, Cl<sub>2</sub>CH<sub>2</sub> (Labscan Ltd., Dublin, Ireland) were introduced. Boiling chips were added to flask A together with 10 drops of silicon as antifoaming agent. One hundred  $\mu$ L of 2-pentanol, 1 g L<sup>-1</sup>, were added as internal standard. Flask B was heated in a water bath at 55°C and flask A in an oil heater at 160°C. The vapors were condensed by means of a cold refrigerant maintained at -5°C by a cryostat, model Frigiterm (Selecta, Barcelona, Spain). After 120 min of extraction, solvent contained the aroma compounds from almonds samples (Vázquez-Araújo *et al.*, 2008a,b).

The extract was dried over 5 g anhydrous Na<sub>2</sub>SO<sub>4</sub> (Panreac Química S.A., Barcelona, Spain) and concentrated to about 1 mL in a Vigreux column.

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<sup>-1</sup> in a split ratio of 1:10 and a program: a) 40°C for 5 min; b) rate of 3.0°C min<sup>-1</sup> from 40 to 200°C and hold for 1 min; c) rate of 15°C min<sup>-1</sup> 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 spectra range of 45 to 450 m/z was used.

Most of the compounds were identified by using 3 different analytical methods: 1) Kovats indices, 2) GC-MS retention indices, and 3) mass (McLafferty, 2008). Identification was considered tentative when it was based on only mass spectral data. For the semi-quantification of the volatile compounds 2-pentanol was added as internal standard at a concentration of 1 g L<sup>-1</sup>. All the aroma standards used for identification and quantification purposes were food grade (Sigma-Aldrich, Flavors and Fragrances, Milwaukee, WI, USA).

### **Sensory Evaluation with Trained Panel**

Sensory evaluation with trained panel was used to discriminate the intensity of "smoke/fume = burnt almond" odor (perception of pleasant volatile compounds sniffed through the nose). A panel of 10 panelists, ages 20 to 60 years (6 female and 4 male) was trained in descriptive evaluation of *turrón* and its raw materials including *almonds* and honey. Details about panel selection and training could be found in Vázquez-Araújo *et al.* (2005).

Measurements were performed in individual booths with controlled illumination and temperature. Individual almond samples were scored for their intensity of "off-odor" (including smoke, burnt, plastic, ... notes) on a scale of 0 to 5, where:

- 0 = no odor.
- 3 = intense odor.
- 5 = extremely intense odor.

The entire experiment was repeated 3 times (all judges scored the three samples on each session for a total of 3 sessions) and the sensory scores were presented as the overall means. Controlled samples with known concentrations of artificial smoke (used for smoking meat products) were used as control samples.

### Statistical Analysis

All data were subjected to analysis of variance (ANOVA) and the Tukey least significant difference multi-comparison test to determine significant differences among mandarin juices. Significance of differences was represented as  $p \leq 0.001$ . The statistical analyses were done using SPSS 12.0 (SPSS Science, Chicago, U.S.A) and figures using Sigma Plot 8.0 (SPSS Science, Chicago, U.S.A).

## RESULTS AND DISCUSSION

### Analyses of Wall Surfaces

The main PAHs found in the wall surfaces, inside and outside, one of the burnt chambers (number 10) showed that benzo(a)anthracene, pyrene, fluoranthene and chrysene were the most abundant compounds (**Fig 2**). The observed patterns inside and outside chamber 10 for PAHs were identical implying a common origin of the analyzed compounds, as expected. The total concentrations of PAHs were 15 and 5 mg m<sup>-2</sup> inside and outside chamber 10, respectively. These experimental values agree with literature values for domestic houses (Wobst *et al.*, 1999; Ruokojarvi *et al.*, 2000).

The analyses of the wall surfaces (inside and outside) one of the burnt chambers (10) showed that PCDDs and PCDFs were present in measurable concentrations (**Fig 3**). The congeners with the highest concentrations were 23478-PeCDF for furans and 2378-TCDD and 12378-PeCDD for dioxins. The experimental patterns for PCDD/Fs inside and outside chamber 10 were quite similar and implied a common origin of the analyzed compounds, as expected.

Total concentrations of 6.9 ng ETQ m<sup>-2</sup> (inside wall) and 0.9 ng ETQ m<sup>-2</sup> (outside wall) were found. PCDDs represented approximately 53 % of the total concentrations (3.81 and 0.46 ng ETQ m<sup>-2</sup>, respectively). These values are within the normal range for PCDDs and PCDFs in domestic fires according to Rao and Brown (1991) and Wobst *et al.* (1999). According to the Verband der Schadenversicher (1994) values lower than 10 ng ETQ m<sup>-2</sup> are

required to conclude that a room is safe after a fire event. Consequently, from a PCDD/Fs point of view, all chambers affected by this particular fire were safe, implying that no significant sources of PCDD/Fs were present in the burnt chambers.

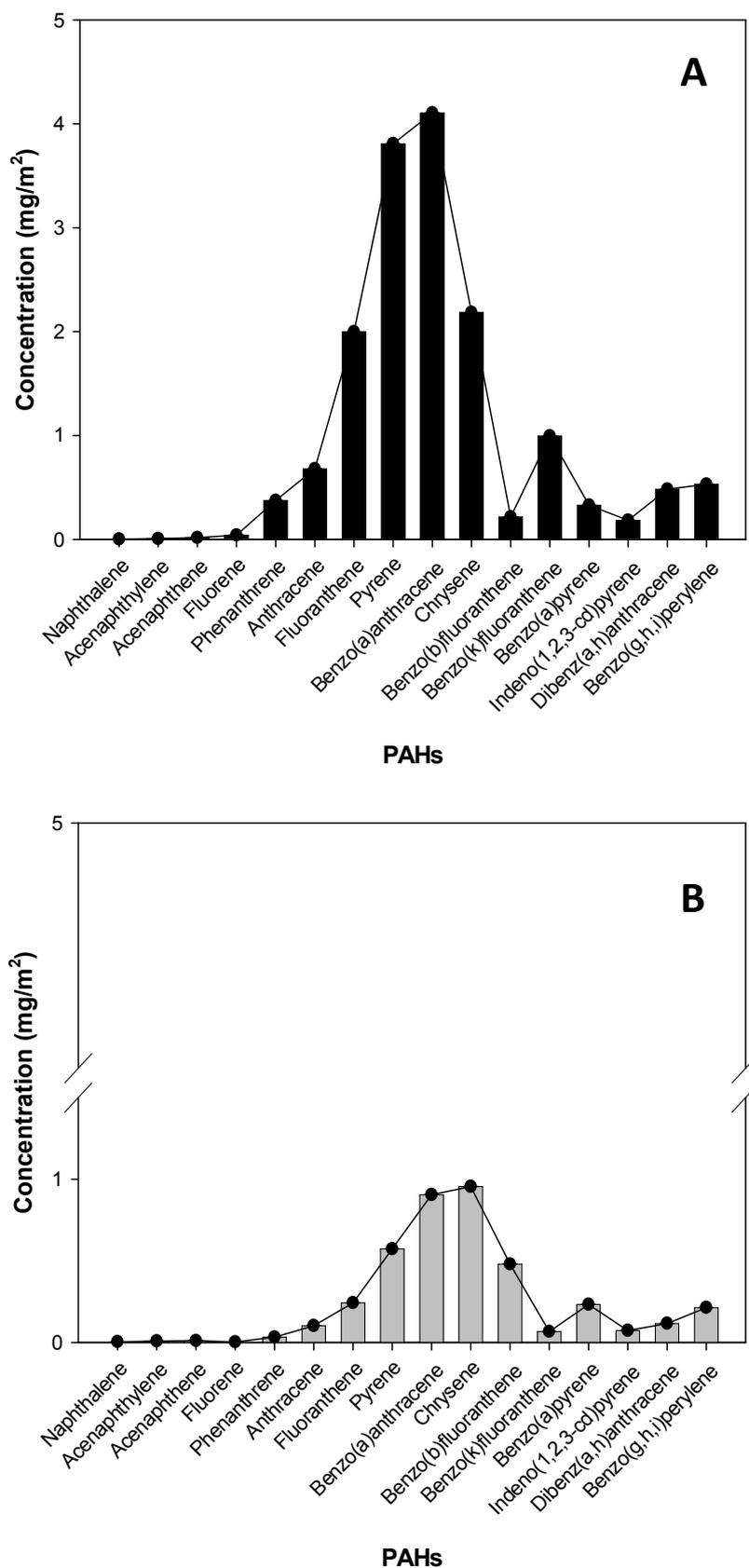
### **Fume Distribution among Cold Chambers**

To study which chambers were affected by the fire fumes, concentrations of several key or tracer compounds in combustion (benzotrile, naphthalene, biphenyl, fluoranthene+pyrene, aniline, isoquinoline, and phenanthrene) were analyzed in the external surface of the packaging of almond bins (**Fig 4**). It is important to remark the low experimental levels found of aniline and benzotrile, compounds originated from the combustion of polyurethane (Font *et al.*, 2001). These authors concluded that for instance aniline was originated from the cracking of the diphenylmethane *p,p'*-diisocyanate. These low levels implied that fire fumes did not reach cold chambers numbers 4, 5 and 6. However, precautions should be taken with almonds stored in chamber number 13, which presented the highest concentrations of all studied tracer compounds; especially high were the concentrations of phenanthrene and fluoranthene+pyrene, with concentrations of  $0.85 \pm 0.05$  and  $0.86 \pm 0.11 \text{ mg m}^{-2}$ , respectively. The experimental fact that chamber 13 was the most affected area by the fire fume was expected because it was a corridor being used for storage of almond bins, without any type of doors or temperature control. Consequently, fumes from the fire could easily reach bins stored in chamber 13 without any physical obstacle (see **Fig 1**).

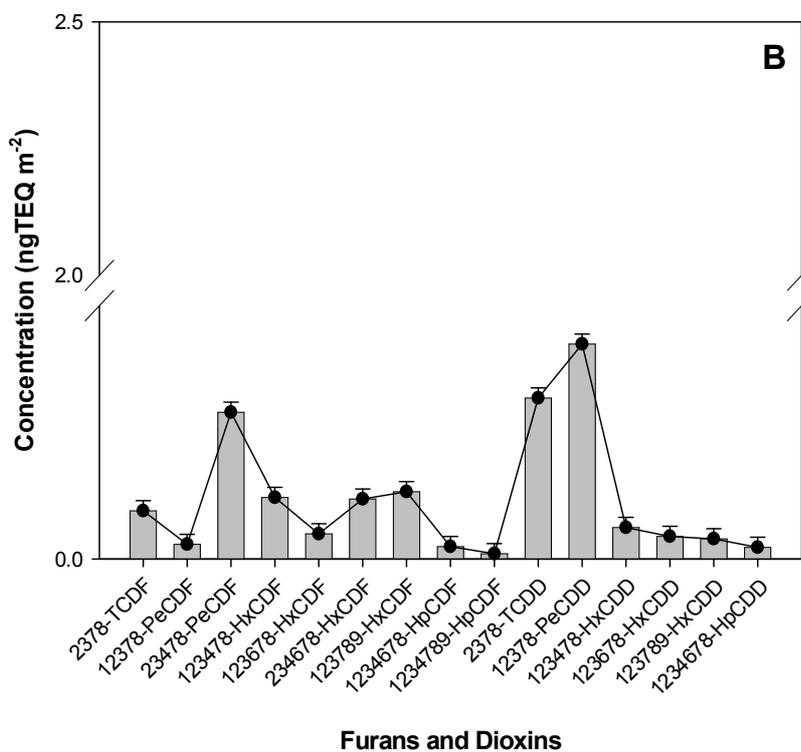
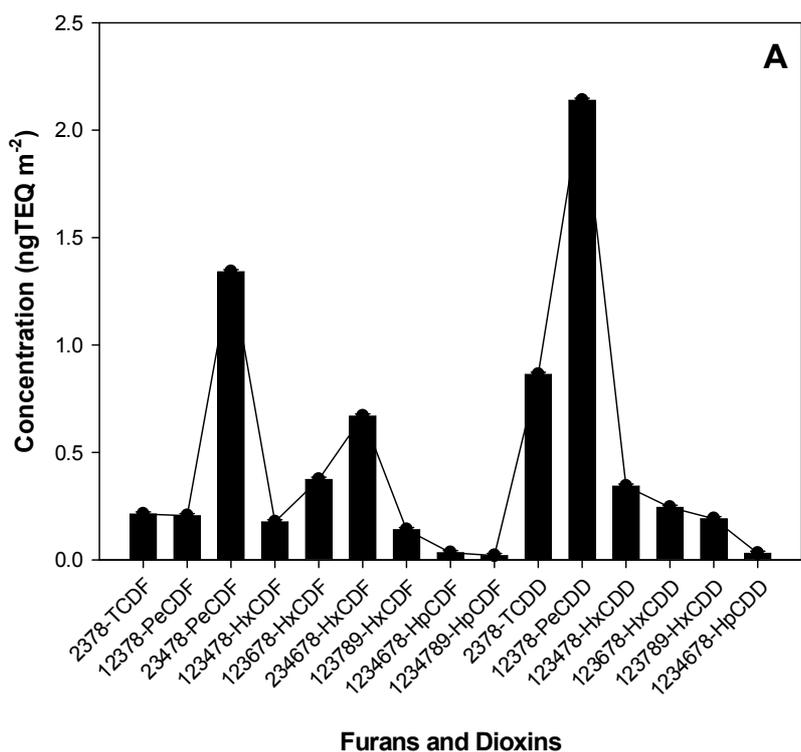
### **Fume Contact with Almonds**

To study whether the fire fumes had reached the stored foods, raw almonds were extracted with  $\text{Cl}_2\text{CH}_2$  and the concentrated extracts were analyzed for benzo(a)pyrene. The experimental values found for the stored almonds were: (a) *chamber 4*:  $0.16 \pm 0.04 \text{ } \mu\text{g kg}^{-1}$  (with maximum value of  $0.45 \text{ } \mu\text{g kg}^{-1}$ ); (b) *chamber 5*:  $0.09 \pm 0.03 \text{ } \mu\text{g kg}^{-1}$  (with maximum value of  $0.31 \text{ } \mu\text{g kg}^{-1}$ ); (c) *chamber 6*:  $0.13 \pm 0.04 \text{ } \mu\text{g kg}^{-1}$  (with maximum value of  $0.36 \text{ } \mu\text{g kg}^{-1}$ ); and, (d) *chamber 13*:  $0.17 \pm 0.04 \text{ } \mu\text{g kg}^{-1}$  (with maximum value of  $0.46 \text{ } \mu\text{g kg}^{-1}$ ).

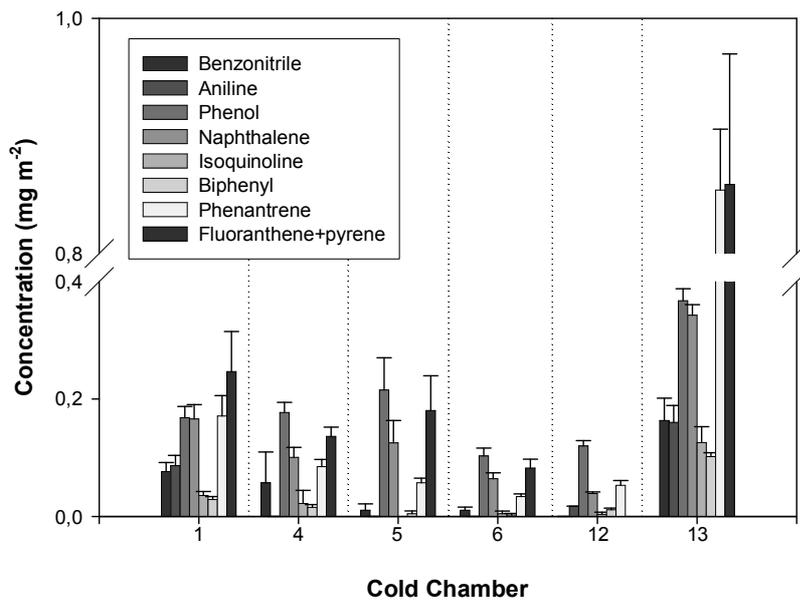
The maximum limit established by the Spanish legislation for the content of benzo(a)pyrene in foods is  $5.0 \text{ } \mu\text{g kg}^{-1}$  [REAL DECRETO 1089/2005; REGLAMENTO (CE) N° 1881/2006]. Benzo(a)pyrene is used as a marker for the occurrence and effect of carcinogenic PAHs. Consequently, it can be concluded that the fire fumes did not get in direct contact with the stored almonds, and therefore no contamination was detected.



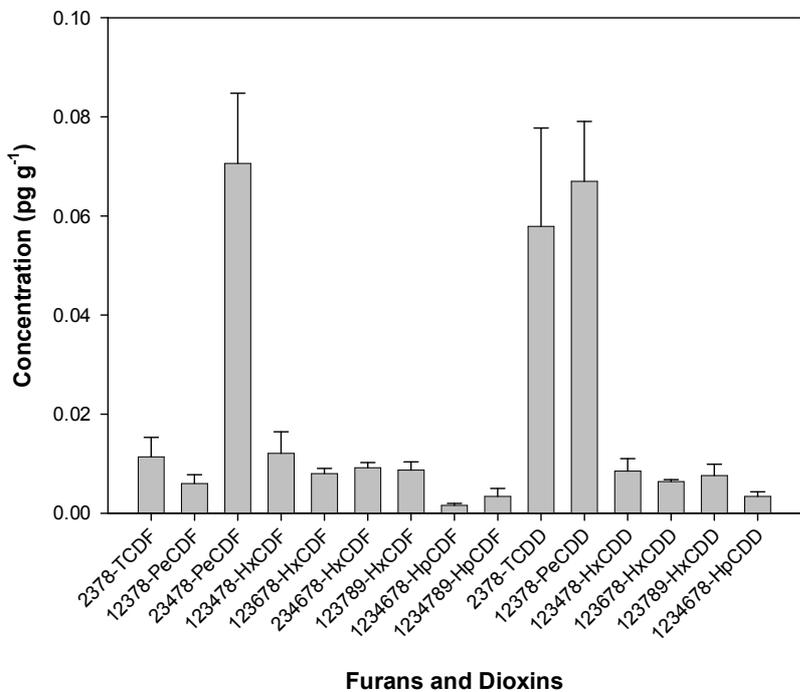
**Fig 2** Concentrations of polycyclic aromatic hydrocarbons (PAHs) found at walls inside (A) and outside (B) of the burnt chamber number 10.



**Fig 3** Concentrations of furans (PCDFs) and dioxins (PCDDs) found at walls inside (A) and outside (B) of the burnt chamber number 10.



**Fig 4** Concentrations of volatile compounds found in the carton packaging, at different cold chambers (1, 4, 5, 6, 12 and 13).



**Fig 5** Concentrations of furans (PCDFs) and dioxins (PCDDs) found in raw almonds. Values are the mean of almonds stored in chambers 4, 5, 6 and 13 (2 samples per chamber).

Finally, the concentrations of furans and dioxins were also quantified in almonds stored in chambers 4, 5, 6 and 13. No significant differences were found for the concentrations of any of the congeners identified and quantified in the samples under study; therefore, the mean values of all the studied samples (2 samples  $\times$  4 chambers) are represented in **Fig 5**. In general, it is very difficult to talk about admissible contents of dioxins in almonds because maximum contents are only set for meat and fish products. The European Commission Regulation (EC) No 1881/2006 of 19 December 2006 sets maximum levels of certain contaminants in foodstuffs; values ranged from 6.0 pg g<sup>-1</sup> in liver of terrestrial animals and 0.75 6.0 pg g<sup>-1</sup> for vegetable oils and fats. In any case, the mean total concentration of dioxins in almonds was 0.28 pg g<sup>-1</sup>, which is well below the maximum content establish for vegetable oils, which is the closest legislated food. rekjnhuihuo

### **Volatile Aroma Compounds**

The volatile composition of raw and toasted almonds has been previously described by Vázquez-Araújo *et al.* (2008a, 2009); besides, these authors have also reported the aroma composition of *turrón*, a typical Spanish confection made mainly with toasted almonds (Vázquez-Araújo *et al.*, 2008b,c). All almonds affected by the fire in the facilities under study were “California” cultivar, which is one of the almond cultivars studied by Vázquez-Araújo *et al.* (2008a), and their final destination was the manufacturing of *turrón*. Therefore, the typical volatile compounds expected in the aroma extracts of the almonds potentially affected by the fire fumes have been well described and are easy to identify.

All almonds under study belonged to a *turrón* company and must undergo toasting before its use as ingredient in *turrón* manufacturing; therefore, almonds were toasted using normal conditions (temperature and time) and their aroma profiles (**Fig 6**) were compared with those previously studied by Vázquez-Araújo *et al.* (2008a).

The aroma profile of raw almonds included, among others, the following compounds: hexanal, hexanal,  $\alpha$ -pinene,  $\beta$ -pinene, benzaldehyde, limonene, 1-octanol, nonanal, 2,4-nonadienal, 2,4-decadienal, caryophyllene, and humulene. After toasting the concentrations of some chemicals (pyrazines, furans, and pyrroles) significantly increased, while the concentrations of some others significantly decreased, for instance benzaldehyde and  $\alpha$ -pinene. A total of 58 volatile compounds were identified in toasted and included (i) *alcohols* 2-hexanol, 1-hexanol, etc., (ii) *ketones* 3-hydroxy-2-butanone, 2-heptanone, etc., (iii) *aldehydes* heptanal, 2-heptenal, etc., (iv) *terpenes* limonene, carvone, etc., (v) *aromatic*

*hydrocarbons* toluene, benzaldehyde, etc., (vi) *furans* dihydro-2-methyl-3(2H) furanone, furfural, etc., (vii) *pyrroles* 1H-pyrrole, 2-methyl 1H-pyrrole, etc., (viii) *pyrazines* 2-methyl pyrazines, 2,5-dimethyl pyrazines, etc., and (ix) *linear hydrocarbons* octane, dodecane, etc.

Compounds such as 4-methylpentanenitrile, butylbenzene, methylphenol, dimethyl phenol, benzenepropanenitrile, nonanenitrile, heptadecanenitrile, etc. were tentatively identified in burnt almonds from chamber 10 but were never found in any of the other samples under study.

The detailed study of the aroma compounds of all almonds samples led us to the conclusion that no “unexpected” or “non-typical” volatile compounds were detected neither in the raw almonds nor in the toasted almonds from chambers 4, 5, 6 and 13.

### **Sensory Analysis**

The trained panel specialized in *turrón* and almond products (Vázquez-Araújo *et al.*, 2008b) did not detect odor or aroma to fume, smoke or burnt in any of the 43 samples of almond studied (43 and 13 samples of raw and toasted almonds, respectively). Five almond samples were spiked with artificial smoke odor at different intensities; all panelists distinguish these five samples and scored their intensities according to the amount of artificial smoke odor spiked. Consequently, the final conclusion of this sensory study was that no significant sensory signal of fumes reaching almond samples was found.

### **CONCLUSION**

A fire originated and burnt two cold chambers containing almonds. The affected company had 13 different chambers, storing mainly almonds and concentrated citrus juices. This study was carried out for an insurance company because all foods stored in these facilities were confiscated by the Spanish Public Health Authorities. The study focused only in almonds stored in chambers 4, 5, 6 and 13 and it was divided into two different parts; the first one studying food safety and the second one evaluating the quality of the safe products. Testing for polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs) was carried out in walls of the affected area to establish the nature and composition of the generated fumes, and also in the packaging and foods of potentially affected chambers. Bezo(a)anthracene, pyrene, fluoranthene and chrysene were the most abundant PAHs. The congeners with the highest concentrations were 23478-PeCDF for

furans and 2378-TCDD and 12378-PeCDD for dioxins. Fumes did not reach chambers 4-6, but traces were found in the bins packaging of almonds stored in chamber 13. Consequently, packaging of almonds stored in chamber 13 must be changed avoiding any kind of contact with the stored almonds. Benzo(a)pyrene was used as a marker for the occurrence and effects of carcinogenic PAHs; experimental results proved that the fire fumes did not get in contact with any of the stored almonds under study. Therefore, almonds stored in these facilities were declared safe and the quality study started. Only volatile compounds typical of nuts were identified in raw and toasted almonds; while compounds such as 4-methylpentanenitrile, butylbenzene, methylphenol, etc. were tentatively identified in burnt almonds. Finally, a trained panel concluded that no sensory signal of fumes reaching almonds was found. This manuscript could be taken as a model protocol to establish whether fire fumes have reached and affected the safety and/or quality of foods.

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