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RESEARCH PAPER

Targeted multidimensional gas chromatography using a heart-cutting device and cryogenic focusing for the determination of benzophenone derivatives in foodstuffs

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Abstract Photoinitiators are used to promote the polymerization process during the curing of varnishes or inks on cartonboard packaging. Depending on storage conditions and shelf life, these substances are able to migrate through the packaging layer into the foodstuff. This type of contamination phenomenon is therefore becoming a critical issue in terms of food safety. In order to tackle this problem, a fast and selective method was developed for the determination of benzophenone and three methylbenzophenone isomers in cereal-based foodstuffs and their cardboard packaging. Food samples or packages were efficiently extracted by pressurized liquid extraction using acetonitrile, and the extracts were directly injected onto the analytical system. The analysis was performed by multidimensional gas chromatography–mass spectrometry using a heart-cutting approach to reduce the background noise from complex matrices. The strategy employed two distinct cuts each containing its proper deuterated internal standard leading to accurate quantification. By integrating a cryofocusing effect, an enhancement in signal/noise ratio was achieved by a factor >10, which markedly decreased the sensitivity threshold. Moreover, baseline separation of the critical isomers allowed their unequivocal determination. The method was fully validated on cereal-based foodstuffs based upon an analysis of variance, and excellent performances were obtained at the decision limit making this method well suited for official food controls.

Keywords Multidimensional gas chromatography · Cryotrapping · Food contact material · Packaging · Photoinitiators

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Introduction

Often, we mainly refer to pesticides, dioxins, polychlorinated biphenyl, and other environmental chemicals when speaking about food contamination, thus neglecting to envisage that possibly food contact materials might be one of the predominant sources of tainted foodstuffs. Among the many potential chemical contaminants from food packaging materials, photoinitiators (PIs) are at the forefront as they can easily migrate into foodstuffs by direct diffusion [1] or by contamination from the outer to unprinted inner layers of the packaging during a set-off process [2]. Besides its utilization as a sunscreen agent, benzophenone (BZP) is widely used to promote the polymerization of printing inks and varnishes during UV curing on carton-based packages. This substance is known to increase the prevalence of carcinogenic activity on mice and rats [3] and possess an estrogenic effect

[4]. Consequently, its migration in foods through packaging layer must be eliminated and controlled. Papilloud and Baudraz [5, 6] widely outlined the PI migration phenomenon and emphasized the necessity of performing migration tests and analytical controls when using such volatile substances in printing ink formulations. In 2009, due to several European alerts through the Rapid Alert System for Food and Feed (RASFF), the European Food Safety Authority (EFSA) was urged to reassess the toxicological evaluation of BZP and its tolerable daily intake (TDI). Notwithstanding this assessment, the TDI was finally set at 0.03 mg/kg b.w. per day (instead of 0.01 mg/kg b.w. per day) [7]. However, this value has still no legal force as it has not yet been officially adopted by the EU legislation, and consequently, the specific migration limit of 0.6 mg BZP/kg foodstuffs is still in use. Moreover, in 2009, the EFSA was asked to examine the case of 4-methylbenzophenone (4-MeBZP) migration in breakfast cereals as several cases of food contamination were reported [8]. It was concluded that the current TDI level for BZP could not be applied to 4-MeBZP. In contrast, according to the Swiss regulation, benzophenone and its main methylated isomers, namely, 2-methylbenzophenone (2-MeBZP), 3-methylbenzophenone (3-MeBZP), and 4-MeBZP, have a specific migration limit (SML) in food fixed at 0.6 mg/kg for each individual compound, as well as for the sum of all BZP derivatives [9]. Thus, there is a need to develop accurate methods for the determination of the migration levels of benzophenone derivatives in foodstuffs.

Extraction of benzophenonic compounds in food is generally performed by sonication or liquid liquid extraction using mid polar solvents [10, 11] and possibly followed by solid-phase extraction. These processes are not only tedious and time consuming but also expose the operator and environment to harmful solvents and can contribute to handling errors. More recently, solid phase microextraction was applied to the analysis of BZP and a few other PIs in packed milk [12]. To speed up the sample preparation process and gain in automation, pressure liquid extraction (PLE) can be used to efficiently extract small compounds from complex solid matrices. This alternative extraction technique usually uses an organic solvent at elevated temperature and pressure, both accelerating the extraction kinetics while maintaining solvent in the liquid state. Although the determination of some photoinitiators including benzophenone in foodstuffs by liquid chromatography (LC) has recently been reported [13–15], gas chromatography (GC) is often preferred owing to the low molecular weight and the good volatility of these substances [11, 16–18]. As a rule, mass spectrometry (MS) is the detector of choice, but the sensitivity and specificity afforded by single quadrupole instruments are not always sufficient to detect these compounds in complex matrices. In such cases, tandem mass spectrometry, which allows for improved selectivity and reduced background noise, could be used to detect such trace levels [19].

Alternatively, multidimensional gas chromatography–mass spectrometry (MDGC-MS), consisting in a sequential arrangement of two columns of different selectivities, is usually used to improve GC separation power and peak selectivity, but can also decrease the analytical quantification limits. The benefit of this chromatographic technique is ensured by transferring selected target portions of the first dimension effluent to the second dimension [20]. Also called "heart-cutting," this strategy is mostly controlled by a pneumatic flow switching valve [e.g., Dean's switch valve (DS)]. The general principle of MDGC and DS modulation has been thoroughly outlined in several recent reviews [21–23]. Many MDGC applications have focused on petrochemical, fragrance, environmental and agricultural, forensic, and biological analysis, while most of food applications involving such separation mechanism are dedicated to flavor and aroma analysis. The separation of contaminants in foodstuffs by MDGC using a heart-cutting device is still very scarce [24, 25]. Moreover, in most applications, only screening approaches are described, and accurate quantification is infrequently performed. To date, to the best of our knowledge, only one paper has reported an application of MDGC for food contact material characterization and quantification of their migrants [26].

In the present study, an MDGC-MS set-up coupling a flow switching device to a longitudinally moving cryogenic trap (LMCS) was implemented. The latter interfaced the two dimensions and trapped selected fractions from the primary column before relaunching focused components onto the secondary dimension. This focusing effect [27] allowed reducing the peak width, thereby increasing the signal/noise ratios (S/N) of the target photoinitiators resulting in a significant enhancement in sensitivity. The procedure described herein was fully validated for the quantitative analysis of four BZP derivatives in cereal-based foodstuffs, and a survey was carried out on conventional and chocolate-based cereals from the Swiss market.

Experimental

Chemicals

BZP, benzophenone-d_{10} (BZP-d_{10}), 2-MeBZP, 3-MeBZP, and 4-MeBZP were purchased from Sigma-Aldrich (Buchs, Switzerland), whereas 4-methylbenzophenone-d_7 (4-MeBZP-d_7) was synthesized in our laboratory (see below). Acetonitrile (MeCN), methanol (MeOH), and n-hexane were of high-performance LC grade and supplied by Riedel-de-Haën (Buchs, Switzerland). Water was

purified with a Milli-Q system from Millipore (Molseheim, France). Other chemicals were of analytical grade and were provided by Sigma-Aldrich (Buchs, Switzerland). Standard stock solutions were obtained by dissolving an appropriate amount of each reference substance in MeCN. Working solutions were prepared by diluting stock solutions with acetonitrile to reach concentrations ranging from 10 to 300 μg/L. A benzophenone-free based müesli was used to prepare surrogated standards for quality controls and blanks.

Synthesis of 4-MeBZP-d_7

4-MeBZP-d_7 is not commercially available; thus, its in-house synthesis was undertaken. The synthesis was based on a straightforward Friedel–Crafts reaction between deuterated toluene and benzoyl chloride. Briefly, 1.4 g of benzoyl chloride were dissolved in 3 g of nitromethane and added at room temperature over a period of 5 min to a mix of deuterated toluene (d_8-toluene) and anhydrous aluminum chloride previously dissolved in 20 g of nitromethane. The reaction mixture was stirred again for 10 min to reach an orange-colored solution. The latter was washed with 20 mL of icy water and extracted three times with 15 mL of ether. The organic layer was dried with sodium sulfate and evaporated under a gentle stream of nitrogen. Finally, the reaction product was purified on a silica gel column with a hexane/dichloromethane solution (50:50, *v*/*v*). The purity of the resulting 4-MeBZP-d_7 (>95 %) was verified by GC-MS.

Materials and equipment

The GC-MS experiments were performed on an Agilent Series 7390 apparatus (Agilent Technologies, Palo Alto, USA) equipped with an automatic split/splitless injector, a flame ionization detector (FID), and an LMCS (Chromatography Concepts, Doncaster, Australia). The scheme of the MDGC device is depicted in Fig. 1, and the general

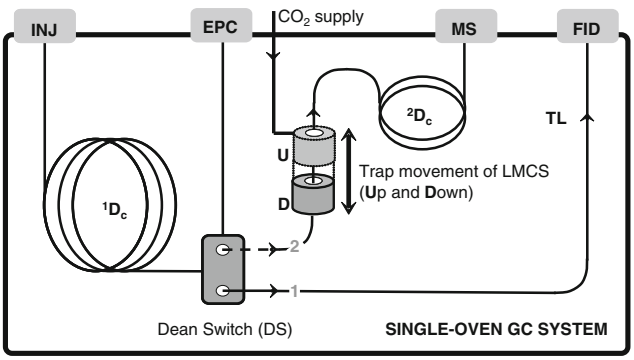

Fig. 1 Schematic representation of the heart-cut MDGC system. *TL* transfer line, 0.88 m×0.1 mm deactivated fused silica, *U* up position of the modulator, *D* down position of the modulator, *1Dc* 15 m×0.25 mm×0.25 μm *df*, 5 % Ph, *2Dc* 5 m×0.15 mm×0.15 μm *df*, 50 % Ph

principle involved a short cryogenic trap able to move longitudinally along the separation column, as previously detailed [28]. Briefly, the trap is initially set in the "up" position, allowing target compounds to be cryofocused at −40 °C using liquid carbon dioxide. By a subsequent movement of the trap to the "down" position (i.e., towards the injector), compounds are quickly remobilized by exposure to the oven heat and are separated into the second separation dimension. Precisely programmed movements of trap/release sequences of the LMCS cryotrap were used for allowing specific compounds to be transferred from the first to the second dimension separation space.

The injector was operated in splitless mode at 250 °C with an injection volume of 1.5 μL. The column set consisted of a 15 m×0.25 mm i.d., 0.25 μm film thickness (d_f) VF-5MS ^{1}D column (5 % phenyl–95 % dimethylpolysiloxane), connected to a 5 m×0.15 mm i.d., 0.15 μm film thickness (d_f), VF-17MS ^{2}D column (50 % phenyl–50 % dimethylpolysiloxane), both sourced from Agilent Technologies (Palo Alto, USA). Temperature program operation was used with an initial oven temperature of 100 °C held for 1 min, ramped at 20 °C/min to 160 °C, then ramped again at 5 °C/min to 205 °C and increased at 20 °C/min to 280 °C, then held at the final temperature for 1 min.

The first dimension separation was monitored by FID and used to determine the heart-cut regions, whereas the second dimension was coupled to the MS. The FID operated at 200 °C with a data acquisition rate of 20 Hz, and air, hydrogen, and make-up (N_2) flows were adjusted to 450, 40, and 45 mL/min, respectively. The MS transfer line was set at 280 °C. Pressures applied to the inlet and the DS were estimated with the DS calculator (Agilent Technologies) so as to fix an initial first dimension column flow at 1.0 and 2.0 mL/min in the second dimension. Final constant pressure conditions were set at 34.7 and 32.9 psi for the injector and the electronic pressure control of the Deans switch module, respectively. At 13.0 min, the injector pressure was reduced to 5 psi at 150 psi/min and held for 5 min to start the back flush process. No gas saver was activated during the entire chromatographic run, and thus, the split line was constantly flushed with 50 mL/min of carrier gas. For quantification, the molecular and fragment target ions of the five compounds were used in selected ion monitoring mode after electron impact ionization at 70 eV with the following *m*/*z* values: 182 and 105 (base peak) for BZP; 192 and 110 (base peak) for BZP-d_{10}; 196 and 195 (base peak) for 2-MeBZP; 196 and 119 (base peak) for 3-MeBZP; 196 and 119 (base peak) for 4-MeBZP; 203 and 126 (base peak) for 4-MeBZP-d_7. BZP-d_{10} was used as the internal standard (I.S.) for BZP and 2-MeBZP quantification within the first heart-cut, whereas 4-MeBZP-d_7 was used as the I.S. for 3-MeBZP and 4-MeBZP within the second heart-cut.

Sample preparation of müeslis samples

Eighty-two conventional and chocolate-based cereals packed in carton boxes were sampled from the Swiss market. Samples were extracted by PLE using an ASE 200 system (Dionex, part of Thermo Fisher Scientific, Sunnyvale, CA, USA). After grinding and homogenization of sample material, 5 g of a representative subsample was spiked with 150 μL of the I.S. solution at 20 mg/L (BZP-d_{10} and 4-MeBZP-d_7) and mixed together with 2.5 g of diatomaceous earth. The resulting mixture was introduced in a 22-mL stainless steel extraction cell containing a cellulose filter in the outlet and partly filled with some inert quartz sand. PLE was performed with acetonitrile at 40 °C at 1,500 psi during 10 min, including 5-min heating and 5-min extraction periods. The collected extract was possibly defatted with 15 mL of n-hexane over a period of 25 min if the initial sample's fat content was higher than 20 %. Otherwise, 1.5 μL of the resulting acetonitrile phase was directly injected into the MDGC-MS system without any further sample preparation.

Sample preparation of packaging samples

Cardboard discs of 2 cm in diameter were cut out of the packaging with a die cutter. Two discs were put together in the extraction cell and spiked with 150 μL of the internal standard mixture. The same extraction scheme as that used for the foodstuff samples was carried out.

Validation and quantification

To assess the quantification limits and the linearity of the developed method, a validation protocol based on the recommendations of the "Société Française des Sciences et des Techniques Pharmaceutiques" [29–31] and the European guidelines for performance criteria and validation procedures of analytical methods used in the control of food contact materials [32] was adapted to our specific requirements. The statistical treatment relied on an analysis of variance to determine the precision and trueness of the data over three nonconsecutive days. For this purpose, two kinds of samples were prepared: calibration samples (CAL), corresponding to standard solutions in MeCN and quality control samples (QCs), where the breakfast cereal matrix was spiked with the four benzophenonic compounds. Each day, four CAL at 10, 25, 100, and 300 μg/L, respectively (60, 150, 600, and 1,800 μg/kg matrix equivalents), were prepared in duplicate to establish the response function. A conventional linear regression using the least square method was applied. The linearity was calculated by fitting the back-calculated concentrations of the QCs as a function of the introduced concentrations. Four levels of QC fortified at 60, 150, 600, and 1,800 μg/kg were prepared in four replicates using a blank müesli blend sample. The precision of the method was determined by computing the relative standard deviations for repeatability (R_{RSD}) and for between-day variability expressed as the intermediate precision (IP_{RSD}) at each concentration level of the QC samples. Trueness, also expressed as a bias and defined as the closeness of agreement between the average value of series of test results and an accepted reference value, was determined by calculating the difference between the measured and theoretical concentration values. The final limit of quantification (LOQ) was set at a sufficiently low concentration in the QCs to both obtain a trueness and precision equal to 100±20 %. Finally, accuracy profiles were constructed by plotting concentration versus calculated bias with two-sided 95 % confidence limits.

Results and discussion

Sample extraction

Four major parameters influencing PLE, namely, solvent type, extraction time, pressure, and temperature, were evaluated on the basis of absolute recovery. Considering the widespread use and efficiency of dichloromethane and acetonitrile for extracting benzophenone derivatives from foodstuffs, only these two solvents and a mixture thereof (50:50, *v*/*v*) were evaluated. Indeed, a solvent selection study was previously performed by Shen et al. [10], who compared the extraction efficiency of several solvents (acetonitrile, dichloromethane, methanol, acetone, and n-hexane) for the isolation of photoinitiators including BZP from milk samples. The authors concluded that acetonitrile gave higher recoveries (10–30 % more) than those obtained with the other solvents. In the present case of pressurized liquid extraction, as exemplified in Fig. 2a, no significant difference were observed between the tested solvents. Therefore, acetonitrile was selected because of its higher innocuousness and superior boiling point, which reduces the possible loss of solvent vapors during PLE. In addition to 5 min heating time, several extraction times (from 5 to 30 min) using standard conditions (1,500 psi and 40 °C) were evaluated, and minor differences in extraction yields were observed (Fig. 2b). Pressure and temperature showed to have almost no influence on recovery; thus, the final operating conditions were 1,500 psi, 40 °C, and 5 min. According to these results, it was estimated that an optimization strategy by design of experiment was not meaningful. To limit introduction of fatty sample material into the GC, MeCN extracts were possibly defatted if the fat content of the initial sample was >20 % using 15 mL of n-hexane to shake out the lipophilic fraction over a period of 25 min.

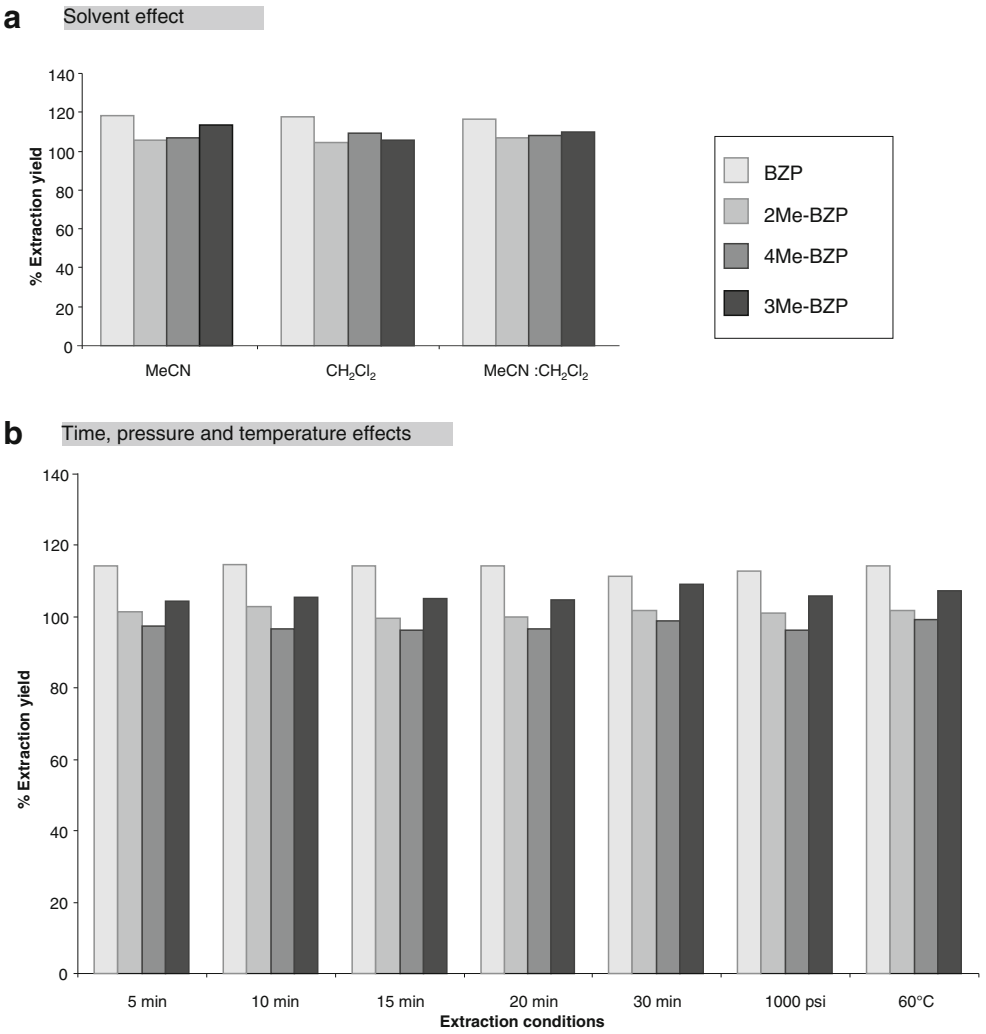

Fig. 2 Evaluation of PLE parameters: **a** solvent selection and **b** evaluation of time, pressure, and temperature with MeCN as extraction solvent

To assess the extraction conditions of benzophenone derivatives from cardboard packaging, the same parameters as those tested for food samples were evaluated on a packaging sample from an interlaboratory study [33] containing BZP and 4-MeBZP in its gloss varnish. When using the above-mentioned conditions, excellent recoveries were obtained when extracting these two residual photoinitiators from a paper-based packaging sample. The low *z*-score values (<1, with 4.42 and 5.08 mg/kg of cartonboard for BZP and 4-MeBZP, respectively; data not shown) confirmed the quality of the results.

Multidimensional GC-MS

Generally, to maximize peak capacity and exploit the full separation power during multidimensional operations, selectivity difference between both phases should be as elevated as possible. In this study, a nonpolar (5 % phenyl–95 % dimethylpolysiloxane) column was used as the first dimension, whereas a shorter and narrower support of mid-polarity (50 % phenyl–50 % dimethylpolysiloxane) was selected as second dimension. Both columns were linked by a Dean Switch valve, and the set-up integrated a modulated cryogenic trap positioned at the entrance of the second dimension column in order to trap and concentrate target components. The present strategy used two consecutive heart-cuts to transfer selected fractions from the first separation dimension to the second one for subsequent analysis. Selected heart-cutting windows were optimized in preliminary assays to ensure a complete transfer of analytes. As depicted in Fig. 3, BZP, 2-MeBZP, and their I.S. (BZP-d_{10}) were trapped (at −40 °C) together during the first cut (from 9.35 to 10.40 min) and released on the second dimension, whereas 3-MeBZP, 4-MeBZP, and their I.S. (4-MeBZP-d_7) were cold trapped during the second cut (from 10.95 to 12.40 min) and relaunched for further separation. Thus, two distinct cuts were produced, each containing its proper deuterated internal standard and allowing for accurate quantification. It is noteworthy to mention that satisfying chromatographic separation of isomeric 3-MeBZP and 4-MeBZ

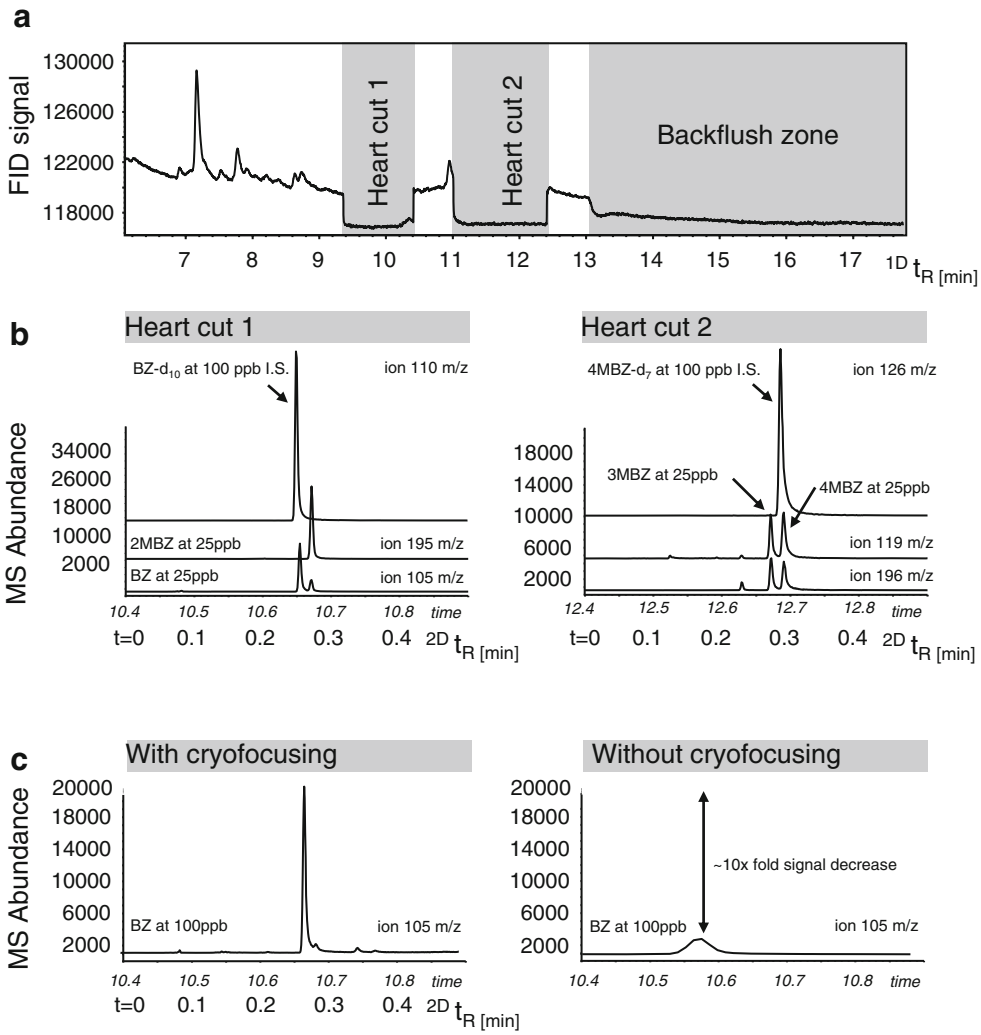

Fig. 3 Representative chromatogram surrogated with standards and IS. **a** Whole chromatogram. **b** Different heart cuts. **c** Cryofocusing effect

was achieved, each possessing the same target ions and thus cannot be distinguished by their mass spectrometric signals.

Owing to the cryotrapping step during the heart-cutting process, chromatographic peaks were efficiently refocused, increasing the peak-signal/noise ratios, which in turn markedly decreased the sensitivity threshold. Indeed, the strategy employed herein allowed signal enhancement without needing any additional concentration step during sample preparation, which may potentially generate loss of the volatile fraction (e.g., by evaporation). As demonstrated in Fig. 3c, it is noteworthy that the peak width at half height was reduced from 3 s to about 300 ms, leading to a signal/noise ratio enhancement by a factor >10. A similar approach demonstrating the benefit of the LMCS device for response amplification has recently been reported by Chin et al. [34].

Closely after the second heart-cut transfer (at 13 min, Fig. 3a), a backflush step consisting of reversing the carrier flow through the first dimension column to flush out the heavier compounds through the split line of the injector was programmed. For this, the mid-point pressure controlled by the Deans switch module was decreased to 5 psi. As a consequence, the final column temperature could be lowered, and column bleeding was reduced while slightly diminishing the chromatographic run time.

Quantification and method validation

As previously described, validation was carried out on four compounds using a specific internal deuterated standard for each heart-cut. Prior any analysis, a müesli blend used for QC preparation was tested to ensure that it was free from interfering contaminants. Four levels (k=4) of independent QC samples covering the entire validation range were prepared on three non-consecutive days in triplicate. Each QC sample was extracted and analyzed three times (n=3). Four CAL ranging from 10 to 300 μg/L (60–1,800 μg/L matrix equivalent) were prepared in acetonitrile in duplicate. In preliminary assays, several regression models were tested to select the most suitable and simple response function. Regardless of the compound tested, the best results were obtained using a $1/x$ weighted least square regression. Linearity was calculated by fitting the back-calculated concentrations of the QCs as a

Table 1 Validation data

Compounds	Theoretical concentration (μg/kg)	Found concentration (μg/kg)	Relative bias (%)	Repeatability (RSD %)	Intermiediate precision (RSD %)	Confidence interval (%)
BZP	60	67	+11.7	2.6	2.8	8
	120	125.4	+4.5	0.8	3.8	10
	600	588.6	−1.9	1.0	1.5	4
	1,800	1,733	−3.7	0.6	0.7	2
2-MeBZP	60	85.2	+44	1.2	2.2	8
	120	142.2	+19.1	0.7	1.7	5
	600	648	+8.1	1.1	1.1	3
	1,800	1,866	+3.7	0.4	1.0	3
3-MeBZP	60	66	+8.5	2	4.1	11
	120	129.6	+6.8	1.6	1.9	5
	600	666	+9.4	0.7	1.8	5
	1,800	2,046	+11.4	0.8	2	6
4-MeBZP	60	64.8	+7.7	1.7	3.8	10
	120	123.6	+4.7	1.6	1.9	5
	600	630	+4.5	1.1	1.2	3
	1,800	1,878	+4.1	1.1	1.0	2

function of the introduced concentrations. With coefficients of determination above 0.9998, assays were found to be linear for each analyte over the entire concentration range tested. The precision, representing random errors, was determined at four levels of QC concentrations and both R_{RSD} and IP_{RSD} values for all compounds were below 4.1 %, as shown in Table 1. Trueness, representing systematic errors, was expressed as the relative bias and generally varied between +19.1 and −3.7 %, except for 2-MeBZP for which it varied between +44 and +3.7 % (Table 1). Final LOQs were chosen at the lowest QC for which both trueness and repeatability were within the range 100±20 %. For food analysis, the limit of quantification was set at 60 μg/kg for BZP, 3-MeBZP, and 4-MeBZP, which is about ten times lower than their respective SML. The limit of quantification was raised to 120 μg/kg for 2-MeBZP as the lowest concentration level (60 μg/kg) did not

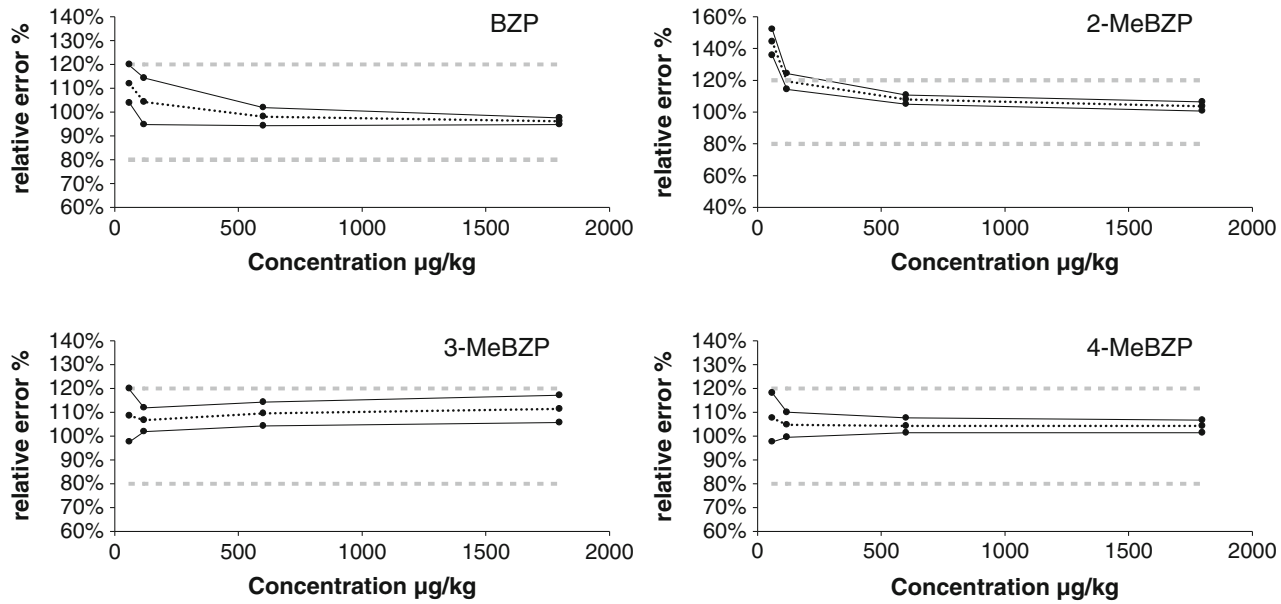

Fig. 4 Relative accuracy profiles obtained for the four benzophenonic compounds with a 1/*x* weight factor. The *continuous line* represents the bias, the *dashed lines* correspond to the upper and lower accuracy limits, and the *dotted lines* delimit the upper and lower 20 % tolerance bounds

fulfill acceptance limit requirements (relative bias=44 %). Overall, excellent validations results were obtained at the SML of 600 μg/kg (decision limit), confirming the applicability of this method for official controls of food products.

Accuracy profiles were constructed for each compound by computing the trueness and precision data over a graphic representation (Fig. 4), which confirmed the very satisfying validation results obtained.

Applications to real sample cases from the Swiss market

A survey of BZP derivatives in conventional and chocolate-based cereal products from the Swiss market was performed to assess the utilization of such photoinitiators in the food packaging area and their potential migration into foods. Eighty-two retail food samples packaged in printed cartonboard, eventually protected by a plastic layer, were selected. The analytical strategy consisted of first analyzing the food product and confirming the origin of contamination by subsequently analyzing the corresponding food contact material. Indeed, BZP or its derivatives are not prohibited substances in packaging but must not migrate above the regulated maximum concentration level in foodstuffs (SML).

This market investigation showed three noncompliant products, and BZP was the sole compound found in foodstuffs at a significant level (above the limit of quantification). This contaminant was found at concentrations ranging from 3.9 to 7.6 mg/kg, which corresponded to a concentration of up to nine times the SML value of 0.6 mg/kg. The related packaging analysis revealed BZP concentrations ranging from 250 to 500 mg/kg, proving food contamination by migration. These results suggest that about 1–2 % of BZP from the packaging is transferred into food samples.

In comparison, several cartonboard samples of compliant food samples were analyzed and showed typical benzophenone concentrations ranging from 5 to 7 mg/kg. Thus, a considerable contamination of foodstuffs is generally observed when the concentration in the corresponding packaging is high.

These severe contamination levels of benzophenone in food gave rise to European alerts through the RASFF system and confirm the safety concerns that may arise when volatile photoinitiators are used in permeable food packaging materials.

Conclusion

The developed MDGC-MS method was based on a heart-cutting approach allowing selective and unambiguous determination of BZP and three MeBZP derivatives in cereal samples and their cartonboard packaging. By integrating a cryotrapping step, compounds were efficiently focused before their release into the second dimension, allowing peak widths to be reduced by a factor of 10 compared to the analysis conducted without the focusing effect. This strategy not only decreased the background signal but also significantly improved the signal/noise ratios and limits of quantification. The latter permitted use of an automatable pressurized liquid extraction requiring no additional time consumption in the reconcentration steps. Moreover, the heart-cut approach preserved the lifetime of the second dimension analytical column by limiting sample transfer to the targeted zones only. Integration of the Deans switch module also served to back-flush poorly volatile compounds in the first dimension column once trapped compounds had been relaunched in the second dimension column. Fast separation of the critical isomeric pair formed by 3- and 4-MeBZP was achieved. Baseline resolution was required for accurate quantitative results as they cannot be distinguished by mass spectrometric signals. Moreover, good analytical performances were obtained in terms of linearity, precision, and accuracy, and the proposed method appeared to be suitable for determining benzophenone derivatives in cereal-based products during routine analysis for food control.

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