Determination of Potential Migrants in Polycarbonate Containers Used for Microwave Ovens by High-Performance Liquid Chromatography with Ultraviolet and Fluorescence Detection

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The determination of several compounds present in a commercial polycarbonate container intended to be used in microwave ovens which could be considered as potential migrants has been carried out by reversed-phase high-performance liquid chromatography (HPLC) with both ultraviolet (UV) and fluorescence detectors. Total dissolution with dichloromethane and polymer reprecipitation with methanol have been used to evaluate 100% potential migration as the worst case. The extract consisted of a complex mixture containing monomers, oligomers, UV stabilizers, antioxidants, degradation products, and other additives. Phenol, Bisphenol A, 2,4-di-*tert*-butylphenol, Cyasorb UV5411, bis(2-ethylhexylphthalate), Irganox 1076, and Irgafos 168 were identified by both retention times and fluorescence-to-UV ratios. Additional confirmation was achieved by HPLC with diode array detection and gas chromatography−mass spectrometry. Recovery percentages were in the range of 73.8−94.4%, the lowest one being for the antioxidant Irgafos 168 due to its transformation into the phosphate form and 2,4-di-*tert*-butylphenol. The concentrations of the studied analytes present in the polycarbonate container ranged between 0.9 and 240 μg·g^{-1}. The total dissolution conditions that may affect the final concentration of analytes, mainly Bisphenol A, are discussed.

KEYWORDS: Polycarbonate; additives; Bisphenol A; analysis; HPLC-UV-fluorescence; total dissolution

INTRODUCTION

Polycarbonate (PC) is frequently used in food storage containers including Tupperware, baby bottles, and kitchen appliances. Especially in reusable food recipients, additives and residual chemicals present in the polymer may be transferred to food by migration processes, which can be dangerous when containers are used for cooking or heating the food, for example, in the case of containers intended for microwave oven use. Although PC is a tough and durable plastic with good physical stability at high temperature, the migration of undesirable substances, even at trace levels, to the food is always possible.

Bisphenol A (BPA), the monomer from which PC is made, exhibits estrogenic activity as stated by different authors (*1*−*3*). The release of significant quantities from PC flasks during autoclaving (*1*), epoxy can coatings (*2, 4*), canned foods or drinks (*5, 6*), resin-based composites used in dentistry (*3, 7*), and plastics in which BPA is used as stabilizer or antioxidant (*8*−*10*) has been reported.

In the scientific literature, most of the analysis of potential migrants into foodstuffs from PC containers is focused on BPA

using high-performance liquid chromatography (HPLC) by means of fluorescence (*11*−*14*), electrochemical (*15, 16*), or mass spectrometry detectors (*5*) and gas chromatography−mass spectrometry (GC-MS) (*17*). Very few references deal with the simultaneous determination of BPA and other compounds present in PC plastics, and none of them studies PC for microwave uses. A limited set of relevant compounds such as phenol, *p-tert*-butylphenol, 4-(1,1,3,3-tetramethylbutyl)phenol (*15, 18*−*20*), Irganox 1010, and Cyasorb UV5411 (*21*) have been analyzed in PC containers by HPLC.

The present work is focused on both the identification and quantification of several compounds present in a commercially available PC container used for microwave applications that could act as dangerous potential migrants to food (*22*). To evaluate the real concentration of substances, total dissolution with dichloromethane has been applied to the plastic, and after reprecipitation of the polymer with methanol, compounds have been analyzed by HPLC with both ultraviolet (UV) and fluorescence (F) detection. The separation conditions necessary to obtain the maximum number of unknown peaks in the chromatogram have been optimized. The detected compounds have been identified as additives such as UV stabilizers (Cyasorb UV5411), primary (Irganox 1076) and secondary antioxidants

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(Irgafos 168), plasticizers (DOP), residual monomers from the PC production (phenol and BPA), and degradation products of additives [tris(2,4-di-*tert*-butylphenyl)phosphate and 2,4-di-*tert*-butylphenol, resulting from the oxidation and hydrolysis of Irgafos 168, respectively]. Stability studies of the analytes have been performed and degradation percentages have been evaluated to get the concentration of the analytes in the plastic. In this way, the potential specific migration to food has been calculated by comparing these values with the established specific migration limits (SML) from the European legislation.

EXPERIMENTAL PROCEDURES

Chemicals. The following compounds, which can be likely found in PC containers as monomers, additives, or degradation compounds, were selected: phenol, 4,4′-isopropylidenediphenol (BPA), BPA diglycidyl ether (BADGE), BPA bis(3-chloro-2-hydroxypropyl)ether (BADGE-2HCl), 2,4-di-*tert*-butylphenol, 2-hydroxy-4-methoxybenzophenone (Cyasorb UV9), 2,4-dihydroxybenzophenone (Uvinul 400), 2,2′-dihydroxy-4,4′-dimethoxybenzophenone (Cyasorb UV12), and 2,2′-dihydroxy-4-methoxybenzophenone (Cyasorb UV24) were from Aldrich (Madrid, Spain); bis-2-ethylhexylphthalate (DEHP), *tert*-butyl-4-hydroxyanisole (BHA), 2,6-di-*tert*-butyl-*p*-cresol (BHT), and 3,5-di-*tert*-butylhydroxyanisole (B-BHA) were from Fluka Chemika (Madrid, Spain); 2-(2-hydroxy-3-*tert*-butyl-5-methylphenyl)-2*H*-5-chlorobenzotriazole (Tinuvin 326), 2-hydroxy-4-*n*-octyloxybenzophenone (Chimassorb 81), 2-(2-hydroxy-3,5-di-*tert*-butylphenyl)-5-chlorobenzotriazole (Tinuvin 327), pentaerythritol tetrakis[3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propionate] (Irganox 1010), 2-(2-hydroxy-5-methylphenyl)-benzotriazole (Tinuvin P), octadecyl-3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-propionate (Irganox 1076), and tris-(2,4-di-*tert*-butylphenyl)phosphite (Irgafos 168) were courtesy of Ciba-Geigy, Additives Division (Barcelona, Spain); 2-(2′-hydroxy-5′-*tert*-octylphenyl)benzotriazole (Cyasorb UV5411) was from Sigma (Madrid, Spain); and 1,1,3-tris(2-methyl-4-hydroxy-5-*tert*-butylphenyl)butane (Topanol CA) was from ICI España S.A. (Barcelona, Spain). Silanized glass wool was from Supelco (Madrid, Spain); 0.45 and 0.22 μm pore size PTFE syringe filters were from Teknokroma (Barcelona, Spain). Standard stock solutions of suitable concentrations were prepared without further purification in dichloromethane, and they were gravimetrically controlled in all cases.

Solvents used were dichloromethane, SupraSolv quality, from Merck (Darmstadt, Germany), and methanol and acetonitrile HPLC grade from Scharlab (Barcelona, Spain). Water was obtained from a Milli-Q system from Millipore (Madrid, Spain). The gases required for the study (nitrogen, synthetic air, and helium, all of them of C-50 quality) were supplied by Carburos Metálicos (Zaragoza, Spain).

The sample under study was a PC commercial container used for microwave oven applications and supplied by a producer company.

Apparatus. The HPLC system was a Hewlett-Packard 1050 (Palo Alto, CA), equipped with a quaternary pump, an automatic injector, and a variable wavelength UV detector set at 280 nm, output range 0.1 AU, attenuation 64 (except 4 AU and 256, respectively, between 14 and 21 min), and a Waters 474 scanning fluorescence detector (λ_{exc} = 285 nm, λ_{ems} = 300 nm). The column was a Waters XTerra C-18, reversed-phase, 5 μm, 10 cm × 4.6 mm i.d. Temperature was set at 25 °C with a Kontron oven controller 480. Mobile phase (1 mL·min^{-1}) consisted of a water/acetonitrile binary mixture as follows: 75:25 (v/v) during 5 min, then linear gradient up to 2:98 at 50 min, kept for 30 min. Injection volume was 20 μL. Chromatographic data were collected and processed on a compatible computer with Waters Millenium^{32} software, version 3.2

Qualitative analysis was performed in a Hewlett-Packard HPLC 1100 series, equipped with a quaternary pump, an automatic injector, and a diode array detector, using the same column and chromatographic conditions as above, and a Hewlett-Packard 6890 gas chromatograph equipped with a 5973 mass-selective detector and an SGL-5 (60 m × 0.25 mm, 0.25 μm film thickness) capillary column from Sugelabor, with helium as carrier (constant flow mode, 1 mL·min^{-1}), the temperature program being as follows: initial temperature, 45 °C, held for 5 min, then raised at 5 °C·min^{-1} to 320 °C, and held for 10 min.

Total Dissolution Procedure. One gram of the PC material previously cut into small pieces (~0.5 cm²) was weighed and transferred to a 250 mL round flask. FIfty milliliters of dichloromethane was added, and the sample was shaken with magnetic stirring to avoid adhesion of the polymer to the flask, until dissolution was complete, which required ~35 min. Then, 75 mL of methanol was added with vigorous hand shaking to reprecipitate the polymer. Solution was filtered under vacuum through silanized glass wool, and the flask was rinsed with three additional methanol fractions of 15 mL. The extract was concentrated in a rotary evaporator up to ~1 mL, and, after sonication for 4 min to remove precipitate from the flask walls, it was filtered through 0.45 and 0.22 μm filters.

To calculate process recovery as well as to check any possible degradation, the same analytical procedure was applied to a dichloromethane solution containing 50, 100, or 1500 μg·g^{-1} (depending on the compound) of the analytes under study. Calibrations by external standard method in all cases after the calculation of recovery percentages were made with methanol solutions of the compounds, which were always gravimetrically controlled.

RESULTS AND DISCUSSION

Chromatographic Separation and UV—Fluorescence Detection. Plastic composition is in most cases very complex, so the first aim was to identify as many analytes as possible in the PC extracts. Because most of the compounds are phenol derivatives, wavelengths were set at 280 nm (UV) and 285 nm for excitation and 300 nm for emission (fluorescence) to get the best signal-to-noise ratio, expressed as the total area of the chromatogram when the number of detected peaks was maximum. Then, preliminary work under isocratic conditions with binary mixtures of water/acetonitrile as mobile phase was performed, using reversed-phase HPLC conditions listed under Experimental Procedures. In this case, when the water content was >85% (v/v) the most apolar compounds were not eluted from the column, even when using up to 3 h per run. Further studies were done in gradient mode, and after fine-tuning, the optimum conditions reached were those described under Experimental Procedures.

Figure 1 shows the chromatogram obtained from the PC extract under the optimum separation conditions. It can be seen that peaks eluted at 15.2 and 18.5 min saturate the detector. So, for accurate retention time assignation, peak area calculation, and UV spectra acquisition in the HPLC diode array chromatograph, the sample was 100-fold diluted with methanol. Its reinjection in this system gave only two peaks at expected retention times, and consequently no coelution of other compounds was noticed.

Then, a mixture of 22 standards (50 μg·g^{-1} each in methanol) of compounds likely present in this type of materials was analyzed by HPLC under the same conditions. **Figure 2** shows the chromatograms obtained with both UV and fluorescence detection.

Identification. Because the specificity of the UV detector is low, qualitative information given is very limited. BPA and its related compounds are fluorescent (*12*), so a second fluorescence detector was connected in series. In this way, besides the clear advantage of having two independent acquisition channels, additional useful information from the qualitative point of view can be obtained, such as the fluorescence to UV absorbance intensity ratio. This mathematical tool has been already used by different authors on polymer additives studied by HPLC: the ratio of UV absorbance at two wavelengths and the ratio of UV absorbance to refraction index response (*23*) or to light scattering response (*24*) in qualitative analysis. As mentioned, these ratios depend on the chemical structure of the compounds and may be used together with retention time values for

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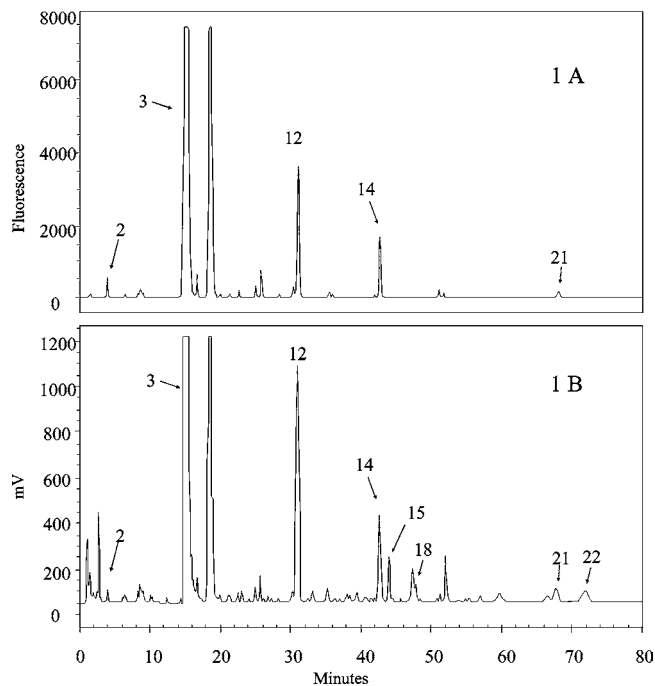
Figure 1. Fluorescence (A) and UV (B) chromatograms of the PC extract in methanol under optimized HPLC conditions. See **Table 1** for peak identity.
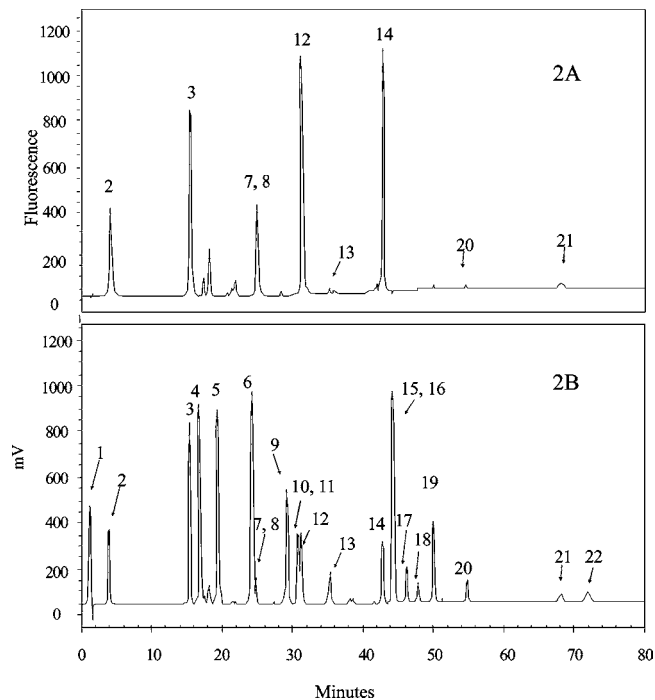
Figure 2. Fluorescence (A) and UV (B) chromatograms of the 22 standards mixture in methanol under optimized HPLC conditions. See **Table 1** for peak identity.

identifying the compounds as well as for detecting overlapped peaks. **Table 1** shows retention times, UV absorption characteristics, and fluorescence ($\lambda_{exc} = 285$ nm, $\lambda_{ems} = 300$ nm) to UV absorbance (280 nm) ratio for each standard. As could be expected, BPA and to a lesser extent, 2,4-di-*tert*-butylphenol, BADGE, BADGE-2HCl, and Topanol CA are more sensitive in fluorescence detection. This fact can be explained from a study of the chemical structure of all the additives under study, because BPA and 2,4-di-*tert*-butylphenol are rigid molecules and, consequently, they show higher fluorescence performance.

Table 1. Retention Times, Ultraviolet Absorption Characteristics, and Fluorescence-to-UV Ratios of the 22 Analyzed Standards

compound	retention time (min)	max UV λ (nm)	UV/F ratio[a]	peak
Cyasorb UV12	1.1	192, 216, 310, 360		1
phenol	3.9	192, 212, 270	2.4	2
BPA	15.3	198, 228, 278, 286	15.8	3
Uvinul 400	16.6	196, 242, 286, 323		4
Cyasorb UV24	19.2	194, 215, 238, 286, 330		5
Cyasorb UV9	24.1	215, 242, 288, 324		6
BADGE-2HCl	24.6	196, 230, 277, 284	4.2	7
BADGE	25.8	198, 230, 277, 284	4.2	8
Tinuvin P	29.1	196, 216, 242, 298, 337		9
DBP	30.8	197, 224, 274		10
B-BHA	30.8	198, 228, 287		11
2,4-di-*tert*-butylphenol	31.1	198, 224, 276	5.0	12
BHT	35.3	200, 220, 278	0.1	13
Topanol CA	42.8	200, 236, 283	4.8	14
Cyasorb UV5411	44.1	205, 242, 298, 350		15
Chimassorb 81	44.1	192, 240, 288, 318		16
Tinuvin 326	46.2	210, 250, 312, 345		17
DOP	47.8	198, 223, 275		18
Tinuvin 327	49.9	214, 250, 312, 350		19
Irganox 1010	54.7	204, 230, 276	0.1	20
Irganox 1076	68.0	200, 230, 276	0.1	21
Irgafos 168	72.0	199, 226, 271		22

[a] Fluorescence attenuation acquisition was set at 256 for BPA and at 64 for the other compounds.

The use of a diode array detector also provides a powerful tool for identification purposes, mainly if coelution is suspected, because a comparison of UV spectra from standards and analytes can confirm or reject a suspicious peak identity. In this sense, **Figure 3** shows the UV spectra of every peak labeled in the sample overlaid with the UV spectra of the surrogate eluted at the same retention time. According to this, the following compounds were without any doubt detected: phenol, BPA, 2,4-di-*tert*-butylphenol, Cyasorb UV 5411, DOP, Irganox 1076, and Irgafos 168. As can be also seen, peaks at 1.1 and 35.3 min, which could be identified as Cyasorb UV12 and BHT, respectively, were rejected, because their UV spectra did not match those of corresponding standards. Moreover, the peak at 44.1 min coinciding with Cyasorb UV5411 and Chimassorb 81 was definitively Cyasorb UV5411. Finally, peaks at 16.6 and 30.8 min that could be identified as Uvinul 400 and DBP or B-BHA, respectively, were not because of their lack of fluorescence response.

Confirmation by GC-MS. The presence of BPA, 2,4-di-*tert*-butylphenol, Cyasorb UV5411, DOP< and Irganox 1076 was additionally confirmed by GC-MS detection. Irganox 1076 was eluted near the practical temperature limit of the column (~320 °C), whereas Irgafos 168 and Topanol CA were not found by this technique because of their intrinsically low volatility.

Analytical Features. Linear range and detection and quantification limits of the identified compounds using both UV and fluorescence detection techniques are shown in **Table 2**.

Detection and quantification limits were expressed as the equivalent concentration to the average signal of background noise plus 3 and 10 times, respectively, the standard deviation of the background noise. Besides their intrinsic sensitivities, Irganox 1076 and Irgafos 168 had the highest detection and quantification limits because their later elution implies higher peak broadening in comparison with the rest of compounds. It was observed that the relationship within detection limits of both detection techniques does not correspond to the response ratio in **Table 1**. This can be attributed to background noise,
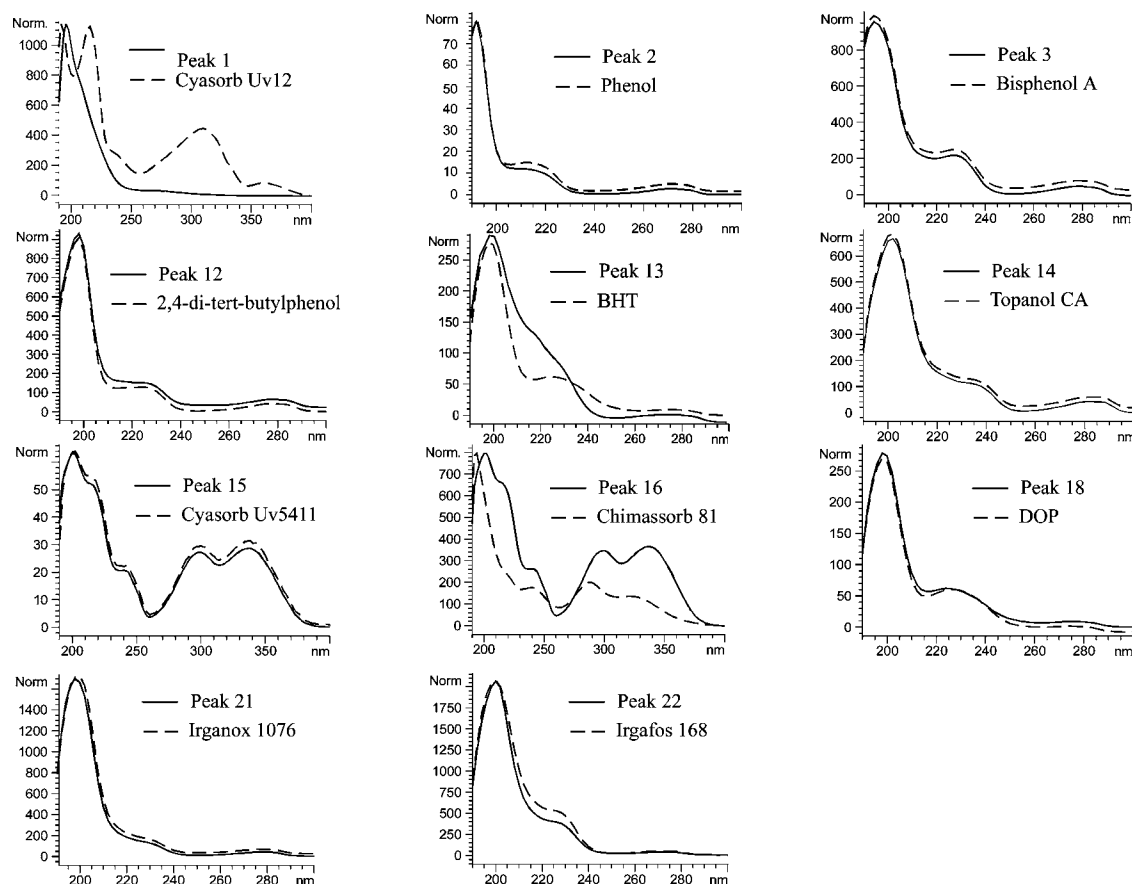
Figure 3. Overlay plot of UV spectra of unknown peaks present in the PC extract from **Figure 1** and those of the likely surrogates from **Figure 2**.

Table 2. Linear Ranges and Detection and Quantification Limits of the Identified Compounds with both UV and Fluorescence Detection

compound	detection	linear range (μg·g^{-1})	linearity (R^2)[a]	detection limit (μg·g^{-1})	quantification limit (μg·g^{-1})
phenol	UV	0.6–120	0.9998	0.2	0.6
	fluorescence	1–120	0.9975	0.3	1
BPA	UV	$(0.3–3) \times 10^4$	0.9855	0.09	0.3
	fluorescence	$(0.1–3) \times 10^4$	0.9890	0.04	0.1
2,4-di-*tert*-butylphenol	UV	0.5–145	0.9982	0.2	0.5
	fluorescence	0.2–145	0.9983	0.07	0.2
Topanol CA (IS)	UV	30–150	0.9993	*b*	*b*
	fluorescence	30–150	1.0000	*b*	*b*
Cyasorb UV5411	UV	0.1–130	0.9983	0.04	0.1
	fluorescence	NA[c]	NA	NA	NA
DOP	UV	0.7–120	0.9935	0.2	0.7
	fluorescence	NA	NA	NA	NA
Irganox 1076	UV	3–300	0.9989	1	3
	fluorescence	110–300	0.9911	33	110
Irgafos 168	UV	6–220	0.9957	2	6
	fluorescence	NA	NA	NA	NA

[a] Five calibration points. [b] Detection limit and quantification limit were not obtained for the internal standard, Topanol CA. [c] NA = not applicable.

whose influence over the detection limit is stronger than the response itself.

Taking into account the established SMLs in the European legislation for BPA, Irganox 1076, and DOP (3, 6, and 3 μg·g^{-1} of food, respectively), the detection and quantification limits provided are appropriate except for Irganox 1076, for which the quantification limit is next to the corresponding SML.

Recovery Studies. As the compounds under study have very different structures it was difficult to find only one internal standard representative of all of them. For this reason only one compound was chosen to evaluate eventual losses during the process and irreproducibility of injection. The proposed internal standard Topanol CA showed an excellent behavior; a recovery

of 96.0 ± 3.3% was obtained in 13 independent analyses. Nevertheless, it could not be used in PC extracts due to the coelution with an unknown compound as will be explained later.

As shown **Table 3**, recoveries of the analytes are >70% in all cases. Irgafos 168 (secondary antioxidant) shows the lowest value because this additive degrades during the applied process to 2,4-di-*tert*-butylphenol and its oxidized form, tris(2,4-di-*tert*-butylphenyl)phosphate, which has been confirmed by other authors (*25*, *26*). In this study, a linear relationship between the percentage of losses of the Irgafos 168 and the peak area of both derivatives was calculated, with regression coefficients (R^2) of 0.924 for the phosphate and 0.933 for 2,4-di-*tert*-butylphenol. On the other hand, the same process for Irganox 1076 (primary

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Table 3. Recovery Percentages

compound	recovery percentage	concn level (μg·g^{-1})
phenol	94.4 ± 1.7	50
BPA	74.9 ± 7.7	1500
2,4-di-*tert*-butylphenol	93.7 ± 5.9	100
Topanol CA	96.0 ± 3.3	100
Cyasorb UV5411	92.7 ± 6.5	50
Irganox 1076	88.0 ± 6.3	50
Irgafos 168	73.8 ± 10.0	100
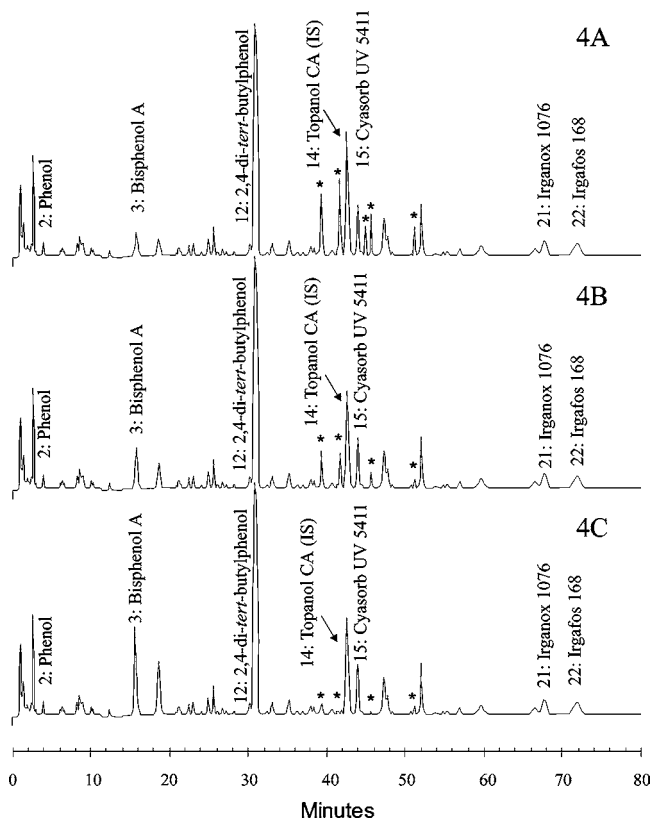
Figure 4. HPLC chromatograms of the same PC extract as in **Figure 3** along the time: (A) PC extract immediately injected; (B) the same, injected 2 days later; (C) the same, injected 4 days later. UV detection at 280 nm. Output range = 0.1 AU (except 4 AU from 14 to 21 min). * indicates peaks whose decrease was noted along the time.

antioxidant) did not provide detectable degradation products at the concentration tested (50 μg·g^{-1}).

Quantitative Analysis. Several relevant behaviors have to be taken into account before the quantification of the analytes in the PC sample:

First, the disappearance of several unidentified peaks in the PC extract chromatogram with time was noticed, as can be seen in **Figure 4**, where the comparison of the chromatograms obtained when the same PC extract was immediately analyzed as well as 2 and 4 days later, after room temperature storage. In this way, the presence of precipitate strongly adhered to the vial walls, with no redissolution or reappearance of peaks even when shaken by ultrasonic bath for 5 min, was observed. Consequently, a clear conclusion is that sample extracts must be analyzed as soon as they are available to avoid erroneous results, because final solutions are not completely stable even when being stored at 5 °C. Besides, the fast disappearance of one of the compounds present in the PC extract and coelution at the retention time of Topanol CA gave erroneous values when

quantification of analytes by internal standard was done. Therefore, despite its excellent behavior in recovery studies, this internal standard was not considered in the quantitative study.

An important contamination of DOP was observed in all of the analyses, which could be attributed to the contribution of plastic syringes, fittings, glass wool, and other common materials used in the laboratory. Unfortunately, this contamination could not be eliminated even when all of the materials were washed exhaustively and high-quality solvents were used. The ubiquity of phthalates has been already described in other papers (*27, 28*). For this reason, DOP concentration could not be accurately determined.

It was also observed that the peak corresponding to BPA increased with time and, simultaneously, the peaks above-mentioned decreased. Although methanol has been commonly used as an extracting solvent for PC samples by different authors (*29−31*), the most likely cause is that these unidentified peaks were oligomers of PC which were affected by the methanol present in the final solution. In this way methanol seems to decompose PC and/or its oligomers generating free BPA, as mentioned by Hu et al. (*32*), under controlled methanolysis conditions. These authors have reported up to 96% depolymerization with a 1:1 mixture of methanol/toluene at 60 °C for 70 min, with 8.5% mol of NaOH per ester unit of PC. Nevertheless, there are two important differences between this reference and the present work: (a) The extraction (dissolution/reprecipitation) conditions are much softer (room temperature or 40 °C at reflux temperature) excluding methanol until the polymer is completely dissolved, and (b) the contact of reprecipitated PC−methanol is reduced to several minutes, just the time needed for a vigorous hand shaking of the flask and its filtration through glass wool. From this moment (∼5 min), only the remaining dissolved polymer (only the quantity limited by its−reduced−solubility in the mixture DCM−methanol) is subjected to degradation. Therefore, assuming that methanol degrades PC and that this effect is temperature dependent, as the results demonstrate, the estimation on the degradation extension is no higher than 5%, because, according to the same authors, PC with only methanol and NaOH as catalyzer gives only 7% degradation after 330 min at 60 °C. In any case, and for this reason, it is extremely important to analyze the solution of the polymer as soon as it has been prepared, as already commented.

To check this point, the extraction procedure was repeated at reflux temperature by fitting a Vigreux column to the round flask. In this case, higher values of BPA were obtained, showing that differences of free BPA measured in the PC extract can be unmistakably attributed to the effect of temperature increase. **Table 4** shows the quantitative values obtained for the PC sample subjected to both total dissolution procedures, taking into account the correction due to the recovery values. Very significant differences were found between them, especially for BPA, the concentration of which at reflux temperature was up to 400 times the values obtained at room temperature. Thus, results obtained using the total dissolution procedure with reflux cannot be considered real and are attributed to the decomposition of the PC with temperature and solvent. The same reason could be given for the differences found for phenol and 2,4-*tert*-butylphenol.

As can be seen, most of the compounds are below 240 μg·g^{-1} of plastic, which is of the same order of magnitude as the concentrations of additives added to plastics in contact with food.

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Table 4. Quantification Results and Comparison with SML for Total Dissolution–Reprecipitation at both Room and Reflux Temperatures

compound	concn (μg·g^{-1} of PC), room temp	concn (μg·g^{-1} of PC), reflux temp	concn (mg·dm^{-2} of PC), room temp	potential migration[a] (μg·g^{-1} of food)	RSD[b] (%)	SML (μg·g^{-1} of food)
phenol	0.9	3.5	0.03	0.19	13	
BPA	30	13100	1.1	6.5	14	3
2,4-di-*tert*-butylphenol	76	100	2.7	16	18	
Cyasorb UV5411	19	19	0.68	4.1	7	
Irganox 1076	20	15	0.72	4.3	13	6
Irgafos 168	240	142	8.6	52	10	

[a] Potential specific migration values calculated on the basis of 6 dm^2 plastic surface to 1 kg of food, room temperature   [b] Results obtained for six independent analyses.

The concentration value for BPA (30 μg·g^{-1} of PC) in the PC container used for microwave ovens is comparable to the results found for PC containers in other publications (*11*, *12*, *14*, *15*). The value obtained at reflux temperature (13100 μg·g^{-1}) is more related to the content in plastic materials when BPA is added as a stabilizer additive (*9*, *14*).

According to the philosophy of this work, assuming a 100% migration and considering that the analyzed PC containers have an average weight-to-surface ratio of ∼36, the potential migration of these compounds is given in **Table 4**. As can be seen, the calculated potential specific migration for BPA is approximately double the SML. Because methanol can overestimate the real value due to the possible degradation of the PC matrix, these results should be taken into account in further studies, and migration tests would be recommended to confirm if the real migration is similar to the potential one.

Further work will be focused on determining the real migration of the identified compounds and especially of BPA to establish whether its value actually exceeds the SML. In any case, due to these results, the PC containers under study have been preventively withdrawn from the market by the producing company.

SAFETY

Phenol is a systemic poison and constitutes a serious health hazard. The risks of using it in the laboratory must be fully assessed before work begins. It is a vesicant, TLV 5 ppm. Acute poisoning by ingestion, inhalation, or skin contact may lead to death; it is readily absorbed through the skin and highly toxic by inhalation, and it causes burns. As personal protection, safety glasses, gloves, and good ventilation should be used. **BPA**, **BADGE,** and **BADGE-2HCl** are estrogenically active and can cause both eye and skin irritation; prolonged or repeated skin contact should be avoided. **DOP** may be harmful if swallowed or inhaled and causes irritation to skin, eyes, and respiratory tract; it affects the central nervous system, liver, reproductive system, and gastrointestinal tract; it is a possible cancer hazard and may cause cancer on the basis of animal data; risk of cancer depends on duration and level of exposure; DOP may cause adverse reproductive effects. **Dichloromethane** can cause gastrointestinal irritation, nausea, vomiting, and diarrhea; excessive inhalation of vapors can cause nasal and respiratory irritation, central nervous system effects including dizziness, weakness, fatigue, nausea, headache, possible unconsciousness, and even death. It is irritating for both skin and eyes. Resistant gloves and splash goggles should be worn. **Methanol** is a flammable liquid and may cause skin irritation and central nervous system depression; it may be absorbed through the skin and may cause kidney damage and respiratory and digestive tract irritation. Methanol may be fatal or cause blindness if swallowed and may cause fetal effects. It causes severe eye irritation and possible injury. Target organs include the kidneys, central nervous system, and eyes. **Acetonitrile** may cause nose and throat irritation, flushing of the face, tightness in the chest, cough, nausea, vomiting of blood or bile, dizziness, rapid respiration, headache, drowsiness, hypotension, paralysis, rapid pulse, shock, unconsciousness, and death.

The rest of the additives do not require special handling or protection measures different from those habitual for other chemical products.

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