Journal of Liquid Chromatography & Related Technologies, 35:1102–1113, 2012

ISSN: 1082-6076 print/1520-572X online
DOI: 10.1080/10826076.2011.615098

Taylor & Francis
Taylor & Francis Group

CONFIRMATION OF THE ABSENCE OF BISPHENOL A IN COPOLYESTERS BY POLYMER HYDROLYSIS IN COMBINATION WITH LC-MS/MS AND LC-FLD

Curtis D. Cleven, Warren A. Jackson, Amanda S. Watts, Joshua A. Tyhurst, and Shelley R. Porter

Eastman Chemical Company, Kingsport, Tennessee, USA

□ *A method was developed to validate that certain polyester and copolyester resins do not contain bisphenol A (BPA). This method satisfies the need for a timely screening method that can be utilized on a timescale that is appropriate for a laboratory in a manufacturing facility. This was accomplished by hydrolyzing the polymer and then analyzing the hydrolysate by either liquid chromatography-tandem mass spectrometry (LC-MS/MS) or liquid chromatography-fluorescence detection (LC-FLD). A hydrolysis procedure offers the unique advantage of a faster sample preparation step as compared to extraction procedures. The hydrolysis was complete after 20 min and the procedure was fully automated with the use of an autosampler. By hydrolyzing the polymer, total BPA is measured rather than only extractable monomeric BPA. Copolyester samples were purposely spiked with polycarbonate to validate the method. The detection limit for the LC-MS/MS method was 0.8 mg kg^{-1} in the polymer, while the detection limit for the LC-FLD method was 2.6 mg kg^{-1} in the polymer.*

Keywords bisphenol A, copolyesters, free BPA, hydrolysis, LC-FLD, LC-MS/MS, total BPA

INTRODUCTION

A number of analytical methods have focused on determining the amount of extractable bisphenol A (BPA) in polymers. These methods involve extracting the free BPA from various matrices via solvent extractions,[1–4] thermal desorption,[5–7] or dissolution.[8–10] Some methods use solid phase extraction (SPE)[2,3,10–16] or solid-phase microextraction (SPME)[1,17] as a pre-concentration step. The concentration of the extracted BPA can then be determined using a variety of analytical techniques.[18] Most of these approaches involve either gas or liquid

Address correspondence to Curtis D. Cleven, P.O. Box 431, Eastman Chemical Company, Kingsport, TN 37662, USA. E-mail: cdcleven@eastman.com

chromatography. Methods involving gas chromatography are typically performed in conjunction with mass spectrometry,[1–8,15–17] while liquid chromatography methods often utilize ultraviolet absorption,[9] fluorescence,[9,10] electrochemical,[19–21] or mass spectrometry[11–13] detectors.

Brand owners, original equipment manufacturers, and molders are requesting analytical testing to validate that polyester (or copolyester) resins and articles produced from these polyesters do not contain BPA. With this growing trend, there is a need for a method designed for screening polyester resins. Methods based upon extraction are dependent upon the diffusion rate through the various polymers as well as the experimental conditions (solvent, temperature, time). Also, the limited surface area of hard resin pellets is not particularly favorable for a timely extraction. Moreover, the long (hours or days) timescale required to perform an extraction is not adequate to support a polyester manufacturing facility. This paper looks at a more exhaustive and faster approach whereby the polymer is subjected to base hydrolysis. Any resulting BPA is then measured as "total BPA." Total BPA (BPA_t) is defined herein as the total amount of BPA present in a sample, no matter if the BPA molecules were in the extractable monomeric form or if they were polymerized into the backbone of the polymer.

For polyesters, a method was developed to determine the BPA_t rather than simply the free extractable BPA. By utilizing hydrolysis, the sample preparation could be easily automated and easily performed on a timescale which is practical for a quality control laboratory at a manufacturing facility. This method was demonstrated with Eastman Tritan copolyester, which is not manufactured from BPA. To measure the BPA_t, the polymer was hydrolyzed to its monomeric components. This hydrolysate was analyzed by either liquid chromatography-tandem mass spectrometry (LC-MS/MS) or liquid chromatography-fluorescence detection (LC-FLD). These methods have their own advantages for quantifying BPA in the hydrolysate. LC-MS/MS offers high selectivity to eliminate the possibility of false positives while LC-FLD offers ease of use and cost effectiveness.

MATERIALS AND METHODS

Reagents and Standards

Methanol (high purity, >99.99%), acetonitrile (high purity, >99.99%), and dimethyl sulfoxide (DMSO high purity, >99.9%) were purchased from Honeywell Burdick and Jackson (Morristown, NJ, USA). Purified water was generated by a Milli-Q system manufactured by Millipore (Billerica, MA,

USA). The bisphenol A standard was obtained from Sigma-Aldrich Chemical (St. Louis, MO, USA). Tetramethylammonium hydroxide (TMAH) reagent (25% w/w in methanol) was purchased from Reagents Inc (Nashville, TN, USA). The Eastman Tritan copolyester samples were production samples from Eastman Chemical Company (Kingsport, TN, USA).

Preparation of Standards

In the LC-MS/MS laboratory, stock solutions were prepared in DMSO. The BPA standards were prepared via serial dilutions at concentrations of $10\,\mu g\,l^{-1}$, $25\,\mu g\,l^{-1}$, $50\,\mu g\,l^{-1}$, $100\,\mu g\,l^{-1}$, $250\,\mu g\,l^{-1}$, $500\,\mu g\,l^{-1}$, and $1000\,\mu g\,l^{-1}$. In the LC-FLD laboratory, stock solutions were prepared in acetonitrile, and serial dilutions were used to create concentrations of $25\,\mu g\,l^{-1}$, $50\,\mu g\,l^{-1}$, $100\,\mu g\,l^{-1}$, and $1000\,\mu g\,l^{-1}$. The choice of diluents did not affect the calibrations.

Hydrolysis

A Leap COMBI-Pal autosampler (Carrboro, NC, USA) was utilized for the automation of sample hydrolysis and injection. The autosampler was placed in a hood so as to minimize the odors from the reagents. Polyesters were hydrolyzed with the use of solvent, heat, and a base. To hydrolyze the samples, a hydrolysis reagent was prepared by mixing the purchased TMAH reagent with DMSO (40/60 volume/volume). Five milliliters of this mixture were added to 0.1 g of polymer. Five additional milliliters of DMSO were added and the mixture was agitated and heated at 121°C for 15 min. After the heating procedure, the hydrolyzed sample and solution were quenched with 5 mL of 30% acetic acid (in DMSO, volume/volume) and allowed to cool. This hydrolysate sample was analyzed.

Preparation of Thin Films for Precision and Accuracy Experiments

To validate the method, thin films were made by deliberately spiking polycarbonate into Eastman Tritan copolyester. First, a blank was made by extruding a film of only Tritan polymer. Then, varying amounts of polycarbonate were mixed with Tritan so that hydrolysis would yield sample concentrations of bisphenol A of $1\,mg\,kg^{-1}$, $5\,mg\,kg^{-1}$, $10\,mg\,kg^{-1}$, and $100\,mg\,kg^{-1}$. The polymers were mixed by solvent casting a polycarbonate solution (in tetrahydrofuran) onto the Tritan pellets. The polymer mix was then extruded into thin films. The extrusion was performed at 285°C on a

Killion (Pawcatuck, CT, USA) 1 inch extruder outfitted with a Maddock screw.

Liquid Chromatography-Tandem Mass Spectrometry

The samples were analyzed using LC-MS/MS. The chromatographic separation was achieved using a HP Series 1100 liquid chromatograph (Santa Clara, CA, USA), which was fitted with an Agilent Zorbax Eclipse XDB-C8 (4.6×150 mm, 5 μm) column. The injection volume was 10 μL.

A binary linear gradient was used for analytical separation. The initial conditions of the mobile phase were 50% water (solvent A) and 50% methanol (solvent B). The flow rate was 0.8 ml/min. Solvent B was increased to 100% over 9 min. At the conclusion of the separation, solvent B was returned to 50% to equilibrate for 5 min.

The LC was coupled to a Waters Quattro Micro triple quadrupole mass spectrometer (Milford, MA, USA) using a tee to split the flow into the electrospray probe by a factor of 10. Ions were generated using electrospray ionization in the negative-ion mode. The capillary voltage was 3.0 kV while the cone voltage was held at 37 V. The source temperature was held at 150°C. The desolvation gas (nitrogen) was maintained at a temperature of 450°C and a flow rate of 400 L/hr. Fragment ions were generated in the collision cell using argon at a pressure of 5×10^{-3} torr. The mass spectrometer was operated in the multiple-reaction monitoring (MRM) mode. Under these conditions, the major fragment ions were m/z 212 and m/z 133 at a ratio of 1.8:1. The transition from the m/z 227 parent ion of BPA to the m/z 212 fragment ion was used for quantitation, while the transition from the m/z 227 parent ion to the m/z 133 fragment ion was used for confirmation.

Liquid Chromatography–Fluorescence Detection

In a separate laboratory, a LC-FLD method was developed independently. The chromatographic separation was achieved using an Agilent 1200SL liquid chromatograph (Santa Clara, CA, USA), which was fitted with an Agilent Zorbax Eclipse SB-C18 (4.6×150 mm, 1.8 μm) column. The injection volume was 5 μL.

An isocratic method was used for analytical separation. The mobile phase consisted of 64% of 0.14% H_3PO_4 in water (solvent A) and 36% acetonitrile (solvent B). The flow rate was 1.2 ml/min. The initial conditions were held for 12 minutes for the elution of BPA and then solvent B was ramped up to 100% to clean off the column. Detection was made with an Agilent fluorescence detector. The excitation wavelength was set at 225 nm while the emission wavelength was monitored at 310 nm.

RESULTS AND DISCUSSION

Hydrolysis

The hydrolysis of the polyester is the key to a timely analysis. A faster sample preparation step was preferred for analyzing many polyester production samples at a manufacturing facility. The goal was to find a hydrolysis procedure that was more efficient than the hours to days of time required by extraction procedures. Rapid hydrolysis occurs when polyester is heated in an aprotic solvent with a base and an alcohol. Aprotic solvents enhance hydrolysis rates as compared to water-based systems.[22] For this study, various hydrolysis solutions were explored. A mixture of DMSO, tetramethylammonium hydroxide, and methanol was found to work best to hydrolyze the polyester samples. The efficacy of this mixture for the hydrolysis of polyesters has been noted to be among the best systems available, rivaling the classical mixture of potassium hydroxide, DMSO, and methanol.[22] A significant advantage of the TMAH system is the lack of salt and precipitate formation upon quenching the final reaction mixture with acetic acid. This greatly improves the visual clarity of the final preparation and makes this approach more amenable to automation. Additionally, it has been shown that similar mixtures were potent enough to hydrolyze other polyester formulations, even materials which showed a significant crystalline character.[22] In general, the TMAH hydrolysis system has proven to be a versatile preparation tool for polyester samples requiring HPLC analysis.

The DMSO/TMAH/methanol system was found to rapidly hydrolyze the polyester in less than 20 minutes. This is a workable timescale for a quality control laboratory. It was also necessary to find a procedure that could be easily automated to minimize labor. With this procedure, a Leap COMBI-Pal autosampler was utilized for the easy automation of the sample hydrolysis. Since the final preparation is free of particulate matter, owing to the use of the TMAH hydrolysis system, a filtration step was not required. The workflow was optimized so that the hydrolysis was performed while the prior sample was being analyzed.

Eastman Tritan copolyester and polycarbonate are reduced to their respective monomers when undergoing such a hydrolysis as shown in Figure 1. In the case of Tritan, the hydrolysate would contain the following monomers: terephthalic acid (TPA), 1,4-cyclohexanedimethanol (CHDM), and 2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD). In the case of polycarbonate, the polymer would hydrolyze to bisphenol A, carbonic acid (which would then be in equilibrium with carbon dioxide and water), and the corresponding end groups of that polymer.

It is important to note that the hydrolysis procedure introduces a dilution factor of 150 (0.1 gram polymer in 15 mL solvent). This dilution

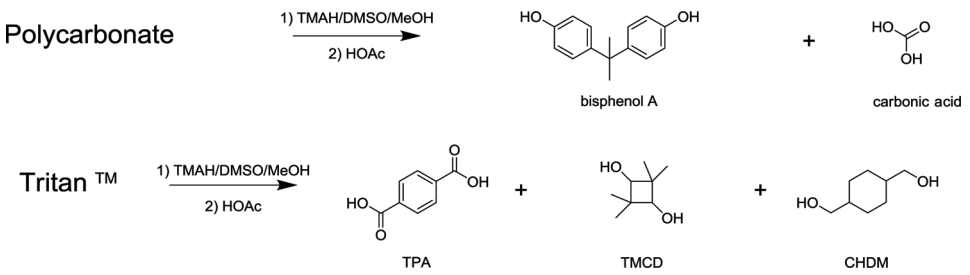

FIGURE 1 Comparison of the hydrolysis of polycarbonate and Tritan copolyester resins.

factor affects the limits of detection of the analyses. For example, if the analytical instrument can quantify to a limit of $10\,\mu g\,l^{-1}$ *as a solution concentration*, then the limit for quantifying BPA *as a sample concentration* is $1.5\,mg\,kg^{-1}$.

Analytical Performance of LC-MS/MS Procedure

Selectivity

LC-MS/MS was used to analyze the hydrolysate samples. LC-MS/MS offers the advantage that it is highly selective, reducing the possibility for false positives. The mass spectrometer uses three quadrupoles to make the measurement. The first quadrupole passes only the precursor $[M\text{-}H]^-$ ion (m/z 227) of BPA into the second quadrupole where fragmentation occurs via collision induced dissociation. The third quadrupole can then be set to only allow the $[M\text{-}H\text{-}CH_3]^{-\cdot}$ fragment ion (m/z 212) to pass to the detector. The high selectivity comes from the fact that a signal is seen at the detector only if an ion can satisfy the requirements of having a m/z 227 ion that fragments to a m/z 212 ion. Additionally, the $[M\text{-}H\text{-}C_6H_5OH]^-$ fragment ion (m/z 133) was also monitored for additional confirmation. Controlled experiments showed that matrix effects did not affect the ionization of BPA. This was not surprising as the samples were relatively simple as they were comprised of only monomers that did not co-elute with BPA.

Linearity

A calibration curve was generated using seven calibration standards ranging in solution concentration from $10\text{–}1000\,\mu g\,l^{-1}$. This corresponds with a *sample concentration* range of $1.5\text{–}150\,mg\,kg^{-1}$ when accounting for the hydrolysis dilution factor. Each calibrant was analyzed in duplicate and the averages were used to create a linear calibration curve. Calibration curves routinely had a correlation coefficient (R^2) of 0.9999. External calibration was performed using such a calibration curve.

Accuracy, Precision, and Recovery

Spiked samples were generated in order to test the precision and accuracy of the method. Such experiments typically involve spiking the analyte, at multiple concentrations, into the expected sample matrix. In this case, Eastman Tritan copolyester offers a good BPA-free polymer matrix. Polycarbonate is a hydrolysable source of BPA so it was spiked into Tritan pellets. To ensure homogeneous mixing, the Tritan and polycarbonate polymers were mixed, melted, and co-extruded into thin films. The amount of polycarbonate was chosen so that the thin films would contain $1\,mg\,kg^{-1}$, $5\,mg\,kg^{-1}$, $10\,mg\,kg^{-1}$, and $100\,mg\,kg^{-1}$ of BPA_t (sample concentration).

The hydrolysate samples from the spiked thin films were analyzed by LC-MS/MS. The hydrolysis and analysis steps were replicated on different days for a total of seven replicates at each concentration level. The results of the seven repeated analyses are shown in Table 1. The experimental data compared well with the theoretical numbers. The accuracy and recovery numbers are good considering the BPA spike has been through mixing, co-extrusion, hydrolysis, and analysis. For example, for the $10\,mg\,kg^{-1}$ spiked sample, the recoveries of the seven replicates range from 96% to 103% for the LC-MS/MS data and the relative standard deviation is 2.6%. This compares well to the intra-day relative standard deviation of 3.0% for the $10\,mg\,kg^{-1}$ standard.

Limit of Detection

The guidelines set forth by the EPA[23] were used to calculate the Method Detection Limit (MDL) and Limit of Quantitation (LOQ). These guidelines follow a statistical approach based upon the variability measured for seven replicate samples. The precision and accuracy data provides the standard deviation of replicate samples that were prepared exactly as prescribed by the method. The standard deviation of the seven replicates

TABLE 1 Precision and Accuracy Data for Seven Replicate Samples Using LC-MS/MS

Description (Polycarbonate spiked into Tritan)	BPA_t (Theoretical) ($mg\,kg^{-1}$)	Mean BPA_t (Sample Conc.) by LC-MS/MS ($mg\,kg^{-1}$)	Error (%)	Standard Deviation ($mg\,kg^{-1}$)	Relative Standard Deviation (%)	Recovery (%)
Tritan only	0	None Detected	—	—	—	—
1 ppm BPA Spike[a]	1	1.2[b]	21.4[b]	0.17[b]	13.8[b]	121[b]
5 ppm BPA Spike[a]	5	5.4	8.3	0.31	5.7	108
10 ppm BPA Spike[a]	10	10.2	1.6	0.27	2.6	102
100 ppm BPA Spike[a]	100	89.6	10.4	2.13	2.4	90

[a]Sample concentration of monomeric BPA calculated based on polycarbonate spike.
[b]Statistically below Limit of Quantitation.

of the 10 mg kg^{-1} spiked sample was determined to be 0.26 mg kg^{-1}. The EPA guidelines define the MDL as the standard deviation multiplied by the student's t-value, while the LOQ is defined as the standard deviation multiplied by ten. The student *t*-value of 3.143 represents the desired 99% confidence level. Therefore, the MDL and LOQ were calculated to be 0.82 mg kg^{-1} and 2.66 mg kg^{-1}, respectively. Figure 2 shows an example of an ion chromatogram obtained for the 1 mg kg^{-1} spiked sample which is just above the calculated detection limit but just below the statistical LOQ. Despite the dilution factor introduced by the hydrolysis step, the method detection limit is sufficient for the purpose of screening polyester resins to show that they are not made from BPA. Pre-concentration procedures certainly could be explored if necessary.

Analytical Performance of LC-FLD Procedure

Selectivity

While LC-MS/MS offers a selective and sensitive approach, it can be too complex for routine testing in a quality control laboratory. An alternative approach is to use LC-FLD as a screening tool for BPA_t. LC-FLD is easier than LC-MS/MS to implement in a quality control laboratory setting. Fluorescence detection offers decent selectivity; and LC-MS/MS could be used

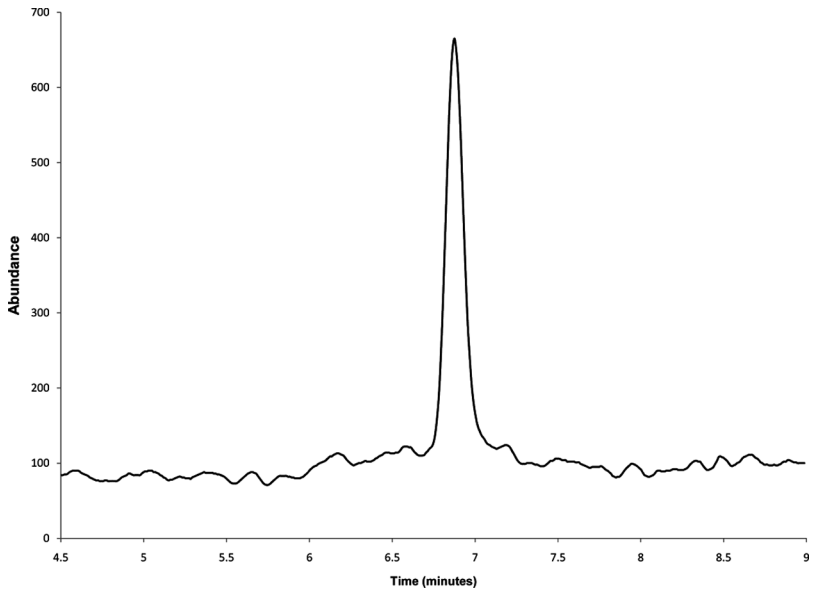

FIGURE 2 LC-MS/MS ion chromatogram of thin film spiked with 1 mg kg^{-1} of BPA.

for further confirmation if there were concerns about false positives in a particular LC-FLD analysis. Again, interferences are not expected given that the hydrolyzed sample is simply composed of monomers.

Linearity

A calibration curve was generated using prepared calibration standards. The calibration curve consisted of four points plus the origin. The *solution concentration* range of 25–100 $\mu g\,l^{-1}$ represents a *sample concentration* range of 3.8–15 $mg\,kg^{-1}$ when accounting for the hydrolysis dilution factor. Calibration curves routinely had a correlation coefficient (R^2) of 0.9999 or greater.

Accuracy, Precision, and Recovery

Seven replicates of the spiked thin films were hydrolyzed and analyzed by LC-FLD. The statistical results of seven repeated analyses are shown in Table 2. The experimental data compared well with the theoretical numbers. For the 10 $mg\,kg^{-1}$ standard, the recoveries range from 80% to 90% for the LC-FLD data. For the 10 $mg\,kg^{-1}$ standard, the relative standard deviation is 9.7% for the LC-FLD data. This compares well to the intra-day relative standard deviation of 8.1% for the 10 $mg\,kg^{-1}$ standard.

Limit of Detection

The guidelines set forth by the EPA[23] were used to calculate the Method Detection Limit (MDL) and Limit of Quantitation (LOQ). The seven replicates of the 10 $mg\,kg^{-1}$ sample from the spike-and-recovery experiments were used to determine the standard deviation of 0.83 $mg\,kg^{-1}$. Therefore, the MDL and LOQ were calculated to be 2.6 $mg\,kg^{-1}$ and 8.3 $mg\,kg^{-1}$, respectively. Again, the MDL is sufficient for

TABLE 2 Precision and Accuracy Data for Seven Replicate Samples using LC-FLD

Description (Polycarbonate spiked into Tritan)	BPA_t (Theoretical) ($mg\,kg^{-1}$)	Mean BPA_t (Sample Conc.) by LC-FLD ($mg\,kg^{-1}$)	Error (%)	Standard Deviation ($mg\,kg^{-1}$)	% Relative Standard Deviation	Recovery (%)
Tritan only	0	None Detected		—	—	—
1 ppm BPA Spike[a]	1	None Detected		—	—	—
5 ppm BPA Spike[a]	5	4.8[b]	5.0[b]	0.80[b]	16.9[b]	95[b]
10 ppm BPA Spike[a]	10	8.6	14.1	0.83	9.7	86
100 ppm BPA Spike[a]	100	86.1	13.9	2.21	2.6	86

[a]Sample concentration of monomeric BPA calculated based on polycarbonate spike.
[b]Statistically below Limit of Quantitation.

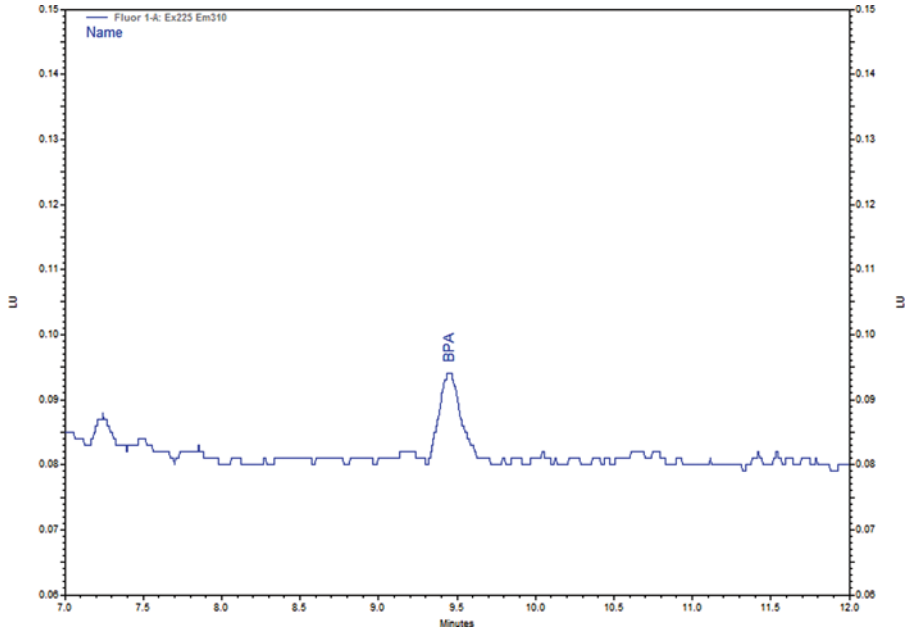

FIGURE 3 LC-FLD chromatogram of thin film spiked with 5 mg kg^{-1} of BPA.

the purpose of screening polymers. Figure 3 shows an example of a chromatogram obtained for the 5 mg kg^{-1} spiked sample, which is just above the calculated detection limit but just below the statistical LOQ.

CONCLUSIONS

Manufacturers and molders of polyesters want analytical validation that the polymers they use do not contain bisphenol A. Based on the need to confirm that polyester or copolyester resin does not contain BPA, two hydrolysis-based methods were developed. These methods measure BPA_t content and can confirm the absence of BPA by hydrolyzing the copolyester and then analyzing by LC-FLD or LC-MS/MS. A hydrolysis procedure offers the unique advantage of a faster sample preparation step than extraction procedures. Furthermore, the hydrolysis procedure was fully automated using the autosampler. The LC-FLD and LC-MS/MS analyses offer their own advantages. The LC-FLD approach is more cost effective and easier to implement in a quality control laboratory without sacrificing much sensitivity. The LC-MS/MS method provides higher selectivity and sensitivity if needed.

REFERENCES

1. Chang, C.; Chou, C.; Lee, M. Determining Leaching of Bisphenol A from Plastic Containers by Solid-Phase Microextraction and Gas Chromatography – Mass Spectrometry. *Anal. Chim. Acta* **2005**, *539*, 41–47.
2. Brede, C.; Fjeldal, P.; Skjevrak, I.; Herikstad, H. Increased Migration Levels of Bisphenol A from Polycarbonate Baby Bottles After Dishwashing, Boiling and Brushing. *Food Addit. Contam. A* **2003**, *20*, 684–689.
3. Kubwabo, C.; Kosarac, I.; Stewart, B.; Gauthier, B. R.; Lalonde, K.; Lalonde, P. J. Migration of Bisphenol A from Plastic Baby Bottles, Baby Bottle Liners and Reusable Polycarbonate Drinking Bottles. *Food Addit. Contam. A* **2009**, *26*, 928–937.
4. Nam, S.; Seo, Y.; Kim, M. Bisphenol A Migration from Polycarbonate Baby Bottle with Repeated Use. *Chemosphere* **2010**, *79* (9), 949–952.
5. DeCoensel, N.; David, F.; Sandra, P. Study on the Migration of Bisphenol A from Baby Bottles by Stir Bar Sorptive Extraction-Thermal Desorption-Capillary GC-MS. *J. Sep. Sci.* **2009**, *32*, 3829–3836.
6. Freeman, R. *The Direct Determination of Residual Bisphenol A Using Thermal Desorption (TD) – GC/MS*, Pittcon Presentation, Orlando, March 3, 2010.
7. Thaxton, K. *Thermal Desorption, Chemical Ionization, and Tandem Mass Spectrometry as a Solution for Monitoring Polymer Contaminants in Beverages and Beverage Packaging*, Pittcon Presentation: Orlando, March 3, 2010.
8. Sakurai, K.; Sugaya, N.; Nakagawa, T.; Uchiyama, T.; Fujimoto, Y.; Takahashi, K. Simultaneous Analysis of Endocrine Disruptors, 4-alkylphenol and Bisphenol, Contained in Synthetic Resin Products Used for Drug Containers and Household Utensils. *J. Health Sci.* **2005**, *51* (5), 538–548.
9. Nerin, C.; Fernandez, C.; Domeno, C.; Salafranca, J. Determination of Potential Migrants in Polycarbonate Containers Used for Microwave Ovens by High-Performance Liquid Chromatography with Ultraviolet and Fluorescence Detection. *J. Agric. Food Chem.* **2003**, *51* (19), 5647–5653.
10. Sun, Y.; Wada, M.; Kuroda, N.; Hirayama, K.; Nakazawa, H.; Nakashima, K. Simultaneous Determination of Phenolic Xenoestrogens by Solid-Phase Extraction and High-Performance Liquid Chromatography with Fluorescence Detection. *Anal. Sci.* **2001**, *17*, 697–702.
11. Lagana, A.; Bacaloni, A.; DeLeva I.; Faberi, A.; Fago, G.; Marino, A. Analytical Methodologies for Determining the Occurrence of Endocrine Disrupting Chemicals in Sewage Treatment Plants and Natural Waters. *Anal. Chim. Acta* **2004**, *501*, 79–88.
12. Stavrakakis, C.; Colin, R.; Hequet, V.; Faur, C.; LeCloirec, P. Analysis of Endocrine Disrupting Compounds in Wastewater and Drinking Water Treatment Plants at the Nanogram per Liter Level. *Environ. Technol.* **2008**, *29*, 279–286.
13. Shao, B.; Han, H.; Hu, J.; Zhao, J.; Wu, G.; Xue, Y.; Ma, Y.; Zhang, S. Determination of Alkylphenol and Bisphenol A in Beverages Using Liquid Chromatography/Electrospray Ionization Tandem Mass Spectrometry. *Anal. Chim. Acta* **2005**, *530*, 245–252.
14. Rykowska, I. Preconcentration of Bisphenol A from Polycarbonate Baby Bottles by Means of New Solid-Phase Extraction Sorbents with Ketoimine Groups. *Trends Chromatogr.* **2007**, *3*, 11–20.
15. Biles, J.; McNeal, T.; Begley, T.; Hollifield, H. Determination of Bisphenol A in Reusable Polycarbonate Food-Contact Plastics and Migration to Food-Simulating Liquids. *J. Agric. Food Chem.* **1997**, *45*, 3541–3544.
16. Baugros, J.; Giroud, B.; Dessalces, G.; Grenier-Loustalot, M.; Cren-Olive, C. Multiresidue Analytical Methods for the Ultra-Trace Quantification of 33 Priority Substances Present in the List of REACH in Real Water Samples. *Anal. Chim. Acta* **2008**, *607*, 191–203.
17. Cao, X.; Corriveau, J. Survey of Bisphenol A in Bottled Water Products in Canada. *Food Addit. Contam. B* **2008**, *1* (2), 161–164.
18. Ballesteros-Gomez, A.; Rubio, S.; Perez-Bendito, D. Analytical Methods for the Determination of Bisphenol A in Food. *J. Chromatogr. A* **2009**, *1216*, 449–469.
19. Watabe, Y.; Kondo, T.; Imai, H.; Morita, M.; Tanaka, N.; Hosoya, K. Reducing Bisphenol A Contamination from Analytical Procedures to Determine Ultralow Levels in Environmental Samples Using Automated HPLC Microanalysis. *Anal. Chem.* **2004**, *76*, 105–109.

20. Watabe, Y.; Kondo, T.; Morita, M.; Tanaka, N.; Haginaka, J.; Hosoya, K. Determination of Bisphenol A in Environmental Water at Ultra-Low Level by High-Performance Liquid Chromatography with an Effective On-Line Pretreatment Device. *J. Chromatogr. A* **2004**, *1032*, 45–49.
21. Inoue, K.; Kato, K.; Yoshimura, Y.; Makino, T.; Nakazawa, H. Determination of Bisphenol A in Human Serum by High-Performance Liquid Chromatography with Multi-Electrode Electrochemical Detection. *J. Chromatogr. B* **2000**, *749*, 17–23.
22. Tindall, G.; Perry, R.; Little, J.; Spaugh, A. Preparation of Polyester Samples for Composition Analysis. *Anal. Chem.* **1991**, *63*, 1251–1256.
23. Code of Regulations, Title 40; Protection of Environment, part 136, Appendix B, *Definition and Procedure for the Determination of the Method Detection Limit*, revision 1.11, 2011, U.S. Goverment Printing Office, Washington D.C.