Migration of an Epoxy Adhesive Compound into a Food-Simulating Liquid and Food from Microwave Susceptor Packaging

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Migration of the diglycidyl ether of Bisphenol A (DGEBA) from microwave susceptor packaging into a food-simulating liquid and into food has been determined. The poly(ethylene terephthalate) (PET) susceptor film did not provide a barrier to migration of DGEBA when the oil or food was cooked in a microwave oven in contact with the PET susceptor film.

INTRODUCTION

Recently it has been demonstrated that the poly(ethylene terephthalate) (PET) film used in microwave susceptor packaging does not prevent adhesive components from migrating into food under microwave susceptor cooking conditions (Begley and Hollifield, 1990a). As a consequence, the adhesives used in susceptor packaging release a variety of chemicals (i.e., dibenzoate plasticizers) to the food. In particular, 4,4'-bis(2,3-epoxypropoxy)-diphenyldimethylmethane, more commonly known as the diglycidyl ether of Bisphenol A (DGEBA), used in an acrylic/epoxy adhesive, also migrates through the PET film of the susceptor package into a food-simulating liquid (FSL) and into food under microwave susceptor cooking conditions.

Miglyol 812 (Miglyol), a fractionated coconut oil, was used in these migration experiments as the FSL. The suitability of Miglyol as an FSL has been demonstrated elsewhere (Begley and Hollifield, 1990a). The food used in the migration experiments was a commercial meat-and-vegetable-filled pastry product designed for microwave susceptor cooking. The analytical methods used to determine migration are similar to those previously described (Begley and Hollifield, 1990a,b; Begley et al., 1990).

Although epoxide-type chemicals are generally toxic to humans (Manson, 1980), no attempt was made to determine the immediate ill effects of consuming food containing DGEBA or any off-odors or tastes created by the presence of DGEBA in food.

EXPERIMENTAL PROCEDURES

A high-purity reference material DGEBA (99%) was obtained from Shell Chemical Co., Houston, TX.

DGEBA (molecular weight 340) in the susceptor package was identified by high-performance liquid chromatography/mass spectrometry and gas chromatography/mass spectrometry on methylene chloride/acetonitrile extracts of the susceptor package. The total amount of DGEBA present in the susceptor package was determined by extraction (Begley and Hollifield, 1990a) to be 19.1 $\mu g/cm^2$ (123 $\mu g/in.^2$) of the area of the package surface.

The foods analyzed were retail packages of frozen meat-and-vegetable-filled pastry products purchased at local food stores. All foods were cooked in an Amana Radarrange microwave oven according to instructions provided on the package (6.5 min on high power for a 700-W oven). After cooking, the food was removed from the susceptor, allowed to cool, and then weighed. After weighing, the crust was separated from the filling, which was discarded. The crust was then blended with hexane, the mixture was filtered, and the DGEBA was extracted from the hexane with acetonitrile, as described by Begley et al. (1990). The amount of DGEBA in the acetonitrile extract, and thus the amount of DGEBA migrating to food, was determined by high-performance liquid chromatography (HPLC).

All migration experiments using the FSL (Miglyol) were performed in a special poly(tetrafluoroethylene) cell designed by Waldorf Corp. (St. Paul, MN) for single-sided extraction. The pastry susceptors were removed from their retail packages, the food was discarded, and the susceptors were cut to fit into the cell. Miglyol was added to the cell (4.3 $g/in.^2$ or 0.66 g/cm^2), and the cell was microwaved for 4.0 min. At the completion of microwaving, an aliquot of Miglyol was withdrawn from the cell for extraction by hexane/acetonitrile and determination of DGEBA by the HPLC procedure described elsewhere (Begley and Hollifield, 1990a,b).

High-Performance Liquid Chromatography. The HPLC system consisted of a Hewlett-Packard Model 1090 liquid chromatograph equipped with a 20-μL injector loop, an additional Rheodyne Model 7125 injector valve with a Brownlee 5-μm C_8 guard column in place of the injector loop, a 250 × 4.6 mm column containing 5-μm Microsorb C_8 (Rainin Instrument Co., Woburn, MA) operated at 40 °C, a Waters Model 480 Lambda Max variable-wavelength detector operated at 240 nm, and a PE-Nelson Analytical Model 3000 chromatography data system operating with an IBM AT computer. The HPLC mobile phase was as follows: solvent A, water/acetonitrile (85:15); solvent B, acetonitrile/water (85:15). A linear solvent gradient was programmed at a flow rate of 1.5 mL/min as follows: from 30% B to 100% B in 18 min; 100% B for 4 min; from 100% B to 30% B in 1 min. DGEBA was quantitated by using external calibration standards.

Recoveries. Recovery experiments were performed by fortifying Miglyol 812 at 0.43, 2.2, 4.3, 8.6, and 12.9 $\mu g/g$ with known volumes of a DGEBA standard solution in chloroform (4.3 mg/mL) and then cooking the oil in a Petri dish heated by a microwave susceptor placed beneath the dish. After cooking, DGEBA was extracted from the Miglyol and determined in duplicate at each fortification level. Figure 1 illustrates that the recovery of DGEBA from Miglyol is consistent over the range measured. The mean recovery of DGEBA from Miglyol was 97.5%, and the standard deviation was 3.8%.

The food crust for the recovery experiments was prepared by cooking the food in a susceptor that did not contain DGEBA. The recoveries from the food were determined by fortifying the food crust at 0.15, 0.28, 0.68, and 2.67 $\mu g/g$ and then by extracting the DGEBA. The mean recovery of DGEBA from the food was 101% with a standard deviation of 8.6%.

RESULTS

Typical chromatograms obtained from the susceptor-cooked pastry and Miglyol extracts are illustrated in Figure 2. This figure demonstrates that measurable concentrations of DGEBA readily migrate through the PET film of the susceptor under microwave cooking conditions into both the food and oil. In addition to DGEBA, Figure 2 shows the presence of the PET cyclic trimer in the extracts. The amounts of DGEBA found to migrate into food and

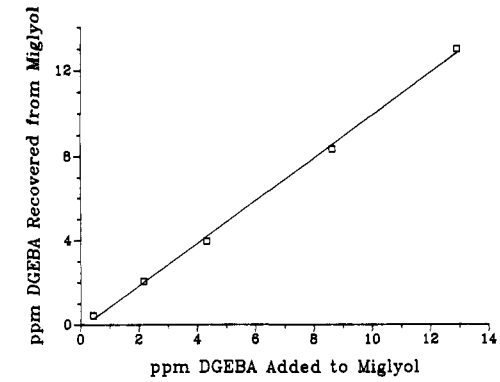

Figure 1. Plot of the recovery of DGEBA from Miglyol after microwaving for 4.0 min.

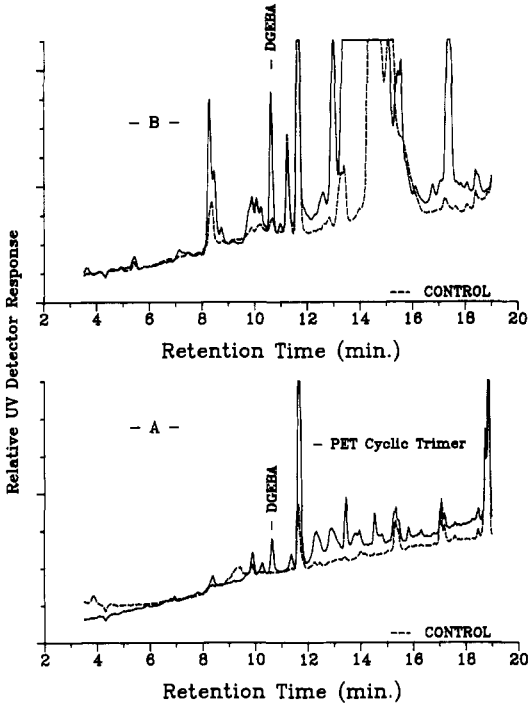

Figure 2. Chromatograms of extracts (A) from Miglyol microwaved for 4.0 min and (B) from pastry food microwaved for 6.5 min.

Miglyol are listed in Table I. Each value in Table I represents the determination of DGEBA from a different package of the same food brand. The average DGEBA migration values of 1.33 and 8.59 μg/g for food (based on the total weight of the crust and filling) and Miglyol, respectively, correspond to a migration on a surface area basis of 1.26 (8.11 μg/in.^{2}) and 5.67 μg/cm^2 (36.6 μg/in.^{2}).

On the basis of the data in Table I for DGEBA migration into food and the FSL, the susceptor package does not meet the requirements of the current U.S. regulations (*Code of Federal Regulations*, 1990), which specify the presence of a functional barrier between the adhesive components and the food. Moreover, the DGEBA migration exceeds the regulations of the European Communities (*Official Journal of the European Communities*, 1990), which require less than 0.02 μg/g DGEBA in the food or FSL. After the producer of the susceptor packages was notified that relatively large quantities of DGEBA were migrating into the food, the producer changed the adhesive formulation used in the construction of the package. Currently the company is not using an acrylic/epoxy adhesive containing DGEBA in its microwave susceptor package applications (private communication, January 10, 1991).

Table I. Migration of DGEBA from Microwave Susceptor Packaging into a Pastry Food and Miglyol[a]

	DGEBA migration, μg/g	
	food	Miglyol
	0.97	11.3
	1.39	7.72
	2.16	6.76
	0.79	
av	1.33	8.59

[a] Each value represents the determination of DGEBA from a different package of the same brand of food.

The percent of the DGEBA from susceptor packaging that migrated into Miglyol (approximately 30%) is similar to the 32% migration of the dibenzoate plasticizers from susceptor packaging found by Begley and Hollifield (1990a) under similar cooking conditions. The observed migration of DGEBA from susceptor packaging is additional evidence to support the conclusions by Begley and Hollifield (1990a) that the PET film in the susceptor package does not act as a barrier to prevent adhesive components from entering the food during cooking.

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