Food and Chemical Toxicology 75 (2015) 79–87

Contents lists available at ScienceDirect

Food and Chemical Toxicology

journal homepage: www.elsevier.com/locate/foodchemtox

Risk assessment derived from migrants identified in several adhesives commonly used in food contact materials

E. Canellas [a,b], P. Vera [a], C. Nerín [a,*]

[a] GUIA Group, Department of Analytical Chemistry, University of Zaragoza, I3A, María de Luna,3, 50018 Zaragoza, Spain
[b] Samtack Adhesivos Industriales, C/ Cerámica, n°3, Pol. Ind. Magarola Sud, 08292, Esparreguera, Barcelona, Spain

ARTICLE INFO

Article history:
Received 11 September 2014
Accepted 30 October 2014
Available online 13 November 2014

Keywords:
Adhesives
Food contact materials
Migration
UPLC-MS/QTOF
GC-MS

ABSTRACT

Adhesives are used to manufacture multilayer materials, where their components pass through the layers and migrate to the food. Nine different adhesives (acrylic, vinyl and hotmelt) and their migration in 21 laminates for future use as market samples have been evaluated and risk assessment has been carried out. A total of 75 volatiles and non volatile compounds were identified by gas chromatography–mass spectrometry and ultra-performance liquid chromatography coupled to quadrupole time-of-flight mass spectrometry. Most of the compounds migrated below their specific migration limit (SML), lowest observed adverse effect level (LOAEL), no observed adverse effect level (NOAEL) and values recommended by Cramer. Six compounds classified as high toxicity class III according to Cramer classification, migrated over their SML and exposure values recommended by Cramer, when they were applied in the full area of the packaging. Nevertheless, these adhesives fulfill the threshold in the real application as they are applied in a small area of the packaging.

1. Introduction

Adhesives are commonly used in the packaging industry. In most of the applications, they are used to manufacture multilayer materials, where the adhesive is applied on the full area of two or more different substrates forming the laminates [substrate–adhesive–substrate]. They can be also applied on a partial area forming boxes or pouches. The substrates used can be different materials as polypropylene, polyethylene, cardboard, etc. according to the final use of the packaging (Ashley et al., 1995).

The adhesives are complex formula of substances such as a polymer, antioxidants, tackifiers, solvents, plasticizers, fillers, adhesion promoters, etc. which provide specialized functions for the adhesives (Petrie, 2007). Besides, they can also contain impurities from raw materials or by-products as result of a side reaction between different ingredients. These substances are called NIAS (non intentioned added substances) (Felix et al., 2012; Isella et al., 2013) which are unknown by adhesive producers.

One of the main parameters that must be considered is the potential migration of these compounds present in the adhesives to the food in contact with the multilayer materials. Although in the most common applications, the adhesive is not in direct contact with the packed food, it has been demonstrated that volatile and non-volatile compounds can migrate from the adhesive through the different layers, except aluminium, to the food (Athenstadt et al., 2012; Aznar et al., 2011; Canellas et al., 2010a; Nerin et al., 2012; Sendon et al., 2012; Vera et al., 2011, 2013, 2014).

All components of food contact materials must comply with the Framework Regulation (EC) N 1935/2004 that requires that materials and articles, must not transfer their constituents to food in quantities which could endanger human health. However there is no specific legislation in the EU for adhesives. Manufacturers currently follow the provisions of the European "Plastics Directive" and the Spanish recent legislation governing food contact materials other than plastics. Both regulations provide positive lists of authorized substances with their specific migration limits (SML).

Previously to migration assay, it is very important to carry out a screening to identify the most of compounds present in the adhesives (Canellas et al., 2010b, 2012; Nerin et al., 2009; Vera et al., 2012), and consequently, to determine their possible risks as potential migrants to the food when the laminates are used as food packaging materials.

The screening of unknown non-volatile compounds involves an important analytical challenge, as it requires the most powerful techniques to provide more structural information to elucidate the molecular structure of the non volatile compounds (Zweigenbaum, 2011). The time-of-flight mass (TOF) analyzer combined with quadrupole provides the sensitivity and selectivity required for screening these types of samples. It provides the possibility of acquiring full scan mass spectra with high sensitivity and high resolution mass

* Corresponding author. GUIA Group, Department of Analytical Chemistry, University of Zaragoza, I3A, María de Luna,3, 50018 Zaragoza, Spain. Tel.: +34 976761873; fax: +34 976762388.
E-mail address: cnerin@unizar.es (C. Nerín).

http://dx.doi.org/10.1016/j.fct.2014.10.029
0278-6915/

spectrometry of any ionizable components in the sample (Hernandez et al., 2008; Lacorte and Fernandez-Albaz, 2006).

The first aim of this work was to carry out a screening analysis of nine different adhesives in order to obtain a list of the possible migrant compounds that can be found in laminates containing these adhesives. The techniques selected to determine the volatile and semivolatile compounds were the solid phase microextraction in headspace mode coupled to gas chromatography and mass spectrometry (HS-SPME-GC-MS) and liquid extraction coupled to gas chromatography and mass spectrometry (LE-GC-MS). The technique used to identify the non volatile compounds was ultra-performance liquid chromatography coupled to quadrupole time-of-flight mass spectrometry (UPLC-MS/QTOF).

Subsequently, migration experiments were carried out on 21 laminates manufactured with the adhesives above mentioned, in order to evaluate the mass transfer of the compounds detected and the risks of exposure for future potential consumers.

2. Materials and methods

2.1. Standards

The following compounds were used as standards to confirm the identification and for calibration plots in quantitative analysis: N-butyl ether (142-91-6), 2-propenoic acid 2-methylpropyl ester (2210-28-8), Propanoic acid butyl ester (590-01-2), Butanoic acid butyl ester (109-21-7), 1-hexanol-2-ethyl (104-76-7), Acetic acid 2-ethylhexyl ester (103-09-3), 1-butoxy-2-ethylhexane, 2-propenoic acid 6-methylheptyl ester (29590-42-9), 2,4,7,9-tetramethyl,5-decyn-4,7-diol (126-86-3), Cyclododecane (294-62-2), 2,4,7,9-tetramethyl,5-decyn-4,7-diol ethoxylate (9014-85-1), Phenol, 2-(1-phenylethyl) (4237-44-9), Isopropyl myristate (110-27-0), Bis (2-ethylhexyl) maleate myristate (142-16-5), Decanal (112-31-2), Butyl acrylate (141-32-2), Mono-(2-ethylhexyl) phthalate (4376-20-9), Diacetin (25395-31-7), Triacetin (102-76-1), Butylated Hydroxy Toluene (128-37-0), Bis (2-ethylhexyl) maleate (142-16-5), 1,2,3-Trimethylbenzene (526-73-8), Decane (124-18-5), Undecane (1120-21-4), Dodecane (112-40-3), Tridecane (629-50-5), Tetradecane (629-59-4), 3,5-di-tert-butyl-4-hydroxybenzaldehyde (1620-98-0) II, Pentadecane (629-62-9), Acenaphthalene (83-32-9), Hexadecane (544-76-3), Diethyl phthalate (84-66-2), Heptadecano (629-78-7), 3,5-di-tert-butylbenzoquinone (719-22-2), Octadecane (593-45-3), Nonadecane (629-92-5), Chrysene octahydro (2090-14-4) III, Fluorene decahydro (5744-03-6) III, Eicosane (112-95-8), Heneicosane (629-94-7), Docosane (629-97-0), Tricosane (638-67-5), Tetracosane (646-31-1), Methyl styrene (98-83-9), Styrene (100-42-5), 3(2H)-isothiazolone, 2-methyl- (2682-20-4), 5-Chloro-2-methyl-1,2-thiazol-3(2H)-one (137662-59-0), Polyethylene glycol (25322-68-3), 5-Chloro-2-methyl-1,2-thiazol-3(2H)-one (137662-59-0) 1,2-benzothiazol-3(2H)-one (2634-33-5), Polypropylene glycol (25323-30-2), 5-chloro-2-methylisothiazol (26172-55-4), Triethylamine (121-44-8), Dimethylol propionic acid (4767-03-7), Sodium 3-[(2-aminoethyl)amino] propanoate (84434-12-8) and Adipic acid (124-04-9). All were of analytical quality.

Water and methanol of HPLC grade were supplied by Scharlau Chemie S.A (Sentmenat, Spain). Tenax TA 80/100 mesh and PDMS fiber of 100 μm of thickness were supplied by Supelco (Bellefonte, USA).

2.2. Adhesive samples and laminates

Twenty one laminates forming the structure [substrate 1–adhesive–substrate 2] have been studied in this work. They were provided by a Spanish company for future use as food packaging. They were not printed but produced in the same run as regular packages. The substrates and the adhesives used for their manufacturing were also separately provided. Nine different adhesives had been used in the manufacture of the laminates: 4 acrylics (AC), 3 vinyl (V), and 2 hotmelts (HM). The substrates used were couche paper, mate or gloss polypropylene (PP), cellulose acetate, polyethylene terephthalate (PET), polylactic acid (PLA), offset paper and cardboard.

Table 1 shows the different laminates studied, their substrates (gramage or thickness) and adhesives used in the manufacture of these samples analyzed, and therefore the amount of adhesive applied per m^2 (gramage) of the laminate.

2.3. GC-MS

A CTC Analytics system from Agilent Technologies (Madrid, Spain) was used as autosampler. The GC system was Agilent 6890 Series connected to 5973 series mass selective detector. Chromatographic separations were carried out on a DB-5 (30 m × 0.25 mm × 0.25 μm) from Agilent Technologies. The oven temperature program was as follows: initial temperature at 40 °C (2 min), a temperature rate of 15 °C/min from 40 to 300 °C, and 2 minutes at the final temperature. Helium was used as gas carrier at a flow of 1 mL/min.

HS-SPME-GC-MS analyses were carried out with a polydimethylsiloxane (PDMS) fiber of 100 μm of thickness. Injection was performed in splitless mode and extraction conditions were as follows: 80 °C extraction temperature, 15 min extraction time and 1 min desorption time at 250 °C. Acquisition was performed in SCAN mode (50–350 m/z).

Liquid injection (LE-GC-MS) was carried out in splitless mode, 1 μL of sample was injected. Acquisition was performed in SCAN mode for identification purposes and in SIM mode for quantitative analysis.

2.4. UPLC separation

Chromatography was carried out in an Acquity™ system using an Acquity UPLC BEH C18 column of 17 μm particle size (2.1 mm × 100 mm), both from Waters (Milford, MA, USA). The solvents used as mobile phase were water and methanol both with 0.1% formic acid. The column flow was 0.3 mL/min and the column temperature was 35 °C. The gradient used here was 5–95% methanol 0.1% formic acid (0–24 min) and the volume of sample injected was 5 μL.

2.5. Mass spectrometry detector/QTOF

The detector was an API source (atmospheric pressure ionization) with an electrospray interface (ESI) coupled to a Xevo G2 mass spectrometer consisting of a hexapole, a quadrupole, a collision cell and a time of flight analyzer (QTOF) supplied by Waters.

Table 1
Sample code, substrates, adhesives used for the laminates manufactured and grams of adhesive per $m^2$of laminate.

Sample code	Substrates	Adhesive type	Adhesive code	gramaje of adhesive (g/m^2)
Lam01	Couche paper (60 g/m^2) / matte PP (15 μm)	Acrylic	AC01	11
Lam02	Couche paper (60 g/m^2) / gloss PP (12 μm)	Acrylic	AC01	11
Lam03	Couche paper (60 g/m^2) / cellulose acetate (15 μm)	Acrylic	AC01	11
Lam04	Couche paper (60 g/m^2) / PET (12 μm)	Acrylic	AC01	11
Lam05	Couche paper (60 g/m^2) / PLA (20 μm)	Acrylic	AC01	11
Lam06	Couche paper (60 g/m^2) / matte PP (15 μm)	Acrylic	AC02	11
Lam07	Couche paper (60 g/m^2) / gloss PP (12 μm)	Acrylic	AC02	11
Lam08	Couche paper (60 g/m^2) / cellulose acetate (15 μm)	Acrylic	AC02	11
Lam09	Couche paper (60 g/m^2) / PET (12 μm)	Acrylic	AC02	11
Lam10	Couche paper (60 g/m^2) / PLA (20 μm)	Acrylic	AC02	11
Lam11	Couche paper (60 g/m^2) / matte PP (15 μm)	Acrylic	AC03	11
Lam12	Couche paper (60 g/m^2) / gloss PP (12 μm)	Acrylic	AC03	11
Lam13	Couche paper (60 g/m^2) / cellulose acetate (15 μm)	Acrylic	AC03	11
Lam14	Couche paper (60 g/m^2) / PET (12 μm)	Acrylic	AC03	11
Lam15	Couche paper (60 g/m^2) / PLA (20 μm)	Acrylic	AC03	11
Lam16	Offset paper (80 g/m^2) / PET (12 μm)	Acrylic	AC04	300 μm
Lam17	Offset paper (80 g/m^2) / PET (36 μm)	Vinylic	V01	300 μm
Lam18	Offset paper (80 g/m^2) / PET (36 μm)	Vinylic	V02	300 μm
Lam19	Offset paper (80 g/m^2) / PET (36 μm)	Vinylic	V03	300 μm
Lam20	Offset paper (80 g/m^2) / offset paper (80 g/m^2)	Hotmelt	HM01	180
Lam21	Offset paper (80 g/m^2) / offset paper (80 g/m^2)	Hotmelt	HM02	180