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Safety aspects related to the Bisphenol A migration process in packed meat and milk products – a review

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Abstract

Bisphenol A (BPA), a chemical compound found mainly in polycarbonate materials, can be used as an additive to obtain other materials such as epoxy, polyphenolic resins. Scientific studies have also shown its presence in packaging, in which, this compound has not been used as a raw material or additive, its presence being due to cross-contamination of materials used or cross-contamination during the recycling process. BPA under the action of certain factors (light, temperature, contact time, pH, type of product, type of food contact materials), can migrate from the packaging material to the packaged product in larger or smaller quantities. According to studies, the main source of BPA exposure is by ingesting food contaminated with this compound. Its presence has been detected in a wide range of foods such as meat and meat products, milk and dairy products, fruits and vegetables and products derived from them, fish and seafood, plain or carbonated water, juices, sauces etc. In addition to these sources, contamination can also occur from non-food sources, such as exposure to dust, air, especially those who work in factories to obtain plastics. According to studies, the adverse effects of this compound has been demonstrated, especially on the reproductive system. It has also been observed that it influences the development of other diseases of the circulatory system, nervous system, immune system, may contribute to the development of type 2 diabetes, etc. In order to avoid exposure to BPA, certain measures are needed to avoid chronic exposure of consumers to this compound. Among these measures would be the replacement of this compound with another, less toxic, decreasing the shelf life of the product to avoid a long period of contact between the product and the packaging material, maintaining food in optimal light and temperature. The purpose of this review was to develop a study, based on the literature, on BPA levels in different types of products, focusing on meat and milk and products derived from them.

Keywords*:* bisphenol A, contamination, food product, packaging

Introduction

Food packaging plays an essential role in preserving, storing products at different temperatures, and protecting them against physical, chemical, biological agents to ensure the quality and safety of food and to extend the shelf life [16, 14].

The primary raw material of these packaging materials is the synthetic polymer to which certain additives are added to improve the mechanical properties such as rigidity, strength, durability, elasticity, flexibility [2, 48] and which under certain conditions can migrate from the packaging into the packaged product.

The main factors influencing this process are the contact time and temperature, the type of packaging material, the type of packed product, the type of contact (direct or indirect), the initial concentration of the migrant in the packaging material [14] mechanical stress [48].

These compounds include bisphenol A, widely used as an elastase, antioxidant, heat stabilizer, waterproofing coating [27] for the production of polycarbonate plastic materials as well as epoxy, polyester, phenolic, polyacrylic resins [47].

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The migration of bisphenol A has been identified in most fresh foods and packaged in different packaging materials such as meat and meat products [22], milk and milk products [3], fruits and vegetables [12], fish and seafood [11], carbonated and non-carbonated beverages [51] and others: sauces, honey [40, 15].

The aim of this review was to summarize, based on the literature, BPA levels found in products of animal origin worldwide (meat and meat products, milk and milk products) packed in different type of packaging materials and analyzed by various techniques.

The studied scientific articles are published in the 2010-2018 period.

Bisphenol A – properties. Bisphenol A, abbreviated as BPA, with the chemical formula 2,2-bis (4-hydroxyphenyl)propane, is a synthetic compound of the phenol group obtained by a condensation reaction between 2 phenol molecules and one acetone molecule in acidic medium [2, 19, 33].

At room temperature, this organic compound presents as a white, solid and crystalline substance, with a molecular weight of 228.18 g/moll [2]. Table 1 summarizes the main physical-chemical properties of this compound.

Table 1. Physical and chemical properties of BPA

Parameter	**Value**	**Reference**
CAS no.	0000080-05-7	[8]
Molecular weight	228.29 g/mol	[33]
Specific gravity	1.195-1.2 g/cm3	[36]
Chemical formula	$C_{15}H_{16}O_2$	[9]
State	crystalline solid substance (flakes or powder)	[21, 33]
Color	White to cream	[9]
Melting point	158-159 °C	[20]
Boiling point	220°C (at 5 hPa pressure)	[33]
Density	1.1 – 1.2 kg/m^3 at 25°C	[21]
Octanol/Water Partition Coefficient, log Kow	3.32	[33]
Vapor pressure	5.3 x 10^{-6} Pa (at 25°C)	[4]
Water solubility	120 mg/L (at 25°C)	[55]
Odor	Mild phenolic odor	[9]
Half-life in water	38 days	[9]
Half-life in soil	75 days	[9]
Half-life in sediment	340 days	[9]
Half-life in air	0.2 day	[9]

Table 2. BPA levels of meat and meat products

Food category	**Origin/ commercial area**	**Packaging**	**Range**	**Method**	**Reference**
Milk	Mahdia, Tunisia	Cardboard box, plastic, Plastic and aluminum/metal foil	< 0,002 mg/kg	UPLC-MS/MS	[3]
Milked by hand, Milked by machine, Milk from cooling tank	Italy	fresh	0.081-2,776 μg/L	SPE-HPLC-LFD	[43]
Goat's milk, Whole milk, Yogurt, Fruit flavored yogurt, Cheese, Cream cheese, Fruit flavored milk	Sivas, Turkey	plastic	< 0,35 - 1,7 ± 0,06 μg/L	UTA – CPE-UV – VIS	[54]
Milk	Turkey	Paper box	81,09 ± 1,39 – 156,22 ± 1,6 μg/kg	HPLC	[47]
Skimmed milk, Infant formula, Infant formula	Spain, Italy	can	< 0,005 – 1,29 mg/kg	PLE-LC-MS/MS	[17]
Infant formula milk based, Advanced infant formula, Evaporated milk vitamin D added	Dallas, Texas	can	< 0,20 -1,24 ng/g	LLE-HRGC/LRMS	[44]
Milk, Powder milk, Powder infant formula, Liquid infant formula	-	can	< 0.2 – 6.31 ± 0.03 ng/ml	SPS	[35]
Milk, Hard cheese, Norwegian brown cheese, Cheese spreads, Butter	Norway	Cardboard box, plastic, Plastic and metal foil	< 0,10 - 0,72 μg/kg	SPE-UPLC–MS-MS	[42]
Milk,	Beijing, China	Tetra pak, can	0,019 - 8,8ng/ml	MIP-SPE-LC–MS/MS	[52]
Bovine milk	China	-	0.09-0.26 μg/kg	IAC-UPLC-MS/MS	[53]
Milk, Infant formula	China	aseptic plastic pouch, tetra fine aseptic	< 0,14 – 0,67 μg/L	SALLE-LTP-UHPLC-MS/MS	[45]
Milk, Milk powder	China	-	0,8 - 128,7 μg/kg	USADLLME -HPLC - FLD	[32]
Milk	-	-	1.32 – 176 μg/kg	MIP-SPE– HPLC-FLD	[39]
Milk beverages,	China	Metal can with metal lid	< 0.08 – 127,2 ± 2,8 μg/kg	QuEChERS -UHPLC-ESI-MS/MS	[6]
Yogurt	China	-	< 0,08 μg/kg	QuEChERS -UHPLC-ESI-MS/MS	[6]
Chocolate milk	Italy	PET, Tetra Pak	1.04 – 17.65 μg/L	SPE-LC-MS/MS	[16]
Pasteurized milk	Italy	PET, PEHD, Tetra Pak	< 2,5 – 481,0 ± 2,0 ng/ml	SPE-LC - FLD	[23]
UHT milk	Italy	PET, PEHD, Tetra Pak, Tetra Brik	< 2,5 – 36,0 ± 2,0 ng/ml	SPE-LC - FLD	[23]
Lowfat pasteurized milk	Italy	PET, Tetra Pak	< 2,5 – 170.0 ± 9,0 ng/ml	SPE-LC - FLD	[23]

Table 3. BPA levels found in milk and milk products

Food category	Origin/ commercial area	Packaging	Range	Method	Reference
Milk	Mahdia, Tunisia	Cardboard box, plastic, Plastic and aluminum/metal foil	< 0,002 mg/kg	UPLC-MS/MS	[3]
Milked by hand, Milked by machine, Milk from cooling tank	Italy	fresh	0.081-2,776 µg/L	SPE-HPLC-LFD	[43]
Goat's milk, Whole milk, Yogurt, Fruit flavored yogurt, Cheese, Cream cheese, Fruit flavored milk	Sivas, Turkey	plastic	< 0,35 - 1,7 ± 0,06 µg/L	UTA – CPE-UV – VIS	[54]
Milk	Turkey	Paper box	81,09 ± 1,39 – 156,22 ± 1,6 µg/kg	HPLC	[47]
Skimmed milk, Infant formula, Infant formula	Spain, Italy	can	< 0,005 – 1,29 mg/kg	PLE-LC-MS/MS	[17]
Infant formula milk based, Advanced infant formula, Evaporated milk vitamin D added	Dallas, Texas	can	< 0,20 -1,24 ng/g	LLE-HRGC/LRMS	[44]
Milk, Powder milk, Powder infant formula, Liquid infant formula	-	can	< 0.2 – 6.31 ± 0.03 ng/ml	SPS	[35]
Milk, Hard cheese, Norwegian brown cheese, Cheese spreads, Butter	Norway	Cardboard box, plastic, Plastic and metal foil	< 0,10 - 0,72 µg/kg	SPE-UPLC–MS-MS	[42]
Milk,	Beijing, China	Tetra pak, can	0,019 - 8,8ng/ml	MIP-SPE-LC−MS/MS	[52]
Bovine milk	China	-	0.09-0.26 µg/kg	IAC-UPLC-MS/MS	[53]
Milk, Infant formula	China	aseptic plastic pouch, tetra fine aseptic	< 0,14 – 0,67 µg/L	SALLE-LTP-UHPLC-MS/MS	[45]
Milk, Milk powder	China	-	0,8 - 128,7 µg/kg	USADLLME -HPLC - FLD	[32]
Milk	-	-	1.32 – 176 µg/kg	MIP-SPE– HPLC-FLD	[39]
Milk beverages,	China	Metal can with metal lid	< 0.08 – 127,2 ± 2,8 µg/kg	QuEChERS -UHPLC-ESI-MS/MS	[6]
Yogurt	China	-	< 0,08 µg/kg	QuEChERS -UHPLC-ESI-MS/MS	[6]
Chocolate milk	Italy	PET, Tetra Pak	1.04 – 17.65 µg/L	SPE-LC-MS/MS	[16]
Pasteurized milk	Italy	PET, PEHD, Tetra Pak	< 2,5 – 481,0 ± 2,0 ng/ml	SPE-LC - FLD	[23]
UHT milk	Italy	PET, PEHD, Tetra Pak, Tetra Brik	< 2,5 – 36,0 ± 2,0 ng/ml	SPE-LC - FLD	[23]
Lowfat pasteurized milk	Italy	PET, Tetra Pak	< 2,5 – 170.0 ± 9,0 ng/ml	SPE-LC - FLD	[23]
Canned butter	Tabriz, Iran	Metallic container with metallic cap	1,3 ±0,08 µg/g	RPDLLME-HPLC	[37]
Milk infant formula	Portugal	can	< 0,060 – 0,40 µg/L	DLLME - GC – MS	[10]
Infant milk powder	Hangzhou, China	plastic	0.8 – 14 µg/kg	SPE-GC-MS	[5]
Liquid infant formula, Powder infant formula, Rice milk formula powder	Naples, Italy	Tetra Pak, PET, Aluminum packaging	0.003 – 0.169 µg/g	SPE-HPLC-FLD	[7]
Milk and milk products	China	-	< 0,01 – 10,8 ng/g	LLE-HPLC – MS/MS	[30]

Abbreviations: LLE- HRGC/LRMS - Liquid/liquid extraction - High Resolution Gas Chromatography/Low Resolution Mass Spectrometry, **SPE-UHPLC-MS/MS** - solid phase extraction - ultra-high performance liquid chromatography - tandem mass spectrometry, **SPE-UPLC–MS/MS** - solid phase extraction - ultra performance liquid chromatography - tandem mass spectrometry, **MIP-SPE- LC−MS/MS** - Molecularly Imprinted Polymer with Solid-Phase Extraction - Liquid chromatography-tandem mass spectrometry, **HPLC/FLD** - High Performance Liquid Chromatography with Fluorescence Detection, **SPE-SIM-GC-MS** - solid phase extraction - Selective Ion Monitoring - Gas Chromatography-Mass Spectrometry, **SIM-GC-MS** - Selective Ion Monitoring - Gas Chromatography-Mass Spectrometry, **HPLC – MS** - high performance liquid chromatography – mass spectrometry, **LE-LC-APCI-MS** - liquid extraction - Liquid chromatography–mass spectrometry with Atmospheric pressure chemical ionization

UPLC-MS/MS – ultra performance liquid chromatography tandem mass spectrometry, **SPS** - solid-phase spectroscopy, **SPE-HPLC-LFD** - solid phase extraction - high-performance liquid chromatography with fluorescence detection, **IAC-UPLC-MS/MS** – ultra performance liquid chromatography tandem mass spectrometry with immunoaffinity column, **UTA – CPE-UV – VIS** - Ultrasonic Thermostatic-Assisted Cloud Point Extraction *UV-visible* spectrophotometric method, **HPLC** - high-performance liquid chromatography, **USADLLME -HPLC – FLD** - ultrasound-assisted dispersive liquid–liquid microextraction combined with derivatization and high-performance liquid chromatography with fluorescence detection**, MIP-SPE-LC−MS/MS** - Molecularly Imprinted Polymer with Solid-Phase Extraction - Liquid chromatography-tandem mass spectrometry, **LLE-UHPLC-MS/MS** - liquid liquid extraction for Ultra High Performance Liquid Chromatography-Tandem Mass Spectrometry, **QuEChERS -UHPLC-ESI-MS/MS** - the Quick Easy Cheap Effective Rugged and Safe - ultra-high performance liquid chromatography-tandem mass spectrometry with electrospray ionization source**, SPE-LC – FLD** - solid phase extraction - Liquid Chromatography Coupled to Fluorescence Detection, **SALLE-LTP -UHPLC-MS/MS** - salting-out assisted liquid/liquid extraction coupled with low-temperature purification - Ultra High Performance Liquid Chromatography-Tandem Mass Spectrometry, **PLE-LC-MS/MS** - pressurised liquid extraction - Liquid chromatography-tandem mass spectrometry, **SPE-DLLME-SFO-HPLC** - Solid-Phase Extraction–Dispersive Liquid–Liquid Microextraction - Solidification of Floating Organic Drop - high-performance liquid chromatography, **RPDLLME-HPLC** - reverse phase dispersive liquid-liquid extraction - high-performance liquid chromatography, **DLLME - GC – MS** - dispersive liquid–liquid micro-extraction - gas chromatography-mass spectrometry, **LLE-HPLC – MS/MS** - liquid–liquid extraction- high performance liquid chromatography - tandem mass spectrometry, **SPE-GC-MS** - solid phase extraction- gas chromatography-mass spectrometry, SPE-LC-MS/MS - solid phase extraction - Liquid Chromatography - Tandem Mass Spectrometry

Conclusion

These results taken from the literature review represent a small part of the published scientific papers related to the concentrations of this contaminant in animal origin food products.

Because there are many factors that influence and favor the release of BPA from food contact materials, certain measures are needed to limit and prevent this phenomenon.

Such measures may include the replacement of Bispheol A with other compounds with similar properties, such as Bisphenol S that is more stable and resistant to heat, sunlight and acidic pH compared to BPA. Also Bisphenol M, Bisphenol B and Bisphenol M are other variants for BPA replacing [50].

Another measure would be to reduce foods packing in lacquered cans or polycarbonate plastics, and turning to the foods packaging into the glass because these containers do not contain any more BPA [2].

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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