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AN OVERVIEW ON HUMAN POTENTIAL EXPOSURE TO BISPHENOL A FROM FOOD-CONTACT MATERIALS USED IN FRUITS PACKAGING AND PROCESSING

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Abstract

Food contamination during the migration process from food contact materials is an important food safety issue and many researches are focused on this topic in the last decades.
Bisphenol A is a hazardous chemical compound used as intermediate in the production of polycarbonate-based materials and epoxy resins, used to obtain plastic food containers for packaging and storage, but also for inner surface coatings of cans. Through contaminated products, this compound can reach the human body where it causes a number of adverse health effects. As a result of this consumption, Bisphenol A can cause diseases of the cardiovascular system, endocrine system, reproductive system, metabolic system. The aim of this review was to investigate Bisphenol A levels from worldwide fruits and fruits products, fresh or processed, packed in different food contact materials. Despite the fact that the values found in the literature are not high, it poses a risk to human health because it can accumulate in the body. To prevent this hazard, the European Food Safety Authority recommended a tolerable daily intake (TDI) of 50 µg/kg body weight/day. As a conclusion the authors try to investigate differences between canned and non-canned fruit products and to establish which material can leach more Bisphenol A and what factors influence this process.

***Key words**: Bisphenol A, exposure, fruits, human health.*

INTRODUCTION

Bisphenol A, BPA, is a chemical compound used as an additive in the process of obtaining polycarbonate plastics and epoxy resins with estrogenic activity, being a known endocrine disrupter (Chouhan et al., 2014). Estrogenic endocrine disruptors are exogenous chemicals that mimic or antagonize the effect of estrogenic hormones (Posnack, 2014).
People are exposed to this compound mainly by eating food contaminated with this compound which is able to migrate from food packaging materials in food products under certain time, temperature and pH conditions, but there may be other sources of exposure such as air, dust, contaminated surface water (Michalowicz, 2014).
BPA entered in the body by ingestion, inhalation or dermal contact (Rochester et al., 2013) may undergo bioaccumulation and bioconcentration processes in different tissues or organs (Zielinska et al., 2019) associated with a number of side effects.
The aim of this review is to summarize, on the basis of literature, the level of BPA contamination of worldwide fruits, both fresh and processed, as well as products derived therefrom, but also a number of side effects that may occur as a result of the ingestion of this compound.

BISPHENOL A EFFECTS ON HUMAN HEALTH

Studies have shown that BPA can bind to estrogen receptors, act as an anti-estrogen and block their activity. It can also bind to the receptors of the thyroid gland, perturbing its function, and other organs and systems in the body (cardiovascular system, endocrine system, nervous system) (Rochester et al., 2013). Regarding the reproductive system, it has been observed that BPA can affect the reproduction function (Muhamad et al., 2016; Li et al., 2010), reduces sperm quality (decrease in sperm count, changes in morphology and motility) (Li et al., 2011), can lead to polycystic ovarian syndrome (PCOS) (Muhamad et al., 2016), decreases fertility (decreases the number of mature oocytes) (Ehrlich et al., 2012), and affects prostate function and morphology (Tang et al., 2012).

Increased levels of BPA in the body could also be related to a number of metabolic disorders such as increased incidence of obesity cases (Muhamad et al., 2016) and type 2 diabetes (Kim et al., 2013). Concerning the effects of BPA on pancreatic cells, studies have suggested that this compound produces insulin resistance (Almeida et al., 2018). Also, some correlations have been established between high levels of serum BPA and elevated LDL and HDL cholesterol levels (Olsen et al., 2012). Experimental studies demonstrated its association with altered liver or thyroid function (Muhamad et al., 2016). On the cardiovascular system it has been shown to increase the risk of cardiovascular disease such as heart attack, hypertension or angina pectoris (Almeida et al., 2018) when exposed to BPA. Exposure of the body to low doses of BPA may also result in cardiovascular system dysfunctions such as cardiac arrhythmia, increased blood pressure, atherosclerosis, and a negative impact on ventricular contractility and intracellular calcium circulation (Poscnack et al., 2014b). Also, high levels of BPA in the body could be correlated with increased myocardial infarction (Patel et al., 2015).

High levels of this compound in blood or urine could also be correlated with other side effects, such as premature birth (Cantonwine et al., 2010), lower birth weight (Chou et al., 2011), impaired immune function, the ability to produce oxidative stress and inflammatory processes, effects on the expression of genes (Muhamad et al., 2016) and DNA stability (Almeida et al., 2018).

LEGISLATION ON BISPHENOL A MIGRATION

To reduce the risk of ingestion of this compound from food packed in different materials, a specific BPA migration limit for plastics has been imposed by European legislation, as well as a daily intake value (TDI).

In the European Union, the use of this compound has been regulated for the first time by EC Directive no. 90/128, where the specific migration limit for this compound was 3 mg/kg, later reduced to 0.6 mg/kg (EC Directive No 72/2002). Regulation 10/2011 replacing Directive No. 72/2002, maintained this value of 0.6 mg/kg until 2018, when through EU Regulation No. 213/2018, which is an amendment to EU Regulation No 10/2011, the value was reduced to 0.05 mg/kg.

At the same time, during the years, tolerable daily intake has undergone significant changes. If in 1986 the TDI was 0.05 mg/kg of body weight/day (Scientific Committee for Food, 1986), in 2002 this was 0.01 mg/kg of body weight/day (Scientific Committee for Food, 2002). In 2006, in an EFSA report, TDI increased to 0.05 mg/kg of body weight/day (EFSA, 2006). Between 2006 and 2015, this value remained constant, and in 2015 this value would fall to 0.004 mg/kg of body weight/day, a value that has remained unchanged to date (EFSA, 2015).

Another regulation on BPA across the European Union was to prohibit its use in articles for infants and young children (Directive No 8/2011) because it produces different behavioural or developmental disorders, and because this category is one of the most sensitive and vulnerable categories of the population (Almeida et al., 2018).

The first countries that renounced the use of this compound in packages for infants and children up to 3 years were Denmark and Austria in 2011, Belgium and France in 2012, and Sweden in 2013 (Ludwicka et al., 2015; Boudalia & Oudir, 2016; Almeida et al., 2018).

In countries like Algeria, BPA is an unknown substance, with no known health effects, and this is why there is no legislation on this compound (Boudalia & Oudir, 2016).

BPA IN FRUIT AND FRUITS PRODUCTS

As it can be seen in Table 1, the literature review shows that the highest values of BPA were obtained in canned samples because these food products are the most exposed to BPA which is mostly present in coating lakes

Table 1. Bisphenol A concentrations in fruit and fruit products

Food category	Origin/commercial area	Packaging	Range	Method	Reference
Citrus, apple, strawberry	Florida	Fresh fruit	2.0 ± 1.4 – 9.0 ± 4.9 μg/kg	GC-MS/MS	Lu et al., 2013
Apple, pear, pitaya	Hetey	Fresh fruit	1.056 - 2.35 μg/kg	DSMIP-SPE- HPLC	Li et al., 2014
Fruit mix, Peaches, Pears	Belgium	Can	10.1 - 20 ng/g in content 6.4 - 14.3 ng/ml in syrup	SPE-SIM-GC-MS	Geens et al., 2010
Pineapple, apple sauce	Belgium	Glass	0.3 - 1.28 ng/g	SPE-SIM-GC-MS	Geens et al., 2010
Pineapple	Belgium	plastic	0.11 ng/g	SPE-SIM-GC-MS	Geens et al., 2010
Apple sauce, Orange juice, tropical juice	Belgium	can	0.2 - 4.73ng/g	SPE-SIM-GC-MS	Geens et al., 2010
Fruit and vegetables juice	Belgium	PET	<0.02 ng/ml	SPE-SIM-GC-MS	Geens et al., 2010
Apple juice	Belgium	Tetra Pak	<0.02 ng/ml	SPE-SIM-GC-MS	Geens et al., 2010
Pineapple, peaches	Spain	canned	< 2.9 - 13 ± 1 μg/kg	HPLC/FLD	Alabi et al., 2014
Pineapple, Organic pineapple, Almond jelly, Sliced peaches, Fruit cocktail	SUA	canned	< 2 - 19 ng/g	HPLC-MS/MS	Noonan et al., 2011
Fresh peach, Fruit and vegetable juice	Texas	Non-canned	0.24 - 0.41 ng/g	LLE- HRGC/LRMS	Lorber et al., 2015
Oranges, peach slices	Texas	canned	0.31 - 2.03 ng/g	LLE- HRGC/LRMS	Lorber et al., 2015
Passion fruit pulp, Mango pulp, Papaya in syrup, Pears in syrup, Mango in syrup, Pineapple in syrup, Peach in syrup, Fruit cocktail in light syrup	Thailand, Indonesia, Kenia, European Union	canned	< 1.0 - 10.2 μg/kg	QuEChER-DLLME-GC/MS	Cunha and Fernandes, 2013
Fruits and vegetables	Thailand	canned	<0.0015 - 0.0087 mg/kg	GC-MS	Poovarodom et al., 2017
Walnuts, chestnuts, jujubes, plums, hawthorn, raisins	China	-	< 0.01 - 132 ng/g	HPLC – MS/MS	Liao, 2014
Tropical fruits, Apple in syrup, Mandarin in syrup, Mango in syrup, Pineapple in syrup, Peach in syrup, Grape juice, Cocktail fruits, Coconut milk, Apple juice	Thailand, China, Indonesia, Tokyo	canned	< 1 - 200 ng/g	GC – MS	Kawamura, 2014
Pineapple in syrup, Peach in syrup	Iran	canned	3.7 ± 0.3 - 7.7 ± 0.8	SPE-DLLME-SFO-HPLC	Sadeghi et al., 2016
Pineapple chunks in pineapple juice, Apple juice from concentrate	Texas	can	< 0.20 - 0.49 ng/g	LLE-HRGC/LRMS	Schecter et al., 2010
Organic cinnamon apple sauce	Texas	plastic	< 0.20 ng/g	LLE-HRGC/LRMS	Schecter et al., 2010
Fruit juice, Peach juice	Mahdia	Cardboard box with plastic cap and metal foil	< 0.002 mg/kg	UPLC-MS/MS	Beltifa et al., 2017
Orangeade	Dongguan, China	can	6.16 ± 0.13 μg/L	UA-ULME-MSD	Mo et al., 2017
Orangeade	Dongguan, China	Plastic bottle	< 1.10 μg/L	UA-ULME-MSD	Mo et al., 2017
Nectar juice, cocktail, guava	Egypt	Tetrapak, aluminium pouch	2,23 - 26,4 ng/ml	HPLC	El-Dars et al., 2018
Pomegranates fresh juice, mango juice drink, strawberry jam, fig jam	Egypt	plastic	0.46 - 82.97 ng/ml	HPLC	El-Dars et al., 2018
Jam	Norway	Glass with plastic or metal cap	0.38 μg/kg	SPE-UPLC–MS/MS	Sakhi, 2014
Juice	Norway	Cardboard box with plastic cap and metal foil	< 0.020 μg/kg	SPE-UPLC–MS/MS	Sakhi, 2014

GC-MS/MS – Gas-chromatography tandem mass spectrometry; **DSMIP-SPE-HPLC** – Dummy surface molecularly imprinted polymer - solid - phase extraction - high performance liquid chromatography; **LLE-HRGC/LRMS** – Liquid/liquid extraction - High Resolution Gas Chromatography/Low Resolution Mass Spectrometry; **HPLC/FLD** - High Performance Liquid Chromatography with Fluorescence Detection; **HPLC-MS/MS** - High Performance Liquid Chromatography tandem mass spectrometry; **UPLC-MS/MS** - ultra performance 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; **SPE-UPLC–MS/MS** - solid phase extraction - ultra performance liquid chromatography - tandem mass spectrometry; **HPLC** - High Performance Liquid Chromatography; **UA-ULME-MSD** - Ultrasound-assisted upper microextraction and molecular fluorescence detection; **QuEChER-DLLME-GC/MS** - the Quick Easy Cheap Effective Rugged and Safe - Dispersive Liquid–Liquid Microextraction – gas-chromatography mass spectrometry.

(Michalowicz, 2014). This may be mainly due to the sterilization process and storage conditions. Studies have shown that for cans, between 80-100% of the compounds present in the coating lakes can migrate during sterilization (Almeida et al., 2018).
This process is also influenced by the composition of the packaged product, so that in products high in sugar, vegetable oils (corn, soybean, olive oil) or salt, the BPA values found in the product were significant (Almeida et al., 2018; Sungur et al., 2014).
Differences in BPA content from the same product type but from different lots were observed (Sungur et al., 2014), because changes in the composition of can coatings may occur (Almeida et al., 2018; Noonan et al., 2011).
The migration process is also influenced by the type of product packaged, so in the case of foods containing solid and liquid fractions, syrup for example, BPA can migrate in both components, but especially in the solid fraction (Geens et al., 2010; Noonan et al., 2011; Almeida et al., 2018).
In the case of plastic packaging, this compound can migrate from packages through two different processes: diffusion of residual BPA resulted from the manufacturing process of packages or hydrolysis of polymers containing ester bonds (Aschberger et al., 2010; Hoekstra et al., 2013; Ludwicka et al., 2015).
For food packaged in polycarbonate plastics, the migration process is amplified over time due to the hydrolysis of polymers in the packaging material, while for reusable plastics the migration process tends to stabilize (Almeida et al., 2018).
From the factors that can influence the migration of BPA from plastic materials, temperature is the main one, so by exposing the material to about 100°C, the migration rate can be up to 55 times higher than exposure of the same type of material at temperatures of 20°C (Le, 2015; Almeida et al., 2018).
Also, in Table 1, it can be seen that for products packed in glass jars with a lid, the values of BPA are much lower than in the case of cans and plastics. This fact is mainly due to the possibility of migration of BPA only from the lid, which contains inside epoxy resins used as coating paints. In this case, the contact between the food product and the lid is occasional, by shaking the packaging during handling, transport or inadequate storage (Cao et al., 2011; Almeida et al., 2018).
In case of tetra Pak or cardboard boxes laminated on the inside with plastic foil and plastic cap, the possibility of contamination of products with BPA is lower. For this type of packaging, the values obtained for this compound in the product were below the detection limit of the apparatus (Table 1) (Geens et al., 2010; Sakhi, 2014). Also, when packaged products are kept in proper conditions, the migration of BPA from food contact materials takes place at a much lower rate and the concentration found in products are insignificant and do not represent a danger to human health (Almeida et al., 2018).

CONCLUSIONS

From this literature review, it was concluded, that through packaging, food products are predisposed to chemical contamination with a multitude of compounds, among which bisphenol A occupies an important place.
Out of the packaging materials used in the food industry, it can be stated that food packed in cans is more susceptible to be chemically contaminated with BPA, when compared to the rest of the packaging materials. This fact is due to a large number of factors related to the technology of cans manufacturing (type and quality of inner coatings - epoxy-phenolic resins, polyvinyl chloride organosol resins) (Poovarodom et al., 2017), the temperature to which the food is subjected, or composition of the food products (pH, salt content, sugar) (Sungur et al., 2014).
As a preventive measure to reduce this type of contamination, the inner coatings could be replaced with materials that don't contain BPA and have better resistance to different processing temperatures.

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