Polycyclic Aromatic Hydrocarbons (PAH) in Olive Oils and Other Vegetable Oils; Potential for Carcinogenesis

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54.1 INTRODUCTION

Polycyclic aromatic hydrocarbons (PAH) comprise a family of more than 100 compounds, some of which are known or suspected to be mutagenic and/or carcinogenic to mammals. They are lipophilic organic contaminants composed by two or more fused aromatic rings. PAH containing up to four fused benzene rings are known as light PAH and those containing more than four benzene rings are called heavy PAH. Heavy PAH are more stable and considered to be more toxic than the light ones (Wenzl et al., 2006). These compounds are generated by incomplete combustion of organic matter arising, in part, from natural combustion (forest fires, volcanic eruptions) and mostly from human activities (engine exhausts, industrial production, coal-derived products, petroleum distillates, waste incineration, tobacco smoke, among others). Due to their multiple potential sources of contamination, PAH are ubiquitously distributed in nature. Therefore, human exposition, attributable to occupational, environmental and dietary sources, is virtually unavoidable, raising an important public health concern due to their recognized carcinogenic activity (Table 54.1).

In the 1970s, 16 PAH were identified as priority pollutants by the Environmental Protection Agency (EPA), based on their occurrence and carcinogenicity (Table 54.2) (Wenzl et al., 2006). Eight of these PAH are known to be mutagenic or carcinogenic and comprise part of the 15 European Union (EU) priority PAH (Table 54.2). In 2005 the EU introduced new legislation (European Commission, 2005a) in response to food-contamination problems based on data collected by the European Member States and risk assessment by the Scientific Committee for Food (SCF) in 2002. The SCF assessed 33 PAH and concluded that 15 PAH showed clear evidence of genotoxicity, and 14 of these were carcinogenic to animals (European Commission, 2002). As measures are presently widely focused on benzo[*a*]pyrene (BaP), a compound classified as carcinogenic to humans (group 1 of IARC categories), the SCF concluded that BaP could be used as a marker. As BaP constitutes only 1–20% of the total concentration of carcinogenic PAH, the SCF also recommended monitoring another 14 PAH, both in food and the environment, to enable long-term exposure assessments and to verify the usefulness of BaP as a marker (European Commission, 2002). Of the 15 EU priority PAH, 12 were reasonably anticipated to be human carcinogens by the International Agency for Research on Cancer (IARC), which showed sufficient evidence of carcinogenicity in experimental animals (Wenzl et al., 2006). In 2005, the European Commission asked the EU Member States for further investigations on the 15 EU priority PAH
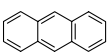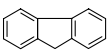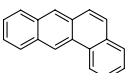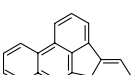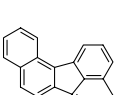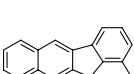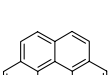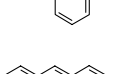
TABLE 54.1 Key features of PAH.
1. PAH comprise a family of more than 100 organic contaminants generated by incomplete combustion
2. Light PAH contain up to four benzene rings, while heavy PAH have more
3. PAH are known or suspected to be mutagenic and/or carcinogenic to mammals
4. Human exposure is attributable to occupational, environmental and dietary sources
5. Due to their lipophilic nature, PAH can easily contaminate oils and fats

TABLE 54.2 Molecular structures of PAHs of concern by different world organizations (adapted from Wenzl et al., 2006).

This table presents the molecular structures of the PAH considered as being dangerous by different world organizations.

Name	Abbreviation	Structure	US-EPA[a]	EU-SCF[b]	JECFA[c]	Group[d]
Acenaphthene	ACP		X			3
Acenaphthylene	ACY		X			NS[e]
Anthracene	ANT		X			3
Fluoranthene	FLT		X			3
Fluorene	FLR		X			3
Naphthalene	NAP		X			2B
Phenanthrene	PHE		X			3
Pyrene	PYR		X			3
Benz[a]anthracene	BaA		X	X	X	2B
Benzo[b]fluoranthene	BbF		X	X	X	2B
Benzo[j]fluoranthene	BjF			X	X	2B
Benzo[k]fluoranthene	BkF		X	X	X	2B
Benzo[ghi]perylene	BgP		X	X		3
Benzo[a]pyrene	BaP		X	X	X	1

Name	Abbr.	Structure	[a]	[b]	[c]	IARC[d]
Chrysene	CHR		X	X	X	2B
Cyclopenta[cd]pyrene	CPP			X		2A
Dibenz[a,h]anthracene	DhA		X	X	X	2A
Dibenzo[a,e]pyrene	DeP			X	X	3
Dibenzo[a,h]pyrene	DhP			X	X	2B
Dibenzo[a,i]pyrene	DiP			X	X	2B
Dibenzo[a,l]pyrene	DlP			X	X	2A
Indeno[1,2,3-cd]pyrene	IcP		X	X	X	2B
5-Methylchrysene	5MC			X	X	2B
Benzo[c]fluorene	BcL				X	3

[a]US-Environmental Protection Agency.
[b]Scientific Committee on Food from European Union.
[c]Joint FAO/WHO Expert Committee on Food Additives.
[d]IARC categories (IARC, 2006): Group 1: carcinogenic to humans; Group 2A: probably carcinogenic to humans; Group 2B: possibly carcinogenic to humans; Group 3: not classified as to their carcinogenicity to humans.
[e]Not studied.

together with one PAH (benzo[c]fluorene) highlighted by the Joint FAO/WHO Expert Committee on Food Additives in the same year (Table 54.2). The areas for investigation were outlined in Commission Recommendation 2005/108/EC (European Commission, 2005b).

54.2 OCCURRENCE OF PAH IN FOODS

The presence of PAH has been reported in all types of foods, including raw or unprocessed products, processed and cooked food products (Phillips, 1999). Its origin in

foods has been widely studied and, in general, in addition to environmental contamination, certain types of food processing have been considered as the main cause of contamination by these compounds (Guillén et al., 1997). In a wide variety of plants, three possible sources of contamination by PAH have been considered: uptake as a result of atmospheric exposure, uptake from the soil and endogenous biosynthesis (Phillips, 1999). However, atmospheric pollution is considered by most investigators as the main source of contamination of unprocessed foods (Guillén et al., 2004; Rodríguez-Acuña et al., 2008). Around 70 different PAH or related compounds have been identified in foodstuffs, from which benzo[a]pyrene and benz[a]anthracene are the most abundant, existing in high quantities in cooked or smoked meat products (Smith et al., 2001).

Regarding processed and cooked foods, some operations, such as smoke curing, cooking over charcoal and roasting, can significantly contribute to increasing the levels of PAH, while others, such as frying of vegetable oils, contribute only to a slight increase of these compounds (Purcaro et al., 2006). In opposition, the refining process of vegetable oils can lead to a decrease in PAH content in the final product (Cejpek et al., 1998; Teixeira et al., 2007).

To evaluate PAH occurrence in foods consumed in the EU Member States, experts participating in the SCOOP (Scientific Cooperation) task collected data on the occurrence of PAH in foods and identified 44 food groups, from which five comprised more than 80% of total studied samples (8861): sausages and ham (27%), vegetable oils (24%), fish/fish products (13%), waters (excluding tap water) (11%), and meat (6%) (European Commission, 2004). The only consistently tested PAH (in 99% of the samples) was benzo[a]pyrene. The highest average levels for BaP found in foods were: $48.1 \mu g \, kg^{-1}$ (wet weight) in dried fruits, $17.1 \mu g \, kg^{-1}$ in olive pomace, $5.28 \mu g \, kg^{-1}$ in smoked fish, $4.2 \mu g \, kg^{-1}$ in grape seed oil, $3.27 \mu g \, kg^{-1}$ in smoked meat products, $3.09 \mu g \, kg^{-1}$ in fresh molluscs and $2.16 \mu g \, kg^{-1}$ in spices and condiments.

Since diet is considered to be the major non-occupational source of PAH for non-smokers (Lodovici et al., 1995), several studies have been carried out to determine the level of intake associated with a normal or average human diet. Meat and meat products, cereals, and oils and fats have been suggested to be PAH main sources in the diet (Dennis et al., 1991). However, due to the numerous differences among diets, the levels and sources of PAH can be quite different (Phillips, 1999). The estimated average BaP intakes for a European adult range from 14 to 320 ng $person^{-1} \, day^{-1}$ among the 11 states that provided intake data in the SCOOP task (European Commission, 2004).

54.3 OCCURRENCE OF PAH IN OLIVE OILS

Virgin olive oil (VOO) is extracted from the olive fruit exclusively by mechanical processes without any further treatment. Generally, the process comprises a series of steps including olive harvesting (manually or mechanically), transportation to olive mills, washing, crushing, mixing the olive paste in a thermobeater (with or without talc addition) and oil separation by centrifugation or pressing.

Although VOO should be naturally free of PAH, contamination can occur either directly during the processing in the mill or indirectly due to olive skin contamination by environmental sources (Fromberg et al., 2007; Rodriguéz-Acuña et al., 2008). In this last situation, PAH present in dust and particles from smoke and air pollution can contaminate olives via atmospheric fallout and this superficial contamination can be transferred to the final product (Rodriguéz-Acuña et al., 2008).

54.3.1 Sources of Contamination of Virgin Olive Oil

Aiming to identify and evaluate the sources of PAH contamination during the processing of VOO, Rodriguéz-Acuña et al. (2008) studied the influence of factors such as the environmental pollution during olive growth, contamination during olive harvesting, contamination during extraction process and environmental pollution at the olive mill site. The authors identified nine PAH (benz[a]anthracene (BaA), chrysene (CHR), benzo[e]pyrene (BeP), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), BaP, dibenz[a,h]anthracene (DhA), benzo[ghi]perylene (BgP), indeno[1,2,3-cd]pyrene (IcP)) and, comparing the total PAH concentration in olive oils with olive fruit surface extracted with hexane, they found identical values for both cases. This finding suggests that the contamination of olive oil is mainly from the olive skin.

Rodriguéz-Acuña et al. (2008), when establishing the influence of different levels of environmental pollution during olive growth, showed that total PAH content in olives and, consequently, in respective oil, is related to the level of air pollution in the vicinity of the olive grove. The same authors compared mechanical and handpicked harvesting, concluding that exposure to diesel exhaust fumes from the combine is the most important source of olive skin contamination, since the highest values of PAH were found in the olives harvested mechanically.

The influence of the olive washing step, micronized talc (hydrated magnesium silicate) addition during oil extraction, and the environmental pollution at the mill site, were also assessed (Rodriguéz-Acuña et al., 2008). The first two factors had no influence on PAH content of VOO, while the latter depends on several other issues, such as tank cleaning, installation of valves in the ventilation shafts to avoid intake of air pollution and the possibility of burning waste olive pomace in the facilities.

According to the SCOOP task report of the European Commission (2004), from the 671 virgin and extra virgin

olive oils (EVOO) analyzed, only 14 presented BaP levels above the maximum imposed by the EU ($2\,\mu g\,kg^{-1}$), from which two samples presented levels between 5–$20\,\mu g\,kg^{-1}$ and one was above $20\,\mu g\,kg^{-1}$. The resumed published results of PAH content in olive oil during recent years are presented in Table 54.2. The majority of analyzed samples presented BaP levels below the maximum imposed by the EU; however, the reported results exceeding the limit reinforce the need for prevention and monitoring.

54.3.2 Sources of Contamination of Olive Pomace Oil

During olive oil production, other low-quality oils, such as olive pomace oil (OPO), are sometimes produced. In OPO production, the dregs of crushed olives are dried and then extracted with organic solvents. For direct human consumption, this oil needs a refining process to remove unwanted minor components and undesirable organoleptic properties. Along OPO production, PAH contamination can occur during the drying and solvent extraction steps (León-Camacho et al., 2003). Sometimes, the olive pomace is dried by direct contact with combustion fumes. In such cases, the extent of PAH contamination is related to the type of fuel used and the exposure time necessary to eliminate water (Moreda et al., 2004). Thus, PAH content depends highly on the conditions used prior to the oil extraction process, and can be relatively high especially if harsh conditions are used. Nevertheless, PAH content is generally reduced during refining, either by the bleaching step, where the use of activated carbon and clay is recommended to remove the heaviest PAH, either by the deodorizing stage, where light PAH can be reduced together with other compounds, such as carotenoid pigments. The efficacy of the refining process can depend on the quality of the initial crude material, i.e., of the initial levels of PAH in the unrefined oil. A detailed study on the efficiency of the bleaching stage for the elimination of BaP in OPO was performed by León-Camacho et al. (2003). These authors reported a slight reduction of BaP to values above the legislation limits ($2\,\mu g\,kg^{-1}$) using earths in the bleaching stage, making necessary the use of active carbon in this step. Different procedures used along the refining process can possibly explain some differences in the values found in OPO (Table 54.3). In fact, for a group of ten refined OPO samples, lower levels of PAH were reported in the five samples submitted to decolorization during refining (Ballesteros et al., 2006).

54.4 OCCURRENCE OF PAH IN OTHER VEGETABLE OILS

Due to their lipophilic nature, PAH can easily contaminate oils and fats, which are a significant dietary source, either directly or indirectly by their incorporation into other foods such as cereal-based products (Dennis et al., 1991).

Two main routes of PAH contamination in vegetable oils have been suggested, namely the contact of seeds with polluted surroundings and the drying process of oil seeds prior to oil extraction, by direct contact with combustion gases (Rodriguéz-Acuña et al., 2008). Another reported form of contamination may arise from direct migration of PAH to the oil seeds from jute bags treated with mineral oils, which are used for raw material storing and transporting (Gfrerer and Lankmayr, 2003).

Recently, the EU has set maximum levels of $2.0\,\mu g\,kg^{-1}$ for BaP in oils and fats intended for direct consumption or used as an ingredient in foods (European Commission, 2005a, 2006). Prior to that, some countries (Spain, Italy, Portugal and Greece) have established limits for the concentration of the following eight heavy PAH: BaA, BeP, BbF, BkF, BaP, DhA, BgP, IcP. The values established were a maximum limit of $2\,\mu g\,kg^{-1}$ for each single PAH and $5\,\mu g\,kg^{-1}$ for the sum of the referred eight heavy PAH (Teixeira et al., 2007). Some organizations establish their own recommendations, such as the German Society for Fat Science (GSFS), which suggests that total PAH in edible oils should not surpass $25\,\mu g\,kg^{-1}$ and heavy PAH should be below $5\,\mu g\,kg^{-1}$ (Cejpek et al., 1998).

A high number of PAH with a wide range of molecular weights can be found in vegetable oils, of which many are alkylated compounds, although they are ignored by legal regulations (Guillén et al., 2004).

54.4.1 Influence of Refining

PAH contamination in crude edible oils varies widely, but refined vegetable oils generally present lower levels than the crude oils, which can be attributed, at least in part, to the reduction observed through refining (Cejpek et al., 1998; Teixeira et al., 2007). The influence of different steps during the refining process (neutralization, bleaching and deodorization) on raw soybean and sunflower oils PAH content was evaluated by Teixeira et al. (2007). The authors observed an evident decrease of PAH content, especially light PAH. After refining, total PAH decreased 72% for sunflower oil and 87% for soybean oil. In both cases, the decrease of light PAH (71% and 88% for sunflower and soybean oils, respectively) was significantly higher than the decrease of heavy PAH (79% and 49% for sunflower and soybean oils, respectively) (Table 54.4).

Regarding the different steps along refining, deodorization seems to have higher impact on decreasing total PAH levels, which agrees with other works (Cejpek et al., 1998). Moreover, the deodorization process seems to have little effect on heavy PAH removing mainly light PAH, while higher condensed heavy PAH are mainly removed by activated charcoal treatment (Dennis et al., 1991; Teixeira et al., 2007). The kind

TABLE 54.3 PAH content ($\mu g\,kg^{-1}$) in olive oils and olive pomace oils.
This table summarizes the PAH content in several olive oil types reported by different authors.

Sample[a]	No. samples	Origin	BaP	Light PAH	Heavy PAH	Total PAH	Genotoxic PAH (average)	Reference
Olive oils								
EVOO	35	Italy	*	*	*	12.0–143.1[b]	*	Moret et al. (1997)
EVOO	9	Croatia	*	*	*	2.95–35.94[b]	*	Moret et al. (1997)
EVOO	5	Italian market	*	*	*	9.3–50.08[b]	*	Moret et al. (1997)
EVOO	54	Italy	*	38–260 80 (average)	*	*	*	Vichi et al. (2007)
EVOO	46	IT, SP, GR, FR, NL[c]	<0.2–0.4	15 (average)	1.6 (average)	16 (average)[d]	2.7[e]	Fromberg et al. (2007)
VOO	6	Spain (locality near airport)				0.5–1.3[f]	*	Rodríguez-Acuña et al. (2008)
VOO	2	Spain (urban locality)				0.5–1.0[f]	*	Rodríguez-Acuña et al. (2008)
VOO	2	Portuguese market	0.07–0.28	16.67–24.91	1.33–1.72	16.67–26.63[g]	*	Teixeira et al. (2007)
VOO	671	EU Countries	0.015–32 0.4 (average)	*	*	*		Fromberg et al. (2007) European Commission (2004)
OO	7	European packed at origin	nd–1.2	*	*	*	*	Pupin and Toledo (1996)
OO	15	European packed at Brazil	nd–9.7	*	*	*	*	Pupin and Toledo (1996)
OO	10	Argentina	nd–164.4	*	*	*	*	Pupin and Toledo (1996)
OO	6	IT, SP	<0.2–0.2	6.8 (average)	1.3 (average)	8.1 (average)[d]	1.9[e]	Fromberg et al. (2007)
OO	280	EU Countries	0.03–89 1.7 (average)	*	*	*	*	Fromberg et al. (2007) European Commission (2004)

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Blend OO	7	Brazilian market	2.2–9.2	*	*	*	*	Pupin and Toledo (1996)
Blend OO	2	Italian market	*	*	*	4.94–20.7[b]	*	Moret et al. (1997)
Olive pomace oils								
OPO	268	EU Countries	<0.1–206	*	*	*	*	Fromberg et al. (2007)
			18 (average)					European Commission (2004)
OPO	3	Spanish refining industries	nd–0.34	*	*	0.0–3.2[h]	*	Moreda et al. (2004)
OPO	5	Spanish market	0.35–92.71	*	*	280.35–3199.79[i]	*	Guillén et al. (2004)
OPO	10	Spain	0.5–49.3	*	*	*	*	Ballesteros et al. (2006)
			19.2 (average)					
OPO	25	Spanish producers	<0.09–6.2			1.6–24.5[j]		Martinez-Lopez et al. (2005)

[a]EVOO: extra virgin olive oil, VOO: virgin olive oil, OO: olive oil, OPO: olive pomace oil.
[b]Total of 13 PAH: FLR, PHE, ANT, FLT, PYR, BaA, CHR, BbF, BkF, BaP, DhA, BgP, IcP.
[c]IT: Italy, SP: Spain, GR: Greece, FR: France, NL: Netherlands.
[d]Total of 17 PAH: ACY, ACP, FLR, ANT, FLT, PYR, BaA, CHR, BbF, perylene, BjF, BkF, BeP, BaP, IcP, DhA, BgP.
[e]Sum of BaA, CHR, benzo[b + j]fluoranthene, BkF, BaP, IcP, DhA, and BgP.
[f]BaA, CHR, BeP, BbF, BkF, BaP, DhA, BgP and IcP.
[g]Sum of NAP, ACP, FLR, PHE, ANT, FLT, PYR, BaA, CHR, BbF, BkF, BaP, DhA, BgP, IcP.
[h]Total of 9 PAH: BaA, CHR, BeP, BbF, BkF, BaP, DhA, BgP, IcP.
[i]Sum of PAH and alkylderivatives: NAP, methyl-NAP isomers, dimethyl-NAP isomers, ethyl-NAP, ACY, ACP, fluorine, PHE, ANT, methyl-PHE isomers, dimethyl-PHE isomers, o-terphenyl, FLT, PYR, methyl-FLT, 11H-benzo[b]fluorine, 11H-benzo[c]fluorine, m-terphenyl, p-terphenyl, BaA, methyl-BaA isomers, dimethyl-BaA isomers,CHR, CHR isomers, methyl-CHR isomers, triphenylene, BbF, benzo[jk]fluoranthenes, benzo[a]fluoranthene, BeP, BaP, methylbenzopyrene or isomer, perylene, IcP, dibenz[a,h or a,c]anthracene, benzo[b]chrysene, picene, BgP, anthanthrene, coronene, dibenzopyrene and isomers, dibenzo[a,e]pyrene.
[j]Sum of BaA, benzo[e]pyrene, BbF, BkF, BaP, DhA, BgP, IcP.

TABLE 54.4 PAH content (μg kg^{-1}) during vegetable oil refining (adapted from Teixeira et al., 2007).

	Sunflower oil				Soybean oil			
	Crude	Neutralized	Bleached	Deodorized	Crude	Neutralized	Bleached	Deodorized
Light PAH	15.59	11.06	7.50	4.53	63.59	42.56	43.45	7.79
Heavy PAH	1.77	0.73	0.46	0.37	1.74	1.60	1.25	0.89
Total PAH	17.36	11.80	7.96	4.90	65.33	44.16	44.71	8.67
Total % of reduction	–	32.0%	54.1%	71.8%	–	32.4%	31.5%	86.7%

of treatment used during the bleaching step seems to be of major importance. In some works, an increase in light PAH content was observed after bleaching, as associated with the use of contaminated clay (Cejpek et al., 1998; Teixeira et al., 2007). On the other hand, a greater reduction in heavy PAH content can be achieved when using activated charcoal compared to activated earth or clay (Teixeira et al., 2007).

54.4.2 PAH Content in Refined Vegetable Oils

Generally, commercial refined vegetable oils show lower levels of PAH contamination when compared to olive oils. Van der Wielen et al. (2006) reported BaP concentrations up to $85\,\mu$g kg^{-1} in olive oils (n = 170), while for other edible vegetable oils (n = 170) they found values up to $9\,\mu$g kg^{-1}. Teixeira et al. (2007) reported total PAH concentrations slightly higher for olive oil (18.0 to $26.3\,\mu$g kg^{-1}, n = 2) when compared to soybean oil (9.3 to $10.8\,\mu$g kg^{-1}, n = 3) and sunflower oil (8.8 to $9.7\,\mu$g kg^{-1}, n = 3). The same authors reported a predominance of light PAH in all evaluated samples, which is in accordance with other works (Dennis et al., 1991; Lodovici et al., 1995). Conversely, the contribution of the more dangerous heavy PAH seems to show much lower significance. Nevertheless, there are reports on vegetable oils exceeding the maximum level admitted for BaP, although in other works the levels of this carcinogenic compound were found to be smaller than the limit imposed by the EU ($2\,\mu$g kg^{-1}) (Teixeira et al., 2007). For example, Dennis et al. (1991) reported BaP concentrations ranging from 1.4 to $64\,\mu$g kg^{-1} in rapeseed oil and Moret and Conte (2000) reported concentrations of the same compound ranging from 8.6 to $44\,\mu$g kg^{-1} in 20 grape seed oils evaluated. In the SCOOP task of the EU (European Commission, 2004), sunflower oils collected in seven EU Member States revealed an average value of $3.2\,\mu$g kg^{-1} for BaP, with 29% of all samples

presenting levels above the maximum limit established for this compound.

54.5 CARCINOGENESIS OF PAH

PAH are themselves chemically inert and hydrophobic. However, as with other carcinogens, metabolic activation in an organism is required, which leads to the formation of electrophilic metabolites capable of binding to nucleophilic centers in DNA. PAH undergo metabolic activation in mammalian cells to diol-epoxides that bind covalently to cellular macromolecules, including DNA, thereby causing errors in DNA replication and mutations that initiate the carcinogenic process (Phillips, 1999). This mechanism of activation, with modifications in some cases, has been found to occur with all carcinogenic PAH studied (Phillips, 1999).

When BaP is oxidized and hydroxylated it involves cytochrome P450 isoenzyme and epoxide hydrolase and is converted to epoxides, phenols, diols, tetrols and quinine derivatives (IARC, 1987). An initial step of tumorigenesis involves the metabolic conversion to compounds that may react covalently with DNA to yield DNA adducts. If those adducts are not repaired or misrepaired, they may initiate gene mutations and lead to adverse health effects in humans. This could be a biomarker of biological effective dose of BaP. Measuring the carcinogen–DNA adducts is thought to be a useful biomarker in molecular epidemiological studies that attempt to determine cancer risk (Phillips, 2005). Several studies reported the link between DNA adducts and colon cancer originated from exposure to PAH (Al-Saleh et al., 2008).

Exposition to PAH has been epidemiologically associated with an increased risk of skin and lung cancer (IARC, 1987). There is strong evidence that the diol epoxide mechanism operates in the mouse lung tumorigenesis of many PAH evaluated. For some PAH, there is strong evidence

that both radical cation and diol-epoxide mechanisms induce mouse skin carcinogenesis. Many of the pathways that lead to PAH carcinogenesis involve genotoxicity (IARC, 2006).

Although studies in experimental animals on individual PAH, most notably BaP, have shown various toxicological effects, such as hematological effects, reproductive and developmental toxicity and immunotoxicity, it is the carcinogenic and genotoxic potential of these compounds that has attracted most attention. A number of PAH as well as coal-tar and some occupational exposures to combustion emissions containing these compounds have shown carcinogenicity in experimental animals and genotoxicity and mutagenicity in vitro and in vivo (IARC, 1987).

As diet is one of the main sources of human and animal background exposure to PAH, the epithelial intestinal cells, the first to be in contact with contaminants, are of particular interest. In vivo studies suggest a transfer in intestinal epithelium by diffusion, which appears extensively governed by the physicochemical properties of PAH, particularly lipophilicity. However, a positive finding is that an intestinal transfer of PAH is not sufficient to characterize their availability and toxicity because intestinal metabolism can reshape the molecules, decreasing the bioavailability of contaminants (Cavret and Feidt, 2005).

SUMMARY POINTS

- Polycyclic aromatic hydrocarbons (PAH) belong to a large class of organic compounds originated from incomplete combustion of organic matter, known or suspected to be carcinogenic and genotoxic compounds to mammals.
- Benzo[*a*]pyrene is the most studied PAH and is used as a marker.
- The main sources of PAH in foods are the environmental contamination and the food processing (such as smoke curing, cooking over charcoal and roasting).
- PAH in olive oil can occur due to environmental contamination of the fruit skin and in olive pomace oil due to the refining process.
- Refining process of vegetable oils may decrease the levels of PAH in the final products.

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