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Review

Concentrations of environmental organic contaminants in meat and meat products and human dietary exposure: A review

José L. Domingo

Laboratory of Toxicology and Environmental Health, School of Medicine, Universitat "Rovira I Virgili", IISPV, Sant Llorenç 21, 43201 Reus, Catalonia, Spain

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ABSTRACT

Meat and meat products is one of the most relevant food groups in an important number of human diets. Recently, the IARC, based on results of a number of epidemiological studies, classified the consumptions of red meat and processed meat as "probably carcinogenic to humans" and as "carcinogenic to humans", respectively. It was suggested that the substances responsible of the potential carcinogenicity would be mainly generated during meat processing, such as curing and smoking, or when meat is heated at high temperatures. However, the exposure to environmental pollutants through meat consumption was not discussed. The purpose of the present paper was to review recent studies reporting the concentrations of PCDD/Fs, DL-PCBs and PAHs in meat and meat products, as well as the human exposure to these pollutants through the diet. It is concluded that the health risks derived from exposure to carcinogenic environmental contaminants must be considered in the context of each specific diet, which besides meat and meat products, includes other foodstuffs containing also chemical pollutants, some of them with carcinogenic potential. Anyhow, meat and meat products are not the main food group responsible of the dietary exposure to carcinogenic (or probably carcinogenic) environmental organic pollutants.

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1. Introduction

It is well established that an appropriate diet, together with a suitable lifestyle, are essential factors for maintaining a good health status, and to prevent a number of diseases (Arena et al., 2016; Barnard et al., 2014; Kokubo, 2014; Notara et al., 2014; Whayne, 2011). A good lifestyle should include regular exercise and must avoid insane habits such as smoking and drinking alcohol, while an adequate balance in the intake of nutrients is, doubtless, a key issue. However, it should be also taken into account that certain dietary habits can also contribute to compromised health by being a source of exposure to environmental contaminants.

Many potentially toxic pollutants are fat-soluble. A number of studies have shown that some foodstuffs, especially those with a high fat content, can be a source of human exposure to certain environmental contaminants with a well-known toxicity. Consequently, any fatty food may often contain not negligible levels of persistent organic pollutants (POPs) and other chemical contaminants. In addition to the usual presence of pesticides in certain

E-mail address: joseluis.domingo@urv.cat.

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kinds of foodstuffs, among the pollutants that stand out in foods, metals, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs) are probably the most relevant. However, other organohalogenated contaminants such as polybrominated diphenyl ethers (PBDEs), polychlorinated diphenyl ethers (PCDEs), polychlorinated naphthalenes (PCNs), or perfluorinated compounds (PFCs) should be also taken into account. Interestingly, information on exposure and adverse effects in humans for some of these organic pollutants (PBDEs, PCDEs, PCNs, PFCs) is still relatively limited (Domingo, 2004, Domingo, 2012a, b; Domingo and Nadal, 2015).

Meat, including also meat products, is one of the most relevant food groups in a great number of human diets. Its regular/frequent consumption means a significant intake of proteins and a number of essential micronutrients (Fe, Zn, vitamin B_{12}, etc.), as well as an important contribution of energy. Notwithstanding, the relatively great quantities of meat currently consumed by some population groups in many countries, have been criticized for contributing to increase the incidence of some chronic diseases, including cancer (De Smet and Vossen, 2016; Hammerling et al., 2016). This increased incidence, and particularly that of certain cancers (colorectal cancer, CRC), is more related with red meats than to white meats. In relation specifically to cancer, in October 26, 2015, the International Agency for Research on Cancer (IARC, 2015) issued a press release informing of the recent evaluation of the carcinogenicity of red and processed meat consumption. Until that IARC decision, it was assumed that consuming moderate amounts of lean red meat, as part of a balanced diet, valuably contributed to the intake of essential nutrients, and possibly also to the intake of long chain n−3 PUFAs and conjugated linoleic acid, being unlikely to increase risk for cardiovascular diseases, and CRC. Therefore, a moderate consumption should have a positive impact on long-term health (De Smet and Vossen, 2016; McAfee et al., 2010). While the IARC statement on the potential carcinogenicity (mainly CRC) of red and processed meat consumption is conclusive, recent reviews have noted that there is limited evidence about the link of meat intake with diseases such as cardiovascular disease, type 2 diabetes, and other cancers than CRC. However, the authors of these reviews also suggested that dietary intervention -mainly reducing the consumption of processed meat-might be a promising approach for prevention of cancers, type 2 diabetes and cardiovascular disease (Boada et al., 2016; Hernández et al., 2015).

The consumption of red meat and that of processed meat have been classified by the IARC as “probably carcinogenic to humans” and as “carcinogenic to humans”, respectively. It was suggested that the substances responsible of the potential carcinogenicity (N-nitroso-compounds, PAHs, and heterocyclic aromatic amines) would be mainly generated during meat processing, such as curing and smoking, or when meat is heated at high temperatures (Bouvard et al., 2015). However, the potential role that can play some environmental organic pollutants, with a well-known carcinogenic potential, and that are already present in raw or unprocessed meat, was not discussed. Recently, we reviewed which could be the role of various chemical contaminants (toxic trace elements, PAHs, PCDD/Fs, PCBs, PBDEs, PCNs, PCDEs and PFCs) on the carcinogenicity of consumption of red meat and meat products (Domingo and Nadal, 2016, 2017). We concluded that not all the potential causes of the carcinogenicity of the consumption of red meat and meat products were still well defined.

Based on the above, the main goal of the present paper was to review recent studies reporting the concentrations of a number of chemical contaminants, with a well-known potential carcinogenic (mainly PCDD/Fs and DL-PCBs, and PAHs), in meat and meat products, as well as the human exposure to these contaminants through their regular dietary consumptions. In recent years, a number of studies have shown that, in general terms, the levels of PCDD/Fs and DL-PCBS, as well those of PAHs in the environment and/or in food, are following a clear decreased trend (Bocio et al., 2004; Domingo, 2004, 2012a: Domingo and Bocio, 2007; Domingo and Nadal, 2015; Leong et al., 2014; Llobet et al., 2008; Malisch and Kotz, 2014; Martí-Cid et al., 2008; Mozaffarian and Rimm, 2006; Perelló et al., 2015). Taking into account that decreasing tendency, to avoid an excessively long list of data in this paper, the present review is only focused on data corresponding to the current decade, with some exception due to its possible particular interest. Information on recent international studies, in which the concentrations of chemical contaminants in meat and meat products were determined, is here summarized.

2. Carcinogenic potential of PCDD/Fs, PCBs and other POPs

PCDD/Fs and (dioxin-like) DL-PCBs are a group of persistent chemicals, which can accumulate in human and animal tissues due to their lipophilic nature and resistance to metabolic degradation. Exposure to these environmental contaminants can result in a wide range of adverse effects, including disturbance of the reproductive and immune system, and cancer. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) is the most toxic member of the family of PCDD/Fs. It has been classified as a human carcinogen by the WHO, the IARC, and the US National Toxicology Program (Apostoli et al., 2011). To avoid levels in humans exceeding a critical concentration, the Scientific Committee on Food (2001) established a tolerable weekly intake (TWI) of 14 pg toxic equivalents (TEQ) per kg of body weight per week, while the US EPA derived an oral reference dose (RfD) of 0.7 pg/kg of body weight per day (Adamse et al., 2017). With respect to PCBs, in an evaluation of the IARC conducted in 2013, PCBs and DL-PCBs were both classified into group 1: “carcinogens to humans”. However, the relative contributions of the different PCB congeners to the carcinogenicity of PCB mixtures are not known yet (Lauby-Secretan et al., 2016).

Regarding the potential carcinogenicity of PAHs, the US Environmental Protection Agency classified benz[*a*]anthracene, benzo[*a*]pyrene, benzo[*b*]fluoranthene, chrysene, benzo[*k*]fluoranthene, dibenzo[*a,h*]anthracene and indeno[1,2,3-*c,d*]pyrene as probable human carcinogens (group B2). In turn, the IARC established that benz[*a*]anthracene and benzo[*a*]pyrene were probable human carcinogens, being benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene and indeno[1,2,3-*c,d*]pyrene possible human carcinogens (Domingo and Nadal, 2015).

With respect to other pollutants with more or less important environmental presence, which can also reach the food chain, PBDEs, PCDEs, PCNs and PFCs are among the most relevant. PBDEs are chemicals found in plastics used in a variety of consumer products to make them difficult to burn. Nowadays, the health effects of PBDEs in people are not all well established. For example, it is not known whether PBDEs are human carcinogens. However, based on experimental evidence in rats and mice, the US EPA classified decabromodiphenyl ether as a possible human carcinogen (ATSDR, 2011). The potential carcinogenicity of other POPs such as PCDEs and PCNs is not currently established, while the ATSDR concluded recently that there is no conclusive evidence that perfluoroalkyls cause cancer in humans. In relation to HCB, it is classified as possibly carcinogenic to humans (group 2B).

3. Levels of PCDD/Fs and PCBs in meat and meat products and human dietary exposure

Polder et al. (2010) reported the levels of various POPs in 70 selected food items purchased (1998–2002) from various cities in Northwest Russia. The group of meats included pork meat, fat and