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An estimation of the carcinogenic risk associated with the intake of multiple relevant carcinogens found in meat and charcuterie products☆

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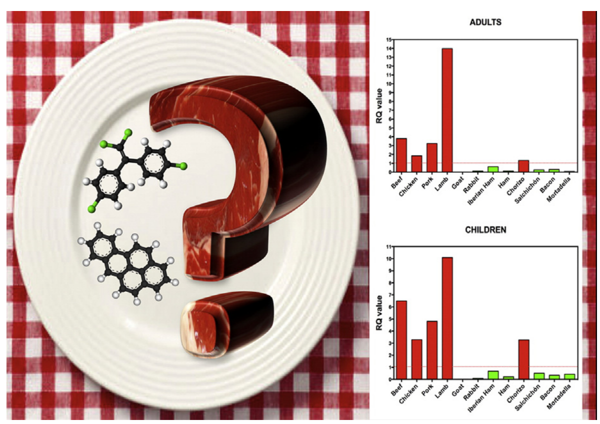
HIGHLIGHTS

- Quantification of 33 potential carcinogens in 58 meat and 42 charcuterie samples.
- Dietary intake of meat carcinogens in Spanish population ranged 0.5–293% of TDIs.
- Consumption of lamb, beef, pork, chicken, and Spanish chorizo poses carcinogenic risk.
- Recommendations of the maximum number of servings/month of each food are provided.

GRAPHICAL ABSTRACT



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ABSTRACT

Numerous epidemiological studies have demonstrated a link between excessive meat consumption and the incidence of various cancers, especially colorectal cancer, and it has been suggested that environmental carcinogens present in meat might be related to the increased risk of cancer associated with this food. However, there are no studies evaluating the carcinogenic potential of meat in relation to its content of carcinogens. Our purpose was to emphasize the relevance of environmental carcinogens existing in meat as a determinant of the association between cancer and meat consumption. Because within Europe, Spain shows high consumption of meat and charcuterie, we performed this study focusing on Spanish population. Based on the preferences of consumers we acquired 100 samples of meat and charcuterie that reflect the variety available in the European market. We quantified in these samples the concentration of 33 chemicals with calculated carcinogenic potential (PAHs, organochlorine pesticides, and dioxin-like PCBs). The carcinogenic risk of these contaminants was assessed for each food using a risk ratio based on the current consumption of meat and charcuterie and the maximum tolerable intake of these foods depending on the level of contamination by the carcinogens they contain. Our results indicate that the current consumption of beef, pork, lamb, chicken, and "chorizo", represents a relevant carcinogenic risk for

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Charcuterie
PCB
Organochlorine pesticides

consumers (carcinogenic risk quotient between 1.33 and 13.98). In order to reduce carcinogenic risk, the study population should halve the monthly consumption of these foods, and also not to surpass the number of 5 servings of beef/pork/chicken (considered together).

1. Introduction

The consumption of certain foods of animal origin has been associated with the increased incidence of different types of cancer (Abid et al., 2014). Among them, the most clear epidemiological associations have been established with the consumption of red meat and processed meats (Abid et al., 2014; Kim et al., 2013). Thus, the consumption of red meat has been linked to an increase in total cancer mortality (Larsson and Orsini, 2014) as well as the increased incidence of colorectal cancer (Kim et al., 2013) and cancers of the esophagus (Zhu et al., 2014), liver (Freedman et al., 2010), pancreas (Pericleous et al., 2014), kidney (Alexander and Cushing, 2009), prostate (Abid et al., 2014), lung (Abid et al., 2014) and breast (Abid et al., 2014). The consumption of processed meat has also been strongly associated with an increased incidence of colorectal cancer (Aune et al., 2013; Kim et al., 2013) as well as kidney (Alexander and Cushing, 2009) and prostate (Alexander et al., 2010) cancers. According to the European cancer registries, in Spain, where this study is based, both the incidence and mortality of some of these cancers are above the average of the European Union, especially in men. This is the case for cancers of the colon and rectum, liver and lungs (Ferlay et al., 2013).

Although the food culture of Spain is contextualized within the framework of the Mediterranean diet, which is considered to be a pattern of consumption of healthy foods that protect against the development of the most common chronic diseases, including cancer (Giacosa et al., 2013), the most recent nutritional surveys show a decrease in adherence to the traditional Mediterranean diet in this country (Varela-Moreiras et al., 2013). Thus, overall meat consumption in Spain has steadily increased over the last few decades (Kanerva, 2013; Leon-Munoz et al., 2012), and currently, the meat industry is ranked in fifth position in the industrial sector of the Spanish economy and is ranked first among the agro-food industries (Chamorro et al., 2012). Thus, meat consumption in Spain has gone from being one of the lowest in the EU to reaching an average per capita consumption of 52.7 kg/year, which is even higher than the European average (51.2 kg/year) (Chamorro et al., 2012). More relevant is the consumption of charcuterie products, and Spain is at the head of the production and consumption of such meat products in Europe, behind Germany, France and Italy (Leon-Munoz et al., 2012).

Different studies have linked an increased risk of cancer from meat consumption with the presence of carcinogenic chemical substances in meat (Trafialek and Kolanowski, 2014), and according to the literature, the content of certain pollutants in meat is particularly relevant (Gasull et al., 2011). This is the case of organochlorine pesticides (OCPs) (Letta and Attah, 2013; Pardio et al., 2012; Schecter et al., 2010; Wang et al., 2011), dioxin-like polychlorinated biphenyls (PCB) (Costabeber et al., 2006; Malisch and Kotz, 2014; Schecter et al., 2010; Schwarz et al., 2014), and especially polycyclic aromatic hydrocarbons (PAHs) (Gilsing et al., 2012; Liao et al., 2014).

During the past 30 years, many of these substances have been highlighted as a concern (Boada et al., 2007, 2012, 2014; Casals-Casas and Desvergne, 2011; Dorgan et al., 1999; Knerr and Schrenk, 2006; Valeron et al., 2009) and have been the subject of extensive study and international regulation in part because of their carcinogenic potential (Dorgan et al., 1999; Knerr and Schrenk, 2006; Liao et al., 2014). A variety of the most common pollutants in meat from the abovementioned chemical groups have been classified in group B of carcinogenicity (WHO, 2014). Although cancer slope factors (CSF) have been calculated for all of these probable carcinogens (EPA, 2014) and this would allow an estimate of the risk of cancer associated with continuous exposure to them through foodstuff, very few studies have attempted to estimate the carcinogenic risks that are associated with the current pattern of consumption of the pollutants associated with meat and meat products (Trafialek and Kolanowski, 2014).

In this study, we first determined the concentrations of 7 PAHs, 18 PCBs and 8 OCPs for which the CSFs have been calculated in a total of 100 samples of meat and charcuterie products that are most commonly consumed by the studied population. Because it is well known that continued exposure to carcinogens, even at very low doses, is not without risk, the main objective of this study was to use these data to estimate the carcinogenic risk associated with the current level of meat consumption by these consumers. For this purpose, we used the data of food consumption (AECOSAN, 2011) and applied the methodology that has been recently used to estimate the carcinogenic risk associated with food intake (Yu et al., 2014). Finally, we calculated the number of monthly servings of meat and charcuterie products that would be exempt from carcinogenic risk to provide a recommendation for consumption.

2. Materials and methods

2.1. Sampling

From January to March 2014, we randomly acquired samples of meat and charcuterie products from multinational retailers settled in the Canary Islands (Spain). Therefore, all the products sampled came from large suppliers who serve the entire European territory, and as a consequence our results could be extrapolated to the entire European population, only considering their differentiated dietary habits. According the most appreciated choices of Spanish consumers (AECOSAN, 2011) we bought meat samples: beef ($n = 14$), chicken ($n = 16$), pork ($n = 8$), lamb ($n = 8$), goat ($n = 6$), and rabbit ($n = 6$); and also traditional charcuterie products: Iberian cured ham ("serrano ham") ($n = 8$), ham ($n = 7$), Spanish chorizo ($n = 8$), Spanish dry-cured sausage "salchichón" ($n = 7$), bacon ($n = 6$), and Italian mortadella ($n = 6$).

The samples were processed immediately upon arrival at the laboratory. Each individual sample was finely chopped with a knife and was then ground using a stainless steel domestic food processor. The lipid content of the samples was determined in triplicate by the modified Gerber method as previously described (de Langen, 1963), to obtain the final lipid-corrected values. Then, all of the samples were frozen at −18 °C until analysis.

2.2. Chemical analyses

Organic solvents (>99.9%) were purchased from Fisher Scientific (Leicestershire, United Kingdom). Diatomaceous earth was purchased from Sigma-Aldrich (St. Louis, USA). Bio-Beads SX-3 were purchased from BioRad Laboratories (Hercules, USA). Standards of OCPs, PCBs, and the internal standards (ISs, PCB 202, p,p′-DDE-d8, phenanthene-d10, tetrachloro-m-xylene, and heptachloro epoxide cis) were purchased from Dr. Ehrenstorfer (Augsburg, Germany). Standards of PAHs were purchased from Absolute Standards, Inc. (Connecticut, USA). All standards were neat compounds (purity ranged from 97% to 99.5%). Solutions diluted from 0.05 ng/mL to 100 ng/mL in cyclohexane were used for calibration curves.

We quantified the levels of 8 OCPs: p,p′-DDT, p,p′-DDE, p,p′-DDD, hexachlorobencene (HCB), and the four isomers of hexachlorocyclohexane (α-, β-, γ-, δ-HCH). We also determined 18 PCB congeners, including marker-PCBs (M-PCBs) and dioxin-like PCBs (DL-PCBs): IUPAC