Science of the Total Environment 542 (2016) 653–664

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Evaluation of serum markers of blood redox homeostasis and inflammation in PCB naturally contaminated heifers undergoing decontamination

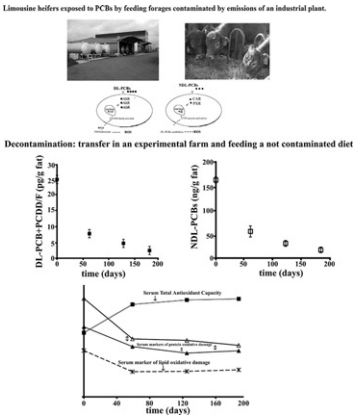
Luisa Cigliano [a], Carlo Nebbia [b], Guido Rychen [c], Cyril Feidt [c], Flavia Girolami [b], Cristina Rossetti [d], Maria Stefania Spagnuolo [d,*]

[a] Department of Biology, University of Naples Federico II, via Cinthia 121, 80126 Naples, Italy
[b] Department of Veterinary Sciences, University of Turin, Largo P. Braccini 2, 10095 Grugliasco, Italy
[c] Université de Lorraine, INRA, 2 avenue de la forêt de Haye, TSA 40602, 54518 Vandoeuvre Cedex, France
[d] National Research Council (CNR), Institute of Animal Production System in Mediterranean Environments (ISPAAM), via Argine 1085, 80147 Naples, Italy

HIGHLIGHTS

- Redox and inflammation indices were evaluated in heifers under decontamination.
- TEQ values of DL-PCBs + PCDD/Fs and NDL-PCBs content in pericaudal fat was measured.
- PCBs exposure negatively affects redox and inflammatory status of heifers.
- N-Tyr and TNF-alpha levels represent biomonitoring markers of decontamination.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 July 2015
Received in revised form 15 October 2015
Accepted 21 October 2015
Available online 4 November 2015

Editor: Adrian Covaci

ABSTRACT

Dioxins and polychlorinated biphenyls (PCBs) are widely spread and long persistent contaminants. The aim of this study was to evaluate physiological changes associated with the decontamination of animals previously exposed to environmental pollutants. Eight Limousine heifers were removed from a polluted area and fed a standard ration for six months. The extent of contamination was defined by measuring total toxic equivalents (TEQ) values of dioxin like-PCBs (DL-PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), and NDL-PCBs amount in pericaudal fat two weeks after the removal from the contaminated area (day 0) and then bimonthly for six months during the decontamination (days 59, 125, and 188). The concentrations of both DL-PCBs + PCDD/Fs and NDL-PCBs at the start of decontamination (day 0) were higher than those legally admitted, and they were strongly decreased at the end of the experimental period. Specific

Abbreviations: Ret, Retinol; Toc, alpha-Tocopherol; Asc, ascorbic acid; N-Tyr, nitro-tyrosine; PCs, protein-bound carbonyls; LPOs, lipid hydroperoxides; SOD, superoxide dismutase; GPx, glutathione peroxidase; Hpt, Haptoglobin; PCDDs, polychlorinated dibenzo-*p*-dioxins; PCDFs, polychlorinated dibenzofurans; DL-PCBs, dioxin-like polychlorinated biphenyls; PCBs, polychlorinated biphenyls; WHO, World Health Organization; TEQs, toxic equivalents.

* Corresponding author at: Institute of Animal Production System in Mediterranean Environments (ISPAAM), via Argine 1085, 80147 Naples, Italy.
E-mail addresses: luisa.cigliano@unina.it (L. Cigliano), carlo.nebbia@unito.it (C. Nebbia), guido.rychen@univ-lorraine.fr (G. Rychen), cyril.feidt@univ-lorraine.fr (C. Feidt), flavia.girolami@unito.it (F. Girolami), cristina.rossetti@cnr.it (C. Rossetti), mariastefania.spagnuolo@cnr.it (M.S. Spagnuolo).

http://dx.doi.org/10.1016/j.scitotenv.2015.10.104

Keywords:
Biomarkers
Environmental pollution
PCB decontamination
Redox homeostasis
Haptoglobin
Oxidative stress

indices of blood redox homeostasis and inflammation were also measured at each time. Serum concentrations of Retinol, Tocopherol and Ascorbate, the total antioxidant capacity (TAC) and the activities of superoxide dismutase and glutathione peroxidase were lower at day 0 than after 59, 125 or 188 days of decontamination. Protein-bound carbonyls (PC), nitro-tyrosine (N-Tyr), and lipid hydroperoxides concentrations were higher at day 0 than during decontamination. In addition, TAC, PC and N-Tyr levels correlated with both DL-PCB and NDL-PCB concentrations only at day 0. Serum concentrations of TNF-alpha and Haptoglobin were higher in samples collected at day 0 than in those obtained during decontamination. As Haptoglobin and TNF-alpha levels correlated with both DL-PCB and NDL-PCB concentrations at day 0 and at day 59 (when these concentrations are still over legal limit), they might represent easily measurable parameters for assessing acute exposure to pollutants. Further both N-Tyr and TNF-alpha concentrations could be used as bio-monitoring markers of the decontamination procedure.

1. Introduction

Persistent organic pollutants (POPs) are toxic to human health and ecosystems, and are largely transferred in the food chain (Rychen et al., 2005; Antignac et al., 2006). Several POPs, such as dioxin-like and non dioxin-like polychlorinated biphenyls (DL-PCBs and NDL-PCBs respectively) are voluntary produced, for commercial purposes, as a result of industrial activities, while other pollutants, such as polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), designed as *dioxins*, are unintentional by-products of industrial processes. Dioxins and PCBs are toxic chemical compounds of great public health concern, and represent the major sources of environmental contamination. Due to their structural stability and volatility are widely spread, thus affecting agricultural areas near or far away from emitting sources (Beyer et al., 2000; Lohman and Seigneur, 2001). They are also resistant towards chemical and biological degradation processes, thus showing a long persistence in the environment. Although the Stockholm Convention on Persistent Organic Pollutants in 2001 banned PCB production internationally (UNEP, 2001), PCBs are still found in soil, fresh water, aquatic wildlife, and mammals, essentially because of the seepage into the environment, accidental spills, and improper disposal. Food chain contamination occurs as a consequence of the animal ingestion of contaminated water, soil and forage (McLachlan, 1993; Thomas et al., 1999a, 2002; Brambilla et al., 2004; Rychen et al., 2014). Indeed, dioxins and PCBs are lipophilic and accumulate in animal body, mainly in the liver and in the adipose fraction of organs and tissues (Larsen, 2006), being also transferred into milk and eggs. Therefore the consumption of animal products rich in fat represents by far the major source of exposure for humans (Thomas et al., 1999b; Schecter et al., 2006). However, ruminants were reported to be decontaminated (McLachlan, 1994; Thomas et al., 1999b; Huwe and Smith, 2005; Rossi et al., 2010; Rychen et al., 2014), essentially via milk excretion (Thomas et al., 1999b; Glynn et al., 2009; Rossi et al., 2010), or through the allometric increased volume of adipose tissue during growth (Chamberland et al., 1994; Glynn et al., 2009; Rychen et al., 2014).

Dioxins and DL-PCBs share a common toxicity mechanism, that is mediated via binding to a specific intracellular receptor, the aryl hydrocarbon receptor (AhR) (Alsharif et al., 1994; Mandal, 2005), whose activation is responsible for the enhanced expression of genes coding for cytochrome P450 1 family enzymes in liver of several species, including cattle (Safe, 1986; Whitlock, 1990; Machala et al., 1998; Matsumura, 2003; Guruge et al., 2009).

In particular, PCB 126, the most potent AhR agonist among DL-PCBs (Bandiera et al., 1982), not only alters the expression of genes coding for CYP1A1, but also impairs the expression of genes coding for antioxidant enzymes, resulting in oxidative stress in the liver (Hassoun et al., 2002; Parkinson et al., 1983). Dioxin exposure was reported to promote, via AhR activation, highly reactive oxygen species (ROS) production (Slezak et al., 2000; Nebert et al., 2000; Dalton et al., 2002), and to depress several ROS quenching systems (Ishida et al., 2009), thus inducing increased DNA fragmentation, as well as production of superoxide anion, thiobarbituric acid reactive substances, and hydroperoxides (Shertzer et al., 1995; Zhao and Ramos, 1998; Slezak et al., 2000, 2002). This leads to oxidative conditions (Shertzer et al., 1998; Slezak et al., 2000; Senft et al., 2002) that may induce oxidative stress-related processes (Mandal, 2005; Pelclova et al., 2011), that are associated with modifications of physiological and metabolic functions (Halliwell and Gutteridge, 2000). NDL-PCBs, due to their chemical properties, have a low affinity for AhR, and are mainly involved in alterations of signal transduction systems, neurotoxicity, immune suppression and endocrine disruption (Fischer et al., 1998; Selgrade, 2007). NDL-PCB bioaccumulate preferentially in adipose tissue causing disruption of lipid metabolism and induction of IL-6 and TNF-alpha production (Ferrante et al., 2015). NDL PCBs were also reported to reduce cell viability and induce oxidative stress (Westerink, 2014; Abella et al., 2015).

In physiological conditions, the antioxidant defence system, provided by enzymes and antioxidants, scavenges ROS, thus limiting or preventing oxidative damage (Halliwell and Gutteridge, 2000). Oxidative stress occurs as consequence of an imbalance between ROS production and neutralizing capacity of antioxidant mechanisms (Halliwell and Gutteridge, 2000), and is involved in the aetiology of several diseases and metabolic disorders (Lomba, 1996; Bernabucci et al., 2002, 2005; Castillo et al., 2005; Wilde, 2006), also contributing to the reduction of fertility in dairy cows (Wathes et al., 2012). Therefore, the evaluation of blood redox homeostasis has increasingly contributed to knowledge of the processes involved in reproductive and metabolic disorders (Campbell and Miller, 1998; Kankofer, 2002; Sordillo and Aitken, 2009), and it has become important as a complementary tool for the evaluation of health and metabolic status of dairy cows (Bernabucci et al., 2005; Castillo et al., 2005, 2006).

The main objective of this investigation was to evaluate the effect of a decontamination procedure, based on the removal of Limousine heifers from an agricultural area contaminated by emissions of an industrial plant specialized in PCB treatment, followed by the feeding a standard ration, on specific indices of blood redox homeostasis and inflammation, in order to assess the changes associated with decontamination, and to obtain tools for monitoring such a process. We focused on the analysis of oxidative and inflammatory status essentially because both DL-PCBs and NDL-PCBs, although through different pathways, are able to disrupt redox homeostasis and to induce inflammatory response.

2. Materials and methods

2.1. Materials

Bovine serum albumin fraction V (BSA), chemicals of the highest purity, Rabbit anti-human Hpt IgG, Goat anti Rabbit IgG-horseradish peroxidase linked (GAR-HRP), Rabbit anti-dinitrophenylhydrazine (anti-DNP) IgGs, and standards for high performance liquid chromatography (HPLC) were purchased from Sigma-Aldrich (St. Louis, MO, USA).