The role of apples in the PCDD/F daily dietary-intake

D. Cocârță1,2, A. Cemin1, M. Ragazzi1 & A. Badea2
1University of Trento, Italy
2Technical University of Bucharest, Romania

Abstract

Waste incineration processes release substances which can accumulate in various environmental compartments: soils, vegetation, indoor dusts, animals and humans. The research presented in the specialized literature and developed until now demonstrates that food is the major route for human exposure to dioxin and dioxin-like compounds. This paper points out the contribution of apples to daily PCDD/F (dioxin and dioxin-like compounds) intakes in different scenarios. Apples sampled in different locations and literature data have been taken into account. The different roles of pulp and peel have been taken into account too. In the case of low environmental pressure the apples have a minor contribution in PCDD/F intakes, but in specific conditions the PCDD/F intakes by apples can significantly exceed the usual contribution.

Keywords: dioxins and dioxin-like compounds, dietary-intake, exposure assessment, contamination.

1 Introduction

The dioxin and dioxin-like compounds are hazardous chemical organic substances resulting from incomplete combustion, precursor compounds and de novo synthesis. The reasons for why these kinds of compounds are studied are the non-carcinogenic (negative effect on neurodevelopment, birth weight and immunity, skin diseases, immunological effects and diabetes risk, etc.) and carcinogenic effects (United States Environmental Protection Agency US-EPA considers one of the congeners Tetrachlorodibenzo-p-dioxins, TCDD to be a human carcinogen and that other PCDD/Fs are likely to be human carcinogens),
but also the toxicokinetic impact (PCDD/Fs have an ability to modulate a number of biochemical parameters) [6].

The research presented in the specialized literature and developed until now demonstrates that food is the major route for human exposure to dioxin and dioxin-like compounds, and it has recently been estimated that even for a population living in the vicinity of a municipal waste incinerator the dietary exposure accounted for more than 98% of total PCDD/F exposure [3]; this kind of interpretation can be made if we do not take into account the fact that new waste incineration plants which have adopted Best Available Technologies (BAT) can be dioxin destructors [1].

The literature data used in this work in order to assess the contribution of apples to daily PCDD/F intake in normal environmental conditions (without significant environmental pressure) regard the human exposure to dioxin through the diet in Spain and Germany. On the contrary, the contaminated apples were taken from two European towns, one of these, in Italy, being characterized by heavy traffic (because of the presence of an important highway) and the other, in Romania, by industrial contamination (because of the presence of a refinery). An additional case-study defers to Great Britain in the vicinity of an old incinerator (1.5 km, flat region).

2 The dietary risk assessment methodology and tolerable daily intakes

Dioxins and furans are greatly toxic and carcinogenic compounds. For these substances the World Health Organization proposed a TDI value. The TDI (Tolerable Daily Intakes) is a concept derived by the ADI (Acceptable Daily Intake for human); this parameter expresses the "amount of polluting in the food (derived from the pesticides use or residual of veterinary cares and expressed on the base of the body weight) that can be daily ingested for the lifetime without risk for the health". This parameter is obtained by studies on human beings, experiments on animals and culture of bacteria; the results are obtained dividing for opportune precautionary coefficients the derived NOAEL (No Observed Adverse Effect Level) value. The value of TDI initially (1990) [4] proposed for the TCDD from the WHO was equal to 10 pg TEQ/kg bw. In 1998 the value of TDI was revised on the basis of new available data. Studies on animals have in fact detected a LOAEL (Lowest Observed Adverse Effect Level) equal to 14÷37 pg TEQ/kg bw; the value of TDI has therefore been fixed, considering a safety factor of 10, equal to 1÷4 pg TEQ/kg bw [4,16]. The European Community Scientific Committee on Food has concluded to adopted a value of the TDI equal to 2 pg TEQ/kg bw.

A much-discussed question, concerning the risk analysis, is the existence or not of a no effect threshold value. The issue is the following: is it possible that there are values of exposure intrinsically sure, that is values for which the carcinogenic mechanism does not develop, or does not have the possibility to get some effect on the target? The arguments against the existence of threshold values are based on the theory that a single punctual modification of the DNA
structure can cause the uncontrolled growth of somatic cells with consequent possible development of disease; besides, the threshold values would be different from individual to individual, with the possibility, therefore, of having individuals with so low thresholds to be practically equal to a zero dose. On the other hand, it can be hypothesized that the effects of the genetic reparation and the immune defences of the organism are able to realize a threshold effect. The approach to the risk assessment without considering a threshold point is based on the “cancer potency” value; this is the approach chosen by the US-EPA.

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>1.3·10^5</td>
<td>Official value</td>
</tr>
<tr>
<td>2000</td>
<td>1.0·10^6</td>
<td>Unofficial value</td>
</tr>
<tr>
<td>U.S.</td>
<td></td>
<td>Review commission</td>
</tr>
<tr>
<td>Starr</td>
<td>1.6·10^5</td>
<td>Epidemiologic studies on animals,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kociba, (1978)</td>
</tr>
<tr>
<td>2001</td>
<td>1.1·10^6</td>
<td>Epidemiologic studies on human</td>
</tr>
<tr>
<td></td>
<td></td>
<td>exposure U.S.A e Germany</td>
</tr>
<tr>
<td>Crump</td>
<td>3.0·10^6</td>
<td>(2003) linear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steenland et al.(2001) linear at</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intervals</td>
</tr>
<tr>
<td></td>
<td>9.1·10^6</td>
<td>Epidemiologic studies on human</td>
</tr>
<tr>
<td></td>
<td></td>
<td>exposure U.S.A e Germany</td>
</tr>
</tbody>
</table>

Figure 1: Proposed and extrapolated cancer potencies [2, 8, 9, 11, 12].

The official value defined by the Office of Environmental Health Hazard Assessment (OEHHA, US EPA, California [8]) is equal to 1.3·10^5 (mgTCDD / kg bw / d)^-1. Recently a more restrictive revision has been proposed. In September 2000 the National Center for Environmental Assessment Office of Research and Development has released the document “Draft Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds”. The first version of this document was published in September 1994 and updated in 1997 and 1998 up to the version of September of 2000, however this is not official. It is attended in fact to have a last revision from the SAB (Science Advisory Board) before the document can be published as a final report from the EPA. This report indicates a value for the cancer potency equal to 1·10^6 (mgTCDD / kg bw / d)^-1. Considering that the carcinogen individual risk is calculated by multiplying dose for cancer potency, the cancer potency value suggested by U.S.EPA (2000) [13] would determine a higher individual risk in comparison to the risk calculated with the official cancer potency value from U.S.EPA (1985) [14]. Subsequent to the mentioned study, other possible values for the cancer potency have been proposed (Figure 1) but the official value to use in the studies for respect of health risk is still the one pointed out by the EPA in 1985. In fact in 2001 around half of the
members of the Panel of experts called to express their opinion about the most recent studies decided that the data reported in the 2000 Draft can overestimate the probable cancer risk (SAB 2001) [8]. It is finally noticed that also in official documents published more recently (California EPA, 2003 [15]) the U.S.EPA refer however to the 1985 value.

3 The role of apples in the daily PCDD/F intake

3.1 Literature data

The starting point for the literature data are three studies regarding the PCDD/F intakes from food developed in England [5], in the south-western part of Germany [6] and in Catalonia, Spain [4]. The studies were developed in England in 1993, between 1993 and 1996 in Germany and in Spain in 2000. The pathways through which dioxin can accumulate in plants are: 1) root uptake and translocation to upper plant parts, 2) atmospheric deposition, both wet and dry, of contaminated particulate onto exposed plant surfaces, 3) uptake of airborne vapours by aerial plant parts. Regarding apples there are many and different routes for dioxin to be taken up into the fruit. In the literature the available data on apples or apple-like fruits (fruits growing distant to the ground, reflecting the air contamination) do not clarify the relative importance of the pathways. Concerning data of PCDD/F, in the study developed in Great Britain, the average value on apples (8 analyses) resulted 400 pg I-TEQ / kg dry weight (with a maximum of 900 pg I-TEQ / kg dry weight, corresponding to 135 pg I-TEQ / kg wet weight, close to an old incinerator). In Germany the average value (4 analyses) resulted in 4 pg I-TEQ / kg wet weight (apple-like fruits). In Spain, the average value (12 analyses) resulted 60 pg WHO-TEQ / kg dry weight, (apple-like fruits; 9 pg WHO-TEQ / kg wet weight).

3.2 Experimental data

The experimental data generated in the present study concern two case-studies. The used method is US EPA 1613B, dilution ratio: 10, detection limit from 0.1 to 1 (dry weight) depending on the congeners.

The first case concerns an area characterized by heavy traffic because of the presence of an important highway. In this case the 10 kg of apples were taken from an area very close to the road (100 m, with no obstacles) with the attention to select a field where no pesticides were used. A representative average sample was generated. The different role of pulp and peel has been considered: the concentration in the peel resulted in 8.9 ng I-TEQ/kg dry weight. The concentration in the pulp resulted in 1.0 ng I-TEQ/kg dry weight. An overall assessment of the presence of PCDD/F in the apples gives a value around 280 pg I-TEQ / kg wet weight. A comparison of the presence of the homologous compounds and of the toxic congeners in the peel and in the ambient air of the area points out that: a) both in the peel and in the air the most present homologous is OCDD; b) both in the peel and in the air the most present toxic congener is 2,3,4,7,8 PCDF.
The second case concerns an industrial contamination (because of the presence of a refinery at 1 km from the field in a flat area). The fruits (1 kg) were sampled from a field where no pesticide was used. Also in this case the different role of pulp and peel has been taken into account: the concentration in the peel resulted in 122 pg I-TEQ / kg wet weight. The concentration in the pulp resulted in 27 pg I-TEQ / kg wet weight. An overall assessment of the presence of PCDD/F in the apples gives a value around 35 pg I-TEQ / kg wet weight.

3.3 Discussion

Apples are a kind of fruit that reflect the contamination of the air. As a consequence the values of concentration of PCDD/F available in this study can be used for some considerations on the quality of the air of the studied areas.

In the Great Britain case-study the presence of an old incinerator (that can have PCDD/F emission factors even 1000 times higher than the modern ones) seems to have a significant influence on the PCDD/F concentration in apples: 900 pg I-TEQ / kg dry weight (135 pg I-TEQ / kg wet weight) as a consequence of a concentration in ambient air that could be of hundreds of fg I-TEQ / m³. The proximity of an important highway can give similar results. The case-study concerning the refinery seems to be in an intermediate level, while normal conditions give a concentration of few pg I-TEQ / kg wet weight (Germany and Spain).

As a consequence a question concerns the role of apples in the PCDD/F dietary intake. Assuming one eats 250 g of apple per person per day (and assuming 70 kg b.w. for a person), a concentration of 280 pg I-TEQ / kg wet weight gives a daily intake of 1 pg TEQ/kg b.w.. That means that in critical conditions the TDI value could not be respected. On the contrary, a concentration of 5 pg I-TEQ / kg wet weight gives a daily intake of 0,02 pg TEQ/kg b.w. giving apples a secondary role in the daily intake contribution.

4 Conclusions

Local PCDD/F contamination in air can cause a significant increase of dioxin in fruits like apples. Differences can be of about two orders of magnitude changing the role of apples from secondary contributors to significant contributors in the assessment of the daily dietary intake.

The possibility to use apples as trackers of the local PCDD/F contamination depends strongly on the use of pesticides as their adoption can mask the effects of the local air conditions.

References


