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Dioxins, furans, and polychlorinated biphenyls in hen eggs – a new source of hazard for consumers?

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Abstract

The paper presents the results of testing eggs for the content of dioxins and polychlorinated biphenyls (PCBs), determination of the sources that caused the presence of high concentrations of these compounds which exceeded the acceptable contamination levels, and assessment of consumer health risk caused by the consumption of eggs with excessive contents of investigated compounds. In about 9% of free range eggs and 17% of organic eggs, the content of PCDD/Fs was two- or three-fold higher than the acceptable limits, and in some samples the concentration of investigated compounds exceeded the maximum concentration levels. Based on the profile of the compounds, it was confirmed in several cases that their main source was the soil or unsecured refuse. The consumers of eggs and meat produced under these conditions constitute the risk groups, and their dioxin and PCB intake may exceed toxicological reference values.

Keywords: eggs, dioxins, PCBs, risk assessment.

Introduction

Hen eggs belong to the most important components of a daily diet, being a natural source of vitamins, proteins, and fat. However, apart from the concerns about the cholesterol level and the hazards connected with pesticides and veterinary medicine residues as well as *Salmonella* contamination, a new issue has currently emerged. Eggs may constitute a serious source of dioxins in human diet, as some of the poultry farming systems enable a considerable contamination with persistent organic pollutants (POPs). POPs such as dioxins (polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans) and PCBs (polychlorinated biphenyls), ingested with the feeds, penetrate into hen tissue and eggs. Hence, eggs may significantly contribute to dioxin and PCB intake with food of animal origin (1, 13, 15). Dioxins and dioxin-like compounds were qualified as highly toxic pollutants. The lifetime exposure to even minute doses of these compounds may increase the risk of adverse health effects, *e.g.* endocrine, immune, and reproductive systems imbalance, the occurrence of carcinomas, or neuro-behavioural effects. Health effects of exposure to dioxins may emerge in humans many years later and in the next generations as well (2, 4, 25). To assess the risk connected with the exposure to toxic substances, the toxicity reference values are used. In 2001, the European Commission's Scientific Committee on Food (SCF) established the tolerable weekly intake (TWI) of dioxins at the level of 14 pg WHO-TEQ/kg b.w. The following year, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established the value of a provisional tolerable monthly intake (PTMI) at 70 pg WHO-TEQ/kg b.w.

Natural as well as industrial and non-industrial sources of dioxins have been well recognised. However, in recent years the amount of dioxins and PCBs released into the environment from uncontrolled sources has increased, *e.g.* home furnaces (coal and wood combustions in furnaces and fireplaces),

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incineration of organic and plastic wastes in backyards and home gardens (6, 9, 18, 23). According to the National Centre for Emission Balancing and Management (KOBIZE), the share of PCDD/PCDF and PCB emissions from non-industrial sources in Poland in 2013 was 66% and 68%, respectively. The combustion of coal and lignite, fuel oil, firewood, and coke in households in 2010 caused the emissions of 223 790 mg TEQ of dioxins and 475.9 kg of PCBs (http://www.kobize.pl/uploads/materialy/Inwentaryzacje_krajowe/2015/Bilans%20emisji%20%20raport%20podstawowy_2013.pdf).

Foodstuffs of animal origin, including poultry products, contaminated with dioxins and related compounds, have repeatedly threatened the safety of the food chain (Belgium, 1999; Ireland, 2008; Germany, 2011) (7, 9, 26). For this reason, it is extremely important to monitor the health quality of the food. In Poland, table eggs are screened for the presence of dioxins, furans, and PCBs as part of the national surveillance programme, the purpose of which is to identify the existing hazards and detect the cases of the acceptable allowable limits exceedance as well as the sources of contamination.

The paper presents the results of official tests for dioxins and PCBs carried out on eggs from different poultry rearing systems. The results of the search for the sources of contamination in the cases exceeding the acceptable concentration levels are also presented. Furthermore, the study assessed the risk to consumers' health caused by consumption of eggs with excessive contents of the compounds studied.

Material and Methods

Study description. Eggs were surveyed from 2009 to 2015 (Table 1). The eggs were from all four production methods (organic, free range, barn, caged). Most eggs were produced in ways that are described as 'intensive' (battery cage production). The alternative to intensive poultry farming was free-range farming (hens are allowed to roam freely), production in close barn (barn eggs) and organic systems (similar to free-range, but with restrictions on the routinely used feed, medication, feed additives, and synthetic amino acids). The type of eggs, collection sites, and the number of representative samples were annually stipulated in the national surveillance programme (www.wetgiw.gov.pl). Egg samples (10 to 12 eggs per sample) were routinely collected by the Veterinary Inspection. In the case of the non-acceptable concentration levels, measures were taken in order to determine the source of contamination. In each case, the first stage was to examine the feeds, and then, depending on the inspection of the farm and the field conditions, all suspicious materials, such as leftover feed, paddock soil, bedding, fragments of the building materials located in the yards or in paddocks, wooden elements of hen house construction, hen house wall scrapings, plants, *etc*. The materials collected from laying hens, *i.e.* external ovarian follicles, soft-shelled eggs obtained from the uterine part of the Fallopian tube, as well as the liver and muscles, were also analysed. In the analysis conducted to estimate the risks connected with the consumption of eggs which contain the exceeded sum of dioxins and dl-PCBs, the intake of these compounds was estimated and referenced against the tolerable weekly intake (TWI).

Chemicals and analytes. All organic solvents and chromatographic sorbents were of purity suitable for the residue analysis. The PCDD/F and PCB standards were from the Cambridge Isotope Laboratory (Andiover, USA) and Wellington Laboratories Inc. (Canada). The analysis included all 35 congeners of dioxins and PCBs, whose monitoring in food is required by the European Union regulations: seven 2,3,7,8-PCDD congeners, ten 2,3,7,8-PCDF congeners, eight mono-*ortho* PCB congeners (105, 114, 118, 123, 156, 157, 167 and 189), four non-*ortho* PCB congeners (77, 81, 126 and 169), and six ndl-PCB congeners (PCB 28, 52, 101, 138, 153 and 180).

Chemical analysis. The analyses of toxic congeners of dioxins, furans, dl-PCBs, and ndl-PCBs were conducted using a very sensitive and specific method of isotopic dilution (IDMS) with a high resolution gas chromatography/mass spectrometry (HRGC/HRMS). At different stages of the analysis, the samples were spiked with 2,3,7,8-chloro-substituted PCDD/Fs, dl-PCBs, and ndl-PCBs labelled with $^{13}C_{12}$, which enabled to detect and correct potential losses. $^{13}C_{12}$-labelled congeners and native PCDD/Fs and PCBs have similar chemical and physical properties, leading to an identical pattern of behaviour during extraction and purification. After preliminary sample preparation (homogenisation, matrix dehydration through drying or lyophilisation, fragmentation, *etc*.), an accurately weighed amount of a sample was subjected to extraction. The main purpose of the extract purification was to remove the elements of the matrix, which could skew the quantitative analysis or substantially impact the identification process. Sample purification was carried out by multistage column chromatography using a modified silica gel, Florisil and Carbopack C. Concentrated eluates of particular fractions (PCDD/Fs, ndl-PCBs, non-*ortho* dl-PCBs, and mono-*ortho* dl-PCBs) were analysed instrumentally with a combined HRGC-HRMS method. Mass spectrometer operated in the electron ionisation (EI) mode at 10 000 of resolution for a full range of the collected mass spectra. Toxicity coefficients (TEF_{2005}) were used to calculate toxic equivalents (WHO-TEQ). To calculate the concentrations of the PCDDs, PCDFs, and dl-PCBs, the concept of "upper bound" limit of quantification was used, according to which the contribution of each nonquantified congener to TEQ constitutes its quantification limit.

All parameters of the method fulfilled the requirements of EU legislation with reference to the methods of dioxin and PCB determination (Commission Regulation (EC) No 589/2014). Limits of quantification (LOQs) for particular PCDD/F congeners ranged from 0.05 to 1.25 pg/g, for dl-PCB the range was 1–10 pg/g of fat, and for ndl-PCB it ranged from 0.003 to 0.009 ng/g of fat. The recovery for the method was 60–120%. Measurement uncertainty for PCDD/PCDFs and dl-PCBs was equalled 16% and 19%, respectively, whereas for ndl-PCBs it came to 23%.

Quality assurance/quality control criteria. Quality assurance and quality control (QA/QC) were achieved through analyses of blank samples, duplicates, and certified reference materials (BCR-607 and T-0645). The method performance was verified successfully in the proficiency testing (PT) organised by the European Union Reference Laboratory for Dioxins and PCBs in Feed and Food (Freiburg, Germany).

Risk assessment assumptions. To estimate the theoretical intake of the sum of dioxins and dl-PCBs by adults and children, the most up-to-date statistics and dietary guidelines were used (3, 22). The application of the quantification results based on the concept of "upper bound" quantification limit guarantees a risk assessment with a higher safety margin for a consumer (a conservative approach). The risk assessment was performed by referring the estimated intake against the tolerable weekly intake (TWI) value. According to the most up-to-date statistics, the average egg consumption in Poland in 2011 was 12.91 per month (2.97 per week) (3). In order to rationally evaluate the risk in a high egg consumer group, the statistical data on average egg consumption per households in general (4.27 per week) and a single-person farm household (6.22 per week) were taken. In the case of children, who are especially vulnerable subpopulation of consumers, according to the national dietary guidelines for children aged 2–3, a ¾ egg per day was assumed, amounting to 5.25 per week (22). To estimate the intake of the sum of dioxins and dl-PCBs for adults, body weight of 70 kg was assumed, whereas the assumed weight for children was 15 kg (according to the weight percentile chart). It was assumed that the average egg weight was 60 g, with a 10% fat content.

Results

Dioxin, furan, and PCB concentrations. The results of the analyses of PCDD, PCDF, and dl-PCB contents in the samples were provided as toxicity equivalents, *i.e.* pg WHO-TEQ/g, whereas the ndl-PCB contents in ng/g (Tables 1–4). The results of the analyses were expressed as the averages of two ultimate quantifications along with expanded measurement uncertainty (U), with an expansion factor of 2 and a confidence level of 95%. Table 1 shows the average levels of PCDD/Fs, dl-PCBs, and ndl-PCBs in eggs from different poultry farming systems. In battery cage eggs, the average dioxin and furan concentrations were very low, considerably below the acceptable limit (2.5 pg/g of fat for dioxins and furans, and 5 pg/g of fat for the sum of dioxins, furans, and dl-PCBs (WHO-PCDD/F-PCB-TEQ). Non-*ortho* and mono-*ortho* dl-PCBs constituted 4–52%. The ndl-PCB content was also low compared with the acceptable value (40 ng/g of fat). Conversely, the concentrations of the sum of PCDD/Fs and dl-PCBs were on average two or three times higher in free range and organic eggs. These differences were statistically significant. Furthermore, ndl-PCB concentrations were by 50–60% higher in free range eggs and over two times higher in organic eggs. PCB 118 and 105 were predominant congeners.

Table 1. The content of dioxins, furans, dl-PCBs, and ndl-PCBs in hen eggs. The results of quantification for PCDDs, PCDFs, and dl-PCBs are shown in pg WHO-TEQ/g of fat, and for ndl-PCBs in ng/g of fat

Farming system	PCDD/PCDF $X_{av.} \pm SD$ min–max	dl-PCB $x_{av.} \pm SD$ min–max	PCDD/PCDF/dl-PCB $X_{av.} \pm SD$ min–max	ndl-PCB $x_{av.} \pm SD$ min–max	Eggs noncompliant with Regulations 1881/2006/WE and 1259/2011/UE
battery cage n = 72	0.60 ± 0.42 0.32 – 0.76	0.19 ± 0.16 0.12 – 0.61	0.79 ± 0.53 0.44 – 0.91	1.23 ± 1.67 0.04 – 10.80	0
barn n = 13	0.40 ± 0.10 0.30 – 0.60	0.17 ± 0.06 0.14 – 0.30	0.57 ± 0.12 0.44 – 0.77	1.41 ± 0.18 0.18 – 7.39	0
free range n = 117	1.38 ± 3.05 0.30 – 29.32	0.37 ± 0.70 0.13 – 7.17	1.76 ± 3.21 0.44 – 29.84	1.98 ± 3.68 0.13 – 34.31	10 (9%)
organic n = 23	1.66 ± 1.80 0.32 – 8.21	0.48 ± 0.38 0.14 – 1.42	2.14 ± 2.13 0.46 – 9.63	2.92 ± 2.58 0.33 – 9.58	4 (17%)

Concentrations exceeding the acceptable limits were confirmed in about 9% of free range eggs and 17% of organic eggs (Table 1). Excessive contents were mainly found with reference to the congeners of dioxins and furans from small farms located in different regions of the country. Only in one case, the high dl-PCB content was observed. A relatively high level of ndl-PCB (slightly below the acceptable limit) was also detected in the same sample, which indicates a different source of egg contamination than in the other cases. Apart from that individual case, ndl-PCBs generally occurred in low concentrations. When the standard values were exceeded, measures were taken to determine the sources of contamination. The feed fed to the poultry were primarily analysed. However, none of the analysed feed samples from the surveyed farms contained raised PCDD/PCDF concentrations. Average PCDD/F concentrations ranged from 0.05 ± 0.01 to 0.07 ± 0.01 ng WHO-TEQ/kg of feed with a moisture content of 12%, with the acceptable limit of 0.75 ng/kg of feed, meaning that the feed could not have been the source of egg contamination (17).

Table 3 shows the values of dioxin and furan levels in eggs, muscles, and livers of the poultry from the farms where – as it was established – the soil was the source of contamination. The analysis of a few soil samples collected from the laying hen foraging grounds (yards, paddocks) indicated the presence of high concentrations of the same dioxin congeners that had been identified in the eggs from the farms surveyed. In 17 soil samples from the farms surveyed, 10 were confirmed as the sources of dioxin and furan contamination. Dioxin concentrations reached up to 47.03 ± 6.73 pg WHO-TEQ/g of the soil. In this case the transmission of dioxins and furans from the contaminated soil to the eggs was also confirmed by the congeners accumulated in hen tissues and organs. PCDD/PCDF concentrations in muscles reached up to 32.91 ± 5.39 pg WHO-TEQ/g of fat, whereas the acceptable content cannot exceed 1.75 pg WHO-TEQ/g of fat. Furthermore, the sum of PCDD and PCDF concentration in the liver of the exposed hens exceeded the acceptable value, *i.e.* 4.5 pg WHO-TEQ/g of fat (Commission Regulation (EC) No 1259/2011).

Currently, the limit for the liver is 0.3 pg WHO-TEQ/g wet weight (Commission Regulation (EU) No 1067/2013). PCDD/F congener profiles were in agreement with the profile of these compounds in the soil which laying hens had direct contact with (Fig. 1).

Calculated bioaccumulation factors (BFs), which express the ratio of the concentration in tissues or eggs to the concentration in soil, indicated different degrees of bioaccumulation among the congeners studied. The same congeners and in high concentrations were also present in ovarian follicles (from 1.81 ± 0.22 to 26.57 ± 4.35 pg WHO-TEQ/g of fat). PCDD/F profiles in eggs and soil are shown in Fig. 2.

In one case of the limit excess, a characteristic PCDD/PCDF profile was shared in samples of plants, surface soil layer, debris, eggs, and tissues of laying hens. The assumption was that the dioxins could have originated from dust falls and airborne atmospheric particles coming from the nearby arterial road with a high volume of traffic. Other sources of contamination identified in the study were the remains of construction materials located in the yard, an unsecured silo filled with incinerated refuse generated by the household, pentachlorophenol (PCP)-treated wood, and fuel oil. In several cases, the sources of contamination could not be identified. The most probable reason might have been the invalid sample selection of the materials for explanatory analysis, or other unknown factors.

Table 2. Egg samples containing high contaminant concentrations (concentrations exceeding the permitted limits are marked with asterisks)

Sampling year	Sample code	PCDD/PCDF pg WHO-TEQ/g of fat	dl-PCB pg WHO-TEQ/g of fat	PCDD/PCDF/dl-PCB pg WHO-TEQ/g of fat	ndl-PCB ng/g of fat	Province
2011	089	4.63 ± 0.76*	1.94 ± 0.37	6.56 ± 1.24*	5.94 ± 1.35	Świętokrzyskie
	090	5.31 ± 0.87*	1.31 ± 0.25	6.63 ± 1.25*	3.79 ± 0.86	Świętokrzyskie
	130	12.39 ± 2.03*	0.17 ± 0.03	12.55 ± 2.37*	1.12 ± 0.25	Podkarpackie
2012	020	3.42 ± 0.56*	0.65 ± 0.12	4.06 ± 0.77	1.69 ± 0.38	Lubuskie
	132	5.30 ± 0.87*	0.30 ± 0.06	5.61 ± 1.06	2.18 ± 0.49	Kujawsko-Pomorskie
	151	1.02 ± 0.17	7.17 ± 1.35	8.19 ± 2.05*	34.31 ± 7.78	Podlaskie
2013	113	3.24 ± 0.53*	0.65 ± 0.12	3.89 ± 0.97	3.98 ± 0.90	Lubuskie
	146	6.51 ± 1.07*	0.95 ± 0.18	7.46 ± 1.86*	5.73 ± 1.30	Łódzkie
	205	4.61 ± 0.75*	1.31 ± 0.25	5.92 ± 1.48	18.10 ± 4.10	Dolnośląskie
2014	055	29.32 ± 4.19*	0.52 ± 0.09	29.84 ± 6.57*	1.81 ± 0.30	Lubelskie
2015	023	3.88 ± 0.64*	1.04 ± 0.20	4.92 ± 1.23	3.70 ± 0.84	Kujawsko-Pomorskie
	030	8.21 ± 1.34*	1.42 ± 0.27	9.63 ± 2.41*	6.54 ± 1.48	Pomorskie
	044	4.02 ± 0.66*	0.65 ± 0.12	4.67 ± 1.17	3.95 ± 0.89	Dolnośląskie
	079	3.12 ± 0.51*	1.40 ± 0.26	4.52 ± 1.13	7.91 ± 1.79	Dolnośląskie

Table 3. Transfer of dioxins and furans from soil to hen eggs and tissues and bioaccumulation factors (BF)

Sample code	Soil PCDD/PCDF pg WHO-TEQ/g	Eggs PCDD/PCDF pg WHO-TEQ/g of fat	BF	Muscles PCDD/PCDF pg WHO-TEQ/g of fat	BF	Liver PCDD/PCDF pg WHO-TEQ/g of fat	BF
130	25.39 ± 3.63	5.38 ± 0.88	0.2	4.52 ± 0.74	0.2	5.64 ± 0.92	0.2
131	10.37 ± 1.48	15.86 ± 2.60	1.5	12.68 ± 2.08	1.2	20.49 ± 3.36	2.0
113	0.85 ± 0.12	7.36 ± 1.20	8.7	5.15 ± 0.84	6.0	11.54 ± 1.89	13.5
205	1.87 ± 0.27	5.38 ± 0.88	2.8	3.04 ± 0.50	1.6	8.78 ± 1.44	4.7
055	47.03 ± 6.73	26.57 ± 4.35	0.5	32.91 ± 5.39	0.7	26.84 ± 4.40	0.6

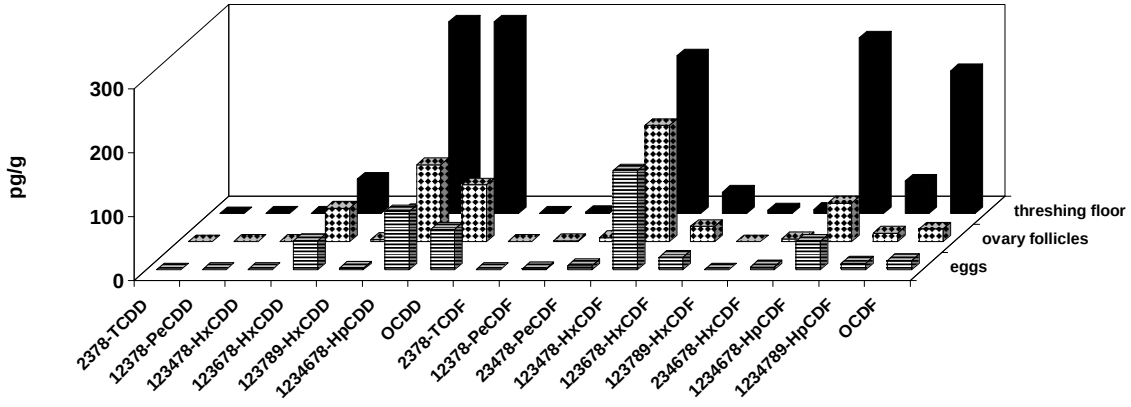


Fig. 1. PCDD/F profiles in eggs, ovary follicles, and threshing floor

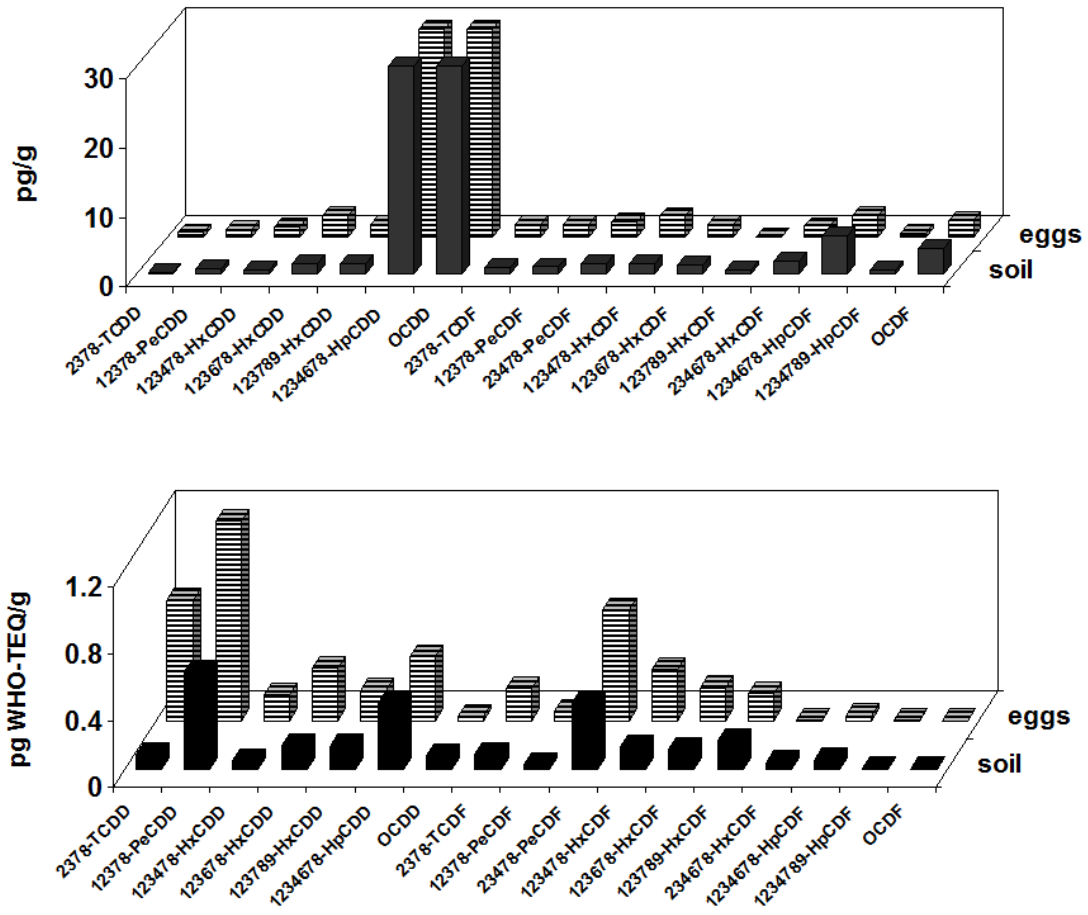


Fig. 2. PCDD/F profiles in eggs and soil (pg/g) and contribution to toxicity (pg WHO-TEQ/g)

Table 4. Characteristics of the risk involving the consumption of eggs containing the sum of dioxins, furans, and dl-PCBs exceeding the maximum limit of these compounds and in particular types of eggs. For clarity, intakes above 50% TWI are marked with asterisks

Egg	Farming system^	Σ PCDD/F/dl-PCBs pg WHO-TEQ/g of fat	Intake expressed as percentage of TWI (70 pg WHO-TEQ/kg b.w.)			
			Adults, average egg consumption			Children
			All households	High consumers		
				One-person households, total	One person households, farmers	
1	FR	3.89	7.1	10.2	14.8	58.4*
2	FR	4.06	7.4	10.6	15.5	60.9*
3	O	4.52	8.2	11.8	17.2	67.8*
4	O	4.67	8.5	12.2	17.8	70.1*
5	O	4.92	8.9	12.9	18.7	73.8*
6	FR	5.61	10.2	14.7	21.4	84.2*
7	FR	5.92	10.8	15.5	22.5	88.8*
8	FR	6.56	11.9	17.1	25.0	98.4*
9	FR	6.63	12.1	17.3	25.2	99.5*
10	FR	7.16	13.0	18.7	27.3	107.4*
11	FR	8.19	14.9	21.4	31.2	122.9*
12	O	9.63	17.5	25.2	36.7	144.5*
13	FR	12.55	22.8	32.8	47.8	188.3*
14	FR	29.84	54.3*	78.0*	113.6*	447.6*
Average		8.15	14.8	21.3	31.1	122.3*
Battery caged eggs – range		0.44–0.91	0.8–1.7	1.2–2.4	1.7–3.5	6.6–13.7
Barn eggs – range		0.44–0.77	0.8–1.4	1.2–2.0	1.7–2.9	6.6–11.6
Free range eggs – range		0.44–29.84	0.8–54.3*	1.2–78.0*	1.7–113.6*	6.6–447.6*
Organic eggs – range		0.46–9.63	0.8–17.6	1.2–25.2	1.8–36.7	6.9–144.5*

^ FR – free range, O – organic

Risk assessment. Two exposure scenarios were assumed in the characterisation of the risk concerning the intake of the sum of dioxins, furans, and dl-PCBs. In the first one, average egg consumption was assumed for both adults and children, whereas the other involved high egg consumption in adult population. In the latter case, due to the lack of national statistics on the actual distribution of food consumption, including eggs, the Central Statistical Office's statistics (2014) were used regarding the average monthly egg consumption in single-person households in general and single-person farms. These assumptions enabled a rational assessment of the Polish consumers' risk exposure. In the first stage, the results of quantification of the studied substances were converted from fat to total egg weight. Next, the dose of the sum of PCDD/Fs and dl-PCBs resulting from theoretical weekly consumption of eggs containing the contaminants exceeding the acceptable EU-established level was calculated, and converted to kilogram of body weight. The character of the risk was presented as an estimated exposure expressed as a percentage of a tolerable weekly intake (TWI) at 14 pg WHO-TEQ/kg. For comparison, TWI ranges for dioxins intake from eggs produced in all farming systems, *i.e.* battery cage, barn, free range, and organic, are shown. The results of the risk characterisation are presented in Table 4. Although for a statistical adult consumer, the intake of the sum of PCDD/F and dl-PCBs was estimated at 14.8% and in general did not exceed 25% of TWI (in one case it reached about 55%), in the case of adult high consumers of eggs, the ingested dose reached an average value of 31% of TWI, and in an extreme case almost 115% of TWI. Due to the almost 5-fold lower body weight, an estimated theoretical dose of dioxins and dl-PCBs ingested by young children was even higher, ranging from 58.4% to 447.6% of TWI. Importantly, the dose of these contaminants calculated on the basis of their content in battery cage and barn eggs did not exceed 1.7% and 1.4%, respectively, for a statistical adult consumer, 3.5% and 2.9% for an adult high consumer of eggs, and 13.7% and 11.6% for a young child. Upper ranges of the ingested dose of dioxins were many times higher in the case of free range and organic eggs.

Discussion

Food of animal origin is a primary route of human exposure to dioxins and dioxin-like compounds. Their presence in food is a result of their affinity to lipids, lack of metabolic changes, and bioaccumulation in tissues, even when their environmental concentrations are low. These compounds are excreted from mammalian organisms during lactation periods, and accumulated in poultry tissues, penetrating into egg yolk along with fat (5, 8, 18). Hens foraging in free-range paddocks ingest various soil elements together with feed. It is estimated that in digging birds, including hens, the feed is contaminated with 2–10% of soil. Experimentally determined transfer of dioxins to eggs equals 40–60% for soil absorption, and 90% for feed absorption. Two factors are equally relevant for the risk assessment as well: the amount of ingested soil, which according to various authors may constitute 2–30 g/day, and the presence of grass in the paddock, which influences the processes of sorption and desorption of dioxins in hens' gastrointestinal system, that is bioavailability and the ultimate transfer of

contaminants into tissues and eggs. Hens consume also such dioxin-contaminated organisms as earthworms, insects and their larvae, and other small organisms (4, 29).

The problem of dioxins in consumption eggs is not a new issue. It concerns all the regions of the world and appears to be grave. For this reason, the European Commission adopted in 2013 special recommendations to increase monitoring of free range and organic eggs (Commission Recommendation 2013/711/EU).

There may be different sources of dioxins in eggs. Both literature on the subject and the authors' own experience indicate that the problem concerns mainly small farms, where poultry forage in places abundant in ashes, unburned wood, household refuse, debris, insulation materials, crumbled roofing, and old preservative-treated wood. Another source of dioxins may be old utility buildings (*e.g.* previous warehouse of agricultural chemicals) converted into hen houses; old buildings constructed from preservative-treated wood (*e.g.* PCP), where birds are kept for the family's and neighbour's own use (19). High concentrations of these compounds have been noted in many European countries, including Poland, and in other continents (12, 20, 21, 24). In Vietnam, despite the wars, which ended 40 years ago, exceptionally high concentrations have been noted (248 pg WHO-TEQ/g of fat for PCDD/F and 249.1 pg WHO-TEQ/g of fat for the sum of PCDD/Fs and dl-PCBs). These eggs were obtained from the hens living in the areas of a defoliant Agent Orange storage or use (10, 11, 28).

In the situation of long-term consumption of eggs with excessive contents of dioxins and PCBs, high exposure to these substances, unacceptable especially in the case of children, may follow. The concern about an increased exposure to dioxins is not only related to those cases in which estimated exposure exceeded toxicological reference values. Based on the literature, an average contribution of eggs to total exposure to the sum of PCDD/Fs and dl-PCBs in Europe does not, in general, exceed 5–6% (14, 15, 16, 22, 27, 30), with the exposure of children always higher than that estimated for adults. Although it is known that incidental or short-term consumption of products containing excessive levels of dioxins do not automatically constitute a health hazard, it must be emphasised that from the public health perspective, each additional exposure to these contaminants should be treated as superfluous. Dioxins and PCBs are subject to accumulation in human organism as well, and their body content increases with age, aggregating the risk of adverse effects. In the case of foetuses and young children, the disorders in the functioning of important systems and organs at that stage of development are far more important than in adults due to the incomplete development of an organism's defence mechanisms. According to the EFSA scientific report released in 2012, an average intake of dioxins and dl-PCBs in Europeans from different age groups was estimated at the level of 0.57–2.54 pg WHO-TEQ/kg b.w. per day (6). Despite a significant decrease of the dioxin industrial emission into the environment, there are still groups of consumers exposed to dioxins at the levels exceeding the established toxicity reference values (6). Hence, there is a need for constant monitoring of the food and feed due to the accumulation of dioxins and dioxin-like compounds in the food chain, at the top of which are humans.

Both the results of the authors' own research and the data available from many countries indicate the presence of important differences in the levels of dioxins, furans, and PCBs in eggs from various farming systems. Free range and organic eggs may contain concentrations of dioxins and PCBs exceeding the acceptable, legally established limits. The data presented in our study show the importance of PCDD/F profiles for discovering sources of the contaminants.

The risk groups involve the consumers of eggs and meat produced in these farming conditions, and the intake of dioxins and dioxin-like compounds may exceed the toxic reference values. Each case of exposure to an increased background PCDD/F and dl-PCB level should be treated as excessive. For this reason, recommendations for producers of food as well as consumers should be adopted based on an independent, scientific risk assessment conducted by the risk management organisations, responsible for food safety.

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