Dioxins in organic eggs: a review

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Abstract

Eggs contribute for about 4% to the daily dioxin intake of humans. Research among layer farms in the Netherlands and other EU countries has shown that organic eggs contain more dioxin than conventional ones and that a significant number of organic farms produce eggs with a dioxin content that exceeds the EU standard. The hens' intake of dioxins from various sources leads to an increase in the dioxin content of organic eggs. These sources include plants, feed, soil, worms and insects, and compared with hens on conventional and free-range farms, organic hens make more use of these sources due to better access to the outdoor run. Plants appear to be relatively unimportant as a source of dioxins. Also commercial organic feed generally has very low dioxin contents, but not much is known about non-commercial feed. Consumption of worms and insects and particularly ingestion of soil are important causes of high dioxin levels in eggs. Management interventions, like a reduction of the time the hens spend outside, may decrease the dioxin levels in organic eggs but at the same time may interfere with the image of the organic production system.

Additional keywords: poultry, free range, organic farming

Introduction

Dioxins form a group of very toxic compounds and may cause serious health problems when humans are exposed to them. Human exposure can occur through the diet, thus also through the consumption of eggs. Research among layer farms in the Netherlands has shown that organic eggs contain more dioxin than conventional eggs (De Vries, 2002). The same holds for organic layer farms in other European countries. In a recent study it was shown that 25% of the 34 organic poultry farms investigated in the Netherlands produced eggs with a dioxin content that exceeded the EU standard. Mainly small farms (less than 1500 laying hens) exceeded this standard. These farms accounted for 14% of the Dutch organic egg production (Brandsma *et al.*, 2004).

In order to reduce human exposure to dioxins, the European Union has decided that as of 1 January 2005 eggs may not contain more than 3 picograms (pg) Toxic Equivalents (TEQ) per gram of egg fat (Anon., 2004a). From this date onwards, layer farms that exceed this standard have to take measures to reduce the dioxin content of their eggs.

Sources of dioxins include feed, worms, insects, grass, herbs and soil (Kijlstra, 2004). Compared with hens on conventional and free-range farms, organic hens make more use of these sources because they spend more time in the outdoor run, which may lead to an increase in the dioxin content of their eggs. This suggests that management interventions can help to reduce the dioxin level in organic eggs. In a meeting of researchers and farmers several measures were proposed. The first measure that was proposed aims to reduce dioxin intake by shortening the time hens spend ranging in the outdoor run. The second measure is to reduce the size of the outdoor run. Also covering the soil in the outdoor run can possibly reduce dioxin intake. Finally, improving the general health status may prevent the hens from ingesting soil.

In this review, theoretical background information is presented on dioxins in eggs and measures are discussed that may be taken at farm level to influence egg dioxin levels.

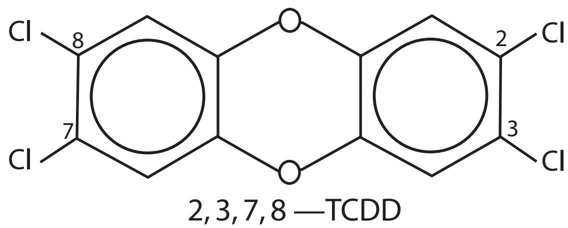

Figure 1. One of the most toxic dioxins: 2, 3, 7, 8 – TCDD.

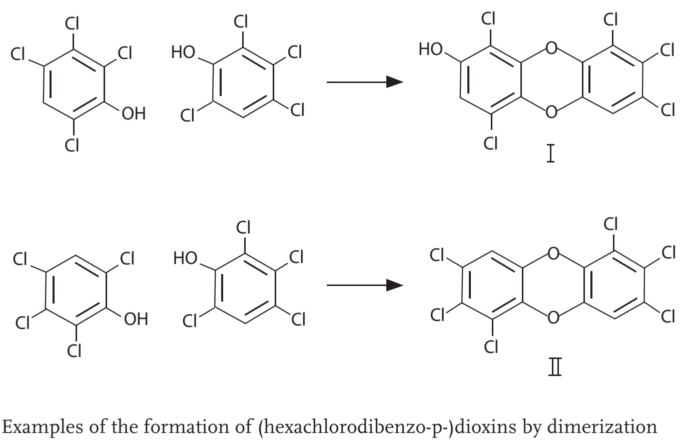

Figure 2. Examples of the formation of (hexachlorodibenzo-p-)dioxins by dimerization of tetrachlorophenol.

Theoretical background

Dioxins

Dioxin is the generic name for a group of very toxic compounds that share certain chemical structures and biological characteristics. Each structural arrangement in the group is called a congener. Scientists use a weighted factor called 'Toxic Equivalence Quotient' (TEQ) to determine the toxicity of dioxins. The most toxic congeners are 2,3,7,8-TCDD (see Figure 1) and 1,2,3,7,8- PCDD.

Exposure to dioxins is generally considered to cause serious health problems in humans, like cancer, chloracne, and reproductive and developmental disorders. Exposure can be divided into short-term exposure to toxic doses (Seveso accident, Ukrainian president Yushchenko's poisoning) and long-term chronic exposure. To decrease the long-term chronic exposure of humans, The Scientific Committee on Food (Anon., 2001a) has set the safe weekly intake level of dioxins at 14 pg TEQ per kg body weight. Most human exposure to dioxins occurs through the diet. Over 95% of the dietary intake of dioxins is accounted for by animal fats in meat, milk products, fish and eggs. The contribution of eggs to the daily dioxin intake of humans is estimated at about 4%. Only small fractions of the dioxin intake are ingested through breathing and absorption via the skin.

Sources of dioxins

Dioxins can be produced inadvertently in nature, e.g. by bush and forest fires, but also by human activities, such as combustion, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing and other industrial processes. Uncontrolled combustion such as burning household trash is expected to become the largest source of dioxin emissions to the environment (Anon., 2001c). Examples of formation of dioxins are shown in Figure 2. The natural background level of dioxins is unknown.

Over the past decade, industry and government have worked together to reduce dioxin emissions, for instance through the introduction of lead-free petrol, and through measures at domestic incinerators and other industries. As a result, dioxin levels in the environment, in feed and food, and the human exposure to dioxins have drastically been decreased. However, reducing the background levels through intervention takes many years, as these extremely persistent compounds are slowly metabolized and eliminated (Anon., 1998).

In some countries it has been shown that the dietary intake of dioxins has decreased in the recent past. According to data on dietary exposure to dioxins in the Netherlands, the median intake has dropped from 10 pg TEQ per kg body weight per day in 1978 to 2 pg TEQ per kg body weight per day in 1994. Studies from the UK and Germany, countries that started to implement measures to reduce dioxin emissions already in the late 1980s, also clearly show a consequent reduction in dietary intake of these compounds (Anon., 1998).

The rate of deposition of dioxin emissions leads to spatial variations in the rate of environmental contamination, showing local sites with increased levels of dioxins in soil and sediment. Dioxin contamination of feedstuffs can incidentally occur due to e.g. accidents in industries. In 'hot spots' around emission sources of dioxins, the dioxin levels in food can be higher than the background contamination. For example, higher contents of dioxins in cow's milk, beef and mutton, and eggs have been found in various countries in Western Europe in the vicinity of local sources than elsewhere. Variation in dioxin levels appears to occur as a function of emission controls that have been implemented over the past decades.

Background contamination of feedstuffs, however, is generally low. Except for fish meal, fish oil and animal fat, the mean dioxin contents of all feedstuffs of plant and animal origin are around or below 0.2 ng TEQ per kg dry matter (Table 1). The contribution of individual feedstuffs to the dioxin content of the whole diet of farmed animals depends on the feedstuffs' particular level of contamination and their proportion in the diet. Greatest concerns arise from the use of fish meal and fish oil of European origin.

Dioxins can be deposited on plants and ingested by animals and aquatic organisms. Dioxins may be concentrated in the food chain and tend to accumulate in the animals' body fat. This causes animals and animal products to have higher contents than plants, water, soil or sediments.

Dioxin levels in eggs

The contamination of animal feed, pastures and organisms at lower trophic levels leads to bioaccumulation (i.e., the accumulation in a biological system) of dioxins in animal fats. As eggs consist of almost 10% fat, dioxins are likely to accumulate in the fat of the yolk.

Dioxin metabolism

During exposure to dioxins, the distribution over tissues in laying hens is congener-dependent, with 5 to 30% of the intake excreted in the eggs, 7 to 54% deposited in the animal fat and less than 1% present in the liver (Stephens *et al.*, 1995). Many researchers handle a standard excretion of 25% in the eggs. Ikeda *et al.* (2004) suppose that dioxins ingested by hens are first stored in fat tissue and then transferred to the eggs at a constant rate for a long period. Absorbed dioxins are incorporated in very low-density lipoproteins (VLDL), the major lipoproteins in chicken plasma. VLDL plays a crucial role in the development of the yolk. Exposure of layers to dioxins can induce a reversible inhibition of egg laying, whereas *in ovo* exposure at > 10 ng TEQ per egg completely inhibits hatching (Ikeda *et al.*, 2004). The chicken embryo is highly sensitive to dioxins. Small doses of dioxins administered to chickens produce no observable effects on their health, but high doses (1000 ng TEQ per day) can cause about 80% mortality (Schwetz *et al.*, 1973).

The dioxin content of eggs depends on the hen's intake (Ikeda *et al.*, 2004) Similarly, the content of dioxin residues in edible tissues of the broiler correlate with the amount of dioxin intake. Feed contaminated with up to 4 ng TEQ per kg resulted in an average of 21.2% of the total TEQ intake in the edible tissues (Iben *et al.*, 2003).

Table 1. Dioxin contents of the basic animal feedstuffs (ng TEQ per kg dry matter). Source: Anon., 2003.

Feedstuff	Low	Mean	High
Roughage	0.1	0.2	6.6
Grains and grain legumes	0.01	0.1	0.4
By-products of grains, grain legumes and sugar	0.02	0.1	0.7
Vegetable oil	0.1	0.2	1.5
Fish meal – Pacific (Chile, Peru)	0.02	0.14	0.25
Fish meal – Europe	0.04	1.2	5.6
Fish oil – Pacific (Chile, Peru)	0.16	0.61	2.6
Fish oil – Europe	0.7	4.8	20
Mixed animal fat	0.5	1	3.3
Meat and bone meal	0.1	0.2	0.5
Milk by-products	0.06	0.12	0.48
Soil	0.5	5	87
Binders, anti-caking agents and coagulants	0.1	0.2	0.5
Trace elements, macro minerals	0.1	0.2	0.5
Premixes	0.02	0.2	0.5

Dioxin disposition

The disposition of dioxins results from urinary and faecal excretion and excretion in the eggs. Accumulation and elimination half-lives are congener- and tissue dependent. A survey of dioxin congeners in eggs and poultry meat conducted by Lovett *et al.* (1998) in England and Wales showed that the environment in which poultry live, influences both the eggs and the meat. They reported that the dioxin contents of poultry products from a site close to an incinerator were appreciably higher than those detected elsewhere. The contrast was, however, less marked for poultry meat than for eggs. Petreas *et al.* (1996) confirmed that dioxins accumulate less in female than in male chickens. Eggs presumably present an elimination pathway for female chickens to 'clear' their body contents, comparable with cow milk for cows.

Wolfe *et al.* (1994) observed that the half-life of dioxins in humans varied with percentage body fat (PBF), relative changes in PBF, and age. Half-life increased significantly with increasing PBF and decreased significantly with increasing relative change in PBF and with age. The half-life of dioxins in hens is unknown. In hamsters it was found to be 14.8 days (Olson *et al.*, 1980). Half-lives of 30 to 31 days have been reported for rats (Rose *et al.*, 1976) and guinea pigs (Olson *et al.*, 1980). Zabik *et al.* (1998) claimed that at low doses and concomitant low residue levels the half-life for chickens is between that of the guinea pig and the hamster. According to Nosek *et al.* (1992), the half-life for whole-body elimination of dioxin-derived radioactivity in ring-necked pheasant hatchlings was 13 days, whereas in adult pheasant hens that were not producing eggs it was 378 days.

Table 2. Dioxin contents (pg TEQ per g fat) of eggs from different housing systems in Germany, in the years 1993 and 1995. Source: Fiedler *et al.*, 2000.

Housing system	n [1]	Year	Minimum	Maximum	Average
Elevated wire cages	20	1993	0.56	2.30	1.16 [2]
	69	1995	0.23	6.04	1.36
Chickens kept on ground	93	1993	1.03	23.4	1.81 [2]
	32	1995	0.19	5.57	1.63
Free foraging	23	1993	0.38	11.4	1.91 [2]
	31	1995	0.49	22.8	4.58

[1] n = number of farms.
[2] Median.

Table 3. Dioxin content (pg TEQ per g fat) of eggs from battery and free-range / organic production systems in different European countries. Source: Kijlstra, 2004.

Country	Battery system	Free-range/organic
Netherlands	1 – 2	0.4 – 8.1
Belgium	1	1 – 10
Germany	0.5 – 2.3	0.4 – 11.4
Ireland	0.1 – 0.6	0.5 – 2.7
Sweden	0.6	0.6 – 3.1
Switzerland	1.3	2.3 – 19

Statistics

The dioxin content of pooled Dutch egg samples dropped from 2.0 pg TEQ per g fat in 1991 to 1.2 pg TEQ per g fat in 1999. In 2001, however, a study in the Netherlands reported much higher dioxin contents in eggs from organic farms than from conventional farms. In four samples (out of eight) they were as high as 8.2 pg TEQ per g fat, which is well above the EU standard of 3 pg TEQ per g fat. Dioxin levels in eggs from battery systems and (not organic) free-range farms did not exceed the EU maximum (Anon., 2003).

Various recent studies have shown that organic eggs have higher dioxin contents than eggs from other housing systems (e.g. Anon., 2004b; Brandsma *et al.*, 2004). According to Brandsma, 25% of the 34 organic poultry farms investigated in the Netherlands in 2004 produced eggs with a dioxin content that exceeded the EU standard. These farms often had small flocks and their contribution to the total number of eggs produced by the investigated farms represented 14% of the daily egg production.

This figure may not be representative of the Dutch organic egg industry, since selection bias may have occurred with regard to the farms that participated in the study. The dioxin content of the eggs from the organic farms varied between 0.4 and 8.1 pg TEQ per g fat. The content was even higher than in 2002, when 9% of the 68 farms investigated exceeded the EU standard of 3 pg TEQ per g fat (De Vries, 2002). Results from a comparison of three housing systems with regard to egg dioxin content from a German study are shown in Table 2. The data concern tests run in 1993 and 1995.

Similar results on dioxin content of eggs from chickens with outdoor access have been found in various other countries (Table 3). Dioxin contents of the eggs from Belgian hobby farmers were as high as 10 pg TEQ per g fat. There was no difference in dioxin content between eggs from (not organic) free-range farms and conventional layer farms. In a study in the UK of eggs from poultry reared on allotments, high levels of dioxin were detected, which was ascribed to exposure to incinerator ashes. When the ashes were removed, the dioxin levels dropped from 16 pg TEQ to 9 pg TEQ per g fat, but still remained above the background dioxin levels for eggs (Anon., 2003).

Regulations

The EU intends to lower the exposure of humans to dioxins with 25% before the end of 2006. To lower the human intake of dioxins from foodstuffs, EU regulations require that as of 1 January 2005 all eggs have to satisfy the dioxin standard set by the EU (Anon., 2004a). This means that apart from conventional eggs, free range and organic eggs may not contain more than 3 pg TEQ per g fat (Anon., 2001b).

The EU based its calculated maximum allowable dioxin level in eggs on a level that is reasonably achievable. However, despite the fact that the level of dioxins in organic eggs often exceeds the EU standard, with normal consumption patterns, consuming organic eggs is not considered to be harmful to human health. Nevertheless, layer farms that exceed the EU dioxin standard are forced to cease production. Although an increase in the dioxin level on the farm may not be due to current farming practices, the European Commission considers the closing down of a farm to be a farming risk.

In order to comply with EU legislation, it is important to lower high dioxin levels at organic farms. To understand the causes of increased dioxin levels, the characteristics of organic farming and conventional farming have to be compared. In the next section an outline is presented of the characteristics of organic farming.

Organic farming

In 2002, the Netherlands numbered 62 organic layer farms, housing 327,643 laying hens varying in age from 18 weeks to 20 months (Anon., 2005a). Barns on organic layer farms have one or more housing levels, comparable to the deep litter or aviary system. Its interior provides nests, perches and litter to the hens. In 2002, Dutch organic poultry farmers mostly used the breeds Bovans Nera and Bovans Goldline. By 2005 this had grown to 550,000 and major breeds included Bovans Goldline, HY-Line Brown and Lohmann Silvernick. Flock density is less compared with the deep litter or aviary system, housing 6 hens per m^2 (1666 cm^2 per hen). Hens can utilize the possibility to free range outside the barn. The free-range area offers at least 4 m^2 per hen. In the free-range outdoor area or in the litter inside the barn the farmer spreads grain for the hens. To secure animal health and food safety, hens are paddocked over several free-range areas. In this way, the grass cover is able to recover from parasites and pathogenic germs. Sometimes the outdoor run is partly covered with wood chips, which improves drainage. In contrast to other production systems, organic poultry farming does not allow beak trimming. Animals are fed special organic feed either obtained commercially or grown on the farm itself. Because of their access to a free-range area, organic poultry may consume forage and insects and ingest soil. In many organic farming systems, extra non-commercial feed is fed in the outdoor run, like bread, grass and food and garden scraps. Hens that are offered extra feed in the outdoor run are considered to be healthier, show lower mortality and less feather pecking (Bestman, 2002). With a view to preventing transmission of Aviary Influenza, farmers are currently (2006) not allowed to feed their chickens in the outdoor run.

If weather conditions are good, i.e., not too much sun and not too wet, at a certain time of the day about 20% of the hens with access to an outdoor run use the possibility to go outside (variation 5–30%; Van Emous & Fiks-Van Niekerk, 2003). The percentage of laying hens using the outdoor area depends on flock size (Bubier & Bradshaw, 1998; Elbe *et al.*, 2005). In flocks with more than 1500 laying hens, the average time spent outside is only 10% of the total time available to go outside. In flocks with less than 500 hens the mean time spent outside ranges from 60 to 70% (U. Elbe, personal communication). Beside flock size, the use of trees, hedges and/or roosters can stimulate hens to use the outdoor run (Zeltner & Hirt, 2003).

An organic laying hen needs more feed than a conventional one, amongst other to fulfil its energy need for extra exercise. In nature, hens spend about 50% of their time roaming around to find food (Bestman, 2002). The daily forage intake of hens can amount to about 35 g (legumes, grass, herbs, etc.). About 20 g of the feed is of animal origin (insects, worms, etc.). Free-ranging hens consume about 4 g animal protein per day. Information on soil intake of free-ranging hens varies from 2 to 10 g per laying hen per day (Anon., 2000a).

Skal, the official Dutch control organization for organic farming, can certify layer farms that comply with the Dutch legislation for organic egg production. Farms holding the Skal certificate have to comply with the following criteria concerning the free-range area (Anon., 2005b):

1. A maximum flock size of 3000 hens;
2. At least 4 m^2 outdoor area per hen;
3. At least 8 hours of free access to the free-range area;
4. A free-range area offering spots for the hens to hide and a sufficient water supply.

As Germany is not self-sufficient in organic eggs, the country has to import them. In order to ensure egg quality, a quality programme was introduced called KAT (Association for Controlled Animal Husbandry). All layer farms registered with KAT have to comply with the KAT rules. As the export of Dutch organic eggs to Germany in 2001 amounted to 36% of the Dutch organic egg production, many organic layer farmers are committed to the KAT rules (Van Horne & Tacken, 2001). By 2006 the export to Germany has grown further and now represents approximately 70% of

the organic eggs produced in the Netherlands. For these farmers, the organic KAT-programme is additional to the EU-legislation for organic egg production. Considering the free ranging of the hens, KAT demands the following rules (Anon., 2005c):
1. A flock size not larger than 3000 hens;
2. One 1-m-long pop hole opener per 150 hens;
3. A maximum outdoor density of 2500 laying hens per hectare; (a minimum of 4 m^2 per hen);
4. Maximally 16 hours of artificial light per day;
5. Unrestricted access to the outdoor area, starting maximally 6 hours after switching on the light in the barn (preferably for 8 hours).

Sources of dioxins in organic eggs

The possible sources of dioxins leading to their transfer from the laying hen to its eggs are numerous. It is without doubt that the dioxins enter the egg following their oral intake by the hen and that they accumulate in the egg fat. The increased levels of dioxins found in organic eggs can be explained by the characteristics of organic farming, as higher dioxin levels are found in this system than in other systems. Possible sources of dioxins on organic layer farms are:
1. Commercial organic feed;
2. Non-commercial feedstuffs;
3. Soil;
4. Plants;
5. Worms and insects.

Kijlstra (2004) calculated the influence of these sources on the dioxin levels in eggs (Table 4). Soil was shown to be the most important source. This is confirmed by many other researchers (Petreas *et al.*, 1996; Schuler *et al.*, 1997; Anon., 2000b; Fiedler *et al.*, 2000). Kijlstra considers worms and insects as the second most important source.

Table 4. Sources of contamination and estimated final dioxin contents (pg TEQ per g fat) of organic eggs, assuming a 25% transfer of the dioxin intake. Source: Kijlstra, 2004.

Source	Estimate	
Source	Low	High
Regular feed	0.05	1.25
Worms and insects	0.25	1.5
Herbs and grass	0.25	0.5
Soil	0.25	2.5
Total	0.80	5.75

Research has also shown that cross-contamination of dioxins between chickens is possible (Zabik *et al.*, 1998). According to Zabik *et al.* the cross-contamination between groups in cages may be due to air-borne dust. Another factor influencing the dioxin level is the age of the hens. Tlustos *et al.* (2004) found a close relation between the age of the hens and the level of dioxins found in the eggs. In their research the age of the laying hens varied from 23 weeks to 4 years. The relation between organic production characteristics and high dioxin levels in organic eggs is explained in the following sections.

Dioxins in commercial organic feed

Generally, low levels of dioxins are found in commercial feed (Tlustos *et al.*, 2004). Cereals, grain legumes and their by-products (such as extracted oil seed meal), cereal middlings and maize gluten are the most frequent commercial feedstuffs. The amounts of fat, cassava, some feeds of animal origin and additives vary according to animal diets. As a result, dioxin contents of feedstuffs vary between 12 and 232 pg TEQ per kg (Anon., 2000b). An intake of 140 g of commercial feed and transferring 25% of the dioxins to 6 g of egg fat, leads to an egg dioxin content of 0.07 to 1.35 pg TEQ per g egg fat. Since Dutch commercial organic feed contains even less dioxin than conventional feed (Kijlstra, 2004), this source is unlikely to contribute to elevated dioxin levels in eggs.

Dioxins in non-commercial feeds

Some organic farmers offer non-commercial feeds to their flocks beside the regular commercial feed. However, not much information is available on the dioxin contents of these additional feeds. Brandsma *et al.* (2004) found a relation between a high dioxin level in the eggs and feeding non-commercial feeds. Non-commercial feeds can be grouped into vegetables, fruits and grains. Results from recent surveys show relatively low dioxin contents in grains, fruits and vegetables, mostly around or below the limits of determination (around 0.05–0.1 pg TEQ per g of product). However, many countries that export grains, fruits and vegetables to western nations have more lenient regulations regarding the use of agricultural chemicals, perhaps leading to greater contamination of imported foodstuffs than is currently thought (Roeder *et al.*, 1998). Bread, which is sometimes fed to hens, contains 0.0277 pg TEQ per g of product (Smith *et al.*, 2002).

Except for data on dioxin levels in human consumption, not much is known about the dioxin contents of non-commercial feed fed to hens. Although Brandsma *et al.* (2004) found a relation between a high dioxin level in the eggs and feeding vegetable and garden scraps this does not necessarily mean that these scraps are a dioxin source. It may well be that feeding scraps in the outdoor run promotes the time spent outdoors or increases the amounts of insects and worms.

Dioxins in soils

In addition to the exposure of animals to dioxins through their diets, soil ingestion may represent an additional source of dioxin contamination. Animals foraging on soil contaminated with dioxins may accumulate these compounds to high levels in their tissues. Although many researchers have attempted to explain the nature of soil ingestion, the lack of standardized sampling protocols for analysing and describing geophagic soils has impeded understanding the reasons why animals ingest soil. Since soil ingestion may have some therapeutic value (Krishnamani & Mahaney, 2000), there is a hypothesis that soil ingestion by animals is akin to self-medication (Wakibara *et al.*, 2001; Engel, 2002).

An equilibrium between the dioxin content of the soil and its content in the eggs is reached relatively fast (Petreas *et al.*, 1991). Estimates of the dioxin levels in the soil in Europe lie between 0.5 and 87 pg TEQ per g dry matter (see Table 1, Anon., 2003). Stephens *et al.* (1995) estimated the amount of soil ingested by hens between 2 and 10 g per hen per day. Indeed, assuming this estimate, the additional dioxin intake can vary from 1 to 870 pg TEQ per hen per day (Anon., 2000b).

In the study of Brandsma *et al.* (2004) a correlation was found between the dioxin levels in the eggs and those in the soil ($P < 0.10$). They also found that the congener pattern in earthworms was similar to that found in the eggs. It was concluded that soil was the main source of dioxins in the eggs. For the Netherlands, Kijlstra (2004) estimated that 10 g of ingested soil may lead to 0.25–2.5 pg TEQ per g egg fat. Many researchers confirmed that soil is a main source of contamination leading to elevated dioxin levels in eggs (Petreas *et al.*, 1996; Schuler *et al.*, 1997). Eggs from free-ranging hens kept on contaminated soils had dioxin contents of several hundreds pg TEQ per g fat (up to 300 pg TEQ per g fat in Baden-Württemberg and 219 pg TEQ per g fat in Hamburg; Buckley-Golder, 1999). The results of these studies were in agreement with the findings that the contents and congener profiles of the dioxins in the eggs appear to be related to the soil on which the hens were raised (Fiedler *et al.*, 2000).

Soil ingestion is obviously a cause of high dioxin levels in the eggs. Factors that may enhance soil ingestion are the time hens spend scavenging outside and the access to soil (Brandsma *et al.*, 2004). As hens on organic farms spend more time outside than hens on free-range farms, organic eggs are bound to have higher dioxin contents.

Dioxins in plants

The daily forage intake (grass, legumes and other herbs) by hens can amount to approximately 35 g, i.e., 7 g of dry weight material (Anon., 2000a). However, absorption and translocation of dioxins by plants grown in polluted soil is negligible. Unless contaminants are near the soil surface and have few chlorination sites, the volatilization-deposition mechanism is of little importance as a source of plant contamination (Roeder *et al.*, 1998). According to Kijlstra (2004), ingestion of 35 g grass per day can lead to an egg dioxin content of 0.25 to 0.5 pg TEQ per g fat.

Dioxins in worms and insects

Free-ranging hens consume about 20 g of feed from animal origin (insects, worms; Anon., 2000a). So increased dioxin levels in eggs can also be due to the ingestion of insects and worms. Kijlstra (2004) found dioxin contents in worms, ranging from 0.3 to 1.9 pg TEQ per g body weight. According to Kijlstra, ingestion of 20 g worms can lead to 0.25–1.5 pg TEQ per g egg fat. The amount of ingested insects and worms will depend on various factors, including the time the hens spend outside and the density of worms and insects in the soil. This density in turn may depend on the density of hens in the outdoor run (Schuler *et al.*, 1997): it may decrease with increasing flock density.

Dioxin-reducing methods

As yet little is known about the effect of measures aiming at lowering the dioxin content of organic eggs. Most likely interventions concern management, like shortening the time the hen spends in the outdoor run, reducing the size of the outdoor run, replacing the soil, covering the soil of the outdoor run and administering vitamins to the hens. Few reports are available about research on inhibiting absorption of dioxins by green vegetables and chlorophyll and on reduction of dioxins in the body tissues by clenbuterol and on eliminating dioxins from the soil.

Morita *et al.* (2001) found that certain types of green vegetables may have an effect on the digestive tract absorption of dioxins and provided evidence that this effect may be mediated by chlorophyll. In rats the faecal excretion of several dioxin congeners remarkably increased with increasing dietary chlorophyll derived from *Chlorella*. These findings suggest that chlorophyll has an effect on dioxin absorption from foods.

Furthermore, Shappell *et al.* (2002) found that the leanness-enhancing agent clenbuterol reduced the accumulation of dioxin in the bodies of rats through the reduction of body fat, the predominant site of accumulation. Clenbuterol reduced body fat by 28% ($P < 0.05$), increased muscle mass by 25% ($P < 0.02$) and decreased liver mass by 7% ($P < 0.02$). Although the contents of most dioxins per gram of fat had slightly increased after clenbuterol treatment, the total amount of dioxins that remained in the fat was reduced by approximately 30%.

Apart from eliminating dioxins from the animal, dioxins can also be eliminated from the soil, using biological, physical or chemical methods. However, the technologies are complex and probably not suitable for application on layer farms. Removal of contaminated soil and replacement with clean soil may be an option for certain farms, but results of such interventions have not yet been reported.

Final conclusions

Dioxin levels are higher in eggs from free-ranging chickens than in eggs from chickens kept inside. This is ascribed to the fact that free-ranging chickens ingest soil and eat insects and worms, all of which contain dioxins, which are efficiently transported to the egg yolk. Environmental dioxin pollution is due to (historical) waste burning and various industrial processes. A relatively high dioxin contamination of the Dutch environment is not surprising since the Netherlands is one of the most densely populated countries in the world. Despite the fact that many sources of dioxin contamination have been eliminated it may still take many years before background levels have decreased to values whereby eggs from chickens roaming outside all day will attain a dioxin content that is in agreement with current EU legislation.

Flock size has an effect on the dioxin levels in eggs, due to the fact that flock size directly influences the behaviour of the hens to use the outdoor run: small flocks being outside most of the time whereas large flocks tend to remain inside. The amount of time spent outside dictates the uptake of dioxin-contaminated soil or insects taken up by the animals. This explains why almost none of the larger laying-hen farms (more than 1500 laying hens) in the Netherlands have problems maintaining their egg dioxin level below the EU standard of 3 pg TEQ. The relatively short time that the hens use the outdoor run may conflict with organic principles. On the other hand it may well be that under these conditions the hens prefer an inside area for reasons of safety and availability of food and water. Many organic farms in the Netherlands have small flocks as a 'minor' business enterprise. On these farms the chickens spend the best part of the day outside, leading to unacceptably high egg dioxin levels. Future studies will show whether management methods can be developed for these small farms that are able to reduce dioxin levels without affecting the basic principles of organic farming.

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